ICNF 2021

5th International Conference on Natural Fibers

Materials of the Future

17. 18. 19 MAY 2021 | Online, Portugal

Book of Abstracts

Edited by R. Fangueiro

BOOK OF ABSTRACTS

Edited by
RAUL FANGUEIRO

Cover
PIXARTIDEA

Publisher
SCIENCENTRIS

Authors
Multiple

Title
Proceedings of the 5th International Conference on Natural Fibers - Materials of the Future

ISBN
978-989-54808-5-2

ORGANIZED BY

Fibrenamics

Universidade do Minho

SCIENCENTRIS

FOREWORD

The International Conference on Natural Fibers is established as the leading scientific event on fields related to natural fibers, from harvesting to its application in high demanding areas. Over the last 4 editions, this event has assumed a very important worldwide position, addressing and defining the most important trends in the field, as an outcome of the high quality of the research works presented and of the strong interaction among the participants.

With a very transversal view on the extraction, processing, functionalization and use of natural fibers, including linen, wool, silk, hemp and cotton, ICNF2021 focuses, in this edition, on the topic “Materials of the Future”, clearly assuming the fundamental role of these materials in building a more sustainable future. In fact, areas such as automobiles, aeronautics, fashion, civil construction, architecture or health-care, have been benefiting strongly from the scientific advances occurred in the last decades in this field, focused mainly on the combination of intrinsic characteristics associated with sustainability and the performance provided by these materials. Biocomposites for use in automobile and aircraft components, geotextiles for use in soil reinforcement, nanocellulose for use in medical devices and fibers for reinforcing construction mortars, are just some examples of fundamental themes for the use of advanced natural fibers. In this context, nanotechnology is also of particular importance in the search for the most appropriate solutions for specific applications, in a logic of multiscale analysis of materials, with a view to their manipulation at the nano, micro and macro scales. Over the last few years, intensive research has been developed to turn natural fibers into smart solutions being able to respond to external stimuli, in addition to their intrinsic sustainable features.

ICNF2021 is covering a wide range of trends defined for natural fibers, with particular emphasis on nanocellulose based fibers and structures, fiber surface treatments, functional natural fibers, smart natural fibers, environmental impact, ecocomposites, biomimetics, and, of course, product development based on natural fibers.

ICNF2021 is the meeting point for all those interested in these fantastic materials called Natural Fibers.

Guimarães, 14th May 2021

Raul Fangueiro
Conference Chairman

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KEYNOTE LECTURE
FIBERS, TEXTILES & SUSTAINABILITY

Seeram Ramakrishna
National University of Singapore, Singapore

ABSTRACT
Worldwide consensus is building up in recent years for greater sustainability while there is no clear strategy on how sustainability friendly public policy goals are to be achieved. On this backdrop, plastics, packaging and textiles are seen as both a hero and a villain. They have played an integral role in shaping our modern society. Their global production and consumption are in several hundreds of millions tons per annum. On the other hand, their wastes are accumulating around the world. Evidences are being piled up on their environmental as well as health hazards associated with the end of life management. This lecture seeks to address questions such as why only a tiny fraction of them is recycled sustainably; what are the end of life management practices; forthcoming policy regulations and international standards aimed at reducing their impact on earth's ecosystem and human health; what options are emerging to enhance their circularity, circular economy and sustainability, and role of symbiosis in reducing their sustainability gap.

KEYNOTE LECTURE
INTERFACIAL MODIFICATION IN GREEN NANOCOMPOSITES TO TAILOR FUNCTIONALITIES

Sabu Thomas
Mahatma Gandhi University, India

ABSTRACT
Green chemistry started for the search of benign methods for the development of nanoparticles from nature and their use in the field of antibacterial, antioxidant, and antitumor applications. Bio wastes are eco-friendly starting materials to produce typical nanoparticles with well-defined chemical composition, size, and morphology. Cellulose, starch, chitin and chitosan are the most abundant biopolymers around the world. All are under the polysaccharides family in which cellulose is one of the important structural components of the primary cell wall of green plants. Cellulose nanoparticles (fibers, crystals and whiskers) can be extracted from agrowaste resources such as jute, coir, bamboo, pineapple leafs, coir etc. Chitin is the second most abundant biopolymer after cellulose, it is a characteristic component of the cell walls of fungi, the exoskeletons of arthropods and nanoparticles of chitin (fibers, whiskers) can be extracted from shrimp and crab shells. Chitosan is the derivative of chitin, prepared by the removal of acetyl group from chitin (Deacetylation). Starch nano particles can be extracted from tapioca and potato wastes. These nanoparticles can be converted into smart and functional biomaterials by functionalization through chemical modifications (esterification, etherification, TEMPO oxidation, carboxylation and hydroxylation etc) due to presence of large amount of hydroxyl group on the surface. The preparation of these nanoparticles includes both series of chemical as well as mechanical treatments; crushing, grinding, alkali, bleaching and acid treatments. Transmission electron microscopy (TEM), scanning electron microscopy (SEM) and atomic force microscopy (AFM) are used to investigate the morphology of nanoscale biopolymers. Fourier transform infra-red spectroscopy (FTIR) and x ray diffraction (XRD) are being used to study the functional group changes, crystallographic texture of nanoscale biopolymers respectively. Since large quantities of bio wastes are produced annually, further utilization of cellulose, starch and chitins as functionalized materials is very much desired. The cellulose, starch and chitin nano particles are currently obtained as aqueous suspensions which are used as reinforcing additives for high performance environment-friendly biodegradable polymer materials. These nanocomposites are being used as biomedical composites for drug/gene delivery, nano scaffolds in tissue engineering and cosmetic orthodontics. The reinforcing effect of these nanoparticles results from the formation of a percolating network based on hydrogen bonding forces. The incorporation of these nano particles in several bio-based polymers have been discussed. The role of nano particle dispersion, distribution, interfacial adhesion and orientation on the properties of the ecofriendly bio nanocomposites have been carefully evaluated.

KEYNOTE LECTURE
RECENT ADVANCES ON THE MULTISCALE USES OF VEGETAL BIOMASS IN THE BUILDING MATERIAL CONSTRUCTION INDUSTRY

Sofiane Amziane
Institut Pascal, Université Cermont Auvergne/CNRS/Clermont-Ferrand, France

ABSTRACT
Sustainable development is a multi scale global issue in the sense that it integrates the contexts of both global warming and the progressive depletion of resources. These two elements constitute points of no return for our civilization. The building sector has a key role in greenhouse gas emissions: more than 30% of final energy consumption and 20% of global emissions are related to the real estate sector, and these figures will continue to increase if no measures are put in place.
Currently, on a global scale, the construction sector consumes more mineral matter than other industrial sectors, including energy production. In addition, the massive use of cement for building construction is responsible for 5% of global CO2 emissions.
The integration of bio-based building materials is one of the best alternatives to limit these negative impacts. In addition to the use of wood for building frames or walls, which provides the basis for many construction solutions which are often based on ancestral and universal know-how, the introduction of vegetal at the scale of ashes, aggregate or into construction products can lead to the development of innovative construction solutions with unusual properties of use. At the scale of ashes, approximately 140 billion metric tons of biomass is produced every year in the world from agriculture. The ashes resulting from burning these agricultural co-products such as rice husk, bagasse, miscanthus, bambou and others can be used as Supplementary Cementitious Materials (SCM).
At the scale of aggregate, many mixes of concrete were designed in order to provide a high performance insulation solution using high volume (until 80% of the total) of various sources of bio-aggregates, such as wood, hemp, coconut, sisal, palm, bamboo, or bagasse, etc.
At the scale of fibbers, many examples shows that the introduction of natural fibbers are already used in cementitious materials to improve the flexural strength and post-cracking behavior. The most commonly used in cementitious composites are flax fibbers, diss fibbers and hemp fibbers. Several works aimed at characterizing the behaviour of these reinforced concretes.
The Keynote proposes to show an overview of the uses of the vegetal at the different scales. A large part of the results are issued from the outputs of the Technical Committee of RILEM on biobased building materials.

NEXT GENERATION HEMP FIBERS USING ENVIRONMENTALLY FRIENDLY PULP PRODUCTION AND HIGHPERCELL® TECHNOLOGY

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ABSTRACT

This work focuses on the analysis of the potentiality of hemp cellulosic pulp produced by an unique (patent-pending) process by RBX Créations and the transformationd into filaments using HighPerCell® technology developed and patented by DITF Denkendorf. The HighPerCell® technology is a sustainable and alternative process for spinning of man-made cellulosic fibers in addition to the industrial applied viscose and lyocell process. Ionic liquids (IL) are used as direct solvent and allowing the environmentally friendly spinning of textile and technical cellulose fibers. No additives are needed and a complete recycling of is possible. The resulting textile fibers are referred to under the name Iroony® of RBX Créations. This process is specifically applied on hemp stems which are hemp seeds - i.e. food - byproducts, for an efficient use of natural resources and arable land. The hemp used here is cultivated without irrigation or chemicals, in an extended rotation cycle, by the farming group Chanvre Mellois, located in the South-West region of France.

INTRODUCTION

Hemp is a robust and resilient plant which grows quickly, generally without water (in contrast to cotton) or chemicals, while cleaning up the soils and massively capturing carbon (about 15 Tons per Hectare per year according to Interchanvre). In culture rotation, it improves following crops yields, especially cereals. Moreover, many resources result from one same crop, as its oleaginous seeds can be valued for food and cosmetics, its flowers for pharmaceutical or food supplements, and its stalks for paper, construction materials or potentially textile.

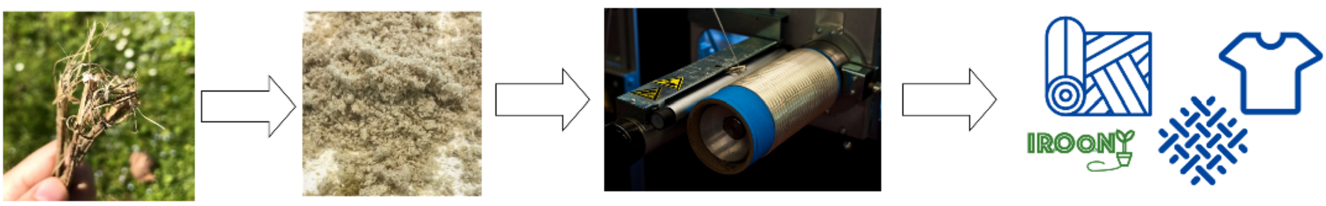

Figure 1: Processing sceme of hemp agriculture into filaments.

The growing market in cellulosic fibres and the forecasted cellulose gap offer great challenges for TREE-FREE, alternative pulp sources. Hemp agriculture, pulp processing and HighPerCell® technology are highly efficient solutions to meet crucial challenges such as reducing pollution, fighting climate change, or becoming more autonomous on the whole supply chain which is strategic for Europe.

RESULTS AND CONCLUSIONS

For the dissolution of the pulps 1-Ethyl-3-methylimidazolium octanoate ([C2C1im][Oc]) was used as solvent. This ionic liquid has a high dissolution capability, is inert and a direct solvent for cellulose rich sources. Rheology measurements of the hemp pulp/IL solution were performed to determine the spin ability of a dope. Concentrations of 10-12 wt.-% of hemp pulp and the dope temperatures between 60-80°C were suitable to establish viscoelastic behavior and optimal spinning conditions. Compared to Lyocell process (80-120°C) lower spinning process temperature were applied and a higher concentration of pulp are possible in comparison to viscose process (8-10 wt.-% cellulose) due to unique, sustainable and environmentally friendly HighPerCell® technology. By air gap spinning endless filaments with 2.0 – 3.3 dtex were realized having high fiber tenacity (> 40 cN/tex) comparable to industrially produced lyocell fibers. As shown in Figure 2 the fibers possess flat surfaces and perfect round shape fibers.

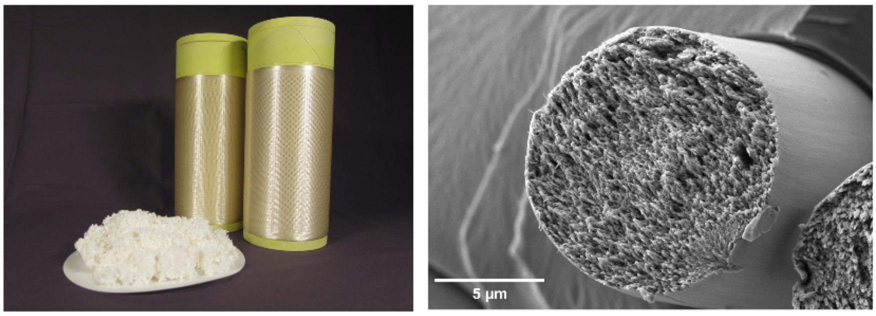

Figure 2: (left) hemp pulp and final filaments. (right) SEM image of endless spun Iroony® hemp fibers.

Next processing steps are knitting and secondary spinning processes to investigate its potential in clothing and apparel market. As there is a growing need for sustainable materials, preserving the ecosystems and mitigating climate change, due to the increasing demand from customers aware of the environmental and social negative impacts of the textile sector, this approach fits into the next generation of textile fibers. Additionally, the upcoming scarcity of natural resources such as water will massively impact the materials sourcing, plus new regulations that could be enforced to compel the sector to change.

European Commission
ELIIT Project is funded by COSME Programme of the European Union for the competitiveness of Enterprises and Small and Medium-Sized Enterprises (SMEs)

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by ELIIT: this research is supported by ELIIT Partnership Project and is funded by COSME Programme of the European Union for the Competitiveness of Enterprises and Small and Medium-Sized Enterprises (SMEs).

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NATURAL FIBERS INSULATION MATERIALS: USE OF TEXTILE AND AGRI-FOOD WASTE IN A CIRCULAR ECONOMY PERSPECTIVE

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ABSTRACT
Fibrous-based materials are among the most used for the thermal and acoustic insulation of building envelopes and among the ones with the best flexibility in use. In building construction, the demand for products with low environmental impact - in line with the Green Deal challenge of the European Community - is growing, but the building market is still mostly biased towards traditional products, missing the many opportunities for using waste materials from existing industrial production. The paper presents the experimental results of new thermal and acoustic insulation products for building construction and interior design, based on previous experiences of the research group. They are entirely produced using waste sheep's wool as a "matrix" and other waste fibers, as "fillers". Proposed materials derive from textile and agro-industrial chains of Piedmont region and have no other uses, different from the thermal valorization as biomass. The panels have characteristics of rigidity, workability, and thermal conductivity that make them suitable for building envelope insulation.

INTRODUCTION
In 2017 in Italian building regulations have been introduced the CAMs (Minimum Environmental Criteria), which are environmental requirements defined for the various phases of the purchasing process, aimed at identifying the best design solution, product, or service from an environmental point of view, along the life cycle. The consequent growing demand for low-environmental-impact building products often does not match adequate availability in the building market. Fibrous-based thermal and acoustic insulation panels are a clear example of building products that could be produced using almost exclusively by-products from already existing industrial production chains, meeting the CAM requirements.
The paper presents innovative solutions in the use of natural fibers for the production of insulating panels, exploring the use of waste materials available in the agri-food and textile production chains. The AGROTESs panels production concept aims to close existing production cycles in a regional industrial system (Piedmont Region, Italy), avoiding the disposal of fibrous waste and reintroducing them into a new production cycle, in a circular economy perspective. AGROTESs panels combine wasted sheep's wool from regional sheep farming and other waste materials like rice straw, chopped corn, fibrous wastes from textile productions.
Proposed rigid panels consist of a keratin “matrix” and a fibrous “filler”. Their production process come from research works, previously carried on at DAD of Politecnico di Torino and CNR-ISMAC of Biella (Piedmont) (Pennacchio et al. 2017), and use keratin in wool fibers as a binder, through a thermochemical fusion in a caustic soda bath, keeping unaltered the main chemical and physical characteristics of employed materials. Further research development recently led to test new waste materials, coming from Piedmont region agro-food production chains, to be used as a filler, as an alternative to hemp, adapting the production process - materials percentage, concentration of soda solution, drying process - according to the specific features of

new selected materials, which also give the panels different density and rigidity characteristics. Among the various local “fillers” experimented during laboratory tests, rice straw fibers and chopped corn showed better compatibility with wool fibers, and their use have been further investigated. At the same time, a different panels’ production process have been developed, using powders from wool textile chains, with high keratin content, with no need of mixing with coarse wool fibers.
Research mainly focused on Piedmont region, but could be extended and adapted to other areas with high availability of coarse wool.
Test and measurements have been provided on experimental samples in order to identify opportunities for the production of new low environmental impact products, suitable for the building sector and meeting the CAM requirements and European Green Deal challenge for nearly zero-emission productions.

RESULTS AND CONCLUSIONS

The paper presents, as a result of the experiments on different natural fibers and waste materials, the production process for the production of the insulating panels’ samples. In the process, the keratin in wool fibers acts as “matrix” which glues the different “fillers” in treatment with caustic soda. Quantity of components, times, and phases of the production process has been tested and optimized to obtain the densities and physical-technical performances necessary for the use of the panels as well-performant insulations for in construction.
Unidirectional steady-state thermal performance measures (tab.1) obtained through laboratory tests carried out using the guarded ring hot plate method (ISO 8302:1991; UNI EN 12667:2002) show thermal conductivity values slightly higher if compared with those found in previous experimental panels and those of natural insulation products on currently the market (Pennacchio et al. 2017).

Table 1 AGROTESs samples measured thermal characteristics

	Dim [cm]	Mass [g]	Bulk Density [kg/m³]	λ [W/mK]	R [m²K/w]	U [W/m²K]
AGROTESs A	15x15x3.5	161	204	0.054	0.648	1.543
AGROTESs B	15x14x3.5	141	249	0.063	0.429	2.331
AGROTESs C	15x15x2.2	134	203	-	-	-
AGROTESs C_1	14.5x13.5x2.2	136	240	0.061	0.475	2.105

Nevertheless, their high bulk density would make interesting the evaluation of panels’ dynamic thermal behaviour. Results obtained, however, eventually open to the possibility of further improving the thermal conductivity performance, through calibrated pressing systems during panels’ production.
AGROTESs insulating panels are suitable for multiple uses in architectural field, both in new construction and rehabilitation processes, as for building envelope insulation, as for internal partitions, offering good workability and adaptation to traditional anchoring systems (Savio et al. 2018).

ACKNOWLEDGMENTS

The authors gratefully acknowledge Agrindustria Tecco s.r.l. (Cuneo, Italy) for the waste materials supply used in the samples production.

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EXTREMELY LIGHTWEIGHT, BIOMIMETIC NATURAL FIBRE-REINFORCED COMPOSITES PRODUCED VIA WINDING PROCESS

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ABSTRACT

Optimised manufacturing processes are required for the production of biomimetic or bio-inspired hollow composite structures. Several established manufacturing processes involve fibre-reinforced composite production through the defined placement of dry or pre-impregnated yarns or rovings. Direct Fibre Placement (DFP) or Automated Tape Laying (ATL) is particularly suitable for creating larger surfaces and is used, for example, in aircraft construction. Another process is the winding process, which creates volume bodies of individual contours by placing dry or pre-impregnated yarns or rovings on a rotating mandrel (Schledjewski et al., 2014). The winding of three-dimensional structures is a well-suited process to meet the component's specific requirements due to its diverse customisation possibilities (Tarnopol'skii et al., 1998). Thanks to a free placement of yarns or rovings at the defined node and load points, it is possible to map specific load paths. In addition to the implementation of lightweight construction principles, the use of less material is also a significant economic advantage (Günnel & Köth, 2015).

The authors report on the state of the art of biomimetic and bioinspired 3-dimensional composite structures. The developments described in the literature are critically evaluated, and it is examined whether the developments are pure copies of biological structures or whether the criteria of a biomimetic working process have been implemented. Following the biomimetic work process (bio-push), the individual steps starting with the biological role model via abstraction and ending with technical implementation, are shown (see Figure 1).

The abstraction process and the realisation of the winding technique for the biomimetic composites will be presented. The unique features of the design and construction of the winding mandrel are presented. Details are given on processing flax yarns, and the properties of the composites determined in the compression test (see Figure 1) are presented. A particular focus is addressed on the failure behaviour of the winded biomimetic composites. The individual layer's failure seems to be independent of the structure's overall failure, which provides a substantial advantage in terms of component safety.

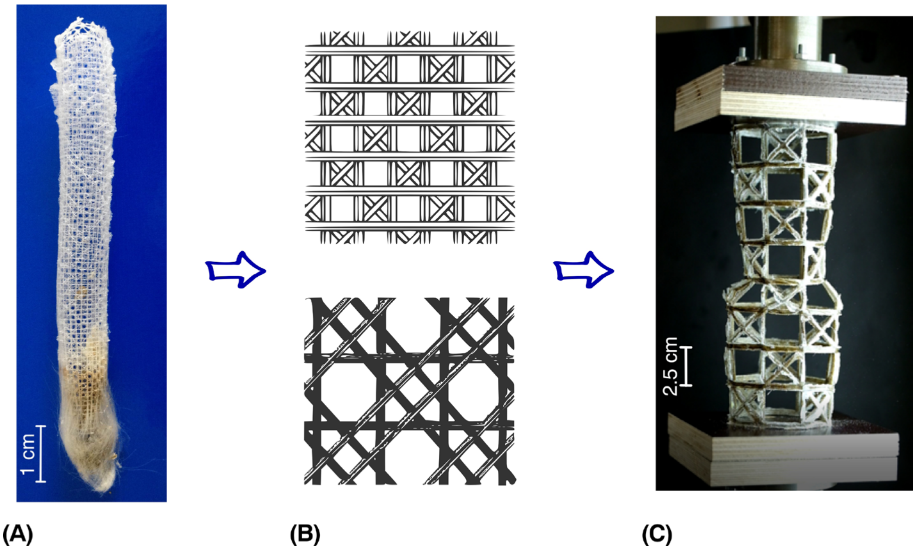

Figure 1: Biomimetic work process (bio-push), starting with the biological role model (A) via abstraction (according to Aizenberg et al. 2005 (B, top) & Weaver, et al. (2007) (B, bottom)) and ending with a natural fibre-reinforced composite structure in compression test (C).

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INSIDE THE KINK BANDS OF FLAX FIBRES: INVESTIGATION OF THE LOCAL STRUCTURE AND PROPERTIES OF CELL WALLS

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ABSTRACT

Several plant fibres, such as hemp and flax, have local defects of the cell wall along their entire length, generally called kink bands. Several studies have investigated their origins and consequences. Here, techniques like SEM microscopy, atomic force microscopy in peak force mode (AFM PF-QNM) and the second harmonic generation imaging microscopy (SHG) are combined to study their inner structure. The investigations allowed to highlight porosities caused by the deformation of the microfibril network. Kink bands were distinguished in type A and B based on the presence, or not, of these porosities and the severity of the change in the orientation of the microfibril network. Interestingly, no substantial difference was found between the transverse stiffness calculated inside kink bands and in defect-free regions.

INTRODUCTION

Kink bands of plant fibres are weak points where cracks begin to propagate in at least two cases, when elementary fibres are tested by tensile testing or when bundles are used as reinforcement in a biocomposite material (Hughes et al., 2000, Aslan et al., 2011). The chemical composition within the kink bands appears to be the same as in the rest of the fibre, but with a less oriented microfibril network (Thygesen and Gierlinger, 2013). Another team also suggested the presence of pores and cavities in kink bands (Zhang et al., 2015) but the origin of these porosities is still unclear, as well as the fine ultrastructure and mechanical properties of these regions.

A batch of flax Bolchoï variety (year 2018) was cultivated and retted by Depestele group, an industrial company, and then mechanically scutched. Two bundles, one covered by a layer of sputtered gold and the other one firstly embedded in Agar epoxy resin, to perform cryofracture, were studied by SEM at 3 kV. Several elementary fibres and one bundle were extracted from the batch, mounted on paper support according to ASTM C1557, and studied by a multiphoton microscope (wavelength of 810 nm, bandpass filters at 460/60 nm, 550/88 nm and 406/15 nm) in the air first and then by adding successively distilled water. Two other bundles were also extracted and embedded in Agar epoxy resin and the surface cut by ultramicrotome to perform AFM PF-QNM mechanical analysis using RTESPA-525 probes. The stiffness of the cantilever (147-203 N/m) was calculated with the Sader method, the deflection sensitivity calculated on sapphire and tip radius (40-55 nm) adjusted on a sample of embedded aramid fibres previously prepared and taken as a reference. The peak force was set at 200 nN.

RESULTS AND CONCLUSIONS

In Fig. 1, results obtained by SEM, SHG and AFM on three type A kink bands are reported. Porosities were identified by SEM and AFM, while a severe change in the orientation of the microfibril network was measured by SHG and angles greater than 30° with respect to the axis of the fibre were calculated. However, no substantial difference in the transverse mechanical properties was found between the kink band region and the rest of the fibre by AFM. To sum up, kink bands show local disorganization of the microfibril network that can create porosities and when the fibre is put in the water environment, a partial re-organization occurs. On the contrary, in type B kink bands, porosities are absent because the change of the angle in the microfibril network is less severe and they are barely distinguishable from the rest of the fibre.

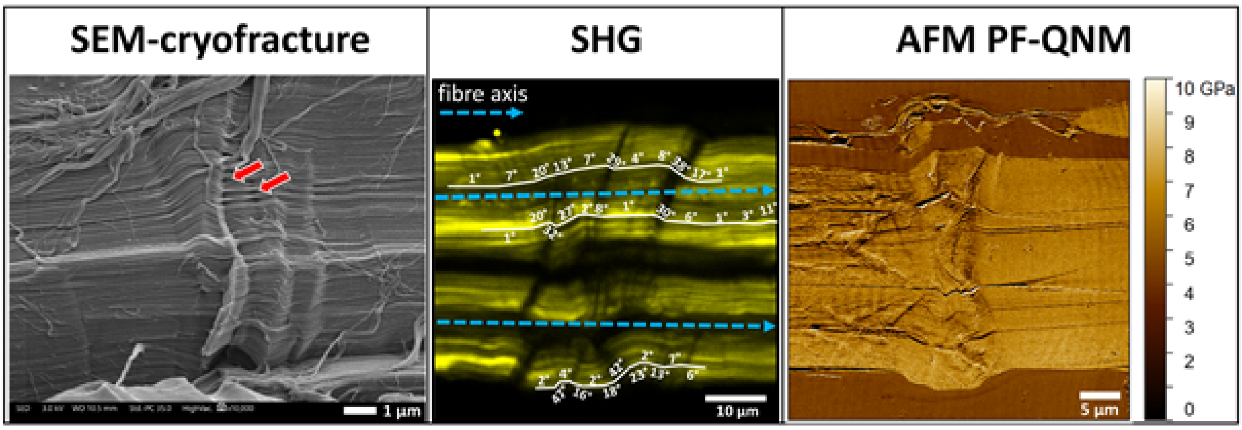

Fig.1 Three bundles of type A kink bands investigated by SEM, SHG and AFM respectively. Red arrows highlight porosities, blue arrows indicate fibres axis taken as reference for the calculation of the local angle of the macrofibrils (white segments) and in AFM the map of indentation moduli are reported

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by INTERREG IV Cross Channel program through the FLOWER project and SOLEIL Synchrotron for funding the 99180266 in-house proposal

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THE ADAPTIVE POWER OF AMMOPHILA ARENARIA: BIOMIMETIC STUDY, SYSTEMATIC OBSERVATION, PARAMETRIC MODEL AND EXPERIMENTAL TESTS

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ABSTRACT

This work aims to carry out a biomimetic approach to the Ammophila arenaria, the scientific name for marram grass, and analyze its sophisticated adaptive capacity to climate conditions. The Ammophila arenaria possess a reversible leaf opening and closure mechanism that acts in response to water and salt stress (hydronastic movement). The study is part of an ongoing Ph.D. research of which the objective is to develop an analogy of this organism to create responsive facades. Hence, the paper will describe the application of the problem-based biomimetic methodology in three stages: the first refers to understanding the morphology, physiology, and behaviour of the object of study from a literature review and two systematic observations; the second one refers to how to abstract and develop a parametric leaf model to simulate the leaf's movement; and the third, we performed an experimental process with thermobimetal (a smart material that curls when heated). We combined this material with Ammophila arenaria's straws, to replicate its movements in response to temperature variation. In future works, we will be able to propose responsive facade solutions based on these results.

INTRODUCTION

The profusion of Ammophila arenaria along the shoreline of Western Europe and Northern Africa is remarkable and demonstrates the high relevance of this organism for the fixation of coastal dunes (Huiskes, 1979). The simplicity and elegance of A. arenaria hide a sophisticated adaptation system to water and salt stress (Chergui, Hafid and Melhaoui, 2017), capable of triggering the reversible movement of the leaf, which closes on itself to reduce light interception, transpiration, and leaf dehydration (hydronastic movement) (Kadioglu et al., 2012; Andrade et al., 2020). This work aims at analyzing the adaptive response of A. arenaria leaves from the problem-based biomimetic methodology (López et al., 2017). The first systematic observation evaluated the response time and average opening variation of the samples (five leaves), depending on dehydration or rehydration. In the second, we carried out an analysis of the morphology of the four cross-sections of A. arenaria, available on the Science Photo Library website, to understand the location of stomatal crypts and possible morphological reference patterns for thermobimetal's creases.

RESULTS AND CONCLUSIONS

The data analysis showed that the intermediate region of the leaf presents a more significant variability of leaf opening, with approximate variation curves (Figure 1).

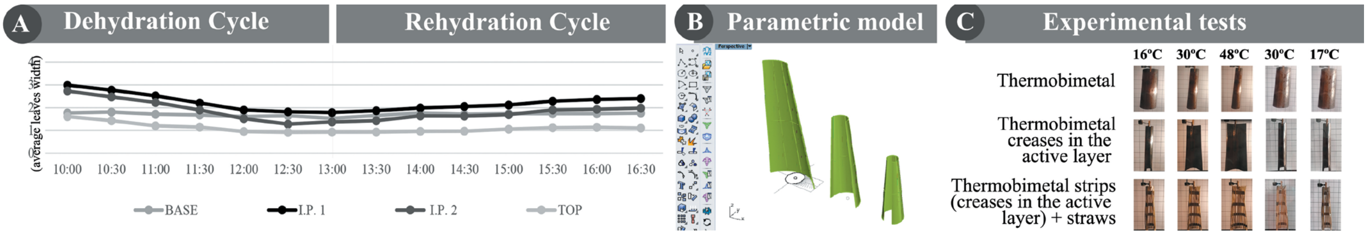

Fig. 1 (A) Average variation of leaf openings: (A1) Sample preparation: the sample bases were placed in drinking water for 20 hours. At 9:30 a.m. we marked the measurement points: Base, Intermediate Point 1 [I.P. 1], Intermediate Point 2 [I.P. 2], and Top. Dehydration Cycle and Rehydration Cycle. (B) Parametric leaf model. (C) Experimental tests with the thermobimetal, and plus Ammophila arenaria's straws, to create pattern of creases in the active layer inspired by A. arenaria. Testing of the samples at 16ºC until 48ºC. Source: Author.

Finally, we sought to abstract the morphological characteristics, and behaviour of the referenced organism to develop a parametric leaf model for simulating the opening and closing of A. arenaria, using Rhinoceros 6.0 software and the Grasshopper plug-in (Figure 2B). The algorithm allows the parametric modification of the following: base radius, top radius, leaf height, and leaf opening control. Afterwards, we concluded the experimental process (with thermobimetal and this material associated with the of A. arenaria straws) and noticed that creases in the active layer of the thermobimetal enable to create resistance to the natural movement of the material, as so to allow opening behaviour when heated, and closing when cooled (Figure 2C). Further research and experimentation will be required in order to fully understand and gain control over the material behaviour. Once having a rigorous understanding and control over the material behaviour, we plan to continue the research to develop responsive facades inspired by A. arenaria, replicating its reversible movement through experiments with responsive materials and digital design.

ACKNOWLEDGMENTS

This work was supported by the Fundação para a Ciência e a Tecnologia (FCT) and hosted by Centro de Investigação em Arquitetura, Urbanismo e Design (CIAUD) of the Faculdade de Arquitetura da Universidade de Lisboa.

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PROPERTIES OF CELLULOSE FIBERS FROM RESIDUAL LEGUME STEMS

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ABSTRACT

Legumes are one of the most prominent sources of food. Legumes such as chick pea and pigeon pea generate considerable amounts of lignocellulosic residues that are considered as waste and disposed either by burning or burying. We demonstrate that cellulose fibers with excellent properties can be extracted from the residues of the legume plants. For example, fibers obtained from pigeon pea (Cajanus cajan) had tensile strength of about 7.5 grams per denier and elongation of 3.5% similar to that of linen depending on the type of extraction used. Further, the fibers showed good ability to absorb residual dyes in the effluents. In this paper, we review some of the properties of the cellulose fibers obtained from the residues of legumes and suggest potential applications.

INTRODUCTION

Extracting natural cellulose fibers is one of the most effective methods to utilize agricultural residues. Fibers offer higher value addition and also a larger market for consumption than using the residues for animal feed or biofuel applications. However, the residues must have appropriate single cells, cellulose and lignin content to be provide fibers suitable for textile and other high value applications. Nevertheless, agricultural residues from most major crops have shown the potential to be used for production of high value fibers. Fibers with properties between cotton and linen have been extracted from corn, wheat, rice, cotton stalks and several other residues. Similarly, residues from biomasses such as switchgrass and sabaigrass have produced exceptional natural cellulose fibers. Natural cellulose fibers with inherent antimicrobial properties could be obtained from turmeric, wild tulsi, Kigelina africana fruit, etc. These fibers would be suitable for wound dressing and other applications (Ilangovan, 2020, 2018; Guna, 2019).

Similar to the cereal crops and biomass, legumes also generate considerable amounts of lignocellulosic residue. The residues are often up to 5 times by weight than the legumes produced. Hence, utilizing the legume residues can be a source for different materials and products. For instance, legumes are reported to be suitable as sources for textile fibers, pulp and paper, commodity chemicals, and specialty chemicals, including enzymes; nutraceuticals; functional foods, and medicinal foods. Chemicals derived from forages include enzymes, nutraceuticals, functional foods, and medicinal chemicals (Weimer, 2009). There have also been attempts to extract natural cellulose fibers from residues of legumes. In this report, we review the properties of natural cellulose fibers obtained from legumes.

RESULTS AND CONCLUSIONS

Table 1 shows a comparison of the tensile properties of natural cellulose fibers obtained from pigeon pea. The fibers were obtained using water extraction and also using alkali. As seen from the table, the pigeon pea fibers had tensile strength higher than that of napier, kapok and coconut tree leaf sheath but lower than that of Arundo, Ferula and other sources. Although the strength is good, the elongation of the fibers was low at about 2.3%. In terms of other properties, pigeon pea fibers had composition of 55% cellulose and

18% lignin similar to that of natural fibers from other sources. The physical structure such as %crystallinity and thermal behaviour are typical to natural cellulose fibers.
Table 1: Comparison of the properties of natural cellulose fibers obtained from pigeon pea with fibers from other sources (Kulandaivel, 2018).

Fiber Name	Tensile strength (MPa)	Young's modulus (GPa)	Elongation (%)
Pigeon pea fiber	131	2.1	2.31
Piassava	76.9	2.93	10.45
Artichoke	201	11.6	-
Ferula	475	52.7	4.2
Arundo	248	9.4	3.24
Bamboo	140–230	11–17	-
Coir	95–174	2.5–4.5	13.7–41
Luffa cylindrica	385	12.2	2.65
Bagasse	20–290	19–27	1.1
Snake grass	78	9.7	-
Napier grass	106	39–47	-
Rachis	74.26	2.31	13.5
Rachilla	61.36	2.34	8.1
Spatha	75.66	3.14	6
Kapok	45–64	1.73–2.55	2–4
Coconut tree leaf sheath	46.4	2.3	2.84

Agricultural residues such as the stems of legumes show great potential to be sources for excellent natural cellulose fibers. The fibers obtained from the legumes have properties similar to that of other lignocellulosic fibers and useful for textile and composite applications. The fibers have also shown potential to absorb dyes from waste water and carbon made from the fibers has excellent ability to remove sorbents from water and air. Value addition to residues of legumes will help to obtain sustainable fibers and also increase the economic value of the residues.

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VALORISATION OF HEAVY METAL CONTAMINATED LAND BY INDUSTRIAL HEMP FOR FIBER PRODUCTION

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ABSTRACT
This study investigated the potential of cultivating industrial hemp (Cannabis Sativa L.) on contaminated land for fiber production. 6 cultivars were grown on a Cd, Pb and Zn contaminated soil and heavy metal concentrations were analysed in the fibers and total above ground biomass and compared between cultivars. Results were also compared with toxicity thresholds from the textile industry. Optimistic results were observed towards the potential of fibers from hemp grown on heavy metal contaminated land to be used in the textile industry.

INTRODUCTION
Large areas of contaminated land can be found in Europe. These lands, mostly degraded due to former industrial activities, cannot be used for food production (Payá Pérez & Rodríguez, 2018). The pressure arising from the necessity to increase both food production for a growing population and biomass production for the biobased economy results in the need to valorise such sites. Hemp (Cannabis Sativa L.) is an eco-friendly, fast growing crop with no need of pesticides and a low fertiliser demand. Hemp is going through a revival in the biobased industry, where fibers are used as emerging raw materials in the composite and textile industries (Angelini, Tavarini, & Di Candilo, 2016). Moreover, hemp can tolerate stress from heavy metals (HMs), being suitable for cultivation in contaminated land. Although hemp is no hyperaccumulator, it does accumulates HMs in certain in its tissues (Kos, Grčman, & Leštan, 2003; Pietrini et al., 2019), which makes an evaluation of HMs concentration in the plant parts necessary before further valorisation.
A pot experiment was set up with 6 hemp cultivars on a Cd, Pb and Zn contaminated soil originating from agricultural land nearby the former metallurgic industry Metaleurop in the North of France. Cultivars were chosen based on their flowering stage (early to late) and on their fiber content and quality. Plants were grown under controlled greenhouse conditions and were harvested at 50% flowering to ensure good fiber quality. The above ground plant parts were weighed, oven dried and grinded. Samples were digested with concentrated HNO3 in closed microwave conditions prior to elemental content analysis with ICP-OES.

RESULTS AND CONCLUSIONS
The results from the Cd, Pb and Zn concentrations in fibers and total above ground biomass in the 6 hemp cultivars are shown in Fig. 1.

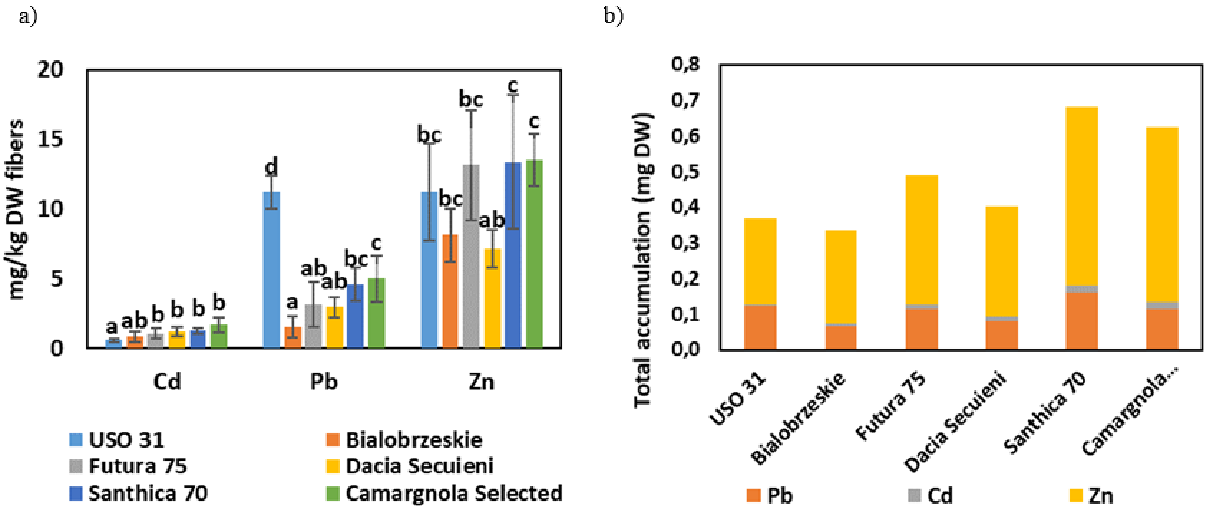

Figure 1 a) Cd, Pb and Zn concentrations in the fibers in the 6 hemp cultivars; b) Total Cd, Pb and Zn accumulation in the total above ground biomass in the 6 hemp cultivars.

Highest Cd and Zn concentrations in the fibers were observed in “Carmagnola Selected” and “Santhica 70”, while USO31”contained highest Pb concentrations. Lowest concentrations were observed in “USO31” for Cd, in “Bialobrieskie” for Pb and in “Dacia Secuieni” for Zn. “Bialobrzeskie” and “Santhica 70” respectively accumulates least and most HMs.
Cd and Pb concentrations were far below the toxicity tresholds for textile products (OEKO-TEX, 2020), while Zn is not mentioned as a target contaminant in the list.
This study suggests that hemp fibers grown on contaminated land could be used to produce safe and clean textile products. Further tests should be performed in order to analyse whether the extractable fraction of the heavy metals meet the toxicity thresholds as well.

ACKNOWLEDGMENTS

The research project was financially supported by the European Commission within the framework of the Interreg FWVI project New-C-Land.

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[3] OEKO-TEX. (2020). Annex 4 : Limit values table Anhang 4 : Tabelle der Grenzwerte Annex 4 / Anhang 4 Limit values table / Tabelle der Grenzwerte Any value measured in the laboratory (which is measured in mg / kg , Jeder im Labor gemessene Wert (welcher in mg / kg , µ g /.
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CHEMICAL TREATMENT OF PAPER YARN FROM SWEDISH FORESTS TO ENHANCE THE YARN KNITTABILITY

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ABSTRACT
The knittability of Swedish paper yarn was attempted to be enhanced using different chemical treatments. To evaluate the effect of the treatments, the coefficient of friction between the yarn and metal was investigated. In addition, the tensile properties of the yarn were clarified.

INTRODUCTION
The global fibre production is estimated to increase by 30% in the next decade. In 2019, 52%, 23%, and 6.4% of the global fibre production volume corresponded to polyester, cotton, and artifical cellulosic fibres, respectively (Textile Exchange 2020). A potential approach to identify novel sustainable alternatives for the textile industry is to employ the paper yarn produced from a renewable resource such as the Swedish forest. However, paper yarn exhibits a low handleability and knittability and high stiffness and grip. These factors must be enhanced to facilitate the use of the paper yarn in a wider market and applications related to the textile industry (Peterson, Eckard, Hjelm & Morikawa 2019). Consequently, this study was aimed to address the following questions:

RQ1: Can paper yarn be modified through chemical treatments to reduce the coefficient of friction between the paper yarn and metal?
RQ2: Which chemical treatment can enhance the knittability of paper yarn without decreasing the strength of the paper yarn?

To this end, paper yarn was treated using six different chemicals and winded on to bobbins. Tensile and friction tests of the untreated and treated paper yarns were conducted. Moreover, knitting tests were performed using the Stoll CMS 822 HP knit & wear flat knitting machine with the E5.2 gauge to evaluate the knittability. The data obtained from the tensile and friction tests were analysed, and statistical calculations were performed by conducting a one-way analysis of variance.

RESULTS AND CONCLUSIONS
The results of the tensile tests, shown in Fig. 1, indicate that the tenacity of the Stearamide yarn was 4.78% higher than that of the untreated paper yarn.

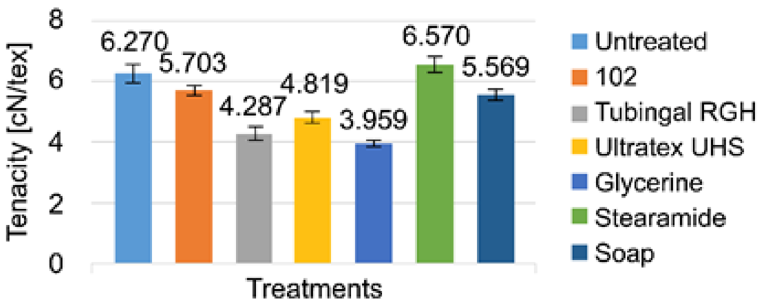

Fig. 1 Tenacity [cN/tex] of the untreated and treated paper yarn

The result of the friction tests, in terms of the coefficient of friction, of the untreated and treated paper yarn are presented in Fig. 2. The untreated paper yarn has a coefficient of friction of 0.35.

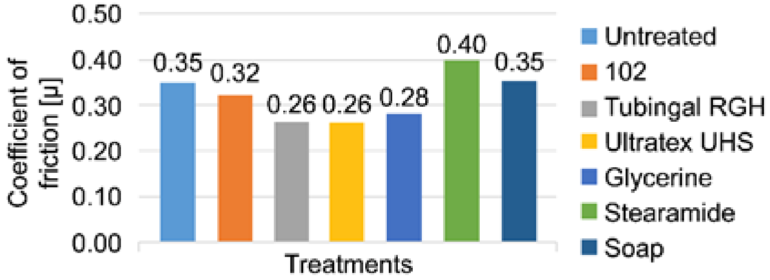

Fig. 2 Coefficient of friction [μ] of untreated and treated paper yarn

The results shows that chemically treating the paper yarn can help decrease the coefficient of friction; however, the mechanical properties may be degraded. In the knittability tests, it was noted that the untreated paper yarn could not be knit when it was dry, as the yarn broke or the knitting machine stopped. In contrast, when wet untreated yarn was used in the knitting process, the yarn did not break, and no machine stops occurred. This phenomenon was also observed for yarn treated with 102, Tubingal RGH, Ultratex UHS, and glycerine.

The findings demonstrate the potential of Swedish paper yarn in serving as a sustainable yarn in the textile and fashion industry.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by the Vinnova project Skogens Tyg, which is aimed at creating an alternative sustainable textile fibre made from twisted paper from the Swedish forest as a renewable resource.

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INFLUENCE OF DEW RETTING DURATION ON THE CHARACTERIS-TICS OF FIBRES EXTRACTED FROM LINSEED FLAX STRAW FOR LOAD BEARING APPLICATION

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ABSTRACT

This work was conducted to investigate the potential of fibers extracted from linseed flax straw for geotextile applications. Four different batches of linseed flax were studied, having different dew retting durations (i.e., from 0 to 14 weeks). Furthermore, a method comprising horizontal breaker rollers, a thresher and then a breaking card was used for extracting continuously the fibers. The different analyses (fibre content inside the starting material, their chemical composition, the length of extracted fibre bundles, the tensile properties of individual fibres, and the fibre purity and yield) show that this resource can be considered for load bearing engineering applications such as geotextiles and composite materials.

INTRODUCTION

Natural fibres get the attention of many researchers, due to versatile properties, renewability, and environmental concerns. For engineering applications specifically, jute, flax, hemp, sisal, kenaf, abaca, and pineapple are nowadays the most used natural fibers (Ghosh et al., 2009). For the next future, linseed flax straw could be an alternate source of bast fibres for technical textiles. In France, 26,000 ha were cultivated for linseed flax in 2017 (Le Ravalec et al. 2020).

In a previous study, Ouagne et al. (2017) extracted successfully fibres from non-retted straw. This mode of extraction was aggressive, and it resulted in the reduction of the mechanical and morphological properties of fibres (350 MPa and 35 GPa for strength and modulus, respectively). In fact, it is not adapted for producing load bearing reinforcement textiles.

Dew retting is a key process when considering fibre extraction. In this study, linseed flax was cultivated in 2018 and 2019 in the South-West of France, and straws were collected after different dew retting durations (up to 14 weeks) after seed harvesting. The influence of dew retting on chemical composition, fibre content inside the straw, fibre length, and tensile properties of individual fibres was studied on fibres extracted using a traditional breaking fluted roller/breaking card route, less aggressive than the fibre opener used by Ouagne et al. (2017).

RESULTS AND CONCLUSIONS

Fibre content inside linseed flax straw (from the Angora cultivar) was found to be globally independent of the dew retting duration, varying from 29% to 32%. The chemical composition of bast fibre samples manually extracted from straws with different dew retting durations is presented in Table 1. As this duration increased, the pectin content was progressively reduced whereas the cellulose content logically increased at the same time. A dew retting duration of at least 12 weeks appears as appropriate to favour fibre extraction.

Depending on the batch, the fibre purity inside the obtained lap was between 67% and 85%, and the fibre yield varied from 23% for batch number 1 to 26% for batch number 4 (Table 2). In addition, the longest dew retting durations (12 and 14 weeks) better preserved the length of fibre bundles. The reduction obtained in the pectin content with longer dew retting durations (batches 3 and 4) contributed also to more resistant individual fibres, for tensile strength and especially for elastic modulus.

Table 1. Chemical composition of the bast fibers inside different dew retted batches of linseed flax straw.

Batch number	1	2	3	4
Dew retting duration (weeks)	0	2	12	14
Pectin content (% of dry matter)	4.4±0.2	4.4±0.1	3.0±0.3	2.7±0.3
Cellulose content (% of dry matter)	62.1±0.4	65.5±0.4	73.9±0.6	75.7±0.4

Table 2. Length of the extracted fibre bundles, mechanical properties of the individual fibres, fibre purity and fibre yield (expressed in proportion to the straw weight) for all the treated batches (n.d., not determined).

Batch number	1	2	3	4
Fibre length (cm)	10.9±5.9	11.1±5.3	13.1±7.1	12.8±7.0
Tensile strength (MPa)	832±578	700±402	922±364	855±348
Elastic modulus (GPa)	41.9±24	40.9±22	56.5±20	52.3±17
Fibre purity (%)	67	85	82	73
Fibre yield (%)	23	n.d.	n.d.	26

To conclude, this work shows that load bearing quality fibres can be produced from linseed flax when a traditional breaking rollers/breaking card route is used. Particularly, the tensile properties are much higher than the ones obtained previously using an “all fibre” opener. The tensile properties and particularly the modulus increase for higher dew retting times. This may be due to an easier extraction from the stems following the decrease of the pectic cements linking the fibres. The tensile properties (≈ 880 MPa and 54 GPa for strength and modulus) are globally situated in the same range of values of hemp extracted using scutching/hackling equipment, and in the lower values of textile flax also extracted by scutching/hackling. These properties combined to a fibre production of about 25% of the stem mass indicate that linseed flax straw processed following the study conditions can lead to the production of fibres fully suitable for engineering load bearing applications such as geotextiles or composite materials.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding attributed to the GEOFIBNET collaborative project by Région Occitanie (France), and the FEDER operational program.

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RECENT DEVELOPMENTS IN SURFACE FUNCTIONALIZATION OF NATURAL FIBERS BY DC REACTIVE SPUTTERING

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ABSTRACT

The functionalization of the surface of natural fibers, especially using TiO2 nanoparticle films, shows a growing interest in their application as yarns in fabrics that require advanced properties such as self-cleaning and photocatalysis. The DC-magnetron sputtering technique has the potential to give new properties to various natural fibers, coating these yarns with nanofilms that give them the advanced properties and required in the markets. However, a good adherence of TiO2 layers remains a major technological challenge. In this work the surface functionalization of TiO2 nanofilms by dc magnetron sputtered, tailored by a high sputtering power Ar/O2 gas mixture, is discussed based on the results of X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS) and Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM/EDS).

INTRODUCTION

Currently, a great attention is given to the use of fibers of natural origin, especially those of lignocellulosic composition (Syduzzaman, 2020). Invasive plants, such as ginger lily (Hedychium gardnerianum), are abundant in various regions of the world and are therefore a sustainable source of fibers for technological applications as an alternative to traditional synthetic glass, polymer or carbon fibers. Although they exhibit good mechanical characteristics, such as high tensile strength, good flexibility and rigidity, the fact that they were manufactured in nature and so have certain specificities that perfectly suit the normal biological functioning of the plant, but that do not serve for technological applications without first being improved. One of these characteristics is the ease of water absorption, which causes them dimensional changes and swelling. This is due to the chemical structure of cellulose, which is an almost linear polymeric chain, with OH groups, highly hydrophilic.

The TiO2 coatings can impart to fibers photocatalytic properties, self-cleaning and anti-fogging properties and a wide range of uses in many other applications There are many methods used for deposition of TiO2 films in fibers such as sol-gel, chemical vapor deposition (CVD) and DC-magnetron sputtering (Eleutério, 2020). The model of charged cluster suggests that the growth of nanofilms is a self-assembly of nanometer-sized charged clusters formed in the gas phase that interact with the substrate surface after the impact. The morphology of the films can be tailored by change of the partial pressure of the reactive gas (Ar/O2) and the sputtering power (Sério, 2011). Moreover, both dense and porous (anatase) nanofilms can be obtained. The influence of the oxygen percentage in the discharge and the sputtering power on the amorphous/anatase phase transition, surface stoichiometry and surface morphology of the films was investigated.

RESULTS AND CONCLUSIONS

The surface of the fibre, as extracted and untreated, as well the surface morphology of the film deposited at 50% O2 with 1000 W are depicted, respectively in Fig. 1-a and 1-b. The results shown the formation of a porous network in the film. A more detailed observation of Fig.1-b evidences the formation of columnar crystallites with intermediate pores due to the low substrate temperature and low surface diffusion coefficient of atoms adsorbed (which correspond to the zone 1 of Thornton model). This study also shows that the growth of amorphous or anatase TiO2 depends on the oxygen concentration in the sputtering system and sputtering power.

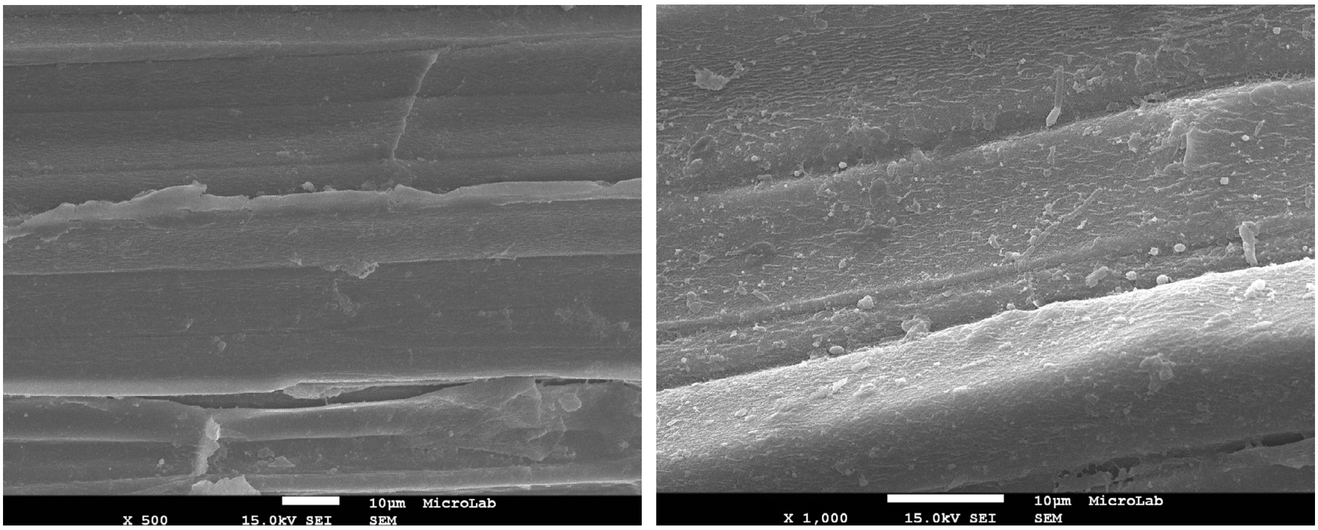

Fig.1 SEM images of ginger lily fibers: a) untreated; b) after TiO_2 sputtered at 1000 W, 50% O_2.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support from (1) FEDER-COMPETE and FCT - UID/FIS/00068/2019; (2) POACORES - Valorização e Desenvolvimento de Produtos da Conteira; (3) Azores FRCT (Fellowship M3.1.a/F/040/2015). The authors also whish to thanks S. Sério and N. Bundaleski, respectively, for help with sputtering equipment and XPS measurements.

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SCREEN-PRINTING OF MICROFIBRILLATED CELLULOSE FOR AN IMPROVED MOISTURE MANAGEMENT, STRENGTH AND ABRASION RESISTANT PROPERTIES OF FLAME-RESISTANT FABRIC

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ABSTRACT

Low moisture absorbency of hydrophobically coated flame-resistant (FR) fabrics do not correlate well with the thermophysiological comfort. In this frame, we were the first to study the effect of screen-printed microfibrillated cellulose (MFC) on fabric's breathability and moisture build-up and transfer as user-friendly and wear-related comfortable coating. The amount of MFC applied and its patterning, evaluated by add-on measurement and microscopic imaging, were studied by using different pressures of the squeegee, and differently dense and thick FR fabrics. The effect of MFC coating and its durability (attachment) after a post-printing of hydrophobic polyacrylate on the same (layer-by-layer) or other side of the fabrics was considered, thus to maintain one inner/side of the fabric hydrophilic (being turned to the body while wearing) while keeping the other outer/side hydrophobic. The results showed that MFC provides uniform and repeatable printing, which gave homogeneous patterning with good layering on the fabrics, although , resulting in the MFC concentration, squeegee' pressure and fabric' structure being dependent on the add-on and its imprinting. This reduced the fabric air-permeability, but increased it surfaces wetting, moisture uptake kinetic and capacity (hydroscopicy), and water vapour transfer. Besides, the polyacrylate could fix the MFC pre-printed on the other side of the fabric, thus maintaining its hydrophilicity, being more pronounced in the case of denser and thicker fabric, while improving its tensile /tear strengths and abrasion resistance.

MATERIALS AND METHODS

The MFC dispersions were prepared from a commercial product Exilva F-01 (Borregaard, Norway). Analytical grade (Sigma Aldrich, Germany) hydroxyethyl cellulose / HEC of 380.000 molecular weight was used as a water-retention additive. The acrylate water-based synthetic printing paste / AP, consisting of polyacrylate self-crosslinking binder, ammonium water, polymeric silicone as an antifoam, melamine resin, ammonium salt of polymeric carboxylic acids as a thickener, acrylic-acid as a rheology additive (all commercial products of CHT Bezema, Germany), adjusted to the viscosity of 105±5 dPa s (Haake Viscotester V2, Thermo Scientific, USA) was prepared by Tekstina Ltd (Slovenia), according to their self-developed recipe. Two woven flame-resistant (FR) fabrics with different constructions were used as provided by Tekstina Ltd, Slovenia https://www.tekstina-tech.si; the fabrics were constructed as two-wefts woven fabrics made from spun yarns (a mixture of meta aramid vs. modacryl and FR Lenzing viscose) in both weft (which predominates on the back side of the fabric, e.g. the outside, facing outwards while wearing) and warp directions, and viscous filaments which also appear in the weft direction, and predominate on the face side of the fabrics (the inside, being turned to the body).

The printing was performed on a Zimmer laboratory screen printing machine using a nickel-based rotary screen of 80 mesh size and steel-rod type squeegee of 15 mm in diameter, at different pressures (no. 2 and 6) and a relevant speed (stage 5 ≈ 6 m/min).). The prints were performed as two-layer printings applied in two separate steps: i) on the same (back/outer) side of the fabric, where the MFC-based dispersion was printed first, followed by printing of AP, or ii) on a different side of the fabric where the MFC was applied on the face (inside turned) side, followed by AP on the back side, using the same printing sequence. After each printing step, the fabrics were dried at 100°C for 3 min and finally cured at 170°C for 2 min. The mechanical properties and wearing comfort (surface hydrophilicity, air permeability, water vapour resistance, abrasion resistance) of the fabrics were analysed.

RESULTS AND DISCUSSSION

The results indicated that the fabrics` properties were affected primarily by the coatings` add-on and their imprinting into the fabric (thus influenced by the fabric density and thickness, and the pressure of the squeegee), and secondly on the way of MFC pre-printing, that may have preserved one side of the fabric as hydrophilic, while improving its surfaces wetting, moisture uptake kinetic and capacity, and water vapour transfer. Improved tensile and warp tear strengths are confirmed (not presented here), as well as abrasion resistance. This is the first study showing potential usage of nanocellulose as a green and user friendly nanomaterial also in textile finishing.

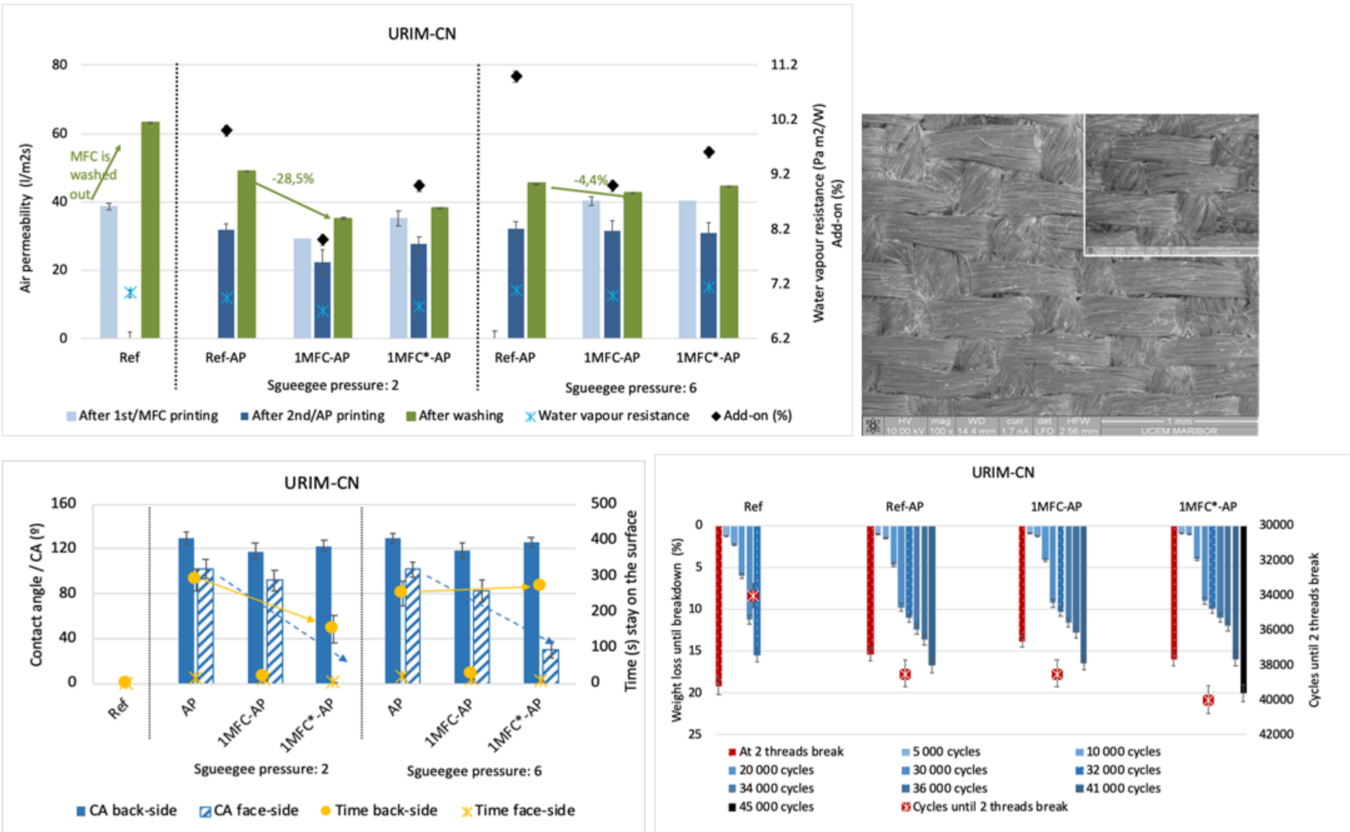

Figure 1. The effect of MFC printing (back or face* side) and squeegee pressure, followed by acrylate paste (AP) post-printing (back side), on fabric` add-on values, air permeability, water vapour resistance, Contact Angle (CA) values and time of milliQ water drop staying on the surface (measured on both-sides of the fabric), and abarions resistance properties (measured on face-side).

FUNDING

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme (Grant Agreement No. 760601), as well as from the Slovenia Research Agency (No. L2-9249 and P2-0118).

FUNCTIONAL PH-SENSITIVE CELLULOSE FABRIC DYED WITH BACTERIAL EXTRACT FROM STREPTOMYCES SP.

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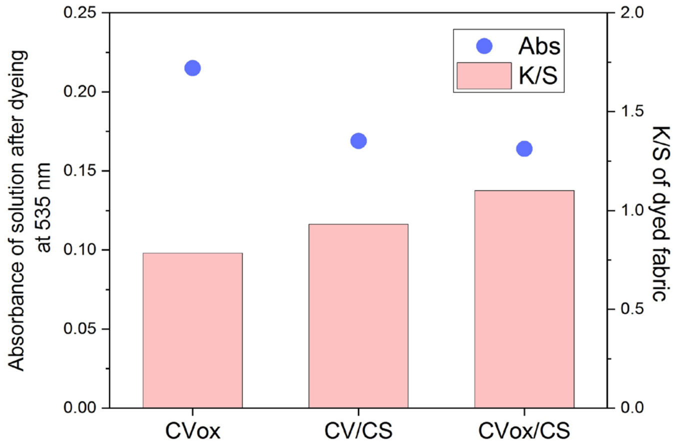
ABSTRACT
In this work, cellulose (viscose) was functionalized with chitosan and dyed with an extract of Streptomyces sp. NP4 bacterial culture. Cellulose was first converted to dialdehyde cellulose; afterward chitosan was deposited, making fabric susceptible to dyeing. The dyed fabric exhibited pH responsiveness in a broad range of pH, 4-7-10, where colour shade of the fabric, exposed to buffer solutions, was pink, red, and blue, respectively. Response to the pH change was measured in seconds, whereby faster colour shift is from blue to red/pink. The dyed fabrics can withstand 10 cycles of colour change. Due to the broad range of pH activity, the presented cellulose product has the potential to be used as a textile pH sensor, and, more importantly, it is completely made from natural and sustainable resources.

INTRODUCTION
Functionalization of cellulose textile materials is usually performed to introduce new functionalities and to obtain a new class of materials for special purposes. The pH-responsive textiles can have an important role as various sensors, i.e. for wound dressings, sweat, or detection of various compounds (Sun et al., 2015; Van der Schueren & de Clerck, 2012) and the development of cellulose-based pH-responsive textiles can contribute to the expansion of application areas for cellulosic materials. Prodigiosins, as bacterial secondary metabolites, have a very high affinity towards textiles and represent a diverse source of colouring agents for textiles (Stankovic et al., 2014). Extract derived from Streptomyces sp. NP4 however, does not have an affinity towards cellulosic material (Kramar et al., 2014). In this work, the hydroxyl groups of cellulose were converted to aldehydes using sodium periodate and afterward low molecular weight chitosan was deposited onto viscose fibres, making fabric susceptible to dyeing with NP4, due to the presence of aldehyde and amino groups on the surface of the fibres (Kramar et al., 2021). The samples used for dyeing experiments were marked as CV/CS (untreated viscose with chitosan), CVox (oxidized viscose), and CVox/CS (oxidized viscose with chitosan). Dyeing was performed at 85 °C for 60 min using 1 % o.w.f. of crude extract NP4. The UV-VIS spectra of residual dye baths were measured and absorbance at 535 nm was compared for different samples. The colour of dyed fabrics was measured using Spectrophotometer under illuminant D65 and 10° standard observer, and their reflectance was also determined. The intensity of the colour K/S was derived from reflectance value at 535 nm. For testing pH responsiveness, samples were placed in a buffer solution of pH 4, 7, and 10, dried and their colour was also measured.

RESULTS AND CONCLUSIONS
The absorbance measured after dyeing at 535 nm, and K/S values of the dyed fabrics are given in Fig.1 (left). As can be seen, the addition of chitosan onto cellulose fibres improves the exhaustion of the dye bath and causes the higher intensity of the fabrics' colour. The oxidation alone (sample CVox) increases the susceptibility to dyeing with NP4, knowing that pristine viscose is only stained, having K/S value ~0.2.



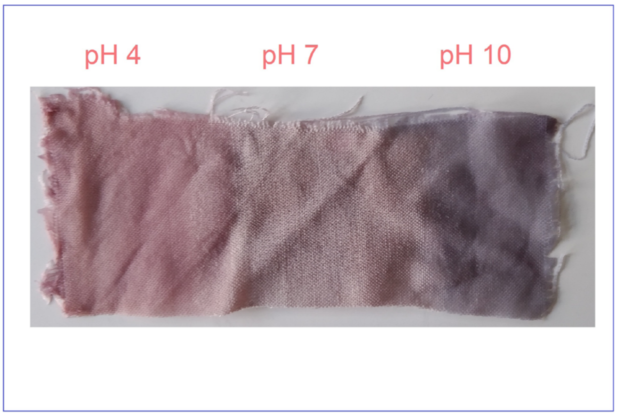


Fig.1 The absorbance of dyebaths after dyeing measured at 535 nm and corresponding K/S of dyed fabrics derived using Kubelka-Munk equation including the reflectances of samples at 535 nm (left); Photograph of the sample CVox/CS exposed to pH 4, 7 and 10

The photograph of the dyed sample CVox/CS and exposed to different pH buffer solutions is given in Fig.1 (right). This study shows that with functionalization of viscose by the introduction of aldehyde and amino groups on fibers surface, cellulose becomes susceptible to dyeing with NP4 and exhibits pH responsiveness in the wide range of pH 4-10.

ACKNOWLEDGMENTS

This work was financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Contracts No. 451-03-68/2020-14/200135 and 451-03-68/2020-14/200042, 2020)

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ECO PRINTING OF LINEN AND TENCEL SUBSTRATES WITH ONION SKINS AND RED CABBAGE

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ABSTRACT
The use of natural materials to design surfaces with colored patterns presents a sustainable approach for textile coloration. This work studied the Eco printing technique through application of onion skins and red cabbage leaves on linen and Tencel substrates, mordanted with tannin and potassium alum. Chromatics and visual effects obtained were analyzed in respect to materials and process variables, namely vegetable, mordant and substrate applied, as well as printing and mordanting methods. Colorfastness properties were also evaluated. The results attained contribute for an understanding of the Eco printing practice and how pattern and color nuances are influenced by the parameters tested. Optimization of the results is also highlighted, namely considering potential application in fashion design.

INTRODUCTION
Increased awareness about the environmental impacts caused by the fashion and textile industry is motivating consumer interest for sustainable products. This fact is stressed due to the excessive use of toxic chemicals in the textile dyeing and finishing processes, presenting threats to human health and contributing to water and soil pollution (Gulzar et al., 2019).
Eco printing is a creative and sustainable technique for creation of colored patterns in textiles, through direct contact with fruits, flowers or other plant materials (Behan, 2018). Also known as bundle dyeing or botanical printing, this technique consists in placing the plant materials on a substrate, which is then folded, rolled and tightly bound. The textile roll is then boiled or steamed, for the dye transfer from the plants to the textile, which results in unique chromatic effects and pattern repeats.
The objective of this work, was to study the Eco printing process of linen and Tencel cellulosic substrates varying a set parameters, namely plant materials used – onion skin and red cabbage – and printing by boiling or steaming.
In addition, coloring textiles with natural dyes commonly requires the use of mordant agents to improve or create affinity between the dye and the textile fiber. Mordant type and concentration as well as mordanting processes were studied in order to analyze their influence in the results. Mordant parameters include 30%, 50% and 70% tannin and 10% potassium alum, applied to the substrates by pre, meta or postmordanting processes.
Samples developed were analyzed according to materials and process parameters influence in the chromatic results and visual effects of the prints. Colorfastness properties were also evaluated for lighting, washing and rubbing, following the test methods AATCC 186-2009, ISO 105-C06 A1S and NP EN ISO 105 D02, respectively. The results were measured in Datacolor International SF600 plus – CT spectrophotometer with Datacolor TOOLS software.

RESULTS AND CONCLUSIONS
All parameters analyzed have directly influenced the effects of color, aesthetics and colorfastness of the

textile patterns. Regarding samples developed with onion peel, it was observed that the tannin generated more discreet colors, while the alum allowed more saturated hues along brown, orange and yellow. Red cabbage printed samples with purple and pink hues obtained more vivid shades when mordanted with tannin than with alum.

Mordanting processes played a significant influence in the expression of the printed patterns. When using onion skin, premordanted samples show an watercolor effect, whereas samples meta and postmordanted present a more defined edge of the onion skin shape. In addition, the simultaneous process also dyed the textiles. Samples printed with red cabbage attained a two colors blurred effect when pre and postmordanted, whereas with the second process, the results were slightly more discreet. Metamordanting process resulted in a textile dyed effect.

The variation of printing processes by boiling or steam did not show a relevant effect in onion peel printed samples, whereas with red cabbage the results were distinct. Patterns created through boiling present subtle stains. By steam, a more attractive pattern of spots similar to jaguar animal print were created showing different colors between the spots outline and fill.

Colorfastness results were also comprehensive. Color differences attained in the light fastness tests showed that after a 72 hour cycle, samples printed with onion skin, pre or postmordanted with tannin attained moderate to good light fastness, both in linen and Tencel substrates. The remaining samples showed higher color change degree results, particularly when printed with red cabbage. For dry and wet rubbing tests, the results showed good resistance with slightly greater degrees in samples mordanted with tannin. Washing fastness tests attained poor or very poor color change degrees in all samples. Though a visual comparison of the samples' images before and after being washed, a decrease of color saturation was observed whereas samples printed with onion skin still presented colored botanical printed patterns.

With the present study it was possible to comprehend the different colors and expressions that can be obtained through adaptations in the printing and mordanting processes, developed with different coloring and mordant materials. The results demonstrate the potential of the Eco printing technique as an approach for the development of differentiated prints for sustainable textile products. Considering the application of the eco prints in the fashion design segment, the low stability in washing of the samples developed, highlights the requirement to test other mordant types to improve affinity between the selected textile fibers and vegetables.

ACKNOWLEDGMENTS

This work is financed by Project UID/CTM/00264/2020 of 2C2T – Centro de Ciência e Tecnologia Têxtil, funded by National Founds through FCT/MCTES. Authors also acknowledge CHEMITEX for linen substrate supply.

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NOVEL TEXTILE FIBERS FROM DATE PALM BYPRODUCTS: PALMFIL

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ABSTRACT

The main aim of the research work was to extract long fibrillated textile fiber and reinforcement from the midrib of date palm. The technical fiber was extracted using a combined alkaline-mechanical process. Different extraction conditions were studied and the technical fiber physiochemical, morphological and mechanical properties were determined. After analysing the SEM results it was apparent that the extraction process was successful in fibrillating the fiber vascular bundles to fine fibrils. Additionally, the delignification was dependent on the severity of the alkaline treatment. The technical fiber density was nearly 1.324 g/cm3 and had tensile strength up to 453 MPa. Moreover, the fiber was thermally stable up to 226 °C and had crystallinity index 58.4 %. The extracted technical fibers had cellulose purity that reached 69%. Date palm fiber extracted in this work, which is named Palmfil, have high potential in being used along with flax, sisal, hemp and jute fibers. The fiber is sustainable, biodegradable, economical, and has excellent properties. The extracted fiber can be used in a wide range of industries such as automotive industry, sporting goods, construction, and packaging.

INTRODUCTION

Date palm (Phoenix Dactylifera L.) is considered one of the abundant sources of cellulosic natural fibers. Date palm is a major crop in the MENA region with a global estimated population of 140 million date palms generating every year 4.8 million tons byproducts of annual pruning. Fibers could be extracted from the midribs, spadix stems, and leaflets (El-Mously 2005; El-Juhany 2010; Elseify et al. 2019, 2020; Elseify and Midani 2020). Date palm as a source of natural fibers is extremely underutilized. Fig. 1 shows the shape of the midribs and spadix stems.

Fig. 1 Date palm midribs (left) and spadix stems (right)

PalmFil could be made into different textile forms; hackled tow, spun yarn, chopped fibers, woven and nonwoven mats as shown in Fig. 2 (2020). PalmFil could be used in various applications such as in automotive, construction and building, packaging, and other application. None of the previous research work succeeded in effectively extracting textile fibers with sufficient length, fineness and cellulose purity, which can be spun into yarns and cordage and then converted into woven fabrics or nonwoven mats. Hence, PalmFil is considered the first successful long textile fiber and reinforcement to be extracted from date palm byproducts of pruning.

Fig. 2 Different textile forms of PalmFil fibers (2020)

EXPERIMENTAL

Material

The Materials used are classified into 2 categories: date palm midribs and chemicals. The midribs were obtained from Egypt at the same time of the year from a female Barhi tree. The chemicals used are high purity sodium hydroxide (NaOH > 99%) and glacial acetic acid (CH3COOH > 98%).

Method

PalmFil fibers were extracted by performing 4-step process; midribs preparation, alkaline treatment, mechanical separation then neutralization. The alkaline treatment used was varied between 27 different combinations of durations, concentrations, and temperature to determine the optimum extraction parameters. After extraction PalmFil fibers were characterized to determine their mechanical, morphological, chemical, and thermal properties. The mechanical properties were determined using single fiber tensile test. Scanning electron microscopy (SEM) was used to determine the fiber's morphological properties. As for the chemical properties, Fourier transformed infrared spectroscopy (FTIR), and chemical composition test were used. Moreover, the fibers density and crystallinity were also determined. Finally, the thermal properties were determined using Thermogravimetric analysis (TGA).

RESULTS AND CONCLUSIONS

The results showed that date palm midrib fibers are composed of cellulosic vascular bundles attached together using lignin. Fig. 3 shows the microstructure of PalmFil fibers (2020). Table 1 the properties of PalmFil fibers

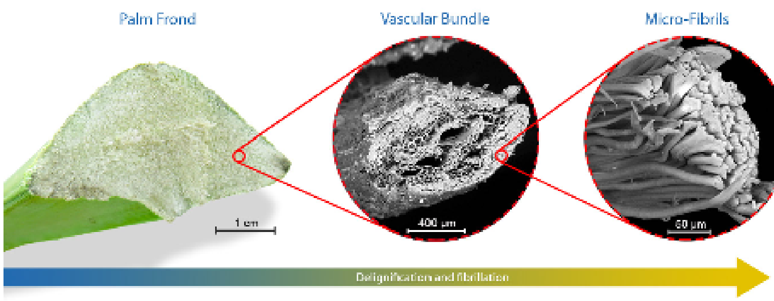

Fig. 3 Microstructure of PalmFil fibers (2020)

	ρ (g/cm³)	d (μm)	Cellulose (%)	σ (MPa)	E (GPa)
PalmFil	1.32	239	69.3	452	21
Sisal	1.33	8 - 200	47.6 - 78	100 - 800	9.4 - 28
Jute	1.46	25 - 200	61 - 75.5	200 - 800	10 - 55
Flax	1.4	40 - 600	70 - 75.2	345 - 900	27 - 80
Hemp	1.48	10 - 500	70 - 75.1	300 - 800	30 - 70

ρ: Density, d: Diameter, σ: Tensile strength, E: Young's modulus

Table 1. Properties of PalmFil compared to other vegetable fibers

It can be concluded that the work in this research is the first successful attempt to effectively extract long fibrillated fibers form date palm midribs. The research succeeded in extracting the fibers using a combined alkaline-mechanical extraction process for the delignification and fibrillation. PalmFil creates value out of the large quantities of underutilized byproducts of the 140 million date palms, which are otherwise open field burned. It expands the palette of natural fibers and increases the biodiversity of fiber crops. Resulting in larger, more sustainable, and economical supply, which supports and encourages the industrial shift back to natural fibers.

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RETHINKING THE WOOL FIBERS DISCARD: DEVELOPMENT OF NEW TEXTILE PRODUCTS

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ABSTRACT

This work proposes and analyse a new textile product completely made from discarded material from the Wool Textile Industry. A Portuguese Textile Industry is a partner on this investigation, where it has been analysed, exposing its most important wastes bottleneck production (that were discarded due to its non-functionality): short fibers discarded from the textile combing process and selvedges discarded from the weaving process. On production of the new and recycled (upcycling) textile material the process of needle punching expressed a satisfactory result and was enhanced by industrial wet felting.

INTRODUCTION

Aware of re-thinking consumption and waste disposal/recyclability, based on scientific studies, the United Nations proposed the “Sustainable Development Goals” which has as mission “A blueprint to achieve a better and more sustainable future for all by 2030” (United Nations, 2021). Thus, as Sustainability has been an important issue throughout academic and scientific fields, expressively increasing in the last years, Textile research field has also enhanced and enlarged investigations on the theme (Muthu, 2017).

To update and remain competitive in the market, within this more sustainable perspective, a Portuguese Wool Textile Industry has sought researchers to develop new products based on its wastes. A survey has been applied on its production chain, expressing two main bottlenecks, considering quantity and solution/recyclability already applied: short fibers, from the textile combing process and selvedges, from the weaving process.

Thus, based on Munari problem solving method (Munari, 2017), literature review was taken as a primary step, which exposed a very few publications/works with the related material. Secondly, Textile Production Technologies were studied for application, where Nonwoven Technology evinced as a better suggestion, due to wastes characteristics (Rewald, 2006). After that, laboratory experiments were performed, notifying a satisfactory result on Needle Punching textile process (within specific sets and configurations). Finally, in order to enhance material consolidation, an Industrial Wet Felting process was done.

RESULTS AND CONCLUSIONS

The textile material reached the Design goal aspect (more aesthetics), remaining Engineering analytics and evaluation to be done (more quantitative), that are in progress tasks.

With the view to analyse quantitatively/numerically material’s industrial and usage potential, Physical characterization tests were chosen – accordingly to the material’s characteristics (Bona, 1992; Miller, 1995) – and performed: a) Determination of tensile strength and elongation – ISO 9073-3; b) Determination of tear resistance – ISO 9073-4; c) Determination of bending length – ISO 9073-7; and d) Determination of the abrasion resistance of fabrics by the Martindale method (mass loss and appearance change) – ISO 12497-3 and 12497-4. All tests were performed comparing this material to another, developed with less short wool fibers, provided by the same industry. Previously, characterization/presentation tests were executed and analysed: fibers identification (by FTIR – Fourier transform Infrared); and grammage (mass per unit area) (ISO 9073-1), on the discarded fibers, two stages of the nonwoven process (base mantle and needle punched) and the material after felting process.

By the moment, where Physical Tests analytics and evaluation are in progress, it is already possible to express that the textile material fully made from short discarded fibers has a satisfactory potential, as an overture for recycling (upcycle) textile wastes, as expressed on Table 1, that shows tensile strength and elongation tests' result, comparing materials.

Material	Breaking St. Mean (N)	Coef. of Var	Extention Mean (%)	Coef. of Var
Short Fib. non-felted	4.93	19.89	41.26	15.11
Normal Fib. non-felted	64.1	13.61	76.5	5.57
Shor Fib. felted	211.5	13.27	80.6	5.64
Normal Fib. felted	308.1	2.707	55.5	3.034

Table 1 Tensile Strength and Elongation Results

Tests expressed on Table 1 were developed on Hounsfield H100 KS dynamometer and following ISO 9073-3. The Wool fiber in case is of 21 microns fineness and the discard on combing machine are of 3 centimeters or less, according to the industry's responsible.

Results show that, comparing, non-felted short fibers material represents 7.69% of non-felted normal size at Breaking Strength Mean, but when felted, short represents 68.64% of normal. On Extension Mean, non-felted short represents 53.93% of non-felted normal, while felted, short represents 145,22% of normal size fibers.

Thus, it is important to express a primarily analytics where results are satisfactory – the material has a considerable physical characterization result. It is also relevant to say that on progress analytics and evaluation are a must for determination of product's usage, by now it is possible to use it for some home textile and decoration. Furthermore, in order to achieve a better status on sustainability issue, it is substantial to apply a Life-Cycle Assessment (LCA), supporting the material's sustainable aspect.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the A Penteadora S.A. and FEPSA industries for its considerable contributions to the development of this work and research.

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THE FORMATION OF A FIBROUS RIBBON OF DENSE STRUCTURE

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ABSTRACT
This article is devoted to the features of the formation of a fibrous ribbon of a dense structure in the process of rotor spinning from fibers of finite length. For this, the fibrous ribbon, depending on its width, is divided into loose, dense and twisted structures. The conditions that ensure the formation in the trough of the rotor of a fibrous ribbon of a dense structure from which high-quality yarn is obtained are considered. The dependences of the width of the fibrous ribbon on these factors are determined. It is established that the twist of yarn and the rotational speed of the rotor have the greatest influence on the width of a fibrous ribbon of a dense structure. The least influence is exerted by the length of the fiber and the diameter of the rotor, which is recommended to take into account when producing OE yarn from cotton fiber.

INTRODUCTION
Professor, University of Manchester (England) J.W.S. Hearle the structure of the OE yarn, divided into a yarn of a free, dense and overlapped structure [1]. The formation of yarn from an uneven screw-like arrangement of the ribbon is observed at free and closed positions. Therefore, it is indicated that a uniform helical arrangement can only be with a dense structure. With this in mind, the factors determining the ribbon width bd in the trough of the spinning rotor, providing a dense yarn structure, were studied [2]. In a number of works, the multi-layered structure was considered and the influence of technological and kinematic factors on the structure and properties of OE yarn were studied. In known works the limiting width of the ribbon necessary for the formation of a yarn from dense structure is considered. For the practical use of the formula for the maximum width of the fibrous ribbon from the trough of the spinning rotor, its dependences on the factors influencing it are determined. The factors determining the limiting width of the ribbon bd from the trough of the spinning rotor, which provides a dense yarn structure, were studied [3].

RESULTS AND CONCLUSIONS
To determine the dependences of the limiting width of the ribbon, affecting the formation of a yarn from dense structure, its formula is derived. For this, the formula for the maximum width of the ribbon, which provides a dense yarn structure, is adopted.

$$b_d = \frac{h}{\sqrt{1 + \frac{h^2}{(\pi d)^2}}} \qquad [1]$$

It is known that the maximum width of a ribbon is affected by the height of one twist of the torsion and the diameter of the yarn. It was found that the ribbon width bp also depends on other factors such as twist factors, spinning rotor rotation frequency, yarn diameter, its linear density, density, fiber length and spinning rotor diameter [4].

Pneumomechanical yarn has a two-layer structure, i.e. core and curl layers. Therefore, when determining the ribbon width of a dense structure, it is recommended to take into account the capture ratio determined by the ratio of half the fiber length to the perimeter of the spinning rotor, i.e. $C_r = \frac{1}{2\pi D}$. With this coefficient in mind, the linear density of both the core and the curl layer with respect to the linear density of the produced yarn changes, i.e.

$$T_{st} = T_d(1 - C_r) \quad \text{or} \quad T_{st} = T_d(1 - (0.159 \cdot l / D)) \qquad [2]$$

Thus, the maximum width of the ribbon is determined by the formula according to which the main factors affecting the maximum width of the ribbon are twist, linear density and density of the yarn, as well as the length of the fiber and the diameter of the spinning rotor.

$$b_d = \frac{1000}{K\sqrt{1 + \left(\frac{8921\sqrt{\rho}}{K\sqrt{T\left(1 - \left(0.159\frac{l}{D}\right)\right)}}\right)^2}} \qquad [3]$$

In order to study in more detail, the influence of independent factors on the width of the ribbon, which provides a dense yarn structure based on formula (3), the change in bd was determined under the influence of the following factors [5].

By solving the equation using the Madhcad program, the optimal parameters were determined at which the minimum width of the fiber ribbon is formed, which ensures the minimum unevenness of the yarn. They are: linear density of the yarn 20-50 tex, rotor speed 100000-150000 min-1, rotor diameter 28-36 mm. Experimental studies have been carried out to determine the influence of the rotor parameters on the width of the ribbon. It was found that with an increase in the speed of rotation of the spinning chamber, the width of the fibrous ribbon decreases due to an increase in the density of the fibers and the quality indicators of the yarn improve.

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CORRELATION BETWEEN RHEOLOGY AND MORPHOLOGY OF ELECTROSPUN RECYCLED POLY(VINYL BUTYRAL) FIBRES

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ABSTRACT

Poly(vinyl butyral) (PVB) dominantly used in car windshields creates ecological threat due to its waste volume every year. Electrospinning of fibrous webs produced from wasted PVB represents an efficient process how to re-use this material. It was shown that quality of recycled PVB fibres can be correlated with rheological properties of the corresponding solutions (ethanol used as a solvent). This enables to estimate an optimal concentration for obtaining acceptably smooth and circular fibres.

INTRODUCTION

Polyvinyl butyral has been used in many applications especially as laminated glass windscreens in the automotive and building industries (Swain et al., 2015) due to excellent adhesion to glass, desired film-forming properties, high optical clarity, flexibility and toughness. Recycling PVB (rPVB) sheets from the windscreens represents an uneasy problem caused by presence of glass scrap and non-negligible content of plasticizers which composition depends on the individual manufacturers (Tupy et al., 2014). However, pressure (including EU) for sustainable life has been reflected in various measures and directives ordering non-cosmetic reduction of PVB deposition in the landfill and paying an attention to recycling. PVB recycling is expensive and hence, application expenses should be minimized. In this respect electrospinning represents a cheap process producing fibrous materials. The aim of this contribution is evaluated quality of fibrous webs (beadless fibres) through rheological properties of rPVB solutions.

RESULTS AND CONCLUSIONS

Analysis of electrospinning process was carried out in two parallel ways: rheological characterization of entry polymer solutions (rPVB dissolved in ethanol) differing in concentration (4, 6, 8, 10, and 12 wt.%) and processing the final fibres (their smoothness and diameters).

Rheological properties measured in shear (shear viscosity) and oscillatory (complex viscosity, loss (G") and storage (G') moduli) modes were obtained using a rotational rheometer Physica MCR 501 (Anton Paar, Austria). A phase angle φ ($\tan \varphi = G''/G'$) describes a measure of viscoelasticity of the studied materials. In other words, the phase angle represents a relation between viscous and elastic components.

Fibrous webs were produced by a needleless electrospinning device with the following pre-set parameters: tip-to-collector distance was 15 cm and voltage attained 20 kV. Morphology of electrospun fibres was characterized using a Vega 3, scanning electron microscope (Tescan, Czech Republic). Fig. 1 depicts quality of fibre surface for the individual concentrations. Usually unwanted beads are characterized by sudden expansion of a diameter followed by its abrupt decrease. Analysing SEM pictures with use of the Adobe Suite software the mean fibre diameters were determined based on the measurement of 300 different fibres.

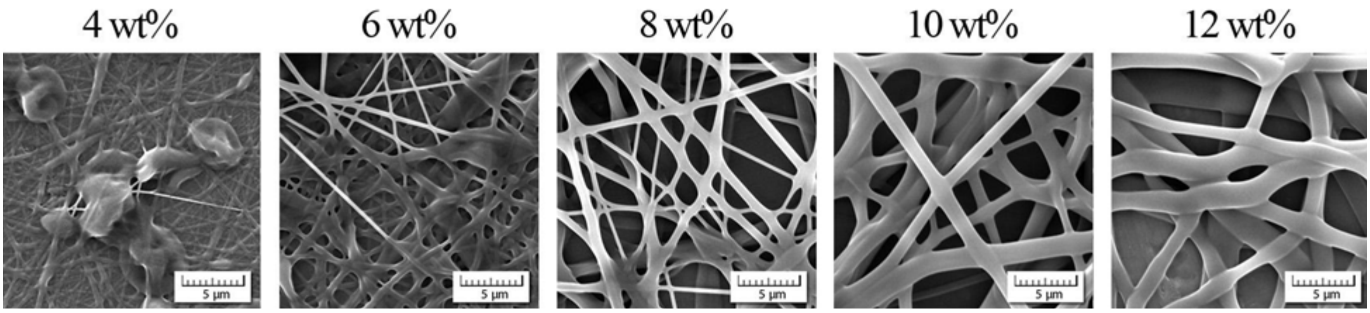

Fig. 1 SEM images of rPVB fibres.

Concentration [wt%]	Shear viscosity [Pa.s]	Complex viscosity [Pa.s]	Phase angle [deg]	Fibre diameter [nm]
4	0.0115	0.0188	90	305±100
6	0.0251	0.0511	90	480±170
8	0.0881	0.0940	90	750±240
10	0.2350	0.2300	88	1320±490
12	0.6570	0.5800	86	1455±450

Table 1 Shear and complex viscosities, phase angle of rPVB solutions and mean diameter of resulted fibres

The preceding findings imply that approximately 8 wt.% solution is optimal for producing fibrous layers with smooth surface potentially applicable in filtration, nanocomposites or sound absorption membranes. The size of an optimal percentage can be relatively fast approximated by cheap rheological measurements eliminating time and cost demanding trial-and-error electrospinning experiments.

ACKNOWLEDGMENT

This research was supported by the Ministry of Education, Youth and Sports of the Czech Republic (Project LTC 19034 and RP/CPS/2020/003).

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TECHNOLOGY DEVELOPMENT FOR BETULIN INTEGRATION INTO NANO-FIBERS WEB

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ABSTRACT

Preparations containing birch bark extract Betulin are used in medicine and cosmetics for skin care and treatment, whereas this biologically active compound is known to restore skin cells. At the same time, studies have shown that application of this compound as potential therapeutic agent is limited by its low bioavailability, high hydrophobicity, and insufficient intracellular accumulation. The use of nano-scale technologies could improve effectiveness of treatment with betulin (BE) -containing medicinal products in cosmetic/medical devices. In the experiment analysed betulin powder was used as biological active substance integrating it into the nanofibers web. During the preparation of spinning solution, the betulin powder was dissolved with ethanol (ET) then the resulting solution was combined with the 10 wt% polyvinyl alcohol (PVA) solution creating three types of spinning solutions with different betulin concentrations. Corresponding nanofibers webs obtained by using Nanospider type electrical electrospinning device.

INTRODUCTION

The use of nanotechnologies in cosmetic and medical materials is increasingly apparent every year in the product supply of manufacturing companies. Included in the polymer, betulin (Peipins, 2015) is able to improve its physical and chemical properties as well as its therapeutic result by significantly accelerating effect (Rigon, 2015, Schwieger-Briel, 2017, Amiri, 2020). The needle electrospun betulin colloidal dispersion blended with aqueous PVA solutions is considered to be a hopeful alternative for wound therapy, where effective remedy is needed (Mwiiri, 2020). Integration of betulin into nanofibres will allow to expand application areas and efficiency

RESULTS AND CONCLUSIONS

The technology presented is based on the acquisition of betulin loaded nanofibers web using a needleless electrospinning device NanoSpiderTM (Elmarco). To obtain spinning solution the betulin powder is dissolved with ethanol, creating 0.04 %wt, 0.7 %wt and 5 %wt solutions. The resulting solutions were obtained by combining each of BE solutions with the 10 wt% polyvinyl alcohol solution in water. This results in three spinning solutions with a very low, low and relatively high Betulin content, respectively marked: A (PVA10%/BE 0.4%), B (PVA10%/BE0.7%), C (PVA10%/BE5%) and D (PVA10%).

Table 1

Nano-web Fiber diameters

	D	A	B	C
Mean (nm)	496.9	387.3	357.7	175.9
-/+	15.8	8.3	20.3	8.6

The average fiber diametrs measured from the SEM micrographs are shown in Table 1. Comparative analysis of Table 1 data leads to the conclusion that the average diametrs of the fibers and the unevenness of the diameters decrease as BE content increase.

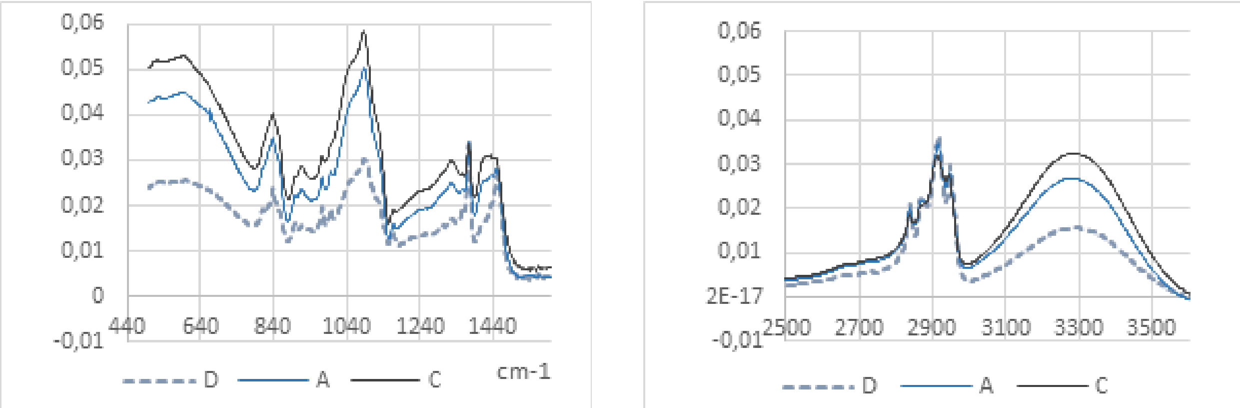

Fig.1. ATR-FTIR absorption graphs. D) PVA10%; A) PVA10%/BE 0.4%; C) PVA10%/BE 5%

A comparison of Fig.1 graphs (left) shows that absorption intensity increases in betulin-containing fibre spectra A and C in a wide wave number range 450-750 cm-1, with a very strong peaks at 1105-1140 cm-1 and medium strong band at 1419-1451 cm-1. Absorption increase at the frequency range 3200-3400 cm-1 (Fig.1, right) indicate a presence of betulin -OH groups. In total, with the betulin content increase in fibers, the intensity of absorption increases. As we can see, absorption spectra make it possible to detect a very low presence of betulin content in the fibers.

ACKNOWLEDGMENTS

This research/publication was supported by Riga Technical University's Doctoral Grant programme. This work has been supported by the European Regional Development Fund within the Activity 1.1.1.2 "Post-doctoral Research Aid" of the Specific Aid Objective 1.1.1 "To increase the research and innovative capacity of scientific institutions of Latvia and the ability to attract external financing, investing in human resources and infrastructure" of the Operational Programme "Growth and Employment" (No. 1.1.1.2/VIAA/4/20/648).

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CAN A FULL VALUE CHAIN BE ESTABLISHED FROM THE FIELD TO THE FIBRES FOR THE PRODUCTION OF FINE GARMENT TEXTILES FROM HEMP FIBRES

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ABSTRACT

This work discusses the potential of hemp fibre for the establishment of a complementary value chain for the production of fine garment textiles. The work seeks to demonstrate that sufficient dew-retted straw can be produced and high fibre yields obtained at the output of the scutching/hackling processes together with a high fibre quality in terms of morphological (fineness) and mechanical potential for the production high added value fine yarns. The possibility to establish a complementary value chain to flax is analysed.

INTRODUCTION

At the present time the main income for the hemp farmers is constituted by the seeds and the surfaces cultivated with this goal are in constant rise. However, the historical resource constituted by the fibres and in a lower extent by the shives (woody part of the plant) should not be neglected in the frame of a long-term valorisation of this plant (Tang 2016). Nowadays, the fibres are used (after the harvest of the seeds) for paper manufacturing or for short fibre reinforcement in polymer composites. In the meantime, the demand for flax long line fibres for fine garment textile is always increasing. However, the land available in traditional European production areas is globally used at its maximum potential and an alternative source of long fibres that could be used for the textile industry for fine garment product would be welcome. Traditionally used for this purpose before its ban in mid-20th century, hemp fibres could be complementary to the flax ones and the cultivation of hemp plant introduced within the flax rotation in traditional production zones. In Normandy, because of its wet weather in the autumn, it is difficult to imagine harvesting hemp at seed maturity if one wants to conduct a dew-retting step in good conditions and bale dry straws in October. The harvest should therefore take place early in the summer close to the flowering period and the crop is therefore dedicated to fibre production (and shives as a by-product).

Several challenges at the harvesting step and at the fibre extraction step using the scutching process have to be tackled. At the harvesting step, new harvesting machines now exist on the market and are improved every year to reach the requirements of an industrial production. The management of dew-retting was also very much studied and can be successfully conducted by the experimented farmers in the traditional flax production zone.

For a new value chain to develop, sufficient fibre yields and particularly the long line fibre which constitutes the highest income for a fibre dedicated crop should be reached.

This work therefore proposes to discuss the straw production yields for different varieties cultivated in

RESULTS AND CONCLUSIONS

During her PhD, (Grégoire 2021) showed that high long line hackled fibre yields could be reached using a laboratory scale scutching/hackling device. Hackling yields of up to 18% of the hemp stem mass was reached and the quality of the fibres was equivalent to the one obtained using an industrial device. Until recently, very low fibre yields were obtained at the output of the scutching/hackling processes (Musio 2018), but improvements suggested following the labscale results conducted with specific process parameters were obtained and fibre yields were globally doubled to reach values close to 20% for the scutching yields and 10% after the hackling process.

The morphological and mechanical properties of the technical fibres obtained at the end of the hackling process were determined for different hemp varieties and analysed in relation to their potential for fine yarn transformation. Beyond the labscale analysis, the fibre produced were analysed and qualified by the spinning industry buyers and judged for the best batches as high potential for fine yarn production, confirming the lab morphological and mechanical tests results.

Straw yields of three dew-retted hemp cultivars in different places coming from different places in Europe are discussed and the fibre yields obtained are also compared to the amounts of flax fibre obtained per hectare. The possible source of income of textile dedicated hemp is discussed, analysed and compared to the ones provided by traditional crops such as wheat for example so that to estimate if hemp can be at the source of a complementary value chain to the flax one.

"hard composites" in toe-puffs, stiffeners and other shoe reinforcement components.

ACKNOWLEDGMENTS

This project has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No 744349 – SSUCHY project. The authors ALSO gratefully acknowledge the funding by the Agence de l'Eau de Seine et Normandie.

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PRODUCTION OF HEMP ROVING USING CLASSICAL FIELD MANAGEMENT TECHNIQUES AND CARDED ROUTE

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ABSTRACT

Hemp fibres can be extracted using different techniques such as scutching/hackling or "all-fibre" extraction. The extraction process used has an impact on the morphological (length, fineness...) and mechanical properties of the fibres obtained. In this study, hemp fibres were extracted from stems of the FUTURA 75 variety grown in Piacenza (Italy) using two different "all-fibre" extraction routes: a fibre opener and a breaker card. The mechanical properties of the individual fibres as well as the morphological properties of the technical fibre bundles extracted using these two techniques were evaluated and compared.

INTRODUCTION

Used for a long time in the textile industry and for the manufacture of ropes and sails for the armament of sailing ships, hemp cultivation declined progressively during the 19th century until it was prohibited in the middle of the 20th century (Bouloc, 2013). Hemp is a plant well adapted to most European growing conditions and its components (seeds, fibres, shives and inflorescences) can be used in many fields. A renewal of interest in this material has been observed in recent years (Carus, Karst, Hobson, & Bertucelli, 2017). However, to date, hemp fibres are mostly used in the paper industry or as short fibre reinforcements for composite materials. The expected fibre qualities for these types of applications are significantly different from those required for composite applications for structural parts. In this case, it is necessary to preserve the highest possible mechanical and morphological fibre properties and one of the most impacting parameters is the type of extraction used.

There are two main extraction routes depending on the type of material presented at the device input (Müssig & Haag, 2015). If the straw is ordered in a parallel maner, it is possible to use a scutching/hackling route to extract the fibres. With this process one can obtain load bearing quality fibres that are suitable for structural composite applications. However, this approach uses the value chain of the flax industry and is therefore only available near its traditional growing areas. If this type of device is not available, it is therefore possible to use other extraction routes, with non-aligned straws, which is the traditional way of hemp harvesting. It consists in using an extraction device called "all-fibre". The hammer mill is the most widely used technique to date when the input material is non-aligned. It is however very aggressive and damages the fibres, in particular by significantly reducing their length. Two other types of all-fibre extraction devices have therefore been studied.

The first fibres were extracted from the stems of hemp of the FUTURA 75 variety grown in Piacenza by the Università Cattolica del Sacro Cuore (Italy) using an all-fibre Cadette line developed by the company Laroche. This fibre opener allows a quick extraction of the fibres but has the main disadvantage of reducing their length (Grégoire et al., 2019), and the fibres are unsuitable for the manufacture of rovings type yarns. A second type of device (breaking rollers and breaker card) was therefore used and its impact on the morphological and mechanical properties of the fibres was studied. The mechanical properties of the fibres were determined by performing tensile tests on single fibres using a tensile device developed by Dia-Stron Ltd. The evolution of the morphological properties was mainly studied by measuring the lengths of technical fibres at the exit of the device.

RESULTS AND CONCLUSIONS

Morphological properties (technical fibre fineness) are presented in in Figure 1. They show that extraction using a carding device allows much greater lengths of technical fibres in comparison to with the fibre opener.

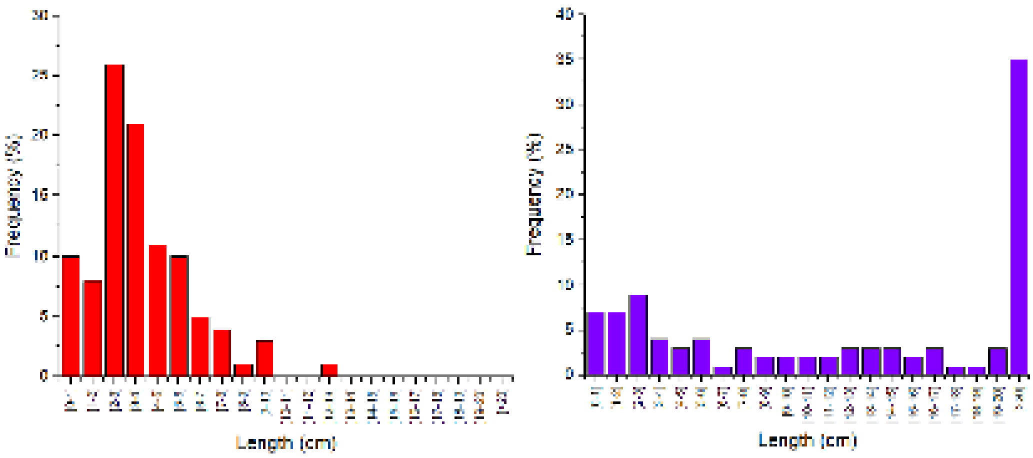

Fig. 1: Frequency of appearance of the fibres on the length ranges. Batch 1 (on the left): extraction with a fibre opener - Batch 2 (on the rigth) : Extraction with a carding system

A manual sorting of the shives trapped in the fibres at the end of extraction has shown that the use of the carding machine eliminates a larger quantity of shives than extraction using a Laroche-Cadette type fibre opener.

The mechanical properties of the elementary fibres determined by tensile tests will also be presented and a full analysis of the carded route performed in relation to its potential to generate load bearing composite reinforcement fibres.

ACKNOWLEDGMENTS

This project has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No 744349 – SSUCHY project.

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PHYSICOCHEMICAL SURFACE CHARACTERIZATION OF HEMP FIBRE REINFORCED POLYMER COMPOSITES: ANALYSIS OF THE EFFECT OF VARIOUS FIBRE SURFACE TREATMENTS ON THE INTERFACIAL ADHESION

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ABSTRACT

Hemp fibres have specific mechanical properties similar to glass fibre and have the potential to serve as an eco-friendly alternative. However, the strength of their composites is greatly reduced due to compatibility problems at the interface between hemp fibres and polymers. This research focuses on the study of the interface of hemp-polymer composites of treated (alkali and silane) and untreated hemp fibres and different polymers (biobased furan, epoxy, polypropylene PP, and poly lactic acid PLA). The interfacial bond strength (practical adhesion) was characterized with the apparent interfacial shear strength (IFSS) by means of pull-out tests. Moreover, surface energy components of hemp fibres and matrix polymers were analysed to asses physical adhesion of the different systems, and X-ray photoelectron spectroscopy (XPS) analysis was used to study the chemical surface composition of treated and untreated hemp fibres. The results show that the interface of hemp-furan systems exhibits the best mechanical properties (fibres break before pull out of the polymer droplet) due to a combination of good physicochemical interactions and a high degree of mechanical interlocking.

INTRODUCTION

With the increasing demand for natural fibre reinforced composites, a lot of effort is put in improving their mechanical properties. The weakest part of these composites is often the fibre-matrix interface. This weakness is usually attributed to a bad compatibility between the typically hydrophilic reinforcing fibre and in particular hydrophobic thermoplastic matrices, and to the anisotropic nature of natural fibres, and particularly hemp in this study, that provokes a great reduction of their transversal and shear mechanical properties. To achieve a composite with good mechanical properties, a strong fibre-matrix adhesion has to be obtained by interfacial interactions, including mechanical interlocking, chemical bonding and physical adhesion.

Here we analyse the interfacial adhesion strength between hemp fibres and different polymers (Furan, epoxy, PP, and PLA) by performing microdroplet pull out tests. The microdoplet test is a method to assess the apparent IFSS of a fibre/matrix system. The apparent IFSS differs from the real IFSS because it is assumed that frictional contributions and thermal stresses can be neglected, and thus their values depend on the embedded area of the fibres. Also, a constant fibre-matrix interfacial shear stress is assumed, which is a simplification. In this work, we assumed that if all samples have similar embedded areas (by controlling the polymer droplet size), the frictional contributions are similar and thus the apparent IFSS values can be compared between different hemp-polymer systems. Physical (surface energy) and practical adhesion (IFSS) were contrasted to determine whether physical or chemical interactions have a higher contribution in the final practical adhesion.

RESULTS AND CONCLUSIONS

Table 1 shows the IFSS shear strength values for the different hemp/polymer systems. Untreated hemp/PP shows the lowest performance due to the non-existence of chemical interactions between hemp and PP and the very low surface energy of PP [1]. The hemp/PLA system exhibits an IFSS of 13.34 MPa, which is only 21% lower than the IFSS of the hemp/epoxy system which is associated to the chemical bonding of OH groups on the surface of hemp fibres to reactive groups of the epoxy resin. The high performance of hemp/PLA is due to the existence of polar surface energy components in PLA. The best mechanical performance was exhibited in the hemp/furan systems, where the pull out of the polymer droplets was not possible due to good fibre/matrix compatibility and the high mechanical interlocking at the interface, as demonstrated by scanning electron microscopy (SEM) analysis.

Table 1 IFSS of different hemp/polymer systems for an embedded area of ~0.08 mm². Pull out of the cured furan droplet was not possible due to high mechanical interlocking and adhesion, producing the breakage of the droplet.

System	IFSS (MPa)
Untreated hemp/Furan	Fibre breakage
Water treated hemp/Furan	Fibre breakage
NaOH treated hemp/Furan	Fibre breakage
Untreated hemp/epoxy	16.09
Untreated hemp/PP	4.75
Untreated hemp/PLA	13.34

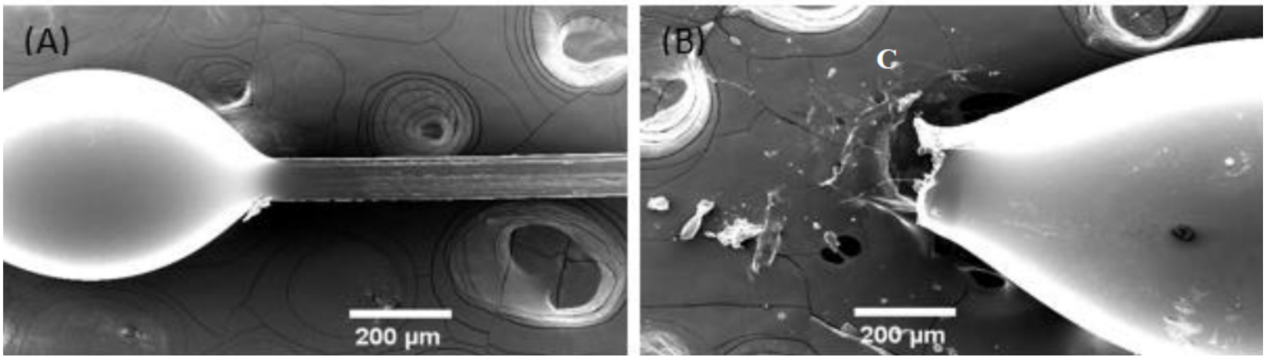

Fig.1 (A) A cured micro droplet of furan formed around a hemp fiber. (B) A droplet of cured resin after an unsuccessful pull out test due to fiber failure at the tip of the droplet.

ACKNOWLEDGMENTS

This project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No 744349

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EFFECT OF DIFFERENT AGEING TESTS ON FLEXURAL PROPERTIES OF NON-DRY FLAX FIBRE/EPOXY COMPOSITES

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ABSTRACT

This work evaluates the flexural behaviour of composites made of non-dry flax fibres (conditioned at 80% relative humidity) and epoxy resin subjected to different ageing tests: water immersion, long-term moisture cycling and natural ageing. The experimental results showed that composites made of non-dry fibre presented better flexural properties than composites made of dried fibre when exposed to different ageing conditions.

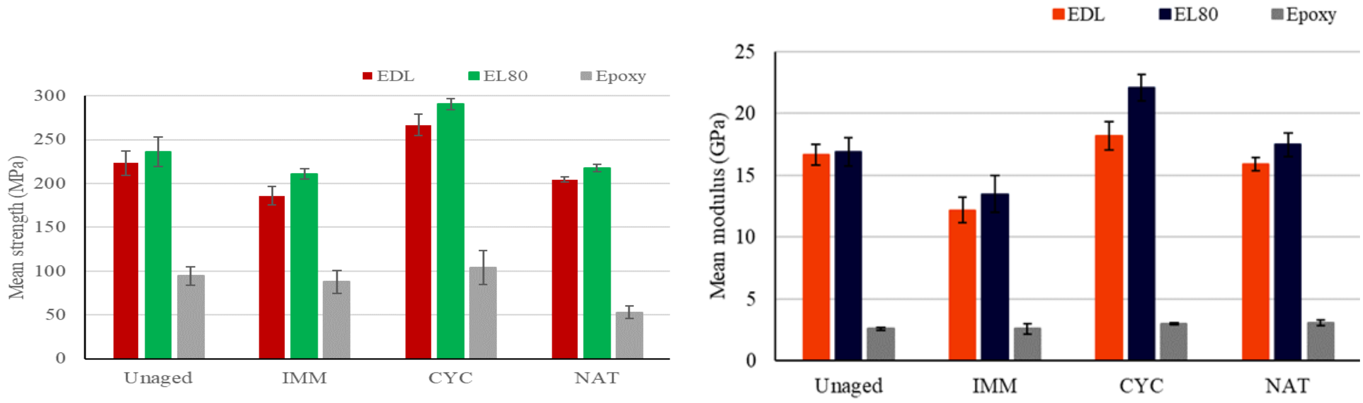
INTRODUCTION

The durability of natural fibre composite (NFC) is one of the critical issues that should be considered in engineering applications. The durability of NFC involves resistance to different weathering factors that may threaten their performance over time which includes moisture uptake, biodeterioration, photodegradation, or a combination of these agents (Lopez et al. 2006). In the literature, several researchers have studied the effects of moisture on the durability of NFC through various approaches. Some of the approaches used are water immersion, cyclic exposure to alternate wetting and drying, and natural ageing tests. The natural ageing test can directly reflect the changes in the mechanical properties of NFC in an outdoor environment. However, most research on the moisture durability of NFC focusses on accelerated ageing tests due to their convenience and time-saving. Although UV accelerated tests were already used in NFC ageing studies (Silva et al. 2020), few works involve natural exposure. Using both the natural ageing and accelerated ageing approaches to study the changes in mechanical properties of NFC has been rarely reported up to now.

It is common practice when manufacturing NFC that the fibres are first dried or conditioned before use. The drying of the fibre is performed to remove or control moisture which can result in voids and poor fibre-matrix adhesion (Rassmann et al. 2010). The disadvantage of using dried fibres as reinforcement in composites is when the composites are subjected to high moisture environment; the composites will definitely sorb water which could cause degradation of the composites. Therefore, this study uses non-dry flax fibre and resins with low sensitivity to moisture to benefit from the moisture present in the pre-swollen fibre to enhance the moisture durability of composites. In our previous study, the water immersion test results of flax/epoxy composites were presented. While in this study, the results of different ageing tests will be compared, and the equivalence effects of each ageing test with the other methods were determined. Specifically, this study determines the effects of using non-dry flax fibre on properties of flax/epoxy composites under the water immersion (IMM), long-term moisture cycling (CYC) and natural ageing exposed to sunlight (NAT) tests. The flexural properties of composites are compared to the unaged composites and neat epoxy resin.

RESULTS AND CONCLUSIONS

The results are presented with a composite coding system. Composites made of dried fibre in longitudinal fibre orientation is presented with a code EDL, whereas, EL80 are composites made of fibre conditioned at 80% RH in longitudinal fibre orientation.



a) b)

Figure 1. Flexural properties of flax/epoxy composites in longitudinal fibre orientation after the different ageing tests: (a) mean strength and (b) mean modulus.

A comparison of flexural properties of composites in a longitudinal direction after the different ageing tests is shown in Fig.1. Overall, results indicate that the retention of longitudinal strength and modulus of EL80 exposed to IMM, CYC and NAT tests are higher than EDL. It means that composites made of non-dry fibre are more stable to moisture degradation than the composites made of dried fibre.
Also, the natural ageing seems better simulated by immersion testing than by cyclic moisture exposure. Remarkably after cyclic moisture treatment, natural fibre composite properties even improve over time.

RESULTS AND CONCLUSIONS

The authors would like to acknowledge the financial support of the EU-H2020 BBI project "SSUCHY" [grant number 744349]; and The University of the Philippines – PhD and Master's Fellowship Program for Faculty and REPS.

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NATURAL FIBRE COMPOSTES MANUFACTURE USING WRAPPED HEMP ROVING WITH PA11

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ABSTRACT

The objective of this study is to realize a hybrid hemp / thermoplastic roving for composite manufacture. The hybrid roving has to be resistant enough to sustain the tension and abrasion stresses during the weaving process. A multifilament of polyamide 11 is wrapped around a hemp roving to obtain the hybrid yarn with a sufficient resistance. This wrapped roving is woven then the composite plate is produced by a thermo-compression process. Textile properties and mechanical properties are characterized at each production scale; roving, preform and composite.

INTRODUCTION

The growing ecological concern leads to increased interest of scientists and industries for natural fibers, such as hemp, for composite applications. These fibers have interesting specific mechanical properties, thanks to their low densities, and good thermal and acoustic insulation properties (Corbin, 2020). Moreover, these fibers are renewable, bio-sourced, biodegradable and safe for human health, unlike synthetic fibers used traditionally in the production of composites (Misnon, 2014 and Pil, 2016). However, the use of natural fibers for structural composite applications can be limited because of their natural variability in terms of chemical composition, morphology, and physical properties due to plant defects and variations of the environmental conditions (Haag, 2017).

The roving is an intermediary scale in spinning process, and it has a low twist compared to a yarn. The compaction increases strongly with the twist level imposing high difficulty for the resin to penetrate inside the yarn structure (Goutianos, 2003 and Omrani, 2017). But a low twist implies poor mechanical properties in the roving.

To improve these mechanical properties, two techniques are mainly used: a chemical treatment or the wrapping process. The chemical treatment produces modification of the fiber microstructure, whereas the wrapping process is a mechanical technique which doesn't cause any change in the microstructure or the chemical composition of the fiber. In this process, a thermoplastic multifilament is wrapped around a roving resulting in increased inter-fiber friction and improved roving cohesion. Another advantage of this technology is the addition of a thermoplastic multifilament to the dry preform with the reinforcing fibers, and serves as the resin. So the composite part can be obtained directly by thermo-compression technique, in which the dry preform is pressed between two hot plates to melt the thermoplastic forming the matrix (Baghaei, 2013), without need for liquid resin injection or infusion step. The thermoplastic multifilaments is a bio-polymer polyamide 11 (PA11) prepared from castor oil (Martino, 2014).

RESULTS AND CONCLUSIONS

The first results show good mechanical properties for wrapped yarn comparatively to roving alone. The tensile properties increase by 24 %.

Therefore, it is possible to weave structure with wrapped roving, then to realize 1 or 2 plies composite by thermo-compression. Porosity, fraction volume, and tensile properties are studied for composite.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Italian company Linificio and Canapificio Nazionale (LCN) for providing the hemp rovings used in this study. This project is funded by "Bio Based Industries Joint Undertaking" under the "European Union's Horizon 2020" Research and Innovation Program with Grant Agreement No. 744349 - SSUCHY Project and Hauts de France Region.

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DAMPING BEHAVIOR OF HEMP AND FLAX FIBRE REINFORCED GREENPOXY COMPOSITES

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ABSTRACT
Plant fiber composites (PFCs) are considered as promising solutions to develop lightweight sustainable structures. However, their damping behavior is not yet fully characterized and understood. This study proposes a multi-scale investigation of the damping properties of two high-grade flax and hemp fiber reinforced Greenpoxy composites on a wide range of frequency using modal analysis, dynamic mechanical analysis and dynamic nano-indentation. The results show the damping properties of PFCs at different frequencies, temperature or scale.

INTRODUCTION
Literature survey shows that the damping properties of plant fiber composites are generally much higher than the one obtained with the more conventional glass and fiber composites (Duc 2014). So, PFCs represent a good alternative to some of the conventional composites to provide a good stiffness to damping ratio in sustainable lightweight structures. The review of the literature on this topic reveals also that the existing knowledge on the damping behavior of PFCs is sometimes deficient or ambiguous and the sources of energy dissipation not fully identify and understood. The complex structure of plant fibers, involving an heterogeneous polymeric composition, various cell wall layers and their interfaces as well as a central void could be at the origin of additional energy dissipation mechanisms in plant fiber composites. It makes the damping sources more complex to comprehend since these ones are associated to the ones commonly observed in synthetic fiber composites and related to the viscoelastic nature of the matrix, friction at the interface between fibers and matrix, inelastic and irreversible behaviors such as damage and/or plasticity. So, the present study proposes the investigation of the damping behavior of two high-grade laminates made of GreenPoxy matrix (Sicomin) reinforced by a flax tape (Lineo-Ecotechnilin) and a balanced woven hemp fabric. The damping properties are measured using three different experimental techniques at different scales, namely modal analysis, dynamic mechanical analysis (DMA) and dynamic nanoindentation (DNI). Before testing all the materials were stored in a climatic chamber at 23 °C and 50% RH for at least 4 weeks. DMA tests were realised on a wide range of temperatures (-100 to 160°C) and frequencies (0.01 to 100 Hz) in the two main material directions (noted L and T). Master curves were built on a wide range of reduced frequencies covering 15 decades using the Time-Temperature Superposition Principle. Free-Free and Free-Clamped configurations were used for the modal analysis. The damping ratio was determined from the different mode shapes on a frequency band varying from 50 Hz to 1 kHz. At last, grid dynamic nanoindentation with constant amplitude method (CAM) was applied on the cross-section of some of the materials to map the in situ damping properties of the constituents.

RESULTS AND CONCLUSIONS
Figure 1 synthesizes the values of the loss factor identified for the two materials in their respective main material directions using the three experimental techniques over a wide range of frequency.

At ambient temperature and a loading frequency of 1 Hz, loss factor values of 1.6% in the longitudinal direction and 2.4% in the transverse direction are measured for the unidirectional flax/GreenPoxy composite when 2% are measured in both directions for woven hemp/ GreenPoxy composite. The loss factor varies significantly and non-linearly on the reduced frequency range. This is due to the presence of the glass transition and secondary transition temperatures of the GreenPoxy matrix (measured at approximately 95°C and -50°C, respectively at 1 Hz).

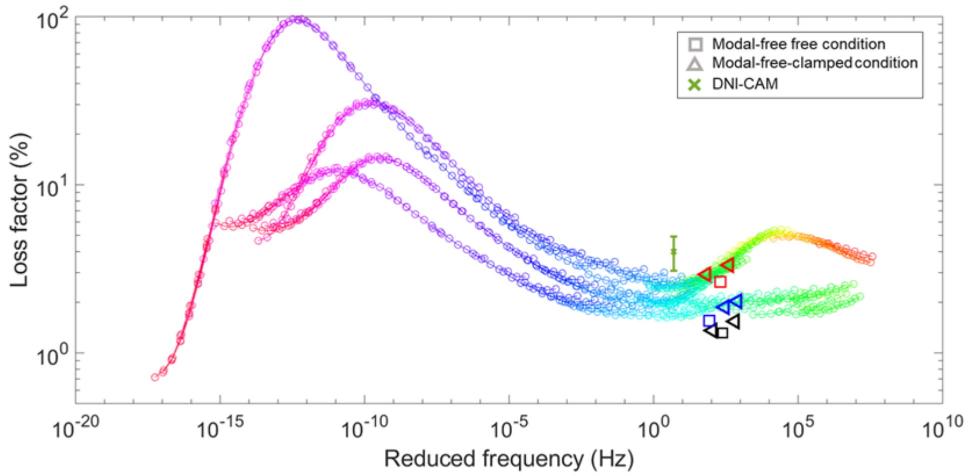

Fig.1 Loss factor of the UD flaxtape/GreenPoxy and woven hemp/GreenPoxy composites and neat GreenPoxy resin identified from DMA, modal, and DNI (fiber wall) tests at ambient temperature

It can also be seen from this figure that a good corresponding is found between the master curve obtained by DMA and the values of loss factor identified from modal tests. In addition, a loss factor of 4% is measured in the flax fiber wall using dynamic nanoindentation. This is consistent with the values back-calculated from DMA tests on composites.

ACKNOWLEDGMENTS

The authors express their gratitude for the funding received from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No. 744349-SSUCHY project and from the EUR EIPHI Graduate school (contract "ANR-17-EURE-0002").

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THERMAL EFFECTS ON THE STATIC AND FATIGUE BEHAVIOUR OF WOVEN HEMP FABRIC/GREENPOXY COMPOSITES

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ABSTRACT

This work investigates the influence of temperature on the static and fatigue behaviour of a balanced woven hemp fibre fabric reinforced GreenPoxy composite. Tensile tests under monotonic and cyclic loading are performed at two different temperatures, 23 and 70°C. Despite a significant decrease in the static properties, results point out a good fatigue strength at 70°C, with a high-cycle fatigue limit close to that measured at room temperature. The studied hemp/GreenPoxy composite presents competitive tensile properties compatible with most of the requirements for semi-structural applications.

INTRODUCTION

To ensure a reliable development of plant fibre composites in engineering structures, a thorough examination, understanding and modelling of their fatigue behaviour is required. If the fatigue behaviour of flax/epoxy composite is quite well documented in the open literature [1], very little fatigue data are available for hemp fibre composites [2-3]. The influence of many testing parameters (loading ratio and frequency), structural parameters (woven pattern, fibre crimp and out-of-plane weaves in fabric) as well as environmental conditions (temperature and moisture) remain to be meticulously studied for composite materials reinforced with hemp fabrics.

The present study proposes an investigation of the thermal effects on the static and fatigue behavior of hemp woven fabrics/GreenPoxy composite. This composite material has been developed very recently [4]. It is produced using thermocompression from a woven hemp fabric manufactured with low-twisted rovings and from the GreenPoxy 56 ® resin (Sicomin). The fatigue behaviour is investigated using tentsile-tensile fatigue loading at a frequency of 30Hz. This high-frequency fatigue protocol was proposed recently for plant fibre composites to accelerate the fatigue tests and explore their high-cycle fatigue behaviour [5].

RESULTS AND CONCLUSIONS

Figure 1 synthetizes the results of the static and fatigue tests performed at 23°C and 70°C. The static modulus and strength of this balanced woven hemp fabric composite are equal to approximately 14.8 GPa and 145 MPa, respectively. A significant decrease of the elastic modulus (approximately 35%), and of the static strength (approximately 28%) is observed at 70°C, when compared to 23°C. Interestingly, the fatigue resistance is less affected by the temperature. The slope of the Wöhler curve is less pronounced at 70°C when compared to 23°C. Indeed, in the high-cycle range, the two fitted S-N curves converge toward the same maximum stress value, around 40 MPa. This high-cycle fatigue limit recorded for the tested temperatures makes this composite material suitable for semi-structural applications.

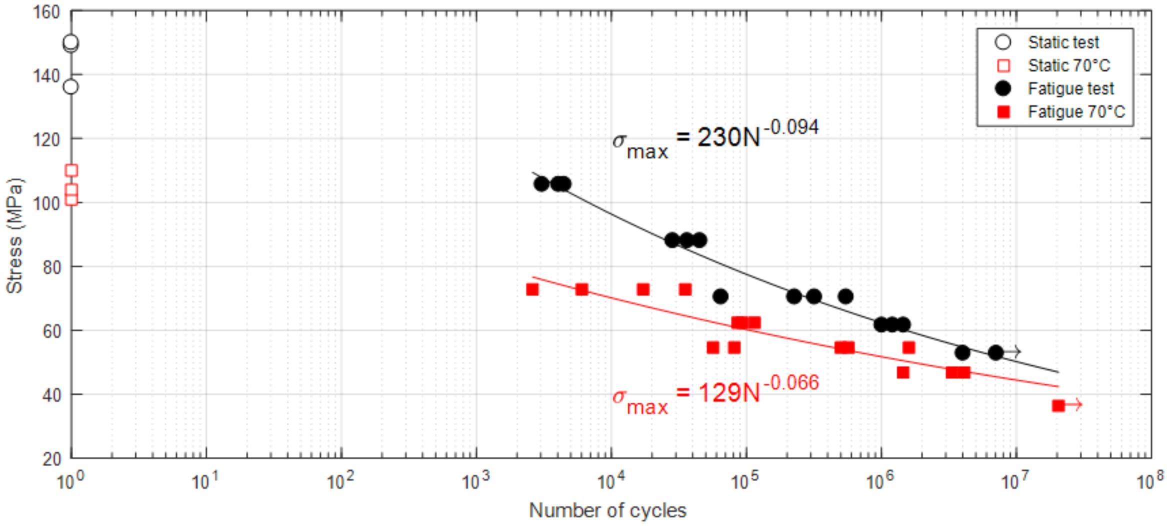

Figure 1: S-N curve collected under tensile-tensile loading (R = 0.1, Frequency = 30 Hz) on a woven hemp fabric/ GreenPoxy composite tested at 23 and 70°C.

The rigidity was also measured during the fatigue tests. While a very slight variation was recorded at ambient temperature (comprised between 0 and 2%) over the cycles, a significant stiffening, varying between 2 and 24% depending on the stress imposed, was observed at 70°C. This behavior is attributed to the softening of the matrix and then to the wider mobility provided for the fiber reorientation within the composite when submitted to tensile loading. It could also be due to softening of the amorphous constituents and the reorientation of the cellulose microfibrils in the fiber wall.

ACKNOWLEDGMENTS

The authors would like to acknowledge the funding received from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No 744349– SSUCHY project.

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IN-SERVICE TENSILE CREEP/RECOVERY BEHAVIOUR OF HIGH-GRADE HEMP AND FLAX FIBRE REINFORCED GREENPOXY COMPOSITES

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ABSTRACT

The aim of this work is to investigate the tensile creep/recovery behaviour of two high-grade flax and hemp fibres reinforced GreenPoxy matrix composites under constant and varying conditions similar to the one experimented during in-service use. Results show the strong influence of environmental conditions on the time-delayed behaviour of these materials as well as the existence of mechanosorptive couplings.

INTRODUCTION

Plant fibre composites represent a suitable solution for the development of sustainable lightweight structures. For several years, plant fibre reinforcements have been used in various composite application sectors such as sports, design and transport (Pil et al. 2016). However, the mechanical potential of these materials is not fully exploited. Although some of these biosourced fibres, such as hemp and flax, have specific mechanical properties that are superior to those of glass fibres (Mohanty et al. 2002), plant fibre composites are rarely used in structural applications. This is mainly due to some locks and limited knowledge and understanding of their in-service behaviour, including: (i) the impact of various and varying environmental conditions on the mechanical behaviour (Abida et al. 2020), (ii) the limited data concerning the time-delayed behaviour, and (iii) the lack of statistical description of the mechanical properties of the materials necessary to achieve reliability analysis (Blanchard et Sobey 2019). This work intends to shed light on these points. This study is in particular focused on the evaluation of the impact of constant and varying hygrothermal conditions on the creep/recovery behaviour of two high-grade composites manufactured with GreenPoxy matrix: a cross-ply laminate made with a flax tape and a laminate made with balanced satin woven hemp fabric.

RESULTS AND CONCLUSIONS

The evolution of the strain during the creep/recovery tests in two constant environmental conditions, 23°C-50%RH and 70°C-85%RH, are represented in Fig. 1 a) and b), respectively. Under ambient environment, the time-delayed behaviours of the two composites are relatively close with an average maximum strain at 0.63% and 0.65% for the flax and hemp reinforced composites respectively. Residual strain, around 0.1% for both composites, is also visible at the end of the recovery phase. The strain response of the materials is greatly impacted by more severe conditions. Indeed, the average maximum strain of flax and hemp fibre composites is multiplied by 1.5 and 3.5 respectively, while the level of the residual deformation is 3 times and 10 times higher than for ambient conditions, respectively. In contrast to the ambient conditions tests where material failure occurs suddenly (Jia et Fiedler 2020), a tertiary creep stage can be observed before the failure of the specimen at 70°C-85%RH.

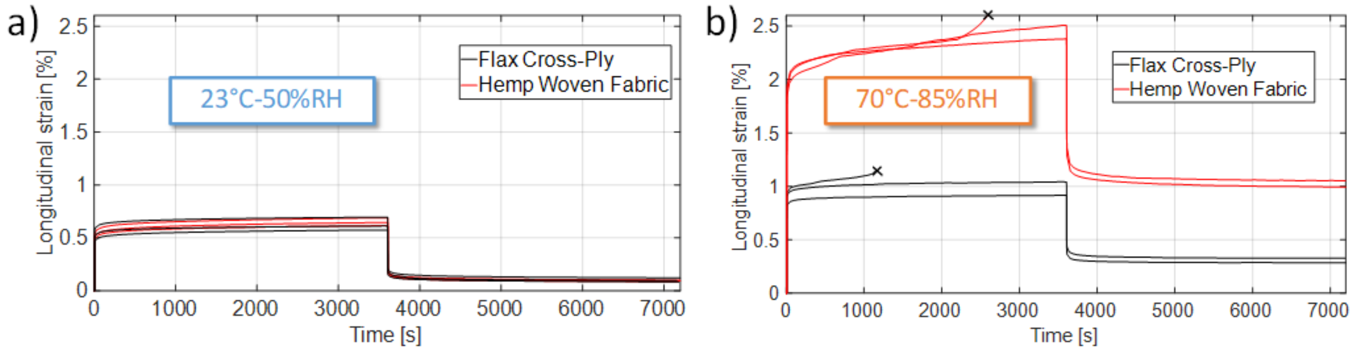

Fig.1 Evolution of the strain of the cross-ply composite reinforced with flax fibre and the hemp woven fabric reinforced composite during a creep/recovery test under environmental condition 23°C-50%RH **a)** and 70°C-85%RH **b)** at a nominal stress of 70 MPa.
(Crosses represent the failure of the specimen)

Using these experimental results, the parameters of an anisotropic viscoelastic model are identified by inverse method. The spread of these viscoelastic properties measured on a large number of specimens is represented using statistical models. Additional results of creep collected under varying controlled hygrothermal conditions as well as under real hygrothermal conditions during several months will also be presented during the conference. All these results provide a better understanding of the mechanosorptive behaviour exhibited by these plant fibre composites.

ACKNOWLEDGMENTS

The authors would like to acknowledge the funding received from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No 744349– SSUCHY project. The authors gratefully acknowledge Linificio e Canapificio Nazionale for providing the hemp fabrics.

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INCORPORATION OF A THIN POLYURETHANE INTERLAYER TO IMPROVE THE HYGROSCOPIC AND MECHANICAL DURABILITY OF FLAX AND HEMP FIBRE COMPOSITES

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ABSTRACT

This study evaluates the effect of a thin polyurethane interlayer on the hygroscopic and mechanical durability of flax and hemp fibre composites. The tough elastomeric interlayer is expected to mitigate hygroscopic stresses during moisture ageing, and potentially improves fatigue and impact properties. Results show an increase in the initial transverse strength of unidirectional flax fibre - epoxy composites having a polyurethane interphase which indicates that the fibre-matrix interface is strengthened. Moreover, the moisture diffusion rate is reduced after sizing with the polyurethane adhesive. For the hemp weave – epoxy composites, only minor changes in the bending properties after production were found. Results of the durability and impact study will be shown at the conference.

INTRODUCTION

In this study the potential benefits of a thin polyurethane interlayer on the hygroscopic and mechanical durability of flax and hemp fibre composites are evaluated. The research is based on the assumption that a tough bonding between fibre and matrix reduces damage development in the interface region. As a result, the resistance against cyclic hygroscopic loads (moisture ageing) and repeated mechanical loads (fatigue), and the impact properties might be enhanced. This research builds on the authors' earlier work on silicon interlayers (Koolen et al, 2020).

Two self-synthesized water borne polyurethane, WBPU, adhesives were used to pre-treat or size unidirectional, UD, flax fibres and a hemp twill 6/6 weave which was developed within the project consortium. The elastomeric WBPU interlayer was created after incorporation of the sized fibres in the epoxy matrix. Description of the WBPU synthesis lies beyond the scope of this paper. For both composite types, moisture cycling was performed between a relative humidity, RH, of approximately 32 and 96% at 40°C. The absorption behaviour was recorded based on weight measurements. For the UD flax – epoxy composites, bending and tensile properties, both longitudinal and transverse were evaluated after production and during ageing. For the hemp weave – epoxy composites, the evolution of the bending properties in warp direction was tracked. All tests were performed after re-conditioning to standard conditions, RH 50%.

At the moment of submission, the ageing experiment, and analysis of perforating and non-perforating impact tests was still ongoing.

RESULTS AND CONCLUSIONS

The transverse bending strength of UD flax fibre composites, before moisture ageing, is shown in figure 1. Results show a significant increase, P-value 0.04, when the interface is toughened with one of the adhesives, WBPU2, while the other yielded similar results compared to the reference. Since the fibre-matrix

interface is often the weakest link when a UD composite is tested perpendicular to the fibre direction, improvement of the transverse strength can be linked with strengthening of the interface.
Registration of the weight variations during moisture cycling, results not shown, showed that the diffusion rate is reduced when the hygroscopic fibres are sealed by the WBPU adhesive.
Although mechanical properties after ageing were not determined at the time of submission, both the strengthening of the fibre-matrix interface and a reduction for the diffusion rate indicate that the incorporation of a thin WBPU interlayer might lead to an improvement of the hygroscopic durability.
For the hemp twill 6/6 – epoxy composites, both the reference composite and those having a WBPU interphase yielded similar bending properties when loaded in warp direction. This could be expected since the properties in warp direction are dominated by the fibres. The bending stiffness and strength of the hemp twill 6/6 – epoxy composites having a fibre volume fraction of 42% were 13 GPa and 155 MPa respectively which corresponds to literature (Corbin et al, 2020).

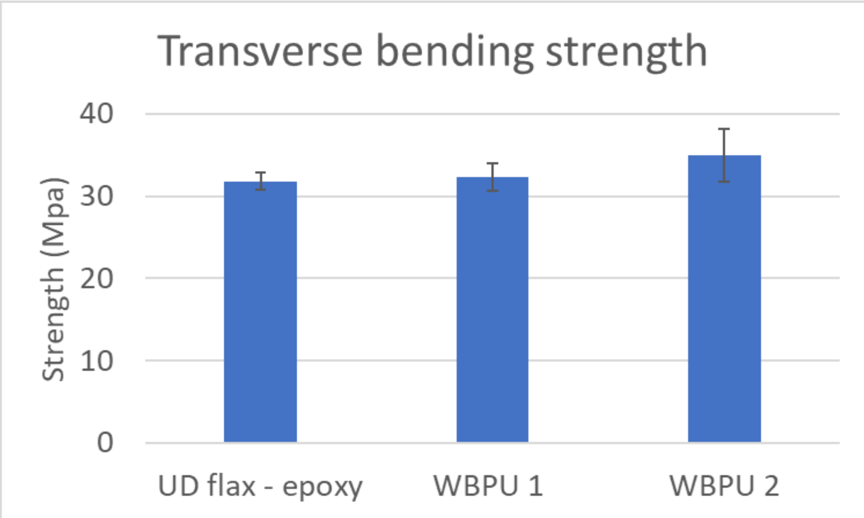

Figure 1 Transverse bending strength of unidirectional flax – epoxy composites. WBPU 1 and WBPU 2 correspond to unidirectional flax – epoxy composites having a thin polyurethane interlayer

ACKNOWLEDGMENTS

This research is conducted in the framework of the European Horizon 2020 Ssuchy project. The authors would like to express their gratitude towards the consortium partners and the Bio-Based Industries Joint Undertaking (BBI-JU) for the acquired funding and support.

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BRAZILIAN AGRO-INDUSTRIAL WASTES AS POTENTIAL TEXTILE RAW MATERIALS: A SUSTAINABLE APPROACH

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ABSTRACT

The textile and agricultural are important Brazilian sectors. The intense demand and productive capacity, in the current economic structure, exploits natural resources and generates waste, causing significant social and environmental risks. Considering the agro-industrial residues and sustainability guidelines, this study investigates the potential to promote new textile materials and products development. The results show that the agricultural biomass of some of the country's main crops has characteristics capable of potential textile application such as natural fibers, composites and polymers. The research results have not yet considered materials applied into industry; however, the set of variables is the assumption of new sustainable materials for the future.

INTRODUCTION

In Brazil, agribusiness plays an important role in food production, processing and transformation. According to the Brazilian Institute of Geography and Statistics (IBGE, 2021), the agricultural production harvest foresees a record of 2.5% in 2021, and to meet food needs in 2050 requires an increase of 60% in planted area, and water consumption in the midst of hydric crises (ABRAS, 2017). The abundance is the result of increased activity in the modern agricultural sector, which produces 291.1 million/ton. of waste in its largest crops (IPEA, 2012).

Although, this system presents unexplored economic opportunities, it pressures resources conservancy, pollutes and degrades the natural ecosystems, causing environmental risks and contamination for society (Macarthur, 2017; ABRAS, 2017). The use, processing and characterization of pulp-based agro-industrial waste shows itself to be a great opportunity for value generation and development of textile products (Berté, 2009; Islam et al., 2013). For Dungani et al. (2016) agricultural waste is the most abundant form of natural fiber.

The aim of this study was to present the Brazilian panorama of the main residual inputs as important source of natural fibers, considering their potential characteristics for textile application. The method displays a systematic review of the literature and the creation of a bibliometric analysis network, based on the concepts of industrial ecology (Giannetti; Almeida, 2006). The network was built by grouping bibliographic sources on the Scopus platform and transcribed by the VOSviewer Software (Universiteit Leiden). The results were compared with data from the Ministries of Agriculture and Environment of Brazil and related associations, examining research on the use of agro-waste for the development of textile materials through sustainability.

RESULTS AND CONCLUSIONS

The organic matter includes 45.3% of the total solid waste generated in 2020 in Brazil (ABRELPE, 2020). The average yield per crop year and product shows main crops being: sugar cane, corn, rice, soybean and coffee (IBGE, 2020). The latest IPEA Organic Waste Report reveals that only sugarcane produces 201,418,487 million/ton of waste, followed by soybean (41,862,129), corn (29,432,678), orange (8,825,276), wheat (3,033,315) and rice (2,530,355) (IPEA, 2012). It is possible to observe a high incidence of these terms in network analysis (Fig 1).

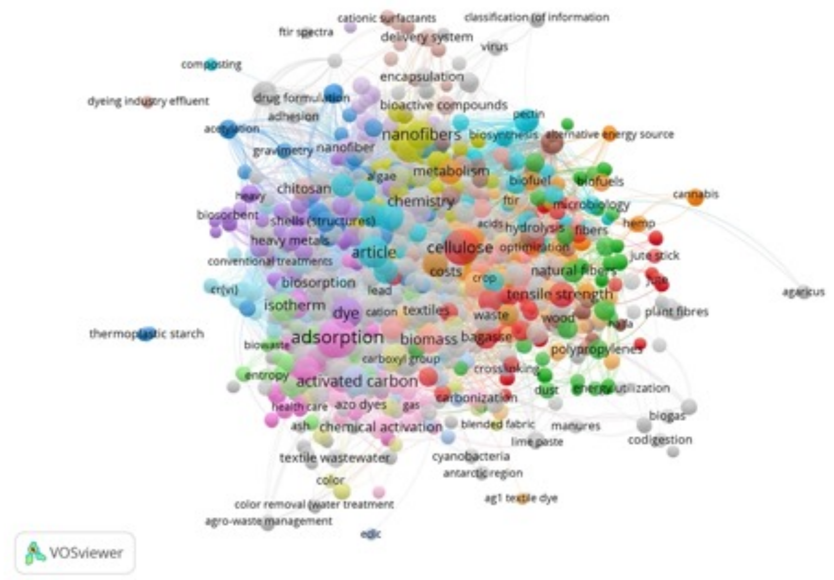

Fig.1 Network built with VOSviewer software (Universiteit Leiden) through the analysis of 305 articles and co-occurrence of 2,496 specific expressions. The agro-industrial materials with the highest co-occurrence are: "sugarcane", "fruits", "soybean straw", "cassava" and "rice". The main formats involve "bagasse," biomass," fibers," nanocrystals" and "polymers," while the applicability is in "absorption," enzymes," textile fibers, "effluents" and "ethanol. There is a great interest in the discovery of physical-chemical characteristics of materials by analyzing the frequency of the term's "crystallinity", "pH", "mechanical properties", "chemical composition" and "degradation".

Based on parameters of chemical composition, growth rate and disposition, in Brazil, soybean straw, followed by sugarcane leaf, bark and corn and sugarcane bagasse straw stand out as the most promising materials (Martelli-Tosi et al., 2017; Araújo et al., 2018). Analysis of these materials has been widely studied for textile applications, such as: the high mechanical strength of sugarcane straw fibers, and its characteristics compatible with lyocell (Costa et al., 2015; Outa, et al., 2016); rice and pineapple husk fiber with a characteristic crystalline structure similar to cotton fiber (Padro; Spinacé, 2011); corn bagasse for strengthening textile modeling bio composites (Satyanarayana, 2009); and biopolymers from açai waste fibers (Euterpe oleracea) (Wataya et al., 2015), among other materials.

It is observed, that some of the main crops in Brazil are the most adequate fibers residually, however, the implementation of material reallocation systems still demonstrates incipient advances. The research results have not yet considered materials applied into industry; however, the set of variables is the assumption of new sustainable materials for the future.

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DEVELOPMENT AND CHARACTERIZATION OF A 3D PRINTED COCOA BEAN SHELL AND RECYCLED POLYPROPYLENE SUSTAINABLE COMPOSITE

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ABSTRACT

This work presents the development of composite filaments for 3D printing based on recycled polypropylene and cocoa bean shell, and the characterization of 3D printed specimens. 3D printing temperature was determined considering the thermal analysis. Physical properties of composite filaments showed an increase in water absorption when fiber is added, but density and swelling diameters did not differ. Tensile tests on printed specimens showed that, with the fiber, tensile strength decreases on specimens printed at 0°, however in specimens printed at 90°, this property increases. Tensile properties differ between 90° and 0° due to the load mechanism. SEM micrographs showed a good bonding between 3D printed layers.

INTRODUCTION

In recent years, world's increasing ecological consciousness has led to the study of 3D printing of natural composites as a promising technology to reduce environmental impact (Mazzanti et al., 2019). Among different approaches to develop such composites, an active research area is the development of filaments for 3D printing from recycled polymers and natural fibers (Shanmugam et al., 2020; Li et al., 2020), which contributes – from an economic point of view, to the valorization of industrial and agricultural waste residues. Hence, in this work, we explore the mechanical behavior of a 3D printed natural composite from a purposely developed filament made of recycled polypropylene (rPP) with the addition of cocoa bean shell (CBS).

The development of composite filaments for 3D printing was carried out through extrusion, using a fiber weight ratio of 0 wt.% and 5 wt.%. A filament of 1.75 ± 0.5 mm of diameter was obtained. Developed filaments were characterized thermally by TGA and DSC, following the ASTM E1131 and ASTM D3418 standards. Density, water absorption, and swelling diameter of neat rPP and rPP/CBS composite filaments were determined according to the ASTM D792 and ASTM D570 standards. 3D printing specimens where manufactured and tensile tested, following ASTM D3039 standard and printed at 0° and 90°. Finally, a morphological analysis was carried out through SEM.

RESULTS AND CONCLUSIONS

The results from the thermal analysis are shown in Fig. 1. Weight loss in composite filaments starts before, compared with the neat rPP filament, due to the lignocellulosic components of the fiber. The 3D printing temperature, 250°C, was determined considering the degradation temperature of the fiber and the melting point of the developed filaments. DSC analysis present an additional peak due to other polymers presented in the rPP. Physical properties in Fig. 2 showed that there is not a significative difference in the density, nor in the swelling diameter with fiber addition. Regarding water absorption increase in the composite, which means that me material must be well dried to avoid the appearance of voids in the final 3D printed part.

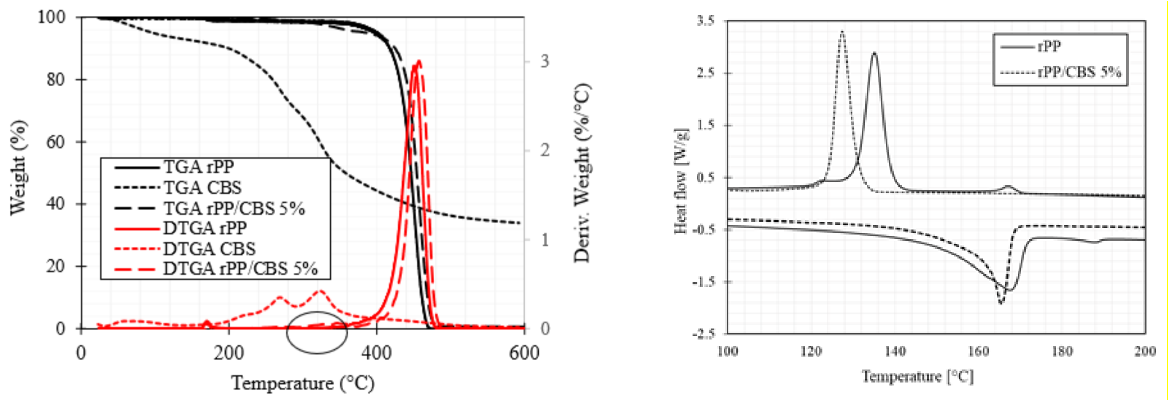

Fig. 1. Thermal characterization of rPP and rPP/CBS composite filaments

Fig. 2 also shows the tensile strength of 3D printed specimens, printed with the developed filaments (neat rPP and rPP/CBS). Properties at 0° are higher than at 90° due to the load mechanism. The addition of 5 wt.% of fiber improves tensile strength in specimens printed at 90°. Fig. 3 shows SEM images of tensile fractured specimens. A good bonding between printed layers is perceived, different layer cannot be identified. Also, images present a poor fiber-matrix interfacial interaction due the gaps that are between compounds. As future work, different superficial treatments and coupling agents will be applied to improve the fiber-matrix adhesion.

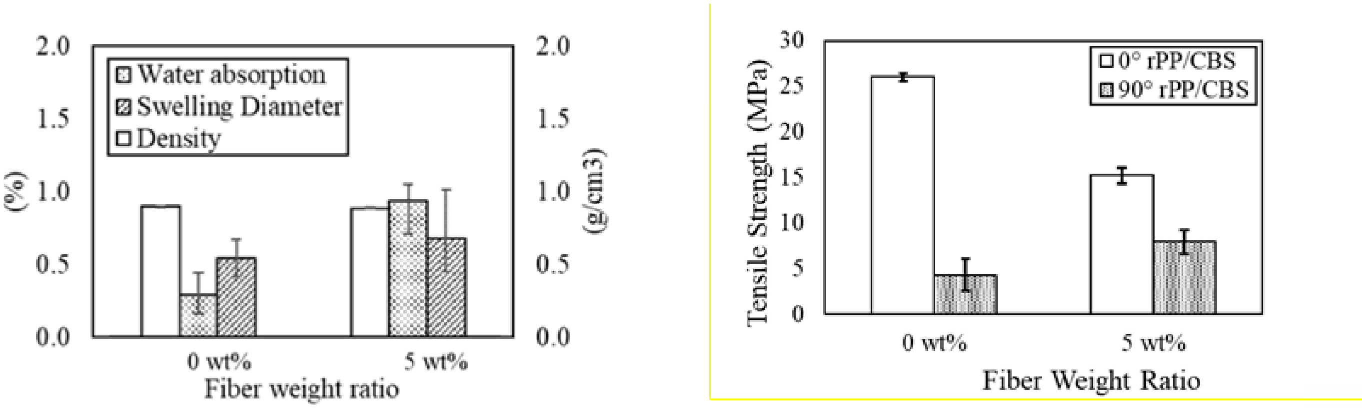

Fig. 2 Physical and thermal properties of rPP and rPP/CBS composite filaments

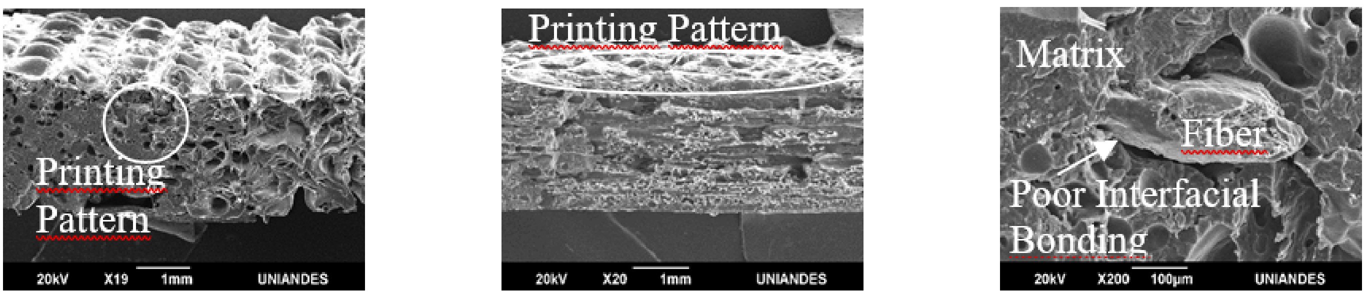

Fig. 3 SEM images of tensile fractured specimens of rPP/CBS composite filaments

This study presents the development of 3D printing sustainable composite filaments and their characterization, showing the opportunity to use this kind of residues to produce composite materials with competitive properties.

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USE OF AGAVE POTATORUM AND SARGASSUM NATANS FIBERS AS REINFORCEMENT OF FILAMENTS FOR 3D PRINTING, BASED ON THERMOPLASTIC STARCH

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ABSTRACT

Currently, agro-industries generate a large amount of waste, within these are natural fibers. The accumulation of these materials can generate environmental problems such as total or partial reduction of ecosystems. Therefore, it is intended that these materials can be used in other processes. For example, natural fibers are widely used, as reinforcing material, of different types of matrices, but mainly in polymeric matrices, due to improvements in the specific properties of these materials. In this work, a thermoplastic corn starch-based 3D printing filament was developed to observe the effects of the type of plasticizer (glycerol or sorbitol) and reinforcement material (Sargassum natans or Agave potatorum), on the thermo-mechanical properties of these materials. The filaments were through an extruder varying the temperature and processing speed due to the characteristics of the plasticizer used. The filaments with sorbitol had the lowest Tg, than those that were produced with glycerol resulting in more flexible filaments.

INTRODUCTION

Currently, it is possible to find in different environments a large amount of plant waste product of agroindustries, such as coffee husks, cane ash, palm leaves, bagasse, etc., on the other hand, we also find them as a non-product desired effect of human interaction with the environment, such as invasive grasses in environments where there are no predators to control growth, excess algae in rivers or sargassum in the sea due to excess nutrients and climate changes (Bhardwaj & Gupta 2012). These effects generate important ecological problems such as final disposal, reduction or even destruction of ecosystems, contamination of groundwater tables These problems affect local economies becausehave financial costs due to transportation problems, impact on income due to lack of fishing or pollution of tourist beaches among many others (Muñoz, 2019). One way to reduce these impacts is to use wastes as fibers of Sargassun natans or Agave potatorum to obtain new materials with attractive functional properties that can have a high environmental impact, such as those from oil or glass fiber.

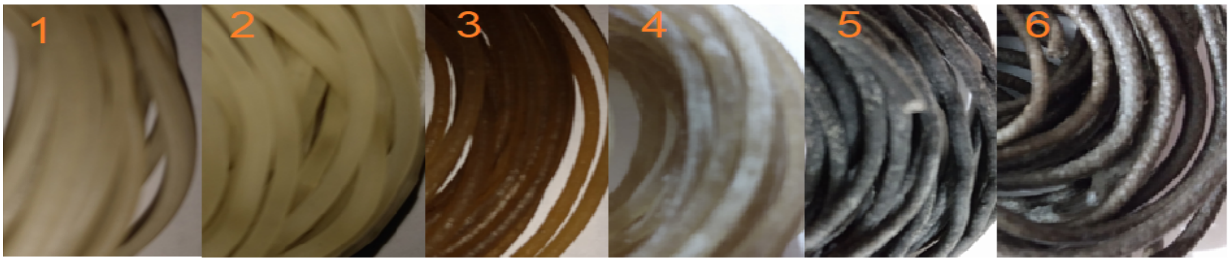
RESULTS AND CONCLUSIONS

6-year-old agave potatorum stalks were used to obtain fibers through the use of a mechanical shredder (CIIDIR Oaxaca). Subsequently, the fibers were washed and immersed in an alkaline medium of 10% sodium hydroxide for 24 hours, after which they were washed until the remains of the alkaline solution were

removed. On the other hand, the fresh sargassum was obtained from the beaches of Cancun, once collected, these were washed with drinking water and put to dry in the shade for 3 days until they dried. Both fibers were ground to a maximum size of 5 mm long in a blade mill.
To obtain the filaments, corn starch (Meyer) was moistened with distilled water and glycerol or sorbitol (Sigma Aldrich) for 24 h. Subsequently, the fibers and starch were processed in an extruder with a double conical thread were processed in the mixing chamber for 10 minutes and subsequently the corresponding filaments were extruded.

Table 1.- The dimensional characteristics and images of the filaments obtained are presented

No.	Code	Length (m)	Diameter (mm)	Weight (g)	Density (kg/m³)	Temperature ºC	RPM
1	AM25G	5.1	1.695+0.13	25.51	1002.81	95	150
2	AM25S	5.88	1.585+0.11	22.49	1005.48	100	20
3	AM25G3A	2.96	1.79+0.10	19.57	1007.08	95	150
4	AM25S3A	4.92	1.61+0.05	22.61	1006.08	100	20
5	AM25G3S	4.58	1.69+0.15	20.33	1003.35	95	150
6	AM25S3S	4.69	1.66+0.05	21.8	1001.89	100	20



A Thermo-mechanical characterization of the sargassum filaments with glycerol and with sorbitol was carried with TMA (model Q400 /TA instruments) to determine the glass transition temperature (Tg) using a macro expansion probe. The analysis was carried from 0 to 120 °C, at a heating rate of 5 °C/min and a constant force of 0.2 N. The Tg of the filaments with sargassum with glycerol was 77.2 °C and with sorbitol was 48 °C, these values are related to a greater stability in the filaments with glycerol with respect to an increase in temperature. Appropriate filaments for 3D printing could be obtained, characterizing them will allow their behavior to be analyzed and equated with conventional materials and existing applications, projecting the possibility of seeking applicable developments to solve environmental problems generated by the use of natural resources seeking to reduce human impact on ecosystems.

ACKNOWLEDGMENTS

The authors acknowledge the CONACyT for the scholarship of Ramirez-Sorroza M.A., and the grants 251504 and 264110, the IPN for the grants SIP 20200758 and 20201696; Dr. Delia Soto for the agave potatorum, engineer Enrique Chavez in Cancun for the Sargassum fiber.

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BIOCOMPOSITES FROM COTTON DENIM WASTE FOR FOOTWEAR COMPONENTS

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ABSTRACT

The materials' production applied in footwear industry corresponds about 80% of the impacts generated in the total useful life of shoe. Denim waste presents great opportunities for recycling. This research aimed to describe the case study of Toritama´s logistics of denim wastes (located in Pernambuco state and known as the “city of jeans”) and to develop biocomposites from cotton denim wastes for application in the footwear industry. This study enabled new material development for cotton denim wastes of different kinds (shredded fibers and powder), transforming these residues in biocomposites. It is concluded that the obtained layers could be improved for applications in footwear, mainly “soft composites” in insoles and “hard composites” in toe-puffs, stiffeners and other shoe reinforcement components.

INTRODUCTION

The evolution of consumers' environmental awareness, connected with the demand for bioproducts is a challenge for the footwear sector (Fernandes et al, 2018). Environmental problems in footwear industry are related to the applied materials in the components. They correspond to about 80% of the impacts generated in the total useful life of shoes (Gottfridsson and Zhang, 2015). In this context, the new composites development, based on natural materials and adopting green production processes, it is a large interest issue (Ngwabebhoh et al, 2020).

The natural fibers’ wastes are valuable sources for biomaterials development (Ngwabebhoh et al, 2020). The wastes from denim industry represents a great opportunity for recycling. However, the main problems in the textile waste processing are related to: logistics (textile waste collection and their separation flow); the distance between the production areas and consumer markets; and material reproducibility (Luiken and Bouwhuis, 2015).

In Brazil, one of the main Brazilian industrial hub of denim clothes is located in Toritama (Pernambuco state), known as the “city of jeans”. Toritama is responsible for approximately 15% of the national denim clothes production, about 60 million pieces per year, concentrating more than 3 thousand clothing factories and more than 50 industrial laundries (SEBRAE, 2019).

In this way, this study aimed: (i) to describe the study case of Toritama´s logistics of denim wastes, through interviews and visits of factories; (ii) to develop biocomposites from cotton denim wastes for application in the footwear industry. For the biocomposites prepare two kinds of denim waste were used: (a) shredded denim cotton fabric (from textile recycling company located in Curitiba, Paraná state); (b) powder (from textile recycling company located in metropolitan area of São Paulo, São Paulo state). The pulp for composite making was prepared by the same way for the two kind of residues. An aqueous solution 50% (v/v) was prepared with biobased additive (Arabic gum). The process of biocomposite production was the same for the two kinds of wastes. In a plastic recipient, the pulp was prepared adding 40 grams of denim waste and five 5 liters of water with 5% (v/v) of Arabic gum. Wood frames (20 x 16 and 20 x 20 cm) with a fixed screen were immersed in the mix and then lifted to form a layer.

RESULTS AND CONCLUSIONS

On a visit to the medium-sized denim clothes factory (89 employees) in Toritama, different kinds of wastes were identified from two sources: fabric cutting and stitching processes (respectively **Figures 1a** and **1b**). The manager reported that the fabric cutting process waste has been sold monthly to a textile recycling company. This waste corresponds to: cotton, denim cotton and denim cotton with elastane, daily generated due from the cutting demand production. The stitching process wastes are disposed in ordinary garbage. It is estimated a waste generation of 5-7% in relation to the final clothing production.

During the biocomposite layer production, it was observed that denim waste formed different thicknesses in the layer, despite of the good cellulose spread in water. In order to provide more stiffness to the layer, it was immersed in the Arabic gum aqueous solution (50% v/v). The resultant composites are shown in **Figure 1c** ("soft and hard composite" from shredded denim waste) and **Figure 1d** ("soft and hard composite" from powder waste).

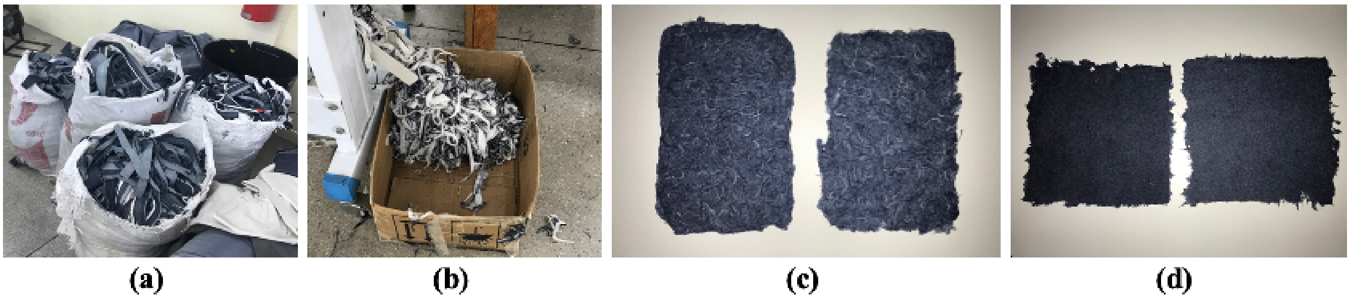

Fig.1 Cotton denim wastes from Toritama's denim clothes factories: (a) from fabric cutting process; (b) from stitching process (b); Biocomposite layers employing: (c) ("soft and hard composite" from shredded denim waste (16x20 cm) (c) and "soft and hard composite" from powder waste (20x20 cm).

This study enabled new material development for cotton denim wastes of different kinds, transforming these residues in biocomposites. However, the extraction of the chemical solutions incorporated in denim fabric for coloration process was not carried out. This could imply in environmental impacts taking in account the material appropriated biodegradation.

It is concluded that the obtained layers could be improved for applications in footwear, mainly "soft composites" in insoles and "hard composites" in toe-puffs, stiffeners and other shoe reinforcement components.

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HYBRID COMPOSITES BASED ON THERMOPLASTIC STARCH AND AGRICULTURAL AND MARINE WASTES FOR 3D PRINTING FILAMENTS

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ABSTRACT

In this work, 3D printing filaments of hybrid composites based on thermoplastic maize starch reinforced with Agave salmiana fiber and calcium carbonate –at three concentrations– as filler were obtained by the extrusion method. At this first stage, the diameter uniformity, density, and surface morphology of hybrid composite filaments were analyzed to use them later in 3D printing technique and obtain mechanical and thermomechanical samples, and finally be further evaluated as a promising coral artificial substrate.

INTRODUCTION

Coral reefs are natural breakwaters that protects coastal areas and act as shelter to highly-productive biodiversity, providing critical services and goods to around 500 million people. However, coral reefs have been increasingly exposed to several natural and anthropogenic disturbances threatening their survival (Adjeroud, 2017). A strategy recently used to restore these damaged ecosystems is installing artificial substrate preferably based on natural non-invasive materials like calcium carbonate (Spieler, 2001). The efficiency of attaching coral fragments in experimental fixation units –based on thermoplastic starch reinforced with agave fibers biocomposites obtained by the extrusion-injection method, was previously evaluated in situ. In the first 24 hours the surface of these experimental units was covered by microorganisms at 28.7% (±8.4), suggesting a good coral-biocomposite interaction (Mazaba-Lara, 2019).

In this work, calcium carbonate particles were added to the mentioned biocomposites to increase their mechanical properties, and coral attraction and fixation, while maintaining their biodegradable character. The results here presented correspond to the properties of hybrid composite filaments obtained by the extrusion method, as a first stage in the production of textured fixation units that will be obtained by 3D printing.

RESULTS AND CONCLUSIONS

In Table 1 dimensions of the filaments from different formulations are shown. The presence of agave fibers improved the dimension stability of TPS during the extrusion process, this was observed in the uniformity of the composite filament´s diameter if compared to TPS filament. Also, increasing the content of calcium carbonate increased the diameter´s uniformity on hybrid filaments, improved the extrusion process, decreased the density and provided an apparently smoother surface texture if compared with TPS/F filaments as shown in Figure 1.

Table 1 Weight, length, and linear density of different formulation filaments obtained by the extrusion method.

Formulation	**Filament weight (g)**	**Filament length (cm)**	**Filament diameter (mm)**	**Filament density (g/cm³)**
TPS	36.1	627	1.82 ± 0.15	2.218
TPS/F	44.3	748	1.97 ± 0.10	1.953
TPS/F/CaCO3-3	46.1	1009	1.93 ± 0.08	1.586
TPS/F/CaCO3-5	46.5	996	1.90 ± 0.09	1.567
TPS/F/CaCO3-7	48.3	1219	1.73 ± 0.07	1.647

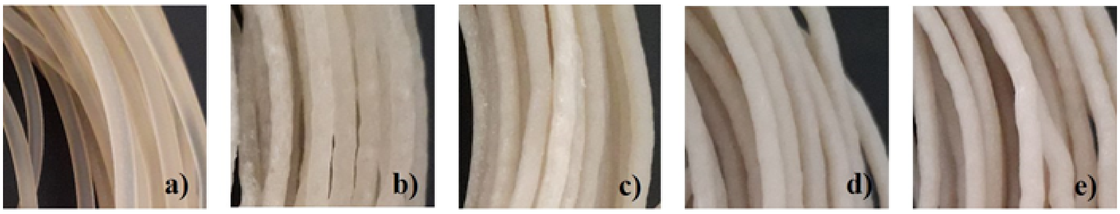

Figure 1 Filaments of different formulations: a) TPS; b) TPS/Fiber; c) Hybrid with 3% of calcium carbonate; d) Hybrid with 5% of calcium carbonate; e) Hybrid with 7% of calcium carbonate.

Further characterization includes morphological (SEM), thermogravimetric (TGA), and thermomechanical (TMA) tests to observe the dispersion of the calcium carbonate particles within the polymeric matrix, the effect of the presence of calcium carbonate particles in the degradation behavior and in the dimension stability of the agave fiber-reinforced TPS biocomposites, respectively.

ACKNOWLEDGMENTS

The authors acknowledge the CONACyT for the scholarship 553944, and the grants 251504 and 264110, the IPN for the grants SIP 20200758 and 20201696; people in Mezquital Valley, Hidalgo, México for providing the Agave salmiana fiber; and Dr. P. F. J. Cano Barrita for the use of the Laboratory of Cement-based Materials, CIIDIR-Oaxaca.

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MICROSTRUCTURE AND MECHANICAL PROPERTIES OF THE FLAX XYLEM AND ITS USE AS COMPOSITE REINFORCEMENT

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ABSTRACT

This work focuses on the xylem tissue of flax plant in order to better understand the reinforcing role of flax shives in injection moulded composites. Here, the microstructure of this tissue is finely studied and described by nanotomography and image analysis on transversal stem sections as function of stem height. Further measurements of the cell walls were carried out with AFM in Peak Force Quantitative Nano Mechanical indentation mode (20-22 GPa were measured for the S2-G layer). Finally, a micromechanical model approach was used to estimate the reinforcing potential of flax shives in injection-moulded composites.

INTRODUCTION

Flax shives have been proven to be relevant injection-moulded reinforcement materials with a stiffness that reaches 90% of that obtained with cut flax fibres [1]. They represent more than 50 %-wt of the flax biomass, against only 15-25 % for high value-added long flax fibres [2]. Nevertheless, little is known on the reinforcing mechanisms of this cellular material. Deeper insight is sought on the mechanical properties of flax shives, which originate mainly from the xylem tissue of the flax stems during the scutching process of retted flax stems. This work targets the microstructure and mechanical properties of the xylem tissue of flax.

RESULTS AND CONCLUSIONS

Results precisely describe the internal organisation from the scale of the stem to that of xylem cell walls. The latter are structured in primary and secondary S1, S2-G and S3-Gn layers and cells are joined by the middle lamellae in a similar manner as flax fibres. The indentation modulus is of 20-22 GPa for the S2-Gn layer (Figure 1), comparable to the commonly used flax fibres [3], the main difference being its relative thinness (2-3 µm)[4]. The surface of cells was measured as function of stem height as well as the cell wall thickness across the xylem tissue cross-section.

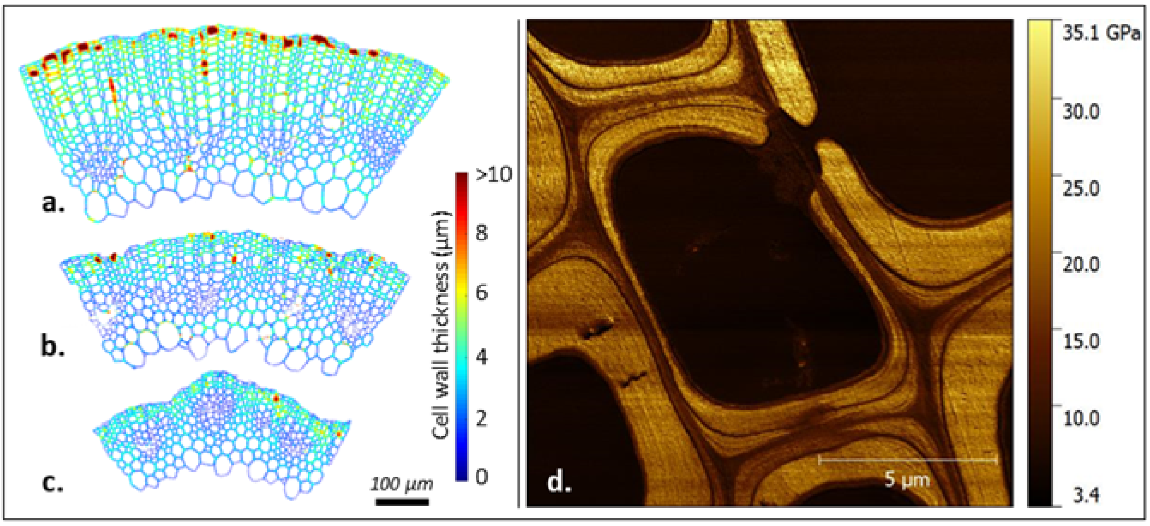

Fig.1 Cell wall thickness distribution in the xylem tissue as a function of stem height for a. the bottom of the stem, b. its middle, c. and its top section. d. AFM PF-QNM mapping of the indentation modulus of the flax xylem taken at fibre maturity stage.

Finally, the micromechanical model showed less than 10% difference between the estimated and measured tensile tangent modulus of flax shives in polypropylene injection moulded composites. These results bring further knowledge on the structure and mechanical properties the xylem tissue, a helpful insight in understanding their reinforcing role for biocomposite applications.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by the French National Association of Research and Technology (ANRT) under grant 2018/0098 of Lucile Nuez's thesis partnership with Van Robaeys Frères and the Dupuy de Lôme Research Institute of the University of South Britany (France). Furthermore, authors would like to thank Dr. David Siniscalco and Dr. Camille Goudenhooft for their valuable contribution on the AFM-PFQNM investigation.

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HYGROSCOPIC SWELLING OF FLAX FIBRE COMPOSITES: THE ROLE OF THE SURROUNDING MATRIX

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ABSTRACT

This study is focused on an experimental investigation of the hygroscopic swelling of flax fibre composites and the role of the surrounding matrix. Two matrices were selected with significantly different stiffness level to investigate any potential constraining effect when compared to the swelling behaviour of an unconstrained single flax fibre. Furthermore, the results indicate that the swelling coefficient in the axial direction of the fibres is significantly lower, and thus negligible, compared to the radial hygro-expansion.

INTRODUCTION

Flax fibres are increasingly used as composite reinforcement in high performance applications due to their high specific stiffness coupled with their highly sustainable nature that provides environmental benefits over their synthetic counterparts. However, the service life of flax fibres can be strongly affected after long exposure in high humidity environments due to the hydrophilic nature of flax fibres, which is the driving force for water molecules to enter the structure of the material causing structural changes. One of the most direct changes is the volumetric increase due to the significantly high water sorption. The ratio of hygroscopic deformation of a material to its mass increase due to water sorption is defined as the hygroscopic expansion coefficient. Le Duigou et al. [1] measured the radial hygroscopic expansion coefficient for a single flax fibre at the value of $\beta = 1.14$ by observing the diameter variation as a function of relative humidity using environmental scanning electron microscopy. In comparison to the radial thermal expansion coefficient of flax $\alpha = 78$ (10-6/oC)

[2] it is obvious that the hygro-expansion coefficient is greatly superior to it's thermal counterpart and therefore can cause significant dimensional instabilities and thus damage development which over time leads to reduced performance during the composite's lifetime.

In this study, we investigate the role of the matrix and its effect on the swelling behaviour of the flax fibres when they are not free to swell, but are surrounded by the matrix material, thus constraining their swelling. Two matrices where selected with significantly different levels of stiffness, namely maleic-anhydride grafted polypropylene (MAPP) with a very low stiffness value at 0.4 GPa and a significantly stiffer Epoxy matrix with a stiffness value of 2.9 GPa. Test samples were prepared and equilibrated at various humidity levels ranging from 22.5%-97% using saturated salt solutions in sealed environments. The weight increase and the in-plane thickness swelling were monitored before and after saturation. The hygroscopic coefficients where obtained using the linear regression of the in-plane hygroscopic strain as function of the water sorption content in saturation for each humid environment and compared to the unconstrained single flax fibre coefficient obtained by [1].

RESULTS AND CONCLUSIONS

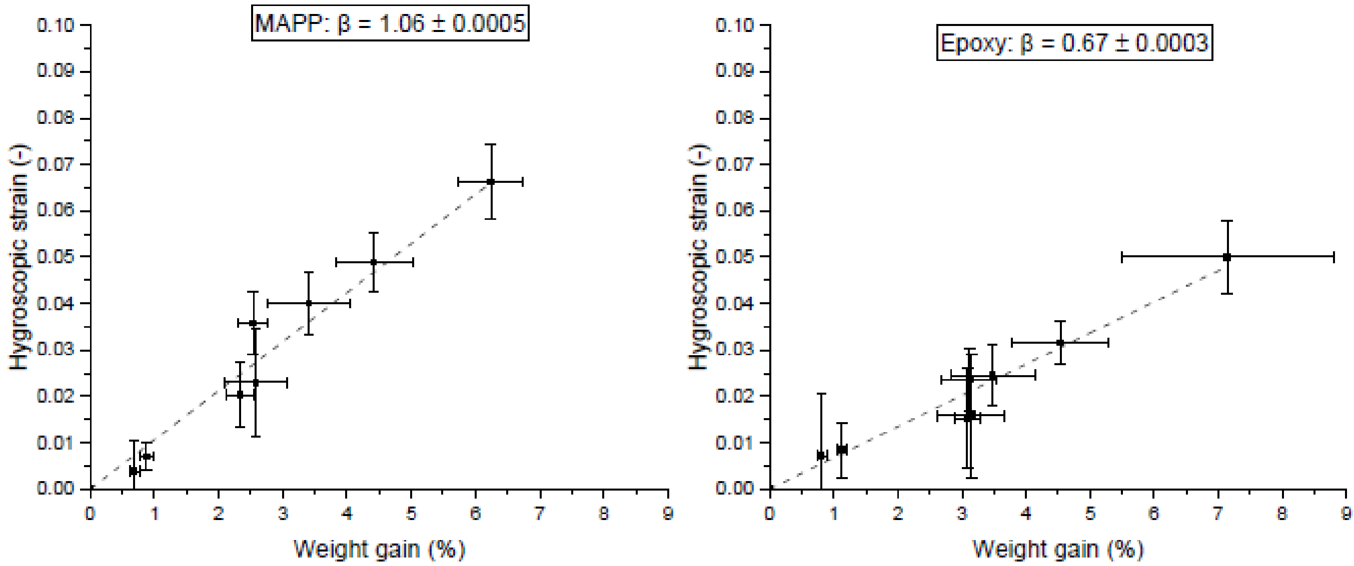

Fig.1 Hygroscopic coefficients of Flax fibre composites (~40% volume fraction, measured with computed tomography) for MAPP and Epoxy matrix.

The results highlight the importance of the matrix polymer. The radial swelling of the fibre is highly reduced by the presence of the stiff epoxy matrix, whereas the softer matrix has a smaller effect on the hygroscopic coefficient. Furthermore, the hygro-expansion coefficient for both matrices in the longitudinal direction was several orders of magnitude lower and its accurate calculation was limited due to the accuracy on the micrometer used (±1μm), leading to the conclusion that the radial expansion is significantly more important and damaging for the composites. Additionally, moisture diffusion measurements revealed that the flax/MAPP composites needed approximately twice longer time to reach saturation levels compared to the flax/Epoxy composites due the strongly apolar nature of the base polymer.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 764713.

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GRAPHENE NANOPLATELETS (GNPS)-BASED WEARABLE PRESSURE SENSOR WITH IMPROVED SENSING PERFORMANCE

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ABSTRACT

Smart textiles are sufficiently capable to sense, react and adapt to external stimuli. Textile-based pressure sensors have been widely explored in recent years for various sports, healthcare, military, and fashion applications. However, the sensors present challenges and drawbacks because of their multilayer design and complex development processes. Here, a novel concept of developing textile-based pressure sensors using machine stitching has been introduced. A single-layer sensor was developed using graphene nanoplatelet-coated cotton thread and fabric to improve mechanical issues such as alignment shift and wrinkling while wearing. The developed sensor possesses better mechanical properties, working range, and sensitivity than the existing textile-based pressure sensors because of its structure and type of conductive coating. The sensor was characterized by applying pressures ranging from 0 to 40 kPa, where they showed a significant reduction in resistance, with a sensitivity of 10 kΩkPa-1 at a pressure ≤ 20 kPa. The sensor's response time was also calculated by applying cyclic pressures up to 10 kPa at a constant rate (10 mm/min), and the time calculated for the sensor to respond was 50 ms. The sensor can be used in various wearable applications and create new knowledge in the existing field of smart textiles.

INTRODUCTION

The sensor is based on 100% mercerized cotton thread stitched on 100% cotton fabric coated with graphene nanoplatelets (GNPs). GNPs are stacks of monolayer graphene sheets with a 2D flat structure and possess excellent conductivity, aspect ratio, surface area and flexibility (Wang, 2018). In this study, GNP powder procured from Sigma-Aldrich was used as an active coating material having 5 µm particle size and around 9 nm thickness. The fabric was coated using the k-bar rod coating method, and the yarn was dip-coated in GNP solution. A yarn coating solution was prepared using 80:20 GNP to binder ratio. In this work, CMC: SBR (70:30) by volume was used as a binder. This GNP/binder active material content was further used in formulating 1% wt/vol solution using DI water. The solution was stirred and sonicated for 30 min respectively to form a homogeneous suspension before the dip-coating process. The cotton yarn was dipped and dried a couple of times until a uniform conductivity reading was reached. The GNP slurry prepared for fabric rod coating consisted of 200 mg of GNP per ml DI water with 20 wt.% of the binder solution mentioned above. The slurry was further diluted with 5 ml DI water to adjust the viscosity of the slurry. Before coating, the slurry was stirred for 30 min.

The single-layer sensor structure was developed using a 301-lock stitch sewing machine with conductive thread in a bobbin stitched on the coated fabric shown in Figure 1. Once the external force is applied, the contact area between the thread and the fabric increases, causing a gradual decrease in the electrical resistance. Sensors were characterized by an INSTRON 5565A with a pressure range from 0 to 40 kPa, as shown in Figure 2. The ends of stitched thread were attached to the KEY SIGHT 34465A Digital Multi-meter terminals to record the change in resistance with the applied pressure.

Figure 1. Actual image of sensor

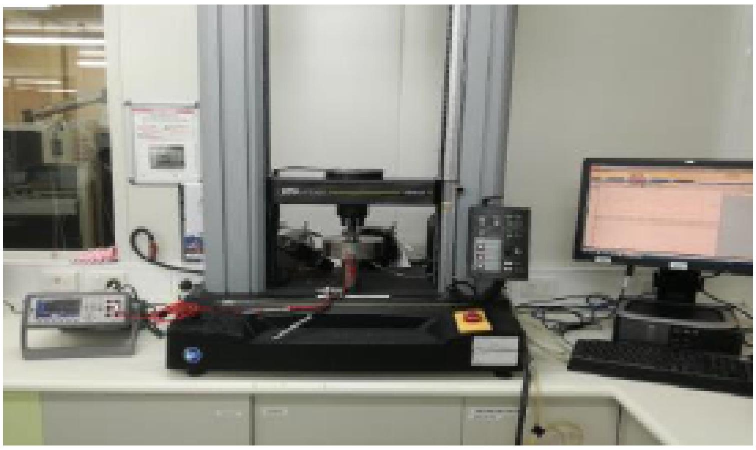

Figure 2. Experimental setup for the characterization of sensor

RESULTS AND CONCLUSIONS

The sensor was tested over the defined pressure range, and the change in resistance was recorded; the resistance curve for a typical sensor is shown in Figure 3. The sensitivity is expressed as , where ΔR is the change in resistance, and P is the applied pressure, was observed 10 kΩkPa-1 (at pressure ≤ 20 kPa). The sensor was also subjected to cyclic loading at 10 kPa pressure at a constant rate at 10 mm/min, and the response time of 50 ms was calculated. Compared to the pressure sensors reported in the literature (Kim,2017), (Gong, 2014), the developed sensor performs well when at the same time considering working range, sensitivity and response time.

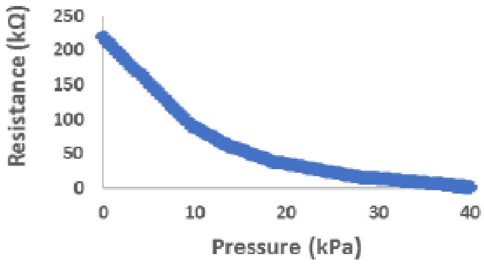

Figure 3. Sensitivity curve

CONCLUSIONS

The novel concept of developing a single layer textile-based pressure sensor was presented in this study. Natural cotton thread and fabric were coated with graphene nanoplatelets to induce conductivity and obtain sensing properties. Stitching was used as one of the very scalable methods to develop the sensor. The characteristics of high-sensitivity, excellent repeatability and flexibility, provide a perfect opportunity for the developed sensor's design to fit for various wearable applications.

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SURFACE MODIFICATION OF BASALT AND FLAX FIBRES BY ZNO NANOSTRUCTURES AND ITS EFFECT ON THERMAL, MECHANICAL AND CRYSTALLIZATION BEHAVIOUR OF THEIR PLA-BASED COMPOSITES

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ABSTRACT

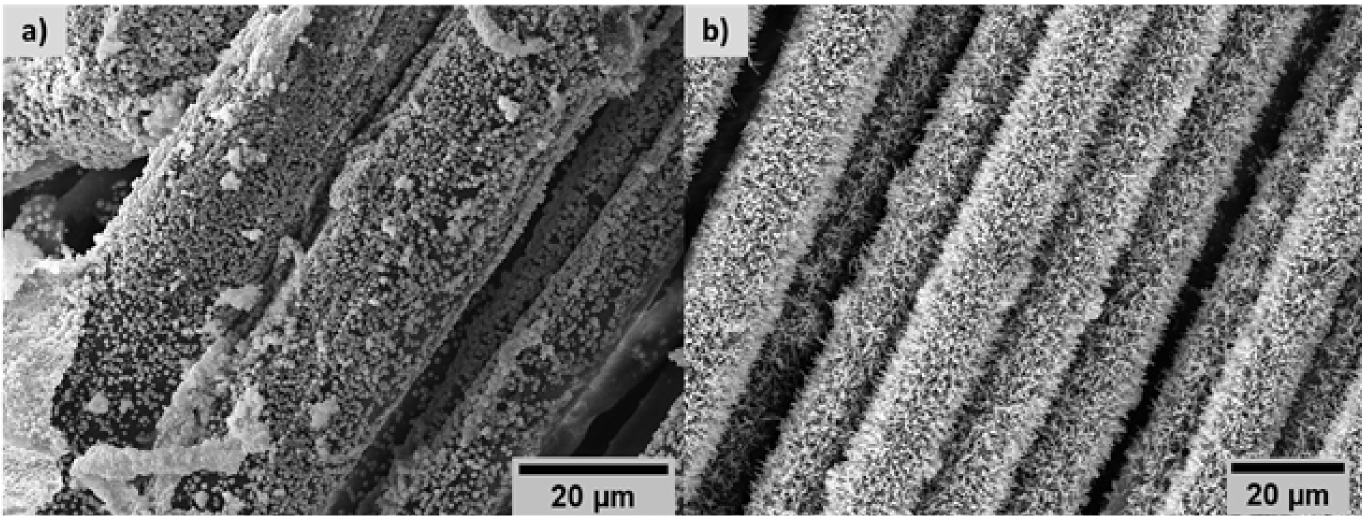
This work studies the effects that the addition of zinc oxide nanostructures has on the thermal and mechanical properties of polylactic acid-based biocomposites reinforced with natural fibres, such as flax and basalt. The laminates were tested by tensile and flexural tests and the thermal properties were analysed through differential scanning calorimetry (DSC). The formation of a homogeneous layer on the surface of the fibres, with different morphologies, makes this process useful for engineering the interphase, also in terms of crystallization nucleating ability, and therefore to improve the resulting mechanical properties.

INTRODUCTION

Polylactic acid (PLA) is one of the most promising materials as it is a biodegradable and biocompatible thermoplastic, with good workability, excellent transparency and relatively low cost. To overcome some limitations in the application of PLA, many fillers have been studied including natural fibres (Siakeng, 2019), which have numerous advantages over synthetic ones, such as low density, low cost, good specific mechanical properties, and are also recyclable and biodegradable. To achieve the best properties it is important to optimize interfacial adhesion. Many efforts have been made by the scientific community to achieve the best possible interface, through various techniques such as chemical functionalization, roughening and / or whiskerization with nanostructures. Among the various metal oxides used as multifunctional nanostructures, particular attention has recently been paid to zinc oxide (ZnO) (Fan, 2005), which can also be used as nucleating agent to increase the crystallinity of semi-crystalline polymers such as PLA (da Cruz Faria, 2020). This work is focused on the study of fibre-reinforced composite materials using basalt and flax fibres, with PLA as a matrix. To improve interfacial adhesion, ZnO nanostructures have been synthesized through two different processes, such as hydrothermal synthesis and electroless deposition, to investigate whether the morphology of the nanostructures, characterized by scanning electron microscopy (SEM), and the crystalline phases, analysed by X-ray diffraction analysis (XRD), could influence the final properties of the biocomposite. The laminates were made by compression moulding, with a symmetrical [0/90] stacking sequence and the mechanical properties were studied in quasi-static tensile and flexural tests with a Zwick / Roell Z010. Thermal behaviour and crystallization process were analysed by differential scanning calorimetry (DSC) and polarized light optical microscopy (PLOM).

RESULTS AND CONCLUSIONS

Figure 1a shows the SEM micrographs of the flax fibres covered by a continuous, homogeneous and densely packed layer of ZnO crystallites synthesized by electroless deposition, while on Fig.1b there is the SEM micrograph of basalt fibres densely decorated by ZnO nanorods through hydrothermal synthesis. From this morphological analysis, it is evident that both synthesis processes led to an excellent coverage of the surfaces of the fibres with ZnO nanostructures, although with different morphologies.
The good degree of coverage of the fibres was also confirmed by the results of the thermogravimetric analysis, showing an increase in the residual weight of 10 % compared to neat fabrics. From the XRD diffraction analysis, the ZnO crystal structure corresponds to the hexagonal Wurtzite, with the highest diffraction intensity peaks (100), (002) and (101) indicate the preferred growth orientation of nanorods, i.e. along the c-axis. Through the analysis carried out with PLOM, the nucleation efficiency of the fibres modified with ZnO compared to those not modified was also confirmed (Wang, 2019). This novel interface highlights the enormous potential of ZnO nanostructures in engineering the interfacial layer and thereby optimizing the mechanical properties of natural fibre-reinforced biocomposites.



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MULTIFUNCTIONAL PROPERTIES OF FLAX FABRICS FUNCTIONALIZED WITH MGO AND SIO2 NANOPARTICLES

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ABSTRACT

This work aims to develop functionalized flax fibers, using the combined effect of magnesium oxide (MgO) and silica (SiO2) nanoparticles (NPs), with the purpose of achieving several functionalities, especially the protection against harmful chemical and biological agents. The flax fabrics were functionalized with both NPs by a simple and sustainable in-situ method. The functionalization with only the MgO nanoparticles was also performed, for comparative studies. All the developed samples were characterized by Field Emission Scanning Electron Microscopy (FESEM), Attenuated Total Reflectance-Fourier-Transform Infrared Spectroscopy (ATR-FTIR) and Ground-State Diffuse Reflectance (GSDR). Several properties were also analysed, including harmful chemicals degradation, anti-bacterial activity and ultraviolet (UV) protection.

INTRODUCTION

The development of multifunctional fibrous systems (MFS), that can be used in a wide array of areas, such as healthcare, sports, and most importantly in the protection against chemical and biological warfare, has become a target of interest for researchers worldwide [1]. The incorporation of NPs, namely metal oxides, is a great alternative for the functionalization of textiles, due to not only to their nanoscale, but also good structural characteristics and high oxidation potential. This functionalization can provide several properties, such as UV protection, easy/self-cleaning and especially the adsorption/decomposition of harmful agents [1]. For this specific application MgO NPs have been gaining special attention, due to their high surface area, large number of reactive sites, high absorption capacity and decomposition ability [2]. One good strategy for the improvement of these properties and the NPs' anchorage onto the substrate, is the addition of SiO2, due to their high surface area [1]. Natural fibers are a great example of a sustainable and adaptable substrate, since they are highly abundant, biodegradable, biocompatible and present good mechanical properties [3]. Therefore, the functionalization of natural fibers with metal oxide NPs emerges as a great alternative for the development of MFS. In this work, flax fabrics were functionalized with MgO and SiO2 NPs by a simple in-situ method (with water as solvent and at room temperature). All the samples were characterized by FESEM, ATR-FTIR and GSDR and properties like UV protection and degradation of harmful chemicals and bacteria were evaluated.

RESULTS AND CONCLUSIONS

At an initial phase, the flax fabrics were functionalized with MgO NPs by in-situ synthesis, using magnesium nitrate as the precursor, ammonia as the reducing agent and water as solvent. The reaction was performed at room temperature and the calcination temperature (150°C) was lower than most temperatures reported in literature. The addition of the SiO2 NPs was also made using a simple in-situ method, once again at room temperature and using the same calcination temperature. The FESEM images of the flax fabrics functionalized with a) MgO and with b) MgO-SiO2 NPs are shown in Fig.1. It's possible to observe not only the presence of the NPs, but also their homogenous distribution. The other techniques (ATR-FTIR and GSDR) also corroborated this successful synthesis (data not shown in this abstract).

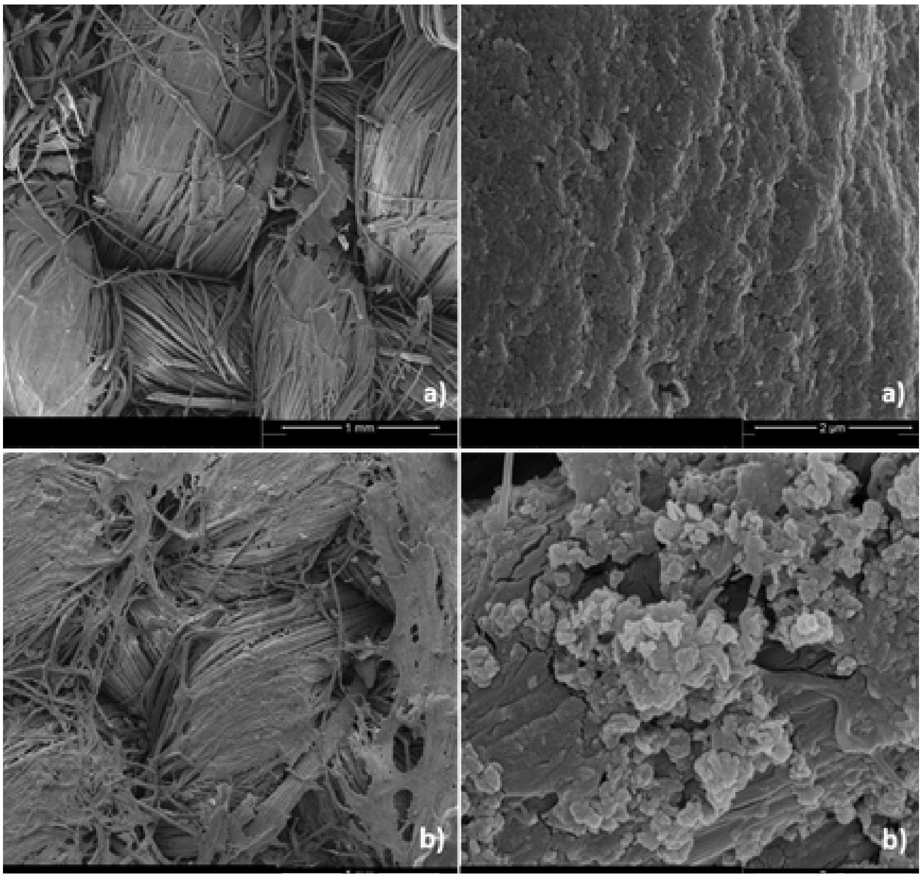

Fig.1 FESEM images of flax fabrics functionalized with a) MgO and b) MgO-SiO2 NPs.

Besides the degradation of harmful chemicals and antibacterial effect, an effective UV protection material, that prevents the harmful effects caused by the sun, is of huge importance. The UV protection behaviour of the developed systems was evaluated (Table 1). It's possible to clearly see the improvement of the UPF values with the NPs incorporation.

Table 1 UPF, classification and UVA and UVB blocking (%) values of the flax, flax+MgO and flax+MgO-SiO_2

Sample	UPF	Classification	UVA blocking (%)	UVB blocking (%)
Flax	50	Excellent	97.96	97.95
Flax+MgO	211	Excellent	99.40	99.54
Flax+MgO-SiO_2	530	Excellent	99.73	99.83

Other properties, like the degradation of harmful chemicals (methylene blue) and bacteria, Staphylococcus aureus and Escherichia coli, are being evaluated, being that some promising preliminary results were already obtained.

ACKNOWLEDGMENTS

The authors are thankful to project UID/CTM/00264/2021 of 2C2T – Centro de Ciência e Tecnologia Têxtil, funded by National Founds through FCT/MCTES" and FCT PhD Scholarship (SFRH/BD/147812/2019).

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CELLULOSE NANOCRYSTAL FROM WATER HYACINTH

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ABSTRACT
In recent years, much attention has been given to biodegradable materials with an interest in sustainable development and environmentally friendly. This research aims to synthesize and characterize the cellulose nanocrystal (CNC) from Water hyacinth (WH) obtained in locally as a raw material, in order to replace microfiber derived from synthetic polymer. CNC also increase value of water-way weed by turning into fillers for composite materials rather than a conventional product as a dried craft. The novelty was elucidated the properties of purified WH and high-quality CNC.

INTRODUCTION
WH is a noxious weed that has attracted worldwide attention due to its fast-spread and crowded growth, which leads to serious unfavorable effects on the environment, human health, and economics. This plant contains up to 60% cellulose. CNC can be isolated from WH, making WH an source for high quality nanomaterials (Malik 2007). CNC usually appear as rod-like or ribbon-like particles, the length of which typically ranges from 50 to 1000 nm and the diameter fluctuates between 3 and 50 nm. Due to their nanometric scale, CNC exhibit physicochemical properties such as a low density, low thermal expansion coefficient, high Young's modulus (138 GPa in the crystal region along the longitudinal axis), and high tensile strength. These properties make CNC an ideal candidate for novel applications such as high performance nanocomposites such as reinforcing fibres, filtration media, paints and coatings, and personal care, in addition to biomedical, hygiene, and absorbent products (Mekonnen et al. 2019). However, the material obtained after each stage of the treatments were necessary and carefully characterized in order to control crystalline and amorphous phase of material. Morphological investigation was performed using transmission electron microscopy (TEM). Fourier transform infrared (FTIR) spectroscopy showed the progressive removal of non-cellulosic constituents. X-ray diffraction (XRD) analysis revealed that the crystallinity increased with successive treatments.

RESULTS AND CONCLUSIONS
For CNC, the acid hydrolysis was performed by varying different temperatures and times of hydrolysis of 40, 50 and 60 °C, for 10, 20, 30, and 60 min. The molecular information of WH after successive treatment was shown in Fig 1. After chemical treatment, the WH (b and c) had similar FTIR spectra because residual, hemicellulose, and lignin were removed. Characteristic bands associated to hemicellulose and lignin were significantly weaker or disappeared, e.g., the 1,640 cm−1, attributable to the carbonyl groups of hemicelluloses and the 1,240 cm−1, attributable to ester, ether, or phenol compounds. Peaks at 1,745cm−1 is attributable to lignin (Tanpichai et al. 2019).

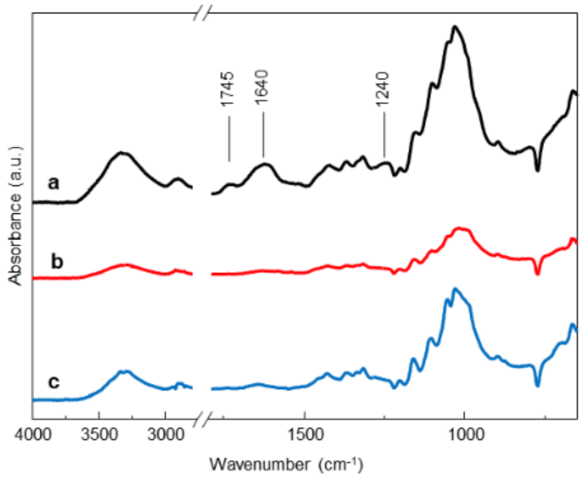

Fig. 1: FTIR spectra of (a) Raw, (b) Alkaline treated and (c) Bleached WH fibers

Bleached WH was hydrolyzed in sulfuric acid solution. After hydrolysis steps, then successive cleaning and centrifugation for removing acid were performed. CNC display clear and bright flow birefringence under cross-polarized light as shown in Fig.2. acid treatment at 50°C for 20 min give the highest CNC yield of 65.2%, compare to previously reported (38.4%) (Balcha 2019). A suitable condition was established to distinguish the very high yield of WH cellulose nanofiber. TEM micrographs obtained for CNC show the size of the fiber from the micron to the nanometre scale (length about 50nm and diameter about 10nm). This means the acid hydrolysis treatment was expected to destroy the amorphous region of cellulosic microfibrils transversely, keeping the straight crystalline domains intact.

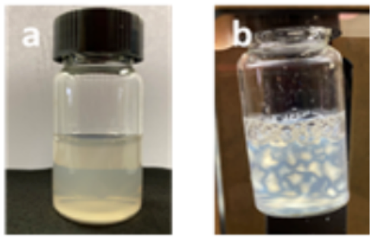

Fig. 1: FTIR spectra of (a) Raw, (b) Alkaline treated and (c) Bleached WH fibers

ACKNOWLEDGEMENT

This research was supported by the program management unit for area-based development (PMU-A), The office of national higher education science research and innovation policy council (NXPO). (Grant no. A13F630067).

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AN OPTIMIZATION OF THE TIME REQUIRED TO PREPARE NANOCELLULOSE FROM DIFFERENT FIBER SOURCES

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ABSTRACT

This work is focused on the possibilities of preparation of nanocellulose from various types of cellulose fibres used in the textile industry, such as cotton, viscose, lyocell fibres. Due to the fact that there are differences between materials (degree of polymerization, morphology), it is obvious that the process of preparation of nanocellulose from individual precursors needs to be optimized.

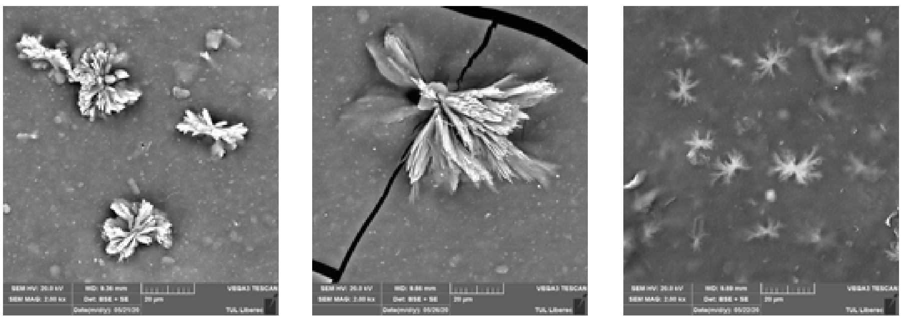
INTRODUCTION

Based on previous experiments, an acid hydrolysis procedure, using sulfuric acid, was chosen for the preparation of nanocellulose. The use of H2SO4 is described in detail, for example, in Mondals book (Mondal, 2016). Here, the recommended concentration for dissolving cellulose at room temperature is 65 - 70%. This procedure was used to prepare nanocellulose from cellulosic fibrous materials in this work (lyocell staple, viscose staple, viscose fabric, gray cotton fibers, cotton fabric). The samples were subjected to acid hydrolysis for various times (1-120 hours), neutralized and homogenized by ultrasound. The stability of the resulting gel, structure (optical and electron microscope) and yield were subsequently monitored for individual samples. From these data, the most suitable ripening time of the precursor for the preparation of nanoparticles can be defined.

RESULTS AND CONCLUSIONS

Appearance and particle size

The samples were observed using a microscope (those samples that were obvious to contain larger particles) and an electron microscope. Electron microscopy confirmed the presence of nanoparticles in samples dissolved for a longer time - 10 or more hours as seen in Fig 1. For regenerated cellulose fibers, the nanoparticles are observed in the form of crystals after 10 hours of maturation, while for cotton material up to 24 hours.



Lyocell (10 h) Viscose staple (10 h) Cotton (24h)

Fig.1 Images of particles from various precursors

Yield

In addition to the structure of the particles, its yield is also important for the process. The ideal case would be if there was 100 utilization of the input material, which is of course unrealistic with regard to the principle of decomposition of the original cellulose. It is logical that the yield is higher with a shorter exposure, but the nanoparticles do not have to be separated in short maturation times. In the optimized times of acid exposure (10 hours for regenerated cellulose fibers and 24 hours for cotton), the yield of nanoparticles was quantified - it reaches approximately 35%, with longer exposure the yield decreases.

Gel stability

After sonication of the samples, a complex system is formed containing, in addition to nanocellulose, a certain proportion of larger particles. Its stability at different times was observed. The kinetics of the process are shown in Fig 2., where the sedimentation of particles prepared from viscose scrap is monitored. The figure shows samples taken immediately after sonication (a), after a week (b) and after 2 months (c)

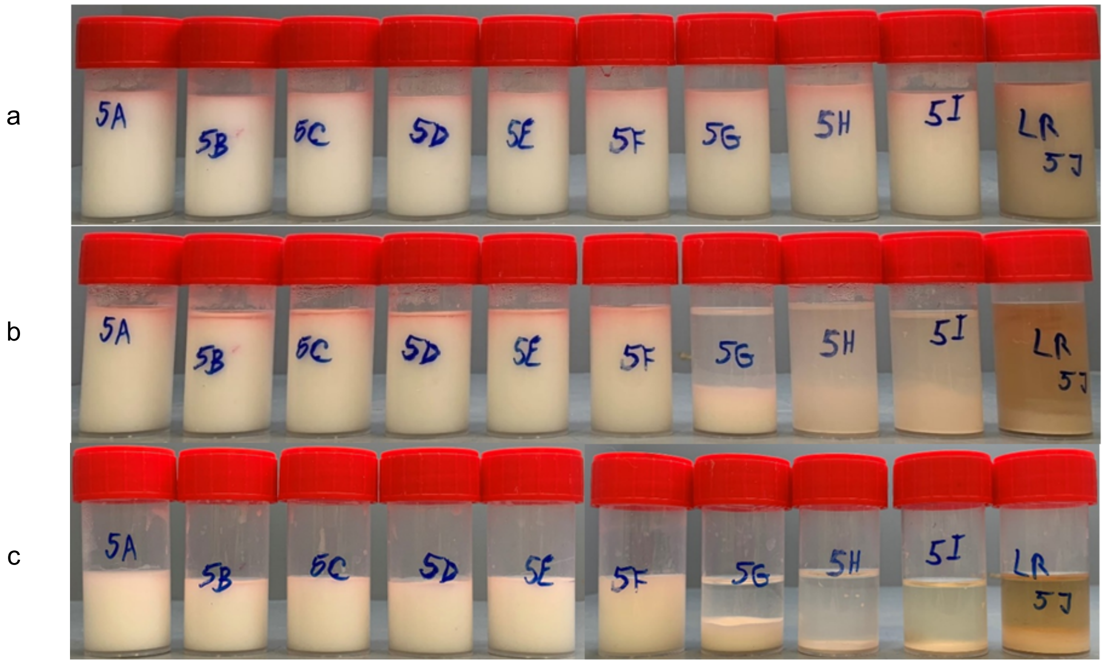


Fig.2 Sedimentation of particles prepared from viscose staple: immediately after sonication (a), after week (b) and after 2 months (c).
(Sample 5A was exposed to acid for the shortest time, sample 5J for the longest time)

From the presented results, it is clear that the form of the final product and its properties depend not only on the input raw material, but also on the time when the material is subjected to hydrolysis.

ACKNOWLEDGMENTS

This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic and the European Union - European Structural and Investment Funds in the frames of Operational Programme Research, Development and Education - project Hybrid Materials for Hierarchical Structures (HyHi, Reg. No. CZ.02.1.01/0.0/0.0/16_019/0000843).

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NANOCOMPOSITE HYDROGEL BIOINKS BASED ON PECTIN AND CELLULOSE NANOFIBRILS FOR 3D-BIOPRINTING APPLICATIONS

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ABSTRACT

The present communication reports the development of pectin/cellulose nanofibrils (CNFs) hydrogel-based bioinks laden with HaCaT cells. These novel polysaccharides-based bioinks were characterized in terms of rheological behaviour and in vitro cytotoxicity. Moreover, the bioprinting parameters were optimized, and the mechanical properties and cell viability of the living tissues evaluated. Overall, the developed hydrogels presented superior mechanical performance and cell viability, and thus, have potential for application 3D-bioprinting of living tissue analogues.

INTRODUCTION

Biopolymeric hydrogels are a fascinating family of materials for panoply of applications, including 3D-bioprinting, due to their singular properties, namely low cytotoxicity, hydrophilicity, and biodegradability. Among the biopolymers collection, polysaccharides are of particular relevance for the preparation of hydrogels for 3D-bioprinting. However, biopolymeric hydrogels have some mechanical and biological limitations, such as structural degradability, and, in some cases, poor cell-adhesion. These restrictions are usually overcome via blending with other materials and cell-adherent molecules. An example of such materials, includes CNFs that present excellent properties in terms of mechanical strength and stability, but also cell-adherent activities, and their use as building nanoblocks in innovative functional nanocomposites has attracted increasing attention in the past two decades (Klemm, 2018).

The combination of pectin, which can easily form hydrogels in the presence of divalent cations (Pereira, 2018), with the mechanically robust CNFs with demonstrated potential in 3D-bioprinting (Markstedt, 2015), and cells (HaCaT), has never been explored for 3D-bioprinting application. Therefore, in this communication, the development and characterization of pectin/CNFs hydrogel-based bioinks laden with HaCaT cells, will be presented.

RESULTS AND CONCLUSIONS

Nanocomposite hydrogel bioinks were prepared by mixing a pectin extract with a CNFs suspension, followed by ionic crosslinking with CaCl2. The developed hydrogels were characterized in terms of chemical composition by infrared spectroscopy (FTIR-ATR), in vitro cytotoxicity by the MTT assay, rheological properties, and morphology by scanning electron microscopy (SEM), and the 3D bioprinting parameters, namely pressure, velocity, nozzle diameter, and printed layers, were optimized, as illustrated in Fig.1.

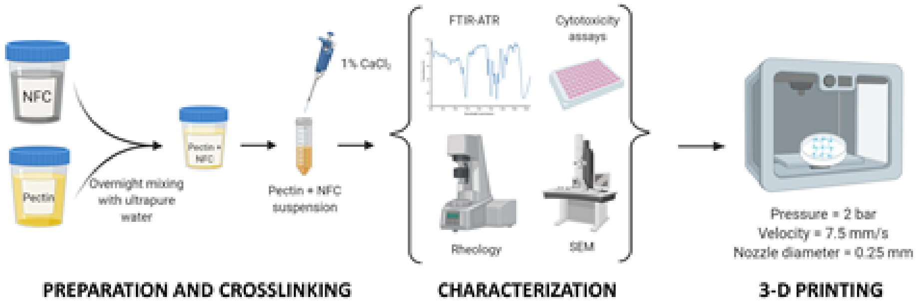

Fig.1 Scheme summarizing the preparation, characterization and 3D printing of the pectin/CNFs hydrogels.

The partnership between pectin, CNFs, and HaCaT cells originated nanocomposite hydrogel bioinks with adequate morphology, shear-thinning behaviour, non-cytotoxicity, and good printability, which allowed the printing of 8 layers without losing resolution, as depicted in Fig.2. Furthermore, these novel polysaccharides-based bioinks showed non-cytotoxicity for HaCAT cells, with higher cell viabilities for the hydrogels with increased content of CNFs. Hence, these results demonstrate the enormous potential of the nanocomposite hydrogel bionks composed of pectin and CNFs for 3D-bioprinting of living tissue analogues.

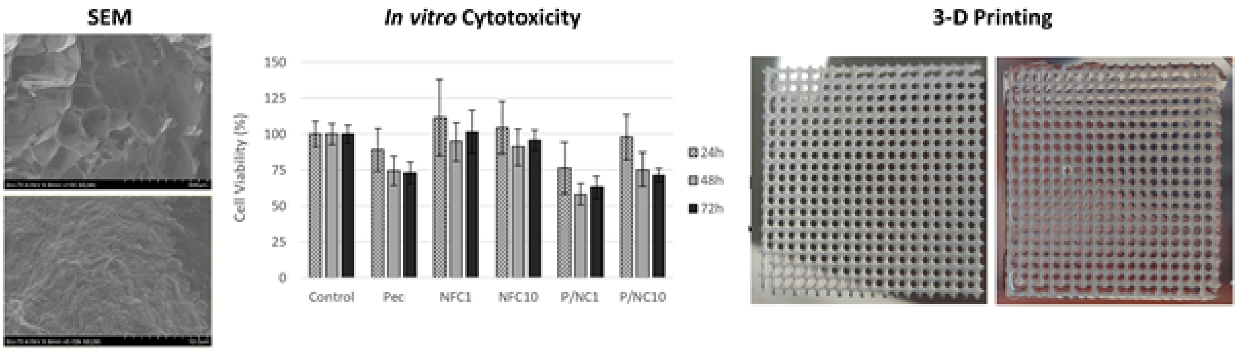

Fig.2 SEM micrographs, cell viability and 3D constructs of the pectin/CNFs hydrogel bioinks.

ACKNOWLEDGMENTS

This work was developed within the scope of the projects CICECO – Aveiro Institute of Materials (UIDB/50011/2020 & UIDP/50011/2020), and NANOBIOINKS – Engineering bio-based nanofibers for the development of high-performance nanostructured bioinks for 3-D bioprinting (CENTRO-01-0145-FEDER-031289), funded by the Operational Program of the Center Region, in its FEDER/FNR component, and by national funds (OE), through FCT/MCTES. FCT is also acknowledged for the research contracts under the Stimulus of Scientific Employment 2017 to C.V. (CEECIND/00263/2018).

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MOROCCAN PLANT FIBERS (ALFA AND JUNCUS) AS GREEN SOURCE FOR THE PRODUCTION OF MICRO- AND NANO-CELLULOSE

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ABSTRACT

The main objective of this work is to exploit abundant Moroccan plant fibers Alfa (Stipa tenacissima L.) and to compare with Juncus (Juncus effusus L) as sustainable green materials for the production of cellulose microfibers (CMF), cellulose nanocrystals (CNC), and cellulose nanofibrils (CNF). The morphology, thermal, and physico-chemical properties of cellulosic materials were analyzed at different treatment stages using multiple characterization techniques such as SEM, AFM, FTIR, XRD, and TGA. The yield of CMF from Alfa was found to be 49.53% and from Juncus to be 37.82%. The CNC and CNF from Alfa exhibited crystallinity of 89.63% and 88.87%, respectively, and from Juncus was 80.75% and 65.34%, respectively. From the obtained results, Alfa and Juncus plant fibers could be useful alternatives to conventional cellulose sources such as wood. Herein, the produced cellulosic materials could be used as fillers in polymer composites for different potential applications such as packaging, water treatment, etc.

INTRODUCTION

For several decades, natural fibers from plants are attracting a lot of interest from researchers because of their biodegradability, cost-effectiveness, non-toxicity, high performance, low density, availability, and easy to process which can replace petroleum-based materials (Labidi et al. 2019). Contrarily, natural fibers have some drawbacks, such as low resistance to humidity, weak interfacial adhesion with most polymer matrices, and their hydrophilic structure (Labidi et al. 2019; Kassab et al. 2020). The latter is related to the lignocellulosic structure of natural fibers containing hydroxyl groups. Accordingly, various chemical and physical modifications of fibers have been suggested to address these disadvantages in order to enhance their compatibility with polymer matrices, which are often hydrophobic (Kassab et al. 2020). Generally, the composition and properties of natural fibers differ depending on the origin of fibers, the plant species, and the climate in which the original plant is grown.

The most common traditional source of producing cellulose is wood (Labidi et al. 2019). In order to satisfy the demand for cellulose-based materials and global climatic change, researchers and industries are steadily looking for alternative resources. Perennial grasses are among the category of lignocellulosic plant fibers identified as renewable sources for the production of cellulose and its derivatives (Kassab et al. 2020). The most common perennial grasses found in Morocco are Alfa (Stipa tenacissima L.) and Juncus (Juncus effusus L). Currently, the Alfa plant is widely distributed in Morocco in a large geographical area in the North-western region totaling approximately 3.1 million hectares (Labidi et al. 2019). While Juncus (Juncus effusus L) is a widespread plant that grows in Morocco's central regions, especially in wet areas, near lakes, rivers, ponds, mountains, etc (Kassab et al. The main objective of this research is to study the effect of physico-chemical treatments on these Moroccan fiber grasses in order to further explore the feasibility of their use as fillers in composite polymers for applications such as packaging, water treatment, textile, construction, etc. The treatments of fibers applied include hot water washing, alkali treatment, bleaching, hydrolysis treatment with sulfuric acid, and mechanical disintegration process. The as-produced micro- and nano- cellulosic materials from Alfa (AF) and Juncus (JNC) were characterized and compared in terms of their morphologies, dimensions, structure, crystallinity, and thermal stability.

RESULTS AND CONCLUSIONS

Table 1 presents the results of morphological, structural, and thermal properties for raw (R) and extracted cellulosic materials (CMF, CNC, and CNF) from AF and JNC. The thermal stability, aspect ratio, and crystallinity were found to be higher for the extracted cellulosic materials from AF than from JNC. Through this work, we have demonstrated a potential strategy for adding value to the cellulose-rich, inexpensive and renewable sources of AF and JNC. From these results, it can be concluded that the cellulosic materials obtained from AF and JNC fibers have wide potential applications in polymer composite processing, water treatment, and food industry applications.

SAMPLE	D (nm)	L (nm)	Aspect ratio	CrI (%)	T_{onset} (°C)	T_{max} (°C)	R at 700°C
R-AF	-	-	-	43.42	216	339	21.28
R-JNC	-	-	-	47.21	253	334.	25.54
CMF-AF	-	-	-	72.81	236	355	10.28
CMF-JNC	-	-	-	76.34	270	352	10.42
CNC-AF	5.1 ± 2.8	330 ± 30	64.71 ± 10.7	89.63	171	353	16.87
CNC-JNC	7.3 ± 2.2	431 ± 94	60.67 ± 5.41	80.75	220	332	32.33
CNF-AF	3.1 ± 1.6	-	-	88.87	162	290	17.61
CNF-JNC	2.5 ± 1.3	-	-	65.34	203	288	26.84

Table 1 Diameter (D), length (L), aspect ratio, crystallinity index (CrI), and thermal properties of raw (R) and extracted cellulosic materials (CMF, CNC, and CNF) from AF and JNC fibers

ACKNOWLEDGMENTS

The financial assistance of the Office Chérifien des Phosphates(OCP S.A.) in the Moroccan Kingdom toward this research is hereby acknowledged.

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DEVELOPMENT AND CHARACTERIZATION OF A BACTERIAL CELLULOSE FILM AS A SUBSTITUTE FOR LEATHER

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ABSTRACT
Bacterial cellulose culture has been used to produce biocellulose films in view of using them as new materials or as an alternative to animal and synthetic leather. The aim of our study is to understand the different bioculture process parameters in relation to the properties of the films obtained. Our first results show that the materials obtained have interesting properties but due to the complexity of working with living organisms, optimization of the process has proved to be difficult. The main interest of this production is the use of 100% natural and renewable resources and to work towards an increasing need for sustainable products.

INTRODUCTION
Real leather is obtained from animal skins from very diverse origins and is very widely used in the fashion industry to make clothes or accessories. However, there is a growing consciousness of consumers to ethical and environmental issues around the origins of the skins, or how the animals were reared or killed, or the pollution generated by the leather tanning process. Veganism is becoming more and more popular, not only for abstaining from the use of animal products in the diet but also in extending this to avoid any animal or animal-derived substances in other commodities such as clothes or shoes. For all these reasons, there have been a growing number of initiatives to provide substitutes to animal leather. Synthetic leather has of course existed for long but uses nonrenewable resources and is therefore not highly desirable for a more sustainable world. A new class of “vegan leather” has emerged in recent years, using natural fibers or bio sourced materials as textile substrate but they also use material coatings from the petrochemical industry, such as polyurethane or other plastic coatings.
It is therefore necessary to look for other alternatives that are more in phase with the demands of today’s conscious consumers. Biofabrication provides one interesting outlook, and the culture of biocellulose films from natural resources in particular has a good potential in the production of 100% based natural materials to substitute animal or synthetic leather, with the advantage of being biodegradable compared to synthetic counterparts.
We propose in our study to develop biocellulose films from Kombucha tea, which is a fermented sweetened black or green tea that is usually consumed as a probiotic health product. Our objective is to better understand the role of different parameters such as culture medium formulation, fermentation and drying conditions etc. in order to optimize the cellulose yield and to characterize the film properties for a textile final application.

RESULTS AND CONCLUSIONS
The influence of different parameters such as the time of culture or different drying processes has been studied. The biofilms obtained have been mechanically characterized in terms of tensile and bending properties. Their behaviour towards humidity has also been investigated.
Fig. 1 shows the evolution of the yield of the bioculture in terms of mass of dry film produced with the

number of days of fermentation. Different batches were prepared for each culture time, represented by the different points. A plateau is reached after about 20 days.

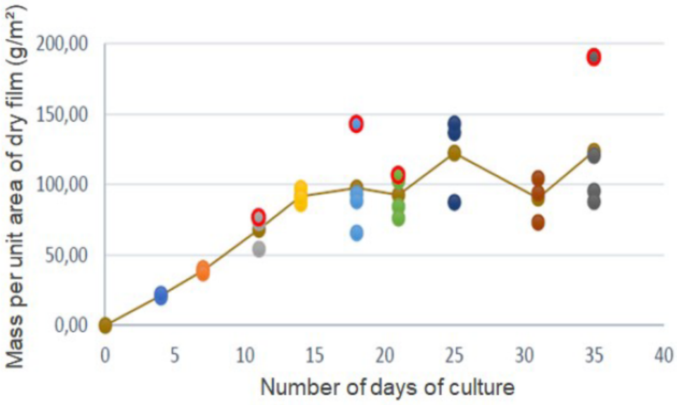

Fig.1. Dry mass of films during fermentation

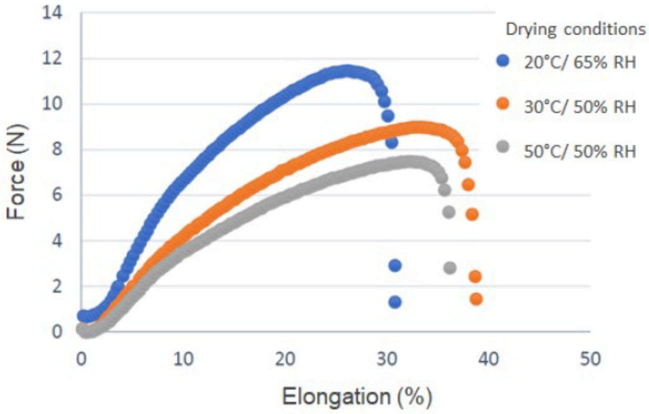

Fig.3. Influence of drying process on mechanical properties

The importance of the drying conditions on the final mechanical properties of the film is illustrated in Fig. 2: a film with a highest tensile modulus is produced at the lowest temperature.

The films obtained were quite thin (0.1-0.3 mm), with a mass per unit area around 100 g/m². They were quite soft in feeling, with a certain degree of transparency.

Different formulations have been used in order to optimize the yield of the bioculture and the properties of the film: the optimum conditions are very difficult to define because living organisms like bacteria are very difficult to control. We have nevertheless been able to produce films with interesting properties that have to be further investigated, namely in terms of better yields and with protective finishing treatments because of their sensitivity to humidity.

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ANTIMICROBIAL PERFORMANCE OF LIGNIN EMBEDDED IN BACTERIAL NANOCELLULOSE MEMBRANES

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ABSTRACT

The development of bio-based antimicrobial polymeric composites has never been so urgent. Novel antimicrobial fibrous-based biocomposites will certainly allow the development of important solutions to fight the present and future Pandemics, while reducing the dependence of petrochemical based polymers and fibers. Lignin has a pivotal function in preventing the invasion of phytopathogens, thus, this work explores the antimicrobial potential of lignin when embedded in a biosynthesized fibrous nanomatrix with superior mechanical properties: bacterial nanocellulose (BNC). Lignin was subjected to alkali treatment to promote the inclusion of lignin within BNC which comprises pores ranging from 20 to 300 nm. Both alkali treatment efficiency, bactericidal and antiviral activities were investigated

INTRODUCTION

The inclusion of lignin within a bacterial nanocellulose (BNC) matrix generates a fully bio-based composite encompassing the excellent properties of both components. BNC is synthesized by bacteria and exhibits mechanical properties roughly equivalent to Kevlar® and an impressive biocompatibility (Padrão, 2021). Lignin has a satisfactory stiffness, good thermal stability and antioxidant activity (Melro, 2018). Lignin antimicrobial activity per se and when embedded within a BNC membrane was assessed. Two model bacteria: Staphylococcus aureus and Escherichia coli, and MS2 bacteriophage, which contains a RNA genome in addition to a capsid which roughly has a similar architecture as SARS-CoV-2. Lignin was obtained from the black liquor of a Kraft pulp mill (ENCE, Pontevedra, Spain) using Eucalyptus globulus as raw material. The black liquor was subjected to lignin precipitation with sulfuric acid and then the lignin was extensively washed with acidic solution and water, dried and milled with a mortar and pestle was submitted to two alkali treatments: 0.05 M and 0.1 M of sodium hydroxide. After neutralization, minimal bactericidal/virucidal concentration was evaluated. Once embedded within a BNC matrix, the composites were analyzed to test their efficacy against bacteria and the MS bacteriophage.

RESULTS AND CONCLUSIONS

The alkali treatment has an obvious impact on the size of the lignin fragments, becoming smaller as the alkali concentration increases (Fig. 1). The minimal bactericidal/virucidal activity (Table 1) confirms the potential antibacterial activity of all lignin samples, by displaying a relevant Log reduction against S. aureus. As for the minimal virucidal activity, the Log reduction is low with the exception of 10 mg mL-1 of lignin treated with 0.1 M of NaOH. Once the different lignins are incorporated into BNC (Fig. 2), the BNC with the highest zone of inhibition against S. aureus contains lignin 0.1 M of NaOH. Nevertheless, the bactericidal activity against E. coli and the antiviral activity are negligible (Table 2).

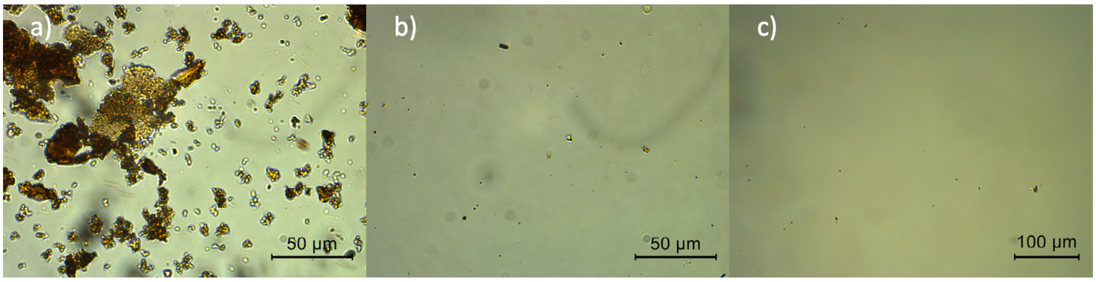

Fig. 1 Microscopy images of: a) lignin, b) lignin 0.05M NaOH and c) lignin 0.1M NaOH

Table 1 – Minimal bactericidal/virucidal concentration

		Lignin			Lignin 0.05 M NaOH			Lignin 0.1 M NaOH		
Concentration (mg mL^{-1})		1	0.1	0.01	10	1	0.01	10	1	0.01
S. aureus	Log reduction (CFU mL^{-1})	3.8	2.9	0	2.4	1.7	0	1.8	1.9	0
E. coli		0.9	0	0	1.2	0	0	0.6	0	0
MS2	Log reduction (PFU mL^{-1})	1.8		1.4	1.68		1.39	3.0		1.2

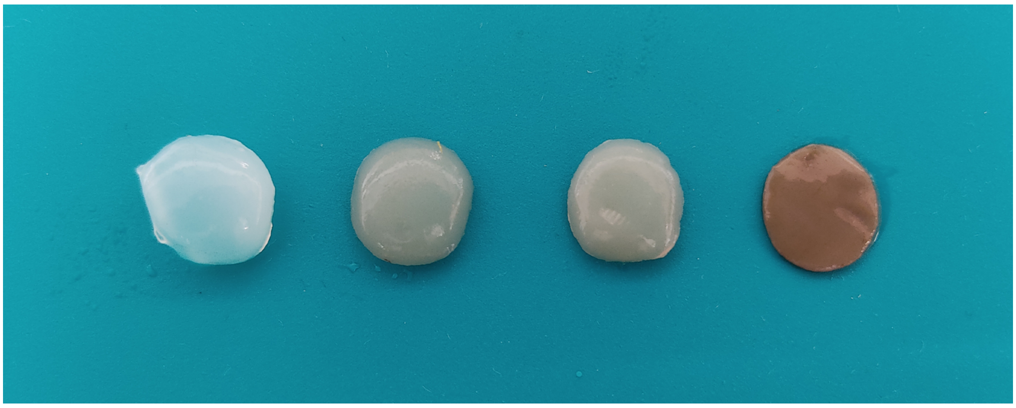

Fig. 2 BNC membranes embedded with lignin. From left to right: BNC, lignin 0.05M NaOH, lignin 0.1M NaOH and lignin.

Table 2 – Minimal bactericidal/virucidal concentration

Sample		BNC	Lignin	Lignin 0.05 M NaOH	Lignin 0.1 M NaOH
S. aureus	ZoI (mm)	0	8.5	7.7	13.2
E. coli		0	0	0	0
MS2	Log reduction (PFU mL^{-1})	0	0.3	0.1	0.3

Further antimicrobial analysis is required to provide further insights of the bactericidal activity of the composites.

ACKNOWLEDGMENTS

The authors would like to acknowledge the project PLASMAMED - PTDC/CTM-TEX/28295/2017 financed by FCT, FEDER and POCI in the frame of the Portugal 2020 program, the project UID/CTM/00264/2019 of 2C2T under the COMPETE and FCT/MCTES (PIDDAC) co-financed by FEDER through the PT2020 program. Liliana Melro acknowledges her Doctoral grant awarded by FCT (2020.04919.BD).

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FUNCTIONALIZATION OF CELLULOSE NANOCRYSTALS FOR APPLICATION IN DENTAL ADHESIVES

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ABSTRACT
In this work, we present a chemical route for preparation of methacrylate functionalized cellulose nanocrystals (CNCs) for application in dental adhesives. These methacrylate-bearing cellulose nanoparticles improved the performance of dental adhesives.

INTRODUCTION
Dental restoration is an important aspect of oral health in European societies. With the rise of public awareness about environmental and health side effects of amalgam fillings in dentistry, alternative composite materials have become popular. Composite materials are adhered to dentin or enamel by dental adhesives. Due to the dynamic and hydrated nature of the substrate, adhesion of composite materials to dentin is challenging. Weak bonding between restorative materials and dentin causes issues that ultimately can result in the failure of the restoration. In recent years, there has been several studies showing that incorporation of a small amount of surface modified inorganic nanofillers can improve the bonding between dentin and composite materials. However, due to their high density, these nanoparticles tend to precipitate relatively fast. Therefore, the composition of the adhesive throughout the application time by dentists is not stable, which results in irreproducibility and unreliability of the restoration outcome 1.
CNCs are bio-based nanoparticles and have a lower density in comparison to their inorganic counterparts, which decreases the chance of fast sedimentation. Their size and surface chemistry can be tuned based on preparation methods and different treatments 2. Furthermore, these functional modifications on the surface of the CNCs can enable them to interact with the dentin structure on one side and the composite on the other side during the curing process and improve the adhesive forces between the composite layer and the dentin.
In this study, we applied a chemical strategy to modify the surface of CNCs to improve their dispersion in an experimental dentin adhesive with more colloidal stability than the previously nanofilled dentin bonding systems over time. Cellulose Nanocrystals (CNCs) are surface modified with 2-Aminoethyl methacrylate to improve the characteristics of their dispersion in the adhesive matrix.

RESULTS AND CONCLUSIONS
The chemical route for surface modification and the IR of the produced modified CNCs are shown in Fig. 1. The disappearance of the peak at 1605 cm-1 (carboxylate group of TEMPO-oxidized CNC) confirms the presence of 2-Aminoethyl methacrylate. The appearance of the characteristic peak of carbonyl group of 2-Aminoethyl methacrylate (1720 cm-1) after modification and three characteristic peaks of amide vibration (Amide I: 1645 cm-1, Amide II: 1540 cm-1, and Amide III: 1250 cm-1) confirm the amide bond formation on C-6 of TEMPO oxidized CNCs after modification.

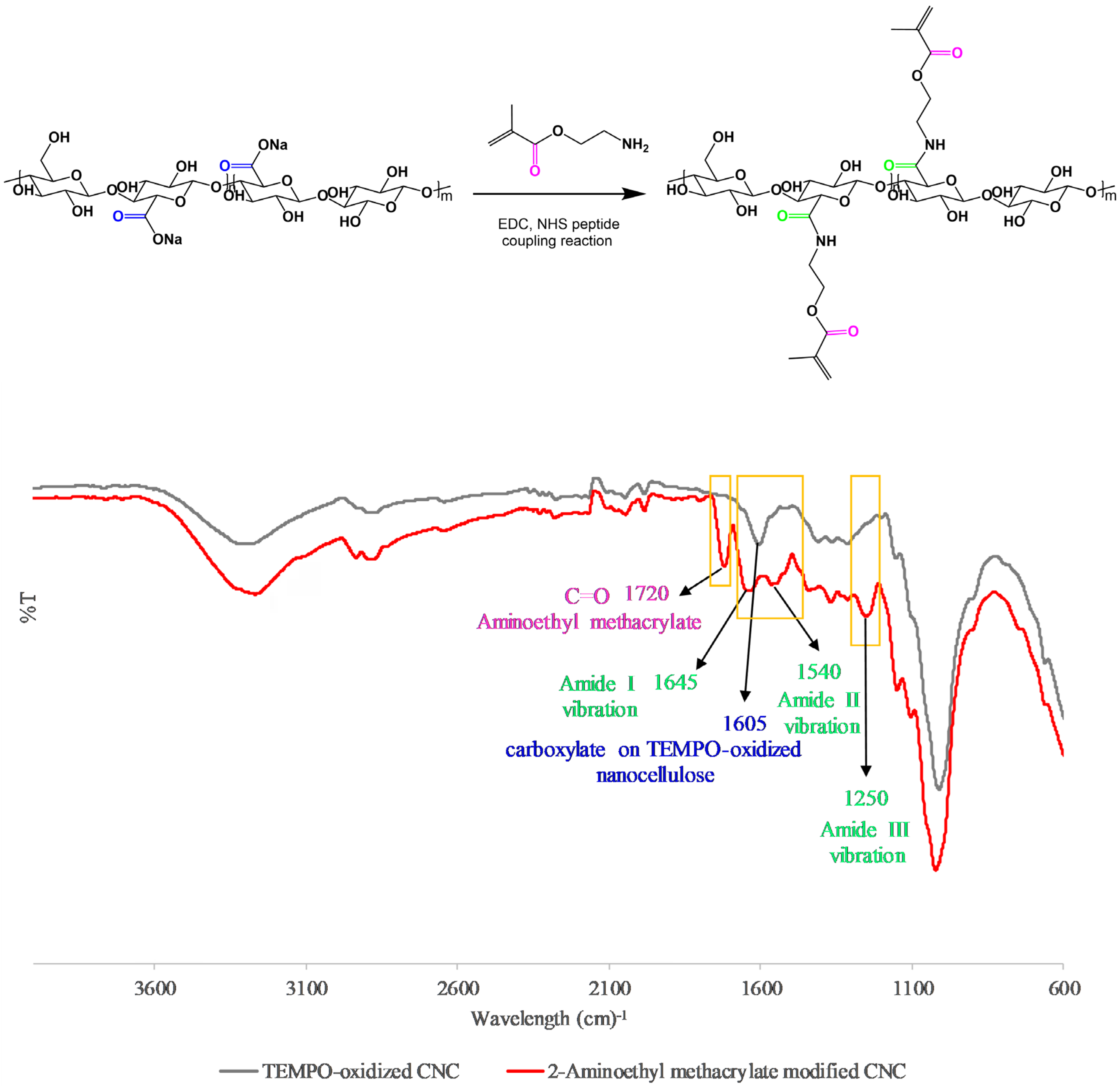

Fig.1 Surface modification of TEMPO-oxidized CNC with 2-Aminoethyl methacrylate

Further characterization techniques were used (e.g. XPS, DSC-MS, Conductometric titration) to affirm the modification reaction. Dispersion analysis results showed the dispersion of surface modified CNC in an experimental dentin adhesive was significantly more stable than that of TEMPO-oxidized CNC.

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CRYSTALLINE NANOCELLULOSE FROM LIGNOCELLULOSIC BIOMASS RESOURCES AS PHYSICAL REINFORCEMENT FOR CHITOSAN BIOFILMS

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ABSTRACT

The aim of this work was to test nanocellulose obtained from two different lignocellulosic biomass (miscanthus and kenaf) as reinforcement in chitosan films. Nanocrystalline cellulose was produced via an alkaline pre-treatment approach applied into the different biomasses, followed by acid hydrolysis. After, these nanocelluloses were incorporated in chitosan at different rates and the bionanocomposites were characterized. Commercial nanocellulose was also tested in the chitosan films for comparison. A film made with pristine chitosan was the control. The results indicate that the incorporation of nanocrystalline cellulose improved the mechanical properties of chitosan as intended. No significant differences were observed among the characteristics of the films produced from miscanthus, kenaf, and the commercial nanocellulose. Hence, results indicate that residues from those lignocellulosic residues may provide a source of nanocellulose to produce bionanocomposites.

INTRODUCTION

Extended years of massive industrialization have been the genesis of uninterrupted exhaustion of nonrenewable resources, being achieved high pollution levels. Yet, nowadays, the overuse of nonrenewable resources has been an incentive for intensive research and development of new kinds of green bio-based and degradable materials obtained from renewable sources (Souza et al., 2020). Lignocellulosic biomass is an under-exploited bioresource, basically composed of lignin, cellulose, and hemicellulose. This type of biomass can be retrieved from multiple sources, among which are wastes from agricultural and industrial lignocellulosic crops (Pires et al., 2019a). Cellulose can be isolated from the lignocellulosic fibers and then depolymerized to give rise to nanocellulose (NC), an extraordinary nanometer-scale bio-based material with applicability in diverse technological areas. Indeed, abundance, biodegradability, renewability, and low-cost, together with excellent mechanical properties nominate NC as one of the most promising nanometric biomaterials (Pires et al., 2019b). Bio-based plastics/polymers, recurrently expressed in literature as bioplastics or biopolymers, have recently been appointed as natural candidates to replace fossil-based plastics. However, when side by side with traditional plastics, biopolymers still demonstrate crucial structural failures, mainly in terms of mechanical, thermal and barrier properties that reduce their industrial exploitation (Pires et al., 2019c). Therefore, the introduction of homogeneously scattered nanoparticles, e.g. NC, as a reinforcement, with a high aspect ratio and high surface area, into the biopolymer matrix is seen as an encouraging solution to overcome these shortcomings, generating a novel functional class of materials, named bionanocomposites (Pires et al., 2020).

Nanocrystalline cellulose was produced via an alkaline pre-treatment approach applied to two different lignocellulosic biomasses (miscanthus and kenaf), followed by acid hydrolysis, and then tested as reinforcement in chitosan films. These nanocelluloses were incorporated in chitosan at different rates (1.5%, 2% and 2.5% w/w) and the bionanocomposites were characterized: X-ray diffraction, mechanical properties, thickness, optical properties (opacity and transparency), surface color, and solubility, swelling degree and contact angle. Commercial nanocellulose at the same rates (1.5%, 2% and 2.5% w/w) were also tested in the chitosan films for comparison. A film made with pristine chitosan was the control.

RESULTS AND CONCLUSIONS

The results indicate that the incorporation of nanocrystalline cellulose improved the mechanical properties of chitosan as intended. Additionally, bionanocomposites are slightly more saturated and showed greater ultraviolet light block than the pristine chitosan films. No significant differences were observed among the characteristics of the films produced from miscanthus, kenaf, and the commercial NC. Hence, results indicate that residues from those two energy crops may provide a source of NC to produce bionanocomposites.

ACKNOWLEDGMENTS

This research was funded by national funding by FCT, Foundation for Science and Technology, through the individual research grant (SFRH/BD/144346/2019) of João Pires. This work has also been supported by the Mechanical Engineering and Resource Sustainability Center - MEtRICs which is financed by national funds from FCT/MCTES (UIDB/04077/2020), and by the CENIMAT/I3N (UIDB/50025/2020).

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NANOCELLULOSE-BASED PATCHES FOR CUTANEOUS WOUND HEALING

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ABSTRACT

The current communication describes the recent developments accomplished in our research group on the design of nanocellulose-based patches through simple and eco-friendly fabrication methodologies. Focus will be put on two advanced nanocellulose-based patch systems, namely (i) nanofibrous patches composed of cellulose nanofibrils (CNFs) and lysozyme nanofibers (Silva, 2020), and (ii) multi-layered patches composed of bacterial nanocellulose (BC), chitosan (CH) and alginate (ALG), loaded with dexpanthenol (DEX) (Fonseca, 2020). Overall, both nanocellulose-based patches exhibit good mechanical performance, antimicrobial activity, non-cytotoxicity, and wound healing capacity.

INTRODUCTION

The fabrication of patches based on natural polymers, such as polysaccharides and proteins, is gaining increasing attention as a detour to reduce the environmental impact linked to their disposable nature. Herein, nanocellulose materializes as a nanostructured raw material with unique properties (e.g., biodegradability, robustness, tailorable surface chemistry, non-cytotoxicity, conformability, and skin compatibility) that can be combined with bioactive molecules (e.g., DEX) and macromolecules (e.g., LNFs) to engineer advanced patches with essential functionalities for effective wound healing (Bacakova, 2019).

In this communication, the preparation and characterization of fully bio-based nanofibrous patches composed of (i) CNFs and LNFs (Silva, 2020), and (ii) BC, CH and ALG, loaded with DEX (Fonseca, 2020), for application in cutaneous wound healing, will be presented.

RESULTS AND CONCLUSIONS

In the first study, LNFs from hen egg white lysozyme were combined with CNFs from softwood bisulphite fibres (2.91 wt.% suspension, $\zeta \approx -13$ mV at pH 7) in a 1:1 mass fraction via a simple and fast one-pot methodology, namely by vacuum filtration of a water-based suspension of both nanofibers and by sequential filtration of the separated suspensions (Silva, 2020). The two nanofibrous patches displayed distinct morphologies, thermal stability up to 250 °C, good mechanical performance with Young's modulus ≥3.7 GPa, and UV-absorbing properties. The addition of the LNFs into the CNFs matrix bestowed antioxidant activity (76–79% DPPH scavenging) and antimicrobial activity against Staphylococcus aureus (3.5–log CFU mL^{-1} reduction), which is beneficial to hinder microbial wound infections. Additionally, the patches are biocompatible towards living L929 fibroblast cells, and the in vitro wound healing assay proven a good migration capacity leading to almost complete occlusion of the wound (Fig. 1). Henceforth, the blend of the two bio-based nanofibrous polymers represents a potential approach to engineer sustainable functional patches for cutaneous wound healing (Silva, 2020).

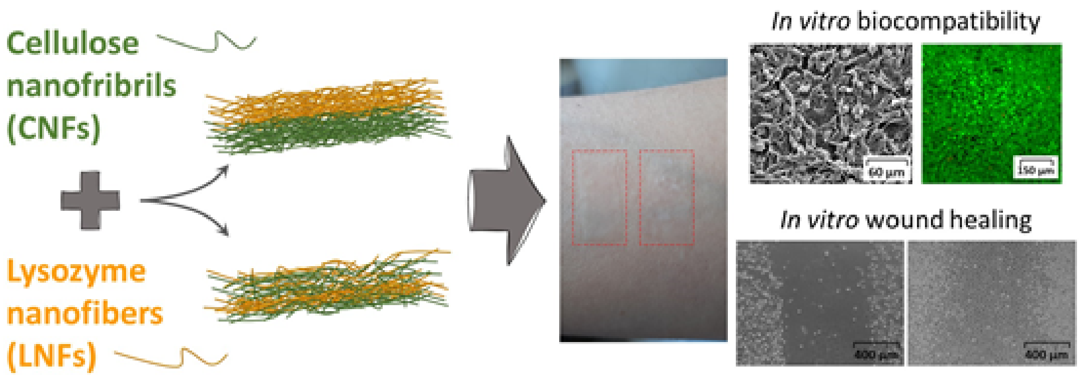

Fig.1 Scheme summarizing the preparation of the CNFs/LNFs patches (Silva, 2020).

In the second study, multi-layered patches composed of oxidized BC (OBC, carboxyl content ≈ 0.54 mmol g−1), CH, ALG and DEX were prepared and characterized (Fonseca, 2020). The multi-layered patches with 5, 11, 17, and 21 layers were assembled by the spin assisted layer-by-layer (LbL) coating technique of oppositely charged CH and ALG polyelectrolytes onto the OBC substrate loaded with DEX. These stratified patches had thermal stability up to 200 °C, mechanical properties with a Young's modulus higher than 4 GPa, and good moisture-uptake capacity (240–250%). In addition, they inhibited the growth of S. aureus with (3.2–log CFU mL−1 reduction) and are non-cytotoxic to human keratinocytes HaCaT cells with a cell viability of ca. 97% after 48 h. The in vitro DEX release profile from the patches is time-dependent and is sustained with the increasing number of layers. Besides, the in vitro wound healing assay revealed a good migration capacity with the full occlusion of the wound scratch after 24 h (Fig 2). These data substantiate the potentiality of these multi-layered polysaccharides-based patches for the topical delivery of DEX, which is a wound healing promoter (Fonseca, 2020).

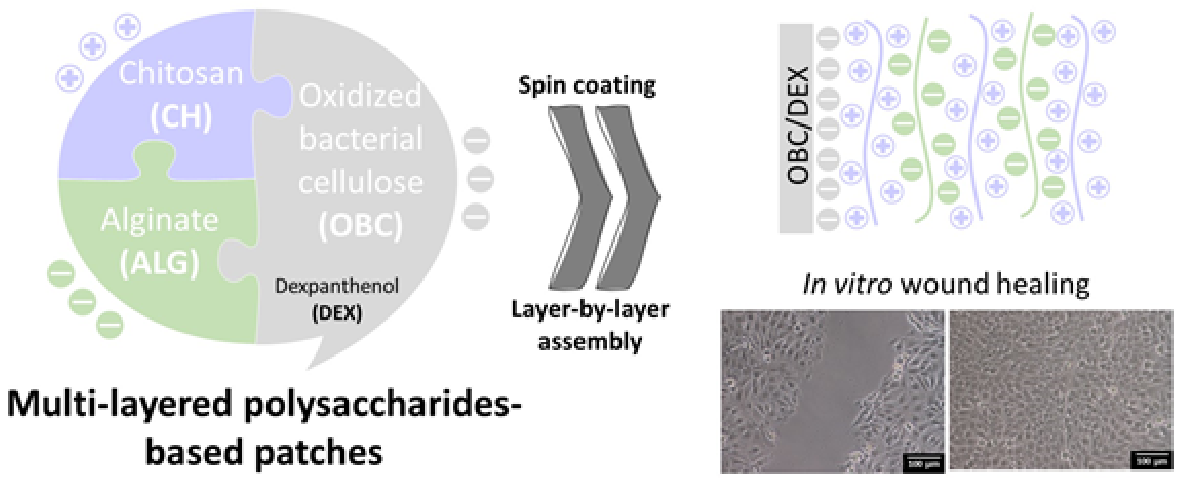

Fig.2 Scheme summarizing the fabrication of the OBC/DEX/CH/ALG patches (Fonseca, 2020).

ACKNOWLEDGMENTS

This work was developed within the scope of the project CICECO-Aveiro Institute of Materials (UIDB/50011/2020 & UIDP/50011/2020), financed by national funds through the Portuguese Foundation for Science and Technology (FCT)/MCTES. FCT is also acknowledged for the research contract under Scientific Employment Stimulus to C.V. (CEECIND/00263/2018).

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SUPERCRITICAL FLUID-ASSISTED NANOMATERIAL REINFORCEMENT OF FLAX FIBERS

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ABSTRACT
Natural fibers are a lightweight, carbon negative, low cost, and low energy alternative to synthetic fillers in polymer composites. However, natural fibers typically exhibit lower mechanical performance than glass fibers due to weak interfacial adhesion between plant cells in a technical natural fiber. Nanomaterials have been shown to be highly effective stiffening and strengthening agents in polymeric matrices, even at low concentrations. Considering these properties, this work aims to develop a novel method for incorporation of nanomaterials into the weak cellular interfaces (middle lamella) within a natural technical fiber to improve interfacial adhesion and enhance fiber stiffness and performance.

INTRODUCTION
Natural fibers exhibit high variability and lower mechanical performance than synthetic fibers typically used to reinforce polymeric composites, making them less favorable for use in structural composite applications (Wambua, et. al.). Technical natural fibers consist of bundles of plant cells (elementary fibers) connected by a weak, amorphous polymer network consisting mainly of pectins (Bos; Sorieul, et. al.; Zamil et. al.). Prior research into the failure mechanism of technical fibers shows the dependence of technical fiber performance on interfacial adhesion between elementary fibers and damage during fiber extraction (Bos; Romhány, et. al.). Supercritical fluid, specifically supercritical carbon dioxide (scCO2), is a popular processing solvent for polymeric materials. scCO2 is effective at swelling amorphous polymers, or amorphous portions of a polymer, can enhance mass transport within a polymer matrix and improves the diffusion of additives in polymers. Additionally, nanoparticles have been shown to be capable of significantly improving the mechanical properties of a polymer matrix even at very small concentrations. This research seeks to improve the performance of technical flax via development of a novel method to incorporate stiffening nanoparticles at the interface between elementary fibers within a technical flax fiber and/ or repair damage from extraction, using supercritical carbon-dioxide (scCO2) as a transport medium.
A lab scale pressure vessel was used to integrate flax technical fibers with calcium carbonate nanoparticles (CaCO3 NPs, d~50nm). Samples consisting of twenty-five technical flax fibers were treated with 100mg of CaCO3 NPs in scCO2 at pressures ranging from 1200-4000psi at 60°C for 2 hours. Plasma-focused ion beam scanning electron microscopy (PFIB) was used to evaluate the fiber surfaces as well as to cut and image cross-sections of the samples.

RESULTS AND CONCLUSIONS
Initial evaluation of flax fibers treated with CaCO3 indicates integration of nanoparticles on the surface of a fiber treated at 4000psi, with particles entering crevices between elementary fibers (Figure 2a). A cross-section of this fiber shows progression of CaCO3 nanoparticles into space between elementary flax fibers (Figures 2b-2c). This technique has potential to further incorporate nanoparticles at the pectin-rich

interfaces between elementary fibers in a technical flax fiber. The effect of varying nanoparticle chemistry/morphology and processing parameters on nanoparticle distribution and fiber mechanical performance are presented.

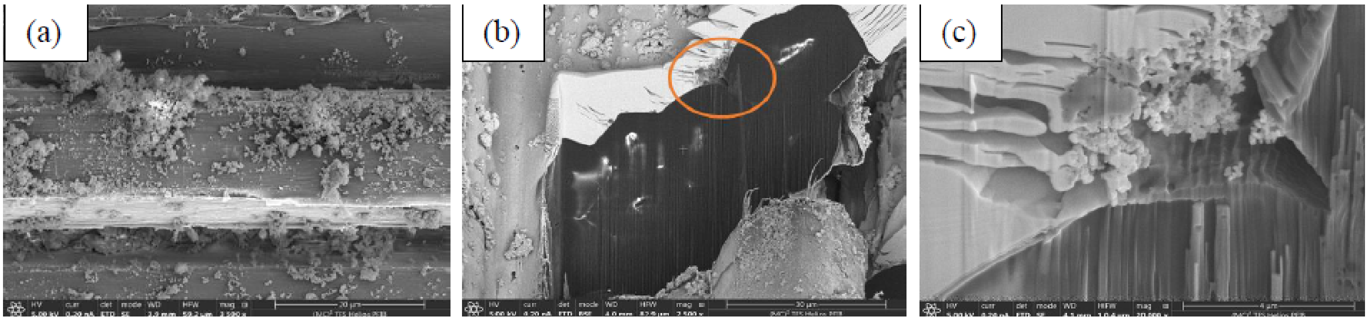

Figure 2 PFIB micrographs of flax fibers after treatment with CaCO3 NPs in scCO2 at 4000 psi. (a) surface of treated fiber showing surface integration of nanoparticles. (b) Cross-section at 2500x with multiple elementary fibers visible. Circled area indicates location of image (c). (c) CaCO3 nanoparticles in a delaminated interface between two elementary fibers.

ACKNOWLEDGMENTS

The authors gratefully acknowledge financial and technical support from Ford Motor Company Research & Advanced Engineering, the University of Michigan College of Engineering, and the Michigan Center for Materials Characterization.

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EFFECT OF THE CHEMICAL DEGUMMING ON SILK FIBROIN PROPERTIES

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ABSTRACT

Colombian silk industry produces silk fibrous waste (SFW) which could be used as raw material to produce silk fibroin (SF). Degumming is the first step in SF production and could affect its structural and thermal properties. In this work, SFW were degummed with sodium carbonate, varying conditions of bath ratio and degumming time, and subsequently degummed fibers were dissolved at the same procedure, and SF thin films were made by solvent casting. To determine the effect of the degumming variables on the properties of SF, the changes in the secondary structures of the protein were analyzed by Fourier transform infrared spectroscopy with attenuated total reflectance (FTIR-ATR). Meanwhile, the thermal properties of SF films were studied by temperature modulated differential scanning calorimetry (TM-DSC). According to the obtained results, increase time and bath ratio results in less crystallinity and thermal stability. These results suggest it is possible to find degumming conditions for controlling the properties of SF obtained from SFW.

INTRODUCTION

Sericultural residues, such as SFW can be used for the extraction of silk sericin (SS) and SF, the latter of great interest due to its properties and the multiple applications in the biomedical area (Puerta, Peresin, & Restrepo-Osorio, 2020). The SF extraction process consists of degumming and regeneration so that the conditions in which these processes are carried out will produce changes in the properties of the SF obtained (Nultsch et al., 2018; Wang et al., 2019). Due to this, the objective of this study is to carry out the variation of the conditions of degumming of the SFW, in order to determine the thermal and structural changes that undergo this process.

The SFW fibers were degummed at boil aqueous solution of 0.5% (w/v) sodium carbonate Na2CO3, under three conditions: SFWA bath ratio of 1:100 and time of 60 min, SFWB bath ratio of 1:100 and time of 30 min and SFWC bath ratio of 1:40 and time of 60 min. The degummed fibers were dissolved in 9.3 M lithium bromide (LiBr) solution at 60 °C, the obtained solution was dialyzed and filtered. Films were then made by solvent casting, with controlled evaporation in an oven at 35 °C.

RESULTS AND CONCLUSIONS

The results of the FTIR-ATR analysis show that all the samples present the characteristic peaks of SF when approaching Amide I and Amide II, with slight movements in the Amides shoulders as function of the degumming conditions. To determine the changes in the secondary structures, the deconvolution of Amide I was carried out, and a higher amount of crystalline structures was obtained in the SFWB and SFWC samples compared with the SFWA sample, which indicates that the degumming process in the SFWA was most aggressive altering the secondary structure of silk fibroin.

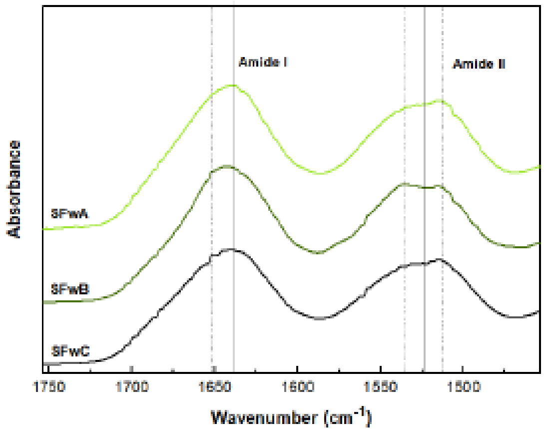

Fig. 1 FTIR-ATR spectra of SFW films obtained from different degummed conditions.

Sample	Tg [°C]	T_c [°C]	Enthalpy of recrystallization peak [J/g]	T degradation silk I [°C]
SFwA	179.7	216.4	2.729	251.3
SFwB	182.2	216.1	1.924	252.4
SFwC	184.8	216.2	1.676	252.8

Table 1 Modulated DSC of SFW films obtained from different degummed conditions.

The data obtained in the DSC for the silk fibroin film samples can be seen in table 1. For the three samples the recrystallization peak occurred at a close temperature but each one different value for the recrystallization enthalpy, being lower these values for the SFWB and SFWC samples, which corroborate the higher presence of crystalline structures compared to the SFWA.
This study shows that the variations in degumming may present changes in the thermal and structural properties of regenerated silk fibroin, which are especially important regards silk residues are used as raw materials to produce silk fibroin for biomedical applications.

ACKNOWLEDGMENTS

The authors would like to acknowledge Minciencias for financing the project called vascular implants with code 121080762864, as well as the Universidad Pontificia Bolivariana.

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CORONA TREATMENT APPLIED IN THE PROCESSING OF SILK WASTE. COMPARATIVE DYEING STUDIES WITH COLOR ANALYSIS.

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ABSTRACT
This work makes a comparative study between the corona treatment and the traditional degumming process. For silk waste to be dyed, they must have good water absorption. The results of the color analysis and wash fastness test are presented in relation to the two processes. The corona treatment promotes compatible dyes when compared to the conventional preparation process. The advantage is that corona treatment has less treatment time, does not use chemicals and does not generate effluents.

INTRODUCTION
Silk waste is a residue of the silk processing industry. To be dyed, silk waste must be hydrophilic, a prime factor. Currently the hydrophilicity of silk-based textile materials is obtained by the removal of sericin, which is a natural protective layer of silk yarn, and this removal is traditionally made by washing with Marseille soap. On average, about 35% by weight of raw silk produced is waste, which is obtained in the primary (producer) and secondary (silk spinning industry) classification processes. Defective cocoons are processed and produce a thread called silk waste. Silk residues undergo primary processing such as cooking and spinning. After being spun, the yarns are ready to be woven. These yarns have a high amount of sericin, which makes it difficult to process them, so it needs to be removed by the conventional processes of degumming with Marseille soap. After degumming the silk waste yarns can be transformed into fabrics or carpets by the weaving process.

RESULTS AND CONCLUSIONS
Silk waste tests were done with three sample fabric types: • raw, untreated; • Degummed with Marseille soap; • Treated with Corona Discharge. The samples degummed with Marseille soup were treated in equipment like bath. The degumming process comprises treating for 1 hour at 90-95 °C, pH 9.3 to 10 for the following bath conditions: • 8-10 g / l soap from Marseille; • 1 g / l sodium carbonate;1 • g / l of sodium tripolyphosphate.
Samples underwent the corona treatment on the basis of parameters of time (0s to 180s) and corona current fixed at 130 microamps for the following ambient conditions: temperature 27 ° C (+/- 3 °) and relative humidity of 45% (+/- 3%).
Figure 1 shows the results of the silk waste samples dyed with reactive dye Blue Novacron C-R by the process “pad dry termofix”: sample 1 - silk waste without treatment; sample 2 - dyed after degumming with Marseille soap; sample 3 - dyed after corona treatment.

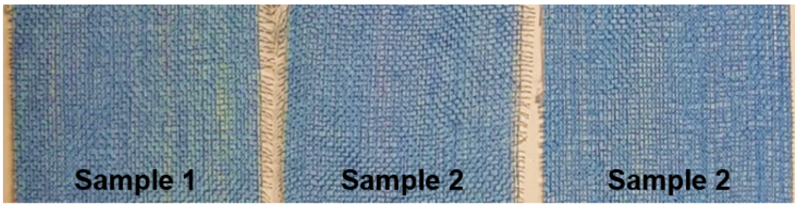

Figure 1 Dyed samples

Figure 2 shows the tolerance ellipse of the colorimetric test.

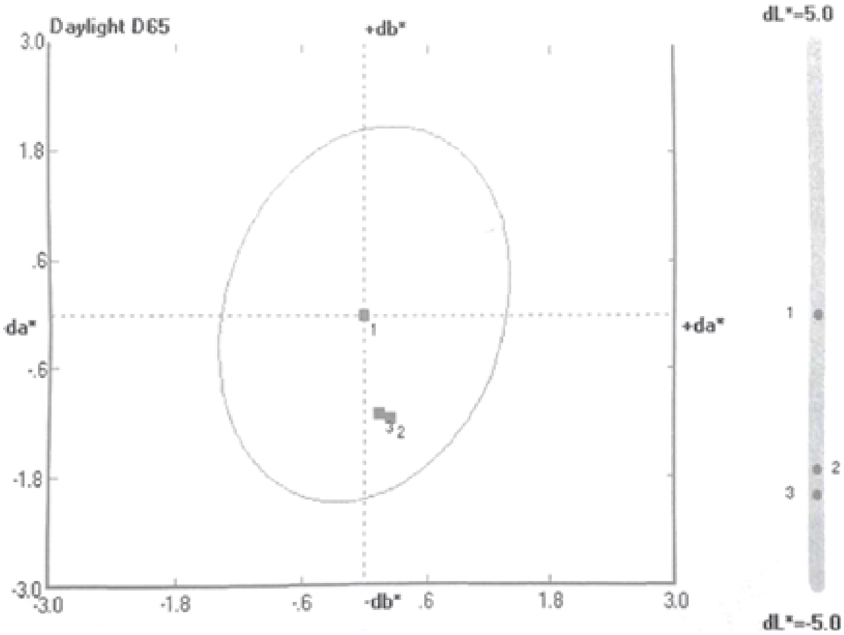

Figure 2 Tolerance ellipse of the colorimetric test

Analyzing the ellipse of tolerance, the results of the apparent % of color are:

• Sample without treatment: 100% - standard
• Sample treated with Marseille soap: 122,5%
• Sample treated with Conona: 126,8%

Comparing the results, sample treated with marseille soap is 22.5% more intense than the standard and the sample treated with corona discharge is 26.5% more intense than the standard. Comparing the two processes, the difference is 3.39%.

Both processes have practically the same color intensity. So they are processes compatible as to the resulting color, a fundamental factor for the success of application of corona treatment in the textile processing industry.

ACKNOWLEDGMENTS

The author gratefully acknowledge the State University of Campinas (Unicamp) and Fatec Americana Textile College.

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FIBRESCANNER — DEVELOPMENT OF A NEW APPROACH TO ASSESS THE LENGTH DISTRIBUTION OF NATURAL FIBRES

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ABSTRACT
This work describes the development of a prototype called 'FibreScanner', which enables the fibre length measurement using a novel method of scanning with subsequent image analysis. The fibre sample is drawn over a statically positioned optics in several steps. During the drawing process, the analysed fibres are in parallel arrangement. The moved collective of fibres is illuminated from the top side and the transmitted light is detected by a line camera. This combines reduced measurement time with increased accuracy in the assessment of the length distribution of natural fibres. The actual state of the work is presented, comprising mainly results obtained from wool and bast fibres.

INTRODUCTION
Analysis of the length distribution of natural or technical fibres is essential for many areas of application. This is actually only possible by using out-dated measurement instrumentation like the well-known Almeter [Grignet 1981]. Actually, there are no new instruments of measure for this purpose commercially available. Within the framework of a research project, a prototype called 'FibreScanner' has been developed, which enables the fibre length measurement using a novel method of scanning with subsequent image analysis. Actual scanning systems use a moving light source over statically positioned samples (scanner-principle), while in the novel method the fibre sample is drawn over a statically positioned optics in several steps [Schmid 2018]. During the drawing process, the analysed fibres are in parallel arrangement. The moved collective of fibres is illuminated from the top side and the transmitted light is detected below by a line camera. This converts the out-dated two-step process into an integral system performing the analysis in only one step.
The improved measurement process combines reduced measurement time with increased accuracy in the measurement of the length distribution of natural fibres. Finally it can be expected, that e.g. the use of (physically) characterized natural fibres in the automotive industry can be increased.
This poster comprises (i) the set-up of the instrument and specifications and (ii) the validation of the prototype system on the example of wool fibre measurement.

RESULTS AND CONCLUSIONS
The results from first measurements of wool samples display a good correlation to results obtained by means of Almeter. Table 1 shows the obtained average length of four wool slivers compared to the Almeter values of these samples. Figure 1 shows the experimental setup with (a) general view of the prototype, (b) fibre sample prepared for measurement and (c) subsample after measurement.

Table 1 length measurement results

	FibreScanner		Almeter (Barbe)	
Wool sliver no.	**length in mm**	**CV in %**	**length in mm**	**CV in %**
250	79,7	40,8	74,0	43,0
204	81,4	52,3	87,5	39,8
238	87,4	37,2	103,0	41,3
223	91,0	38,1	112,7	39,0

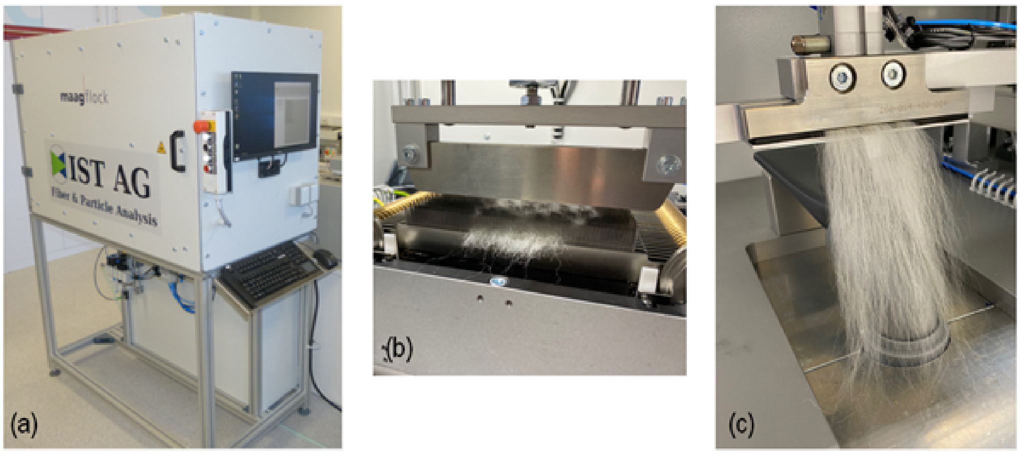

Fig.1 FibreScanner prototype (a) general view, (b) fibre sample prepared for measurement and (c) subsample after measurement.

The results of four wool slivers listed in Table 1 show that the length values follow the same tendency for both devices with the FibreScanner values systematically lower. Two reasons for this effect have been identified: (i) an 'offset' caused by length of each fibre within the clamp and (ii) omission of overlapped fibres in the image analysis process, leading to preferred exclusion of longer fibres from the results.

Elimination of both these effects is subject of our actual work. For compensating the 'offset' the clamped fibre length will be analysed more in detail to consider it in the calculation of results correctly. In parallel, the recognition algorithm has to be modified to identify overlapped fibres correctly.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by the German Ministry of Economy and Energy (Bundesministerium für Wirtschaft und Energie BMWi), within the framework of the program „Zentrales Innovationsprogramm Mittelstand (ZIM)" — cooperation projects, grant no. ZF4554302PK8; based on a decision of the German parliament.

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INDUSTRIAL HEMP AS A SUSTAINABLE SOURCE OF TEXTILE FIBER: PROJECTS ON THE OPTIMIZATION OF HEMP CULTIVATION IN FLANDERS AND PROCESSING ON INDUSTRIAL FLAX EQUIPMENT

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ABSTRACT
In the ‘Own Grown Hemp’ project, we investigated the effective fiber yield and quality of field-retted hemp, scutched on a modern flax processing line. Seven hemp varieties from diverse origin were evaluated. Results indicate that field-retted hemp has potential to be processed into quality fiber on an industrial flax line and that fiber yield can likely further be improved by genotype selection. Yet, to make this approach economically viable, harvest mechanization, dedicated to the processing of ‘hemp like flax’, seems warranted. Also, the spinning and weaving properties of long hemp fiber need further investigation. We are currently tackling these issues in the new project ‘Cannabisness’. Complementary research lines at HOGENT investigate the implementation of short fiber and the optimization of field retting.

INTRODUCTION
After a long absence, industrial hemp (Cannabis sativa L.) is paving its way back into Europe as a high-yielding, environmentally friendly multipurpose crop (Ranalli and Venturi, 2004). Among others, hemp has also great potential as a sustainable source of textile fiber (Cherret et al. 2005). Unlike cotton, world’s most popular natural textile fiber, hemp cultivation requires little water and pesticides (Cherret et al. 2005), and can positively contribute to crop rotation (Amaducci et al., 2015). Moreover, the current excessive demand for the analogous flax fiber and an increasing public interest in locally produced goods, foster the prospects of hemp as a local source of textile fiber within the growing European bio-based economy. Yet, to build a viable hemp-for-textiles industry, agronomic practices and fiber processing need optimization to meet current industrial standards. A straightforward approach for flax-producing regions, such as Flanders, is to process hemp using the existing, industrial equipment for flax, as has been repeatedly suggested in literature (Amaducci 2003; Amaducci et al. 2008; Amaducci & Gusovius 2010, Gusovius et al. 2016, Müssig et al. 2020) and seems supported by small-scale experiments (e.g. Amaducci et al. 2008 – Hemp-SYS & MultiHemp projects; Vandepitte et al. 2020). In the ‘Own Grown Hemp’ project (2017-2019), we set up randomized field experiments (plot size: 15-30 m²) with hemp varieties from diverse European origin and maturity (see Table 1 and Vandepitte et al. 2020 for details). At flowering, stalks were manually harvested, weighted and left in swaths in the field for dew-retting (retting duration ~ 6 weeks). Next, retted stems, cut at 1 meter length, were scutched on an industrial flax processing line, rendering long aligned fiber, probably suitable for high-quality yarn spinning according to the wet-spinning process, in addition to short fiber (‘tow’) and shives. The yield and quality of scutched long fiber, among which tensile properties (per hemp

variety, mixed across plots, 150 randomly drawn fiber bundles were tested), were evaluated.

RESULTS AND CONCLUSIONS

Both 'green' bast yield and the yield of long fiber after scutching differed significantly between varieties (range long fiber yield: 0.6 - 1.4 Mg.ha-1; see YLF in Table 1), suggesting that fiber yield can further be improved by genotype selection. There was little variation in long fiber yield between harvest years (not shown). Tenacity of long hemp fiber was overall high (Table 1) and comparable to flax, indicating a potential long lifetime and successful recycling of used textile products.

Genotype	Origin	Flowering	Y_{BAST} (Mg.ha-^{1})	Y_{LF} (Mg.ha^{-1})	Tenacity (cN / tex)
USO 31	Ukraine	Early	2.33^{a}	0.64^{a}	39
Bialobrzeskie	Poland	Mid-late	2.45^{ab}	0.76^{ab}	45
Santhica 27	France	Mid-late	2.17^{a}	0.86^{ab}	38
Santhica 70	France	Late	3.47^{b}	1.43^{b}	44
Futura 75	France	Late	3.25^{b}	1.01^{ab}	43
Dacia Sequieni	Romania	Late	3.08^{b}	1.03^{ab}	45
Carmagnola S.	Italy	Late	3.08^{b}	1.05^{ab}	42

Table 1. Variety mean yield performance and fiber tenacity for the harvest year 2018. Letters denote statistically significant pairwise differences ($p<0.05$).

Results indicate that field-retted hemp has potential to be processed into quality textile fiber on industrial flax lines. Yet, harvest mechanization, focused on the collection of parallel hemp stem portions of appropriate length (ca. 1 m), is warranted to make the 'hemp like flax' approach economically viable. Also, additional research on the fiber properties following hackling and (semi)wet-spinning will be needed to fully explore the potentiality of long hemp for high-end textile applications, equivalent to flax (Vandepitte et al. 2020). We are currently tackling these issues, and upscaling the production and processing of hemp for textile applications to the (semi-)industrial level in our new project 'Cannabisness' (2020-2022). Complementary research lines at HOGENT investigate the implementation of short fiber, and the optimization of field-retting and fiber yield.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by HOGENT for the research presented (multidisciplinary PWO-project 'Own Grown Hemp'; 2017-2019). We also thank the many industrial partners of this project for fruitful collaboration and use of equipment.

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RESURGENCE OF HEMP – CURRENT STATUS AND PERSPECTIVES OF EXPLORING THIS PLANTS IN AGRICULTURE, INDUSTRY, MEDICINE AND OTHER AREAS

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ABSTRACT

In last five years was observed a growing interest in cultivation and processing of cannabis species in whole world. This is giving a great impulse on improving breeding, cultivation methods, creating more sophisticated methods of harvesting and finding new areas of application of wide range diversified products from hemp. Recently a United Nations commission positively voted to remove marijuana for medical use from a list of the most risky narcotics. This gives a new chance for this multifunctional plant.

INTRODUCTION

Hemp – cannabis sativa L. - industrial hemp continuing less than 0.2% or 0.3% of Δ9-tetrahydrocannabinol (Δ9-THC) and marijuana hemp, both species are known to the world for more that 7000-8000 years. Cannabis sp. is a plant of versatile applications, with yield of dry mass of approximately 10 -12 Mg (tons) from 1 ha (10000 m2) of cultivated area. In growing time this 1 ha of hemp absorbs 2.5 Mg (tons) of CO2 from the atmosphere, and also this plant is capable to absorb about 160g Cu, 70g Pb, up to 7g Cd from the soil ha, which makes this plant useful for the reclamation of soils contaminated by the industry. (a Kozłowski, Mackiewicz-Talarczyk, 2012, b 2020). Chemical composition of hemp plants: 67-78 % cellulose, 16-18% hemicellulose and pectin, and 3,5-6,0 % lignin. Diameter of elementary fibres is 17-24 µm. In the world, in last 5-10 years is observed great interest in cultivation and multifunctional applications of whole hemp plant. China in the last 5 years has become a cannabis super power. Especially farmers and government of China made a revolution in the area of agriculture and industrial use of hemp. According to Chinese National Bureau of Statistics, China cultivates about 50% of all hemp world plantations areas. According to ESCORENA data and Chinese sources in 2018-2019 cultivating and processing of hemp in China accelerated 4 times. It is worth to appoint, that also due to the new applications of whole plants, economy of production of hemp has increased in China two times. Summing up, in China hemp goods made from fibres area exported and fibres are used e.g. from making special, healthy apparels, military textiles and uniforms. New applications of hemp are also developed in many countries of the world. Panicles, which constitute about 30% of whole plants are the source of many cannabinoids and terpenes, as well as other added value agro-chemicals.

RESULTS AND CONCLUSIONS

The main tasks of hemp breeding are: a significant increase in biomass production and fibre content, and its quality (fineness) as well as an increase in the amount of nuts (seeds). Intensive gaining panicles with specific cannabinoids and terpenoids, and also changing the composition of unsaturated fatty acids in hemp nuts, especially increasing the stearidonic acid content (with four double bonds) is also one of the emerging goals (a Kozlowski, Mackiewicz-Talarczyk, 2020). The main active compounds extracted from cannabis sativa are cannabinoids whose psychological functions range from locomotors activity to memory, pain perception, and to other activities. The important role of these phyto-chemicals has perceived in the world and many research centres, and proved by e.g. American Chemical Society, which created in 2014 Cannabis Chemistry Committee and also by a United Nations commission which proved the positive role of marijuana for medical use at the end of 2020. The fibre used for textiles include more friendly apparels, high performance military uniforms (with special functions), and ecological nonwoven used in many areas: from agriculture, environmental protection, defense, composites and packaging areas (c Kozlowski R. et al., 2012). Advances are noticed in processing technology in production not only 100% pure hemp fabrics but also their blends with cotton, viscose and silk, and man-made fibres (Horne, 2012). Shives (by product of straw processing) are used e.g. for production of various composites including healthy building materials glued with lime and Portland cement (d Kozlowski et al., 2017). Works are also carried out on super-capacitors where hemp wastes are processed into carbon-nano materials for the manufacture of high power supercapacitors (Zhi Li, 2015). Cannabis nuts are used for the production of valuable food oils, cake and fodder for birds, fish and other animals. From dried panicles are produced essential oils and cannabinoids. In Cannabis sativa L., 104 diverse groups of compounds have been identified, such as cannabigerol (CBG), cannabichromene (CBC), cannabidiol (CBD), Δ9-THC, Δ8-THC, cannabicyclol (CBL), cannabielsion (CBE), cannabinol (CBN), cannabinodiol (CBND), cannabitriol (CBT), their acidic forms and terpene and terpenoid compounds; a total of more than 545 chemical compounds (Zielonka et al., 2020), (McCoy M., 2018). Currently, research is underway on the use of other interesting hemp ingredients for the production of promising medicines, e.g. Epidiolex, Sativex (marketed in 2018 on the basis of CBD + strawberry flavored syrup) (Halford, 2018), also as such product as Hemp Element (based on the extract from Cannabis sativa), etc. Essential oils are used in cosmetics, food products, aromatherapy, and plant protection. They can be extracted with water vapor and so-called supercritical extraction with CO2, as well as butane extraction. In the world, and especially in the USA, the most prominent specialists and centers such as the Medicinal Genomic Corporation (MGC) in Woburn, Massachusetts, USA have found that the combination of individual genes determines particular cannabinoid lines - specific compounds responsible for psychoactive and therapeutic properties. Currently, more than 350 prominent scientists in the United States and Canada are conducting marijuana and its psychoactive actions studies. According to the BgVV (German Federal Institute for Consumer Health Protection), Δ9 THC limits in food should not exceed 5mg·kg-1 for alcoholic and non-alcoholic beverages, 500μg·kg-1 for food oils, 150μg·kg-1 for all other foodstuffs. A significant group of compounds responsible for the smell and taste of hemp extracts are terpenes, terpenoids and flavonoids. Research is being carried out, what is the psychological impact of terpenes mixed with cannabinoids. EFSA (CONTAM - Panel on Contaminants in the Food Chain) reported that 2.5 mg Δ9 -THC per day (corresponding to 0.036 mg Δ9-THC·kg-1 body weight per day), for a person with a body weight of about 70 kg, is characterized by the lowest harmful effect for humans (Zielonka et a., 2020). It is worth to appoint that medical marijuana has been used by humankind since more than 2737 BC. Currently, is noticed a huge interest in application of cannabis in medicine; in 2015 in Prague, Czech (attended by more than 13 countries) an International Coalition of Hemp Patients was established; there are currently about 40 members who have submitted a special petition to the UN general assembly; the United Nations has recommended the following measures: inviting all countries to secure stable, safe and economically viable medical marijuana based medicines and its derivatives for all those who have a recommendation to use them and the request to withdraw Cannabis sativa as a narcotic plant from the list of controlled drugs (2016 UN General Assembly Special Session on drugs) has been clarified. Subsequently in 2020 a UN commission voted to remove marijuana for medical use from a list of the most risky narcotics. Supportive effects of medical marijuana have been observed in the following diseases: multiple sclerosis, chronic pain, drug-resistant epilepsy, cancer, chemotherapy support, Alzheimer's disease, AIDS, glaucoma, Parkinson's disease, anorexia and stress (Horowitz, Shohami, 2016). Currently, intensive research is carried out on the use of Δ9-THC and other cannabinoids in many of the leading scientific centers in the world, including Poland. Legalization of crops not only Cannabis sativa L., but mainly marijuana hemp is introduced in most states of the USA and countries around the world. Summing up, the developments in cannabis and marijuana hemp contribute to growing area of cultivation, modern processing and application of hemp.

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INFLUENCE OF HARVESTING TIME ON MECHANICAL PROPERTIES OF FOUR HEMP CULTIVARS

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ABSTRACT

The hemp could be one of the best candidate to replace cotton, which is a great water and fertilizer consumer. In this way, SADEF, specialist in the plant nutrition and analysis, produces and studies hemp growing in Alsace (East of France). So, that the mechanical properties of 4 cultivars (Férimon 12, Santhica 27, Santhica 70 and Fibror 79) were reviewed on 3 harvest times (June, July and October). The current study shows that there is no significant difference between cultivars, but a significant difference as a function of the harvest time.

INTRODUCTION

Four fibres hemp monoecious (Canabis sativa L.) cultivars' experiment was carried out in SADEF laboratory in France, in 2018. Generally, the cultivars Férimon 12 (F12) and Santhica 27 (S27) are used for dual-purpose production, whereas the cultivars Santhica 70 (S70) and Fibror 79 (F79) are used for fibre production. Before sowing in May 2018 with a seeding rate 50 kg.ha-1, mixed fertilizer was applied. No herbicide and no fungicide were used. No retting was executed. Stems of each variety were randomly harvested in June, July and October to observe the fibre morphology and to study the tensile behaviour. The stems were manually defibrated. Fibres bundles and shives were separated by peeling and brushing. Shives, coarse fibres and knots were eliminated. For each test, fibres were randomly selected and prepared on a specific cardstock framework adapted to the tensile machine clamps. The fibre gauge length was 20mm. Fibre diameters were measured using a projection microscope using X20 lens. Five diameters were measured along the fiber in accordance with an adaptation of NF EN ISO 137. Tensile tests were carried out in order to determine the fibre longitudinal mechanical properties by means of NF EN ISO 2062 standard. The moisture conditions were met at best due to the COVID-19 epidemic.

RESULTS AND CONCLUSIONS

Two curves types (Figure 1) are observed, The first type, plastic behaviour, corresponds to June and July curves. However, the second type has a non-linear visco-elastic behaviour, which corresponds to the October curve [1][2].

From June to October, breaking stress and the Young's Modulus increased (Figure 1, Table 1) [1]. The extracted fiber diameters decreased from June to October demonstrated that more the plant was developed, more manually defibering allowed thin fiber extraction [1][3][4].

The ANOVA demonstrated that, there is no significant difference as far as mechanical properties are concerned whatever the cultivar represented by the letter "A" in Table 1.

Table 1 The cultivar effect on properties in June, July and October

Cultivar:	Harvest Time:	Diameter [µm]:	Breaking Force [N]:	Breaking Stress [MPa]:	Elongation at break [%]:	Tenacity [cN.tex-1]:	Young's modulus [GPa]:
Férimon 12	June	105,27 b, A	1,15 b, A	156,18 c, A	1,88 b, A	10,41 c, A	7,95 b, AB
	July	78,43 a, AB	1,42 ab, AB	309,89 b, A	1,88 b, AB	20,66 b, A	15,70 ab, AB
	October	70,75 a, A	1,83 a, A	495,24 a, A	2,47 a, A	33,02 a, A	19,31 a, A
Santhica 27	June	107,81 b, A	1,35 a, A	198,38 b, A	1,92 b, A	13,23 b, A	8,87 c, AB
	July	88,15 b, B	1,58 a, B	275,60 b, A	1,93 b, AB	18,37 b, A	12,36 b, B
	October	66,79 a, A	1,85 a, A	535,95 a, A	2,61 a, A	35,73 a, A	19,04 a, A
Santhica 70	June	92,44 b, A	1,19 a, A	208,72 b, A	1,87 b, A	13,91 c, A	9,61 c, A
	July	85,43 b, AB	1,44 a, AB	297,46 b, A	1,58 b, B	19,83 b, A	16,43 b, A
	October	65,56 a, A	1,58 a, A	499,98 a, A	2,22 a, A	33,33 a, A	20,98 a, A
Fibror 79	June	94,48 b, A	1,06 a, A	171,83 c, A	2,16 a, A	11,46 c, A	6,89 c, B
	July	71,35 a, A	1,33 a, A	363,32 b, A	2,24 a, A	24,22 b, A	14,61 b, AB
	October	58,90 a,A	1,38 a, A	548,86 a, A	2,63 a, A	36,59 a, A	18,65 a, A

a, b, or c corresponding to comparison of the harvest time in the same row (ANOVA)
A or B corresponding to comparison of the cultivar in the same row (ANOVA)

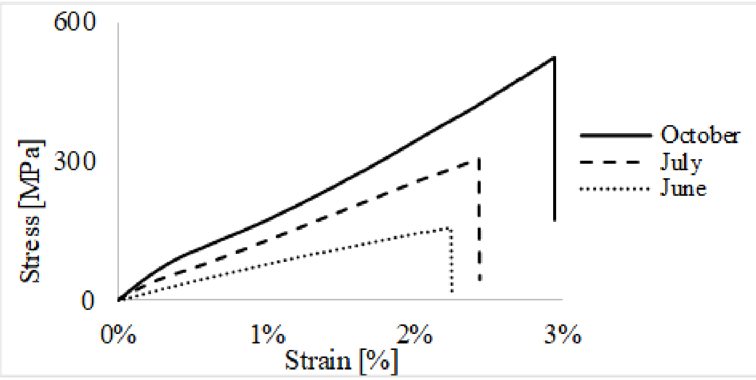

Fig 1 Typical Strain Stress curve case of F12

This study corroborates previous studies that show the importance of harvest time, but concerning the mechanical properties, the current study demonstrates that since July the 4 studied cultivars present no significant difference. Moreover, the study shows that both early and late cultivars could be grown in the Eastern part of France. Further studies will determine between early and late cultivars the best adapted one based on climate variations.

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CHARACTERIZATION OF PLANT FIBER TRANSVERSE MECHANICAL BEHAVIOR USING A MICRO-MECHATRONICAL SETUP

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ABSTRACT
This work aims to showcase the transverse mechanical behaviour of common European plant fibers. To do so, a specially designed micro-mechatronical setup is used to perform transverse compression tests. The elastic and viscoelastic properties of these fibers will be identified from force-displacement curves with sub mNewton and μmeter precision, obtained under repetitive progressive loadings (RPL).

INTRODUCTION
The use of plant fibers as reinforcements in composite materials presents numerous environmental benefits compared to their manmade counterparts (carbon, nylon etc.). Composite behavior is also strongly corelated to its reinforcement's mechanical properties, their accurate knowledge is thus crucial to improve or predict composite behavior. However, the relatively recently adopted use of plant fibers has led to limited research around their mechanical properties, especially in the transverse direction. Furthermore, their small size, anisotropic nature and complex geometry means that "back calculated" properties are not reliable (Shah et al. 2016) and specialized setups with sub mNewton and μmeter accuracy are needed to carry out direct measurements. In order to study the fiber's transverse behaviour, an innovative setup, shown in Fig.1 was developed in our laboratory to perform single fiber transverse compression tests (SFTCT) (Placet et al., 2020).

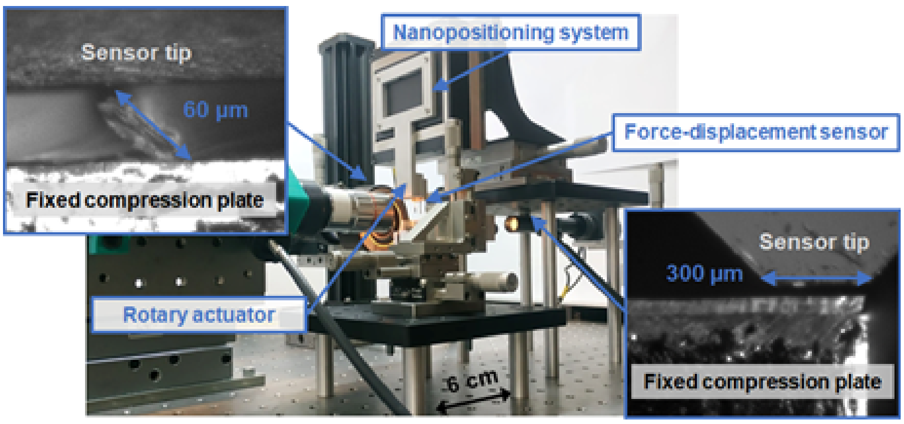

Figure 1. Transverse compression setup, diameter and length wise view of nettle fiber

The test consists of compressing a fiber between a rigid support (fixed plate) and a sensor (mobile plate) that measures the applied force and the fiber's displacement simultaneously. The testing protocol starts with a progressive loading, generated by a movement of the mobile sensor against a fiber laying on the fixed compression plate. The fiber enters a rigid body movement stage where it rotates and slides until it gets trapped between the upper and lower plate ("compression point"). This stage can be observed by imagery or force displacement data. Once the compression point is reached repetitive cyclic charging of the fiber starts, with an increasing amplitude. This protocol offers the possibility to identify the elastic and viscoelastic properties of the fiber by inverse method using Jawad's analytical model (Jawad & Ward, 1978). The setup is now equipped with a rotary actuator capable of ensuring parallelism between compression plates with 10 µ° precision, improving test repeatability and accuracy. Plate parallelism has never been controlled this finely in other compression studies.

RESULTS AND CONCLUSIONS

Part of the loading protocol and a force-displacement curve examples, of single nettle fiber compression test are given in Fig.2. Despite the small displacements that are in play during testing, our setup is accurate enough to produce repeatable results and detect subtle changes in force, displacement or slope, offering insights on complex mechanical phenomena.

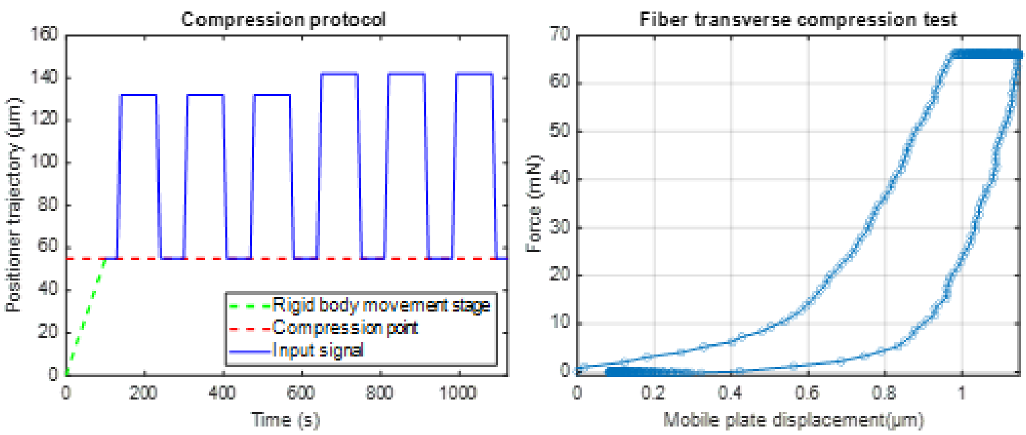

Figure 2. Nettle fiber compression protocol and results from a 300µm compressed sample length

ACKNOWLEDGMENTS

These works have been supported by the European Union's Horizon 2020 research and innovation program under grant agreement No 771134. The project NETFIB was carried out under the ERA-NET Cofund SusCrop (Grant N°771134), being part of the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI). This work has also been supported by EIPHI Graduate School under ("ANR-17-EURE-0002").

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ELABORATION AND CHARACTERIZATION OF PALM/POLYESTER NONWOVEN MATERIAL COATED BY THE SOL-GEL METHOD

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ABSTRACT

The aim of this study is the development of new commercial and industrial value-added nonwoven textile fabrics. These nonwovens were developed using a needling technic by combining palm with polyester fibers in the weight ratio of 3:1. The nonwoven was coated with polyurethane and a silane precursor such as chloropropyltriethoxysilane (CPTS) or tetraethylorthosilicate (TEOS) to combine their technical characteristics. The mechanical properties of nonwoven materials are determined according to ISO 13934-1 standard. Moreover, the water-repellent properties of untreated and treated nonwovens are studied by means of the Water absorption capacity, the rain test according to ISO 9073-6 and the AATCC 22 spray-rating standards. The morphology and the chemical structure of nonwovens have been performed using Scanning Electron Microscopy (SEM) and FTIR analysis. The obtained results suggest that the mechanical properties of Palm/ Polyester nonwovens coated by CPTS or TEOS were improved. Moreover, its thermal stability was also enhanced and the nonwoven coated by CPTS has a good water-repellent properties. These nonwoven materials can be applied in various fields such as automotive, construction and reinforcement of composite materials.

INTRODUCTION

Nowadays, nonwoven materials made of natural fibers are one of the technical fabrics that many researchers have produced due to their high porosity, air permeability, low density, low cost, as well as eco-friendly and renewable resources (Azmami, 2020). The palm fibers were extracted according to our previous work (Sajid, 2019). Then, nonwoven material was prepared by mixing the palm fibers with the polyester fibers in the ratio 75%: 25% by weight and needled using DILO DI-LOOM OD-II machine with a needling density and needle depth equal 100 punches/cm2 and 16 mm respectively. The treatment of nonwoven fabrics was carried out in accordance with the method followed by boukhriss et al., (2015). As the impregnation method (dip-coating) is the most realistic finish for nonwovens, the nonwoven samples were impregnated in the pre-prepared solution for 5 min followed by dripping and drying. The dry temperature was 80 °C while the cure temperature was 120 °C both lasted for 1 h.

RESULTS AND CONCLUSIONS

The contact angle of water was studied to confirm the water repellency properties of fabrics. Fig.1 shows that the untreated nonwoven (NW) has a contact angle of 117.1°. After 2 seconds, the drop of water was retained by the nonwoven. In the case of nonwovens treated by TEOS agent, the drop of water was also retained. In contrast, the surface of the sample treated with CPTS support the formation of spherical droplet (see Fig.1). As a result, we can conclude that the NW-CPTS, sample turned to be excellent hydrophobic nonwovens.

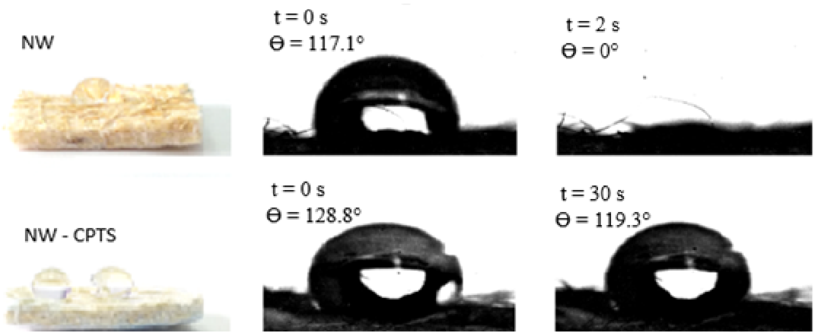

Fig.1 Contact angle (CA) of water droplets over the different water repellency nonwovens

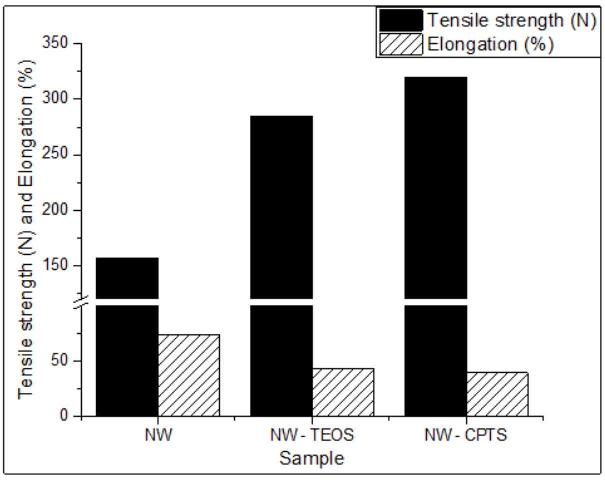

Fig.2 Mechanical properties of untreated and treated nonwovens

It can be observed that the treatment increases the tensile properties of nonwoven palm/polyester. Fig.2 shows that nonwovens treated with CPTS have achieved superior results for those treated with TEOS. In addition, the treatment of nonwovens decreases the elongation of the samples, confirming the increase in stiffness of nonwovens after treatment.

In summary, we have successfully fabricated functional nonwovens with hydrophobic surface, high tensile strength, good thermal stability and excellent fire-resistance property by coating Palm/Polyester nonwoven with CPTS and TEOS agent using sol-gel process.

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ISORA/COTTON BLENDED YARN AND ITS PROPERTIES

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ABSTRACT
The natural fibres such as isora and cotton have their own unique properties and blending helps to combine their superior qualities. The raw isora fibres and cotton were blended in a 30:70 ratio and developed into yarns by the process of ring spinning. The physical properties of blended yarn such as strength, elongation, twist per inch and hairiness were tested and found to be suitable for textile applications.
Keywords: bast fibre, blending, spinning, testing

INTRODUCTION
Helicteres isora commonly known as Indian screw tree grows to a height of five to 15 feet with a stem diameter of one to two inches growing in the wild as shrub found in Asia including India. The bark is the source of a strong fibre used as ropes and cordage for domestic and agricultural uses. The isora fibre is known as kaivun in Kerala, India, where a certain community is engaged in retting the fibre, spinning and weaving done by hand to make bags to carry paddy grains, dried pepper and other things and canvas used for veranda blinds.
Isora is natural lignocellulosic bast fibre extracted from plants reeds by the water retting process and has properties like light weight, low density, good mechanical performance. However, due the presence of 25-37% non-cellulosic materials in its structure the fibre lacks short staple fibre spinning properties. Spinning is the process of creating yarn of one or more types of fibres twisted together to bind them into a stronger long yarn. This paper is an attempt to process Helicteres isora and to achieve a blend with cotton to produce a yarn.

RESULTS AND CONCLUSIONS
Process of Yarn Making (isora 30% / cotton 70 %)
The raw isora fibre reeds are long ranging from 2.5-3 meters, these are cut to 30mm length. The fibre was then put into a trashing machine to open up the individual fibres. This process was repeated 3 times to ensure the fibres were separated. Cotton fibre of an average 29 mm in length along with isora fibre were hand mixed and put into a carding machine. Drawing process oriented the fibres in one direction. In the speed frame machine sliver was given a slight twist followed by ring spinning frame and wound on bobbins. The resultant single yarn in Z twist was tested for its properties.

Analysis of Yarn Properties
Physical properties of the yarn are based on the material used, fibre length, alignment, quantity of fibres used, degree of twist and yarn hairiness. Ten (10) readings were taken to get the average value. Yarn count (Ne) was measured with the help of wrap reel and count strength product (CSP) using Lea strength tester which indicates the quality of the yarn in terms of strength and higher the value better the quality of the yarn. Yarn Tensile is determined by the strength of the yarn and Elongation is the distance that a yarn will extend under a given force in relation to its original length. The yarn diameter is an important factor which is directly associated and inversely proportional to the yarn count Ne. TPI is the number of turns

of twist in one inch of yarn and is needed in yarn to hold the fibres together, affects the yarn in terms of stretchiness and strength.

Zweigle G565 Hairiness tester was used to record the number of hairs for the set test length from the edge. The hairs are counted simultaneously by a set of photocells which are arranged at 1, 2, 3, 4, 6, 8, 10, 12, 15 mm from the yarn. S3 is the total number of protruding fibres having length of 3mm and longer i.e. Max 319 and Min 277. (Table 2)

Table 1: Physical Properties of Isora/Cotton Blended Yarn

	Count Ne	Lea Strength lbs.	CSP	Yarn Tensile Properties		Yarn Diameter µm	TPI
				Strength (gmf)	Elongation%		
AVG	14.18	74.60	1059.95	405.70	4.78	302.20	18.30
MAX	14.72	82.00	1204.90	502.00	6.65	344.00	18.90
MIN	11.74	69.00	810.00	318.00	3.88	277.00	17.40
CV%	6.17	6.63	10.92	12.80	15.72	7.15	2.51

Table 2: Yarn Hairiness of Isora/Cotton (30/70) Blended Yarns

Fineness	14 Ne	Test	3 of 3							
Pretension	5cN	Length	10m							
Bobbin	1 of 1	Speed	50 m/min							
Bobbin test	1mm	2mm	3mm	4mm	6mm	8mm	10mm	12mm	15mm	S3
CV%	1.33	8.99	11.08	6.45	9.45	52.92	43.30	0.00	0.00	7.07
MAX	4700.00	573.00	243.00	43.00	35.00	8.00	2.00	0.00	0.00	319.00
MIN	4577.00	481.00	195.00	38.00	29.00	3.00	1.00	0.0	0.00	277.00

Raw isora fibre seems to have blended well with cotton in the ring spinning system to give a yarn of 14 Ne. Factors influencing tensile properties and yarn hairiness are raw material quality, processing speed, process parameters, mechanical conditions of machines. In respect of the results, the 30:70 isora cotton blended yarn shows prospects for technical uses.

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OPUNTIA SPP. FIBRE CHARACTERIZATION TO OBTAIN SUSTAINABLE MATERIALS IN THE COMPOSITES FIELD

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ABSTRACT
Several studies have evaluated the use of *Opuntia* fruits and mucilage, highlighting its functional properties with multiple benefits in the food sector. However, far too little attention has been paid to the use of *Opuntia* fibre as reinforcement of polymeric matrices. This work provides the chemical characterization of *O. maxima* and *O. dillenii* fibre before and after an alkaline treatment.

INTRODUCTION
During the last years, vegetal fibre composites have demonstrated an important role in the sustainable materials development, allowing to meet environmental specifications, reducing polluting emissions and promoting reuse and recycling. However, alternative vegetable fibres at a lower cost and greater availability are needed (Sarasini, 2018), being Opuntia spp. a candidate to consider. Matrices such as polylactic acid (Scaffaro, 2019), polypropylene (Zampetakis, 2018) and polyester (Bouakba, 2013) have been reinforced with it, mainly by compression moulding, offering good results in energy absorption tests and increasing the tensile elastic modulus (for example from 800 MPa for net polyester to 1480 MPa for the composite). However, no studies focusing on the previous characterization of the fibres and their treatment to improve compatibility with polymeric matrices have been found.
In this work, 4 samples of Opuntia collected in the Canary Islands were analysed. Fibre were treated with NaOH 1 M (1:25 ratio) at room temperature for 1h and washed with distilled water until neutral pH. Moisture, ash and crude protein (CP) were determined according to standard methods as described in the AOAC (2000) (methods 930.15, 942.05, and 976.05 respectively). The structural components (cellulose, hemicellulose and lignin) were estimated according to neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL), known as Van Soest methods. Surface characteristics of the samples were also analysed by Fourier Transform Infrared Spectroscopy (FTIR).

RESULTS AND CONCLUSIONS
Opuntia spp. cladodes are mainly composed of fibre (30-40%), mucilage (14-20%) and ash (15- 33%) according to other authors. However, in this study, cladodes have shown a higher fibre content (50-55 %) and similar ash values, as can be seen in Table 1. Regarding the fibre, the ash content is lower due to its cleaning with water, while the cellulose and lignin content increases due to the removal of hemicellulose and other polysaccharides. After the fibre treatment (TFibre), cellulose content increases, which is important considering that in general, the higher the cellulose content, the better the mechanical properties (Bourmaud, 2018). No significant differences are found between *O. maxima* and *O. dillenii.*

Sample		Moisture	Lignin	Cellulose	Hemicellulose	CP	Ash
O. maxima	Cladode	11.51±0.18	2.34±0.64	8.77±0.65	40.78±0.41	3.85±0.14	19.47±0.93
	Fibre	6.20±0.25	11.36±0.22	55.37±0.91	13.07±0.69	1.97±0.09	3.45±0.22
	TFibre	5.83±0.53	10.22±0.37	62.25±0.34	9.51±0.27	-	1.12±0.15
O. dillenii	Cladode	7.55±0.12	2.73±0.43	9.80±0.35	51.01±1.29	6.08±0.17	13.28±0.04
	Fibre	5.51±0.15	14.11±0.51	50.32±0.62	11.57±0.56	1.33±0.07	6.67±0.70
	TFibre	5.23±0.48	13.52±0.58	58.91±1.01	9.72±0.79	-	1.49±0.13

Table 1. Composition results in % per weight in dry base (average ± standard deviation for 3 assays)

FTIR spectrums also evidence a higher extractive and hemicellulose content in the cladodes than in the fibre. Moreover, treated fibre present a band around 1105 cm-1 attributed mainly to C-O-C glycosidic ether from cellulose (Garside, 2003). This increase in cellulose exposed on the surface increases the number of reaction sites and consequently a strong adhesion with the polymeric matrix can be achieved. These characterization results show that *Opuntia* fibres (treated and untreated) can be good candidates for composites obtaining.

ACKNOWLEDGMENTS

Jessica Castellano express his gratitude for the funding through the PhD grant program cofinanced by the Canarian Agency for Research, Innovation and Information Society of the Canary Islands Regional Council for Employment, Industry, Commerce and Knowledge (ACIISI) and by the European Social Fund (ESF) [Grant code: TESIS2019010048]. The authors gratefully acknowledge the funding by European Funding for Regional Development (FEDER), INTERREG V-A MAC 2014-2020 [MAC Inv2mac, grant number (MAC2/4.6d/229)].

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ENVIRONMENTAL HAZARDS OF GIANT REED *(ARUNDO DONAX L.)* IN THE MACARONESIA REGION AND ITS CHARACTERIZATION AS A POTENTIAL SOURCE FOR THE PRODUCTION OF NATURAL FIBRE COMPOSITES

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ABSTRACT
This paper summarises the results obtained from the characterization of the giant reed *(Arundo donax L.)* plant and fibres from the chemical point of view. An experimental procedure for the extraction of fibre bundles from this plant was developed, and the material obtained was characterised in terms of chemical composition, thermogravimetric behaviour and infrared spectra to evaluate its potential application in the production of polymeric composite materials as a strategy for the valorisation of this invasive species in Macaronesia.

INTRODUCTION
According to the catalogue of invasive species published by the International Union for Conservation of Nature (IUCN), *Arundo donax L.* is one of the 100 most dangerous plant species in the world due to its invasive nature and the alteration of the habitats it colonises [1].
This species, native from East Asia, is widely naturalised in the warm and tropical regions of the world. In the past, it was intentionally introduced to the Macaronesian archipelagos for its use in agriculture (fixing slopes, delimiting land), cattle raising and manufacturing of traditional tools. However, the loss of these traditional uses has favoured its progressive uncontrolled dissemination producing the alteration of natural habitats and becoming an important risk factor in the spread of fires. This work assesses the potential use of giant reed specimens from the control and eradication campaigns of this invasive species, with the aim of supporting the maintenance of these environmental control strategies.

RESULTS AND CONCLUSIONS
Giant reed has been separated in three parts: leaves, roots and stems (where most of fibres are found) for the characterization tests. Fibre bundles obtained with the device developed were also characterised.

Fig.1 A*rundo donax L.*: stems and leaves (left), roots (middle) and fibre bundles (right)

Klason lignin, holocelullose and cellulose of different parts of the plant were obtained following ANSI/ASTM 1997a [2], the procedure described by Browning [3] and ANSI/ASTM1997b (hemicellulose was obtained as difference of holocellulose and cellulose); results are summarized in table 1.

Table 1. Results obtained for *Arundo donax L*

Section of the plant	Lignin (%)	Holocellulose (%)	
		Cellulose (%)	Hemicellulose (%)
Roots	19.11 ± 2.08	21.00 ± 1.01	29.57 ± 2.87
Stems	21.11 ± 0.86	37.95 ± 4.59	34.02 ± 1.46
Leaves	15.52 ± 2.00	27.68 ± 3.51	34.09 ± 3.28
Fibre bundles	24.12 ± 1.40	45.16 ± 2.97	35.10 ± 2.80

From TGA analysis, it is interesting to note that degradation temperature for fibres is around 230 ºC (left limit temperature, onset is 282 ºC), which is quite close to the degradation temperatures of jute or hemp (205 and 250 ºC, respectively) [4]. The FTIR spectra analysis confirms the chemical composition data obtained by hydrolysis, which shows a lower lignin content for the leaves and roots samples, and a higher proportion of cellulose for the fibres. It is interesting to note the acceptable linear correlation in the determination of cellulose content by derivative thermogravimetry versus that determined by quantitative acid hydrolysis. This is particularly interesting as an alternative, faster and cheaper method for the determination the cellulose content of any vegetable fibre and plant species, although further tests are needed to confirm this point.

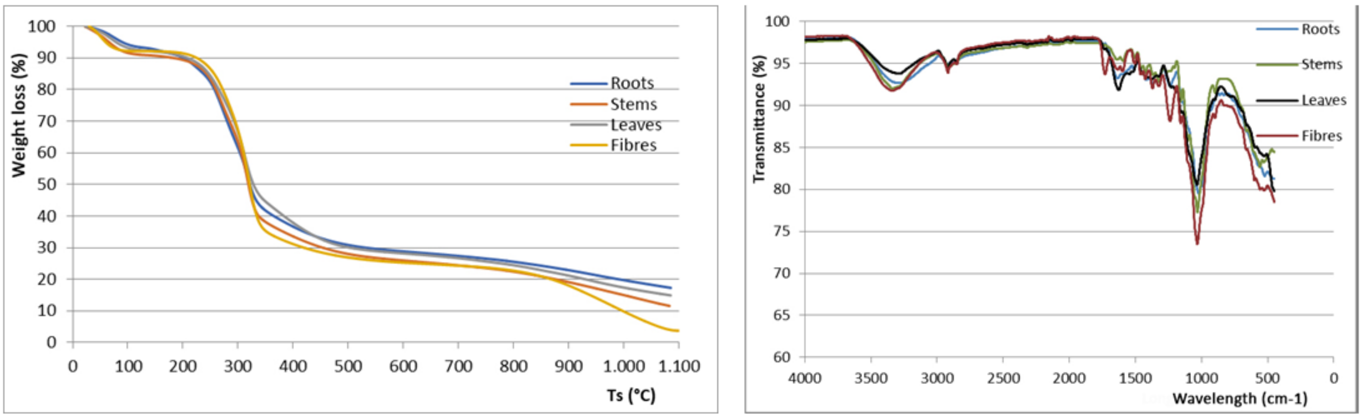

Fig.2. TGA and FTIR curves for different part of *Arundo donax. L.*specimens

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by European Funding for Regional Development (FEDER), INTERREG MAC 2014-2020 [MAC ECOFIBRAS, grant number MAC/4.6d/040 and INV2MAC, grant number MAC2/4.6d/229].

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OPTIMIZATION OF WASHING PROCEDURES OF AS-RECEIVED NATURAL FIBERS PRIOR TO COMPOSITES MANUFACTURING: PHYSICAL, MECHANICAL, CHEMICAL AND WETTABILITY STUDY

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ABSTRACT
In this work, two families of washing procedures of as-received flax, sisal and hemp fiber reinforcements were employed. Such procedures are used to partially extract fats, waxes, and non-cellulosic products from the fibers, aiming at obtaining reinforcing fibers with a higher fraction of the cellulosic backbone. The results define a simple washing procedure based on sequential use of solvents with different polarities (ethanol/acetone/hexane). This approach is believed to be beneficial prior to the application of future surface treatments.

INTRODUCTION
The durability of natural fiber reinforcements is a growing challenge in composites industry. For composites used in the structural strengthening of masonry, natural fibers appear as a good solution to cast a so-called textile reinforced mortar (TRM). However, the fibers hydrophilicity and sensitivity to highly alkaline matrices such as cement or lime mortar represent a severe threat to their lifespan, an issue that highlights the necessity to increase their durability via surface coatings and treatments [1]. Many surface treatments depend upon the chemical crosslinking/coupling with the hydroxyl groups present in the cellulosic backbone rather than the amorphous materials of the fibers [2]. Yet, those groups might be blocked by excessive lipophilic products [3]. In this work, the chemical, physical, mechanical and wettability effects of the partial extraction of such lipophilic products, existing in flax, hemp and sisal fibers employed as reinforcements for lime mortar, is investigated. To achieve this, two families of organic solvents with different polarities (consisting on three different protocols each) were utilized with different sequences, washing times and stirring conditions, see Table 1. To define the physical properties of the fibers (before and after each washing procedure) the density was studied via Archimedes method in hexane to avoid fibers swelling [4] and linear density was measured to calculate the equivalent cross section of fiber yarns. Furthermore, fibers surface wettability was measured by static sessile drop contact angle (SCA) using 10-15µl droplet on 3 samples at 3 different spots each. FTIR was used to characterize the chemical changes after extraction of hemicellulose and fatty products mainly. Tensile properties were characterized according to EN ISO 2062-1995 on 10 samples of each fiber type. All data were analyzed and cleared from outliers applying, Dixon's, Grubbs's or Tietjen-Moore tests (ASTM E178-16a).

RESULTS AND CONCLUSIONS

For tensile tests results (the case of flax fibers for example is shown in Fig. 1a), it was observed that family-B (Table 1) has enhanced fibers tensile properties rather than family-A (Table 1). Furthermore, it was reported that washing process WP-V specifically has resulted in 1.5, 1.1 and 1.2 times the tensile capacities of the non-washed flax, sisal and hemp samples respectively. These results are concordant with SCA results where the family-B has experienced higher hydrophilicity than family-A, Fig. 1b. Given these results in parallel to FTIR outcomes, it is believed that family-B-based washing procedures have resulted in partial degumming of the amorphous regions of the fibers, improving the crystalline structure and exposing higher content of the hydrophilic cellulose fraction.

Table 1 Washing procedures applied to flax, hemp and sisal fibers

Washing ID	Family	Time-Solvent- Mechanical mix
WP-I	Family-B	1h-Ethanol/Hexane/Acetone-ultrasonication
WP-II	Family-B	1h-Hexane/Ethanol/Acetone-ultrasonication
WP-III	Family-A	1h-Ethanol + ultrapure water rinsing-no mechanical mix
WP-IV	Family-A	45 mins-Hexane + ultrapure water rinsing- no mechanical mix
WP-V	Family-B	1h-Ethanol/Acetone/Hexane-ultrasonication
WP-VI	Family-A	1h-Ethanol/water: 1:2, v/v + ultrapure water rinsing- no mechanical mix

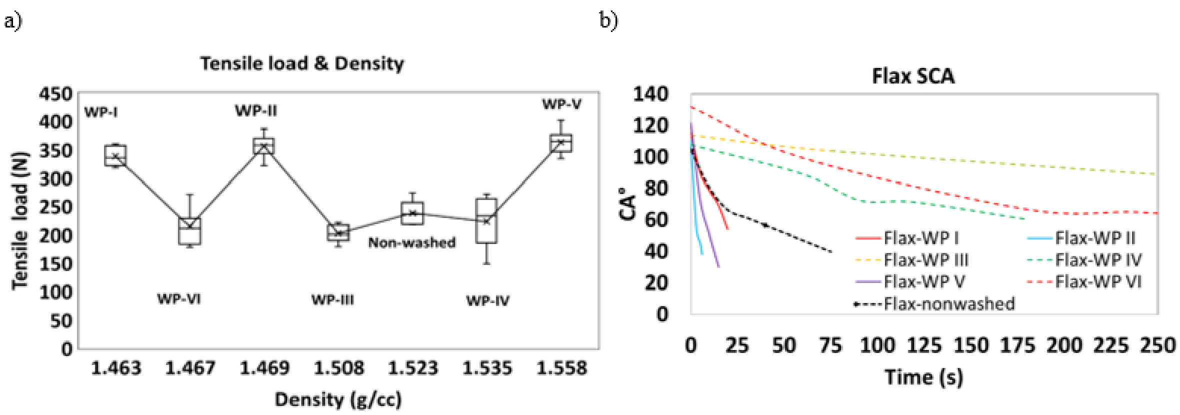

Fig.1 a) Tensile load capacity- Density of Flax fibers, b) Flax SCA-Time

ACKNOWLEDGMENTS

This work was partly financed by the Portuguese Foundation for Science and Technology (FCT/MCTES) through national funds (PIDDAC) under the R&D Unit Institute for Sustainability and Innovation in Structural Engineering (ISISE), under reference UIDB / 04029/2020. IPC acknowledges the support of FCT through National Funds References UIDB/05256/2020 and UIDP/05256/2020. The authors wish to acknowledge FCT for the PhD scholarship granted to the first author (SFRH/BD/144106/2019).

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CONSEQUENCES OF ULTRA-FINE MILLING ON PHYSICAL AND CHEMICAL CHARACTERISTICS OF FLAX FIBRES AND COMPOSITES THEROF

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ABSTRACT

In recent years, lignocellulosic biomass has been increasingly used in various applications, often replacing petro-sourced materials. While for many of these applications, the plant materials required only coarse milling, some new applications for green chemistry, bio-energy and bio-packaging necessitate comminution to obtain very fine and calibrated particles (below 200 µm). This step of milling is never inconsequential for lignocellulosic materials and can have an influence on the physical (size, shape) and chemical characteristics (cellulose crystallinity, composition) of the powder. However, these different effects are still poorly understood. In this work, we study and elucidate the impact of intense and ultra-fine milling on the physico-chemical properties of plant fibres. Flax was chosen for this study because of its hierarchical structure and biochemical composition well described in the literature, which make it a model material. Main results evidence a strong impact of 0 to 23H ball milling on flax fibre morphology, especially on fibre aspect ratio falling from 20 to 5 but also on cell wall ultrastructure and composition. Cellulose content and crystallinity significantly decrease with milling time, opening the way to higher water sorption and lower thermal stability. In addition, we address the debate about fine, are they solely a filling agent or on the contrary, have they a potential of reinforcement in such composites? - depending on their numbers, their length and aspect ratio. We then investigated the mechanical influence of the flax fines in two representative matrix thermoplastic families Poly(amide)-11 (PA11) and poly(butylene-succinate) (PBS) is elucidate thank to thermoplastic composites.

INTRODUCTION

The transformation of composites reinforced with plant fibres is developing and is now reaching a level of maturity in numerous industries, to manufacture products such as automotive non-woven parts (Renouard et al., 2017), sporting goods (Mohanty et al., 2018) as well as for original applications due to their specific hygroscopic behaviour (Abida et al., 2019; Duigou and Castro, 2017). However, the knowledge of these materials still needs to be progressed; not all reinforcement mechanisms or the specificities of these fibres are yet mastered. This is particularly true in the case of extruded and injected blends where the behaviour of the fibres, very different from that of the synthetic reinforcements, has a direct impact on the microstructure (Bourmaud et al., 2013) and consequently on the performance of the composites. The objective of this work is i) to study the impact of ultra-fine grinding on flax fibers, and by the way ii) to study the impact of flax fines particles on mechanical properties of a range of biocomposites. Firstly, batches of flax fines particles were artificially created by a suitable grinding technology and then characterized. Then, the mechanical behaviour of PP-PPgMA matrix composites made with an increasing volume fraction of flax fines (from 0 to 40.2%-vol) was studied and compared with composites reinforced with 2 mm cut flax fibres. The PP-g-MA fines composites were benchmarked with chalk, and also to a ternary mix of fibre + fines. In addition, 20.4%-vol composites were manufactured with PA11 and PBS matrices to deeper investigate the fines mechanical impact according to the various rheological grades of polymers. For each of these batches the tensile and impact mechanical performances were investigated.

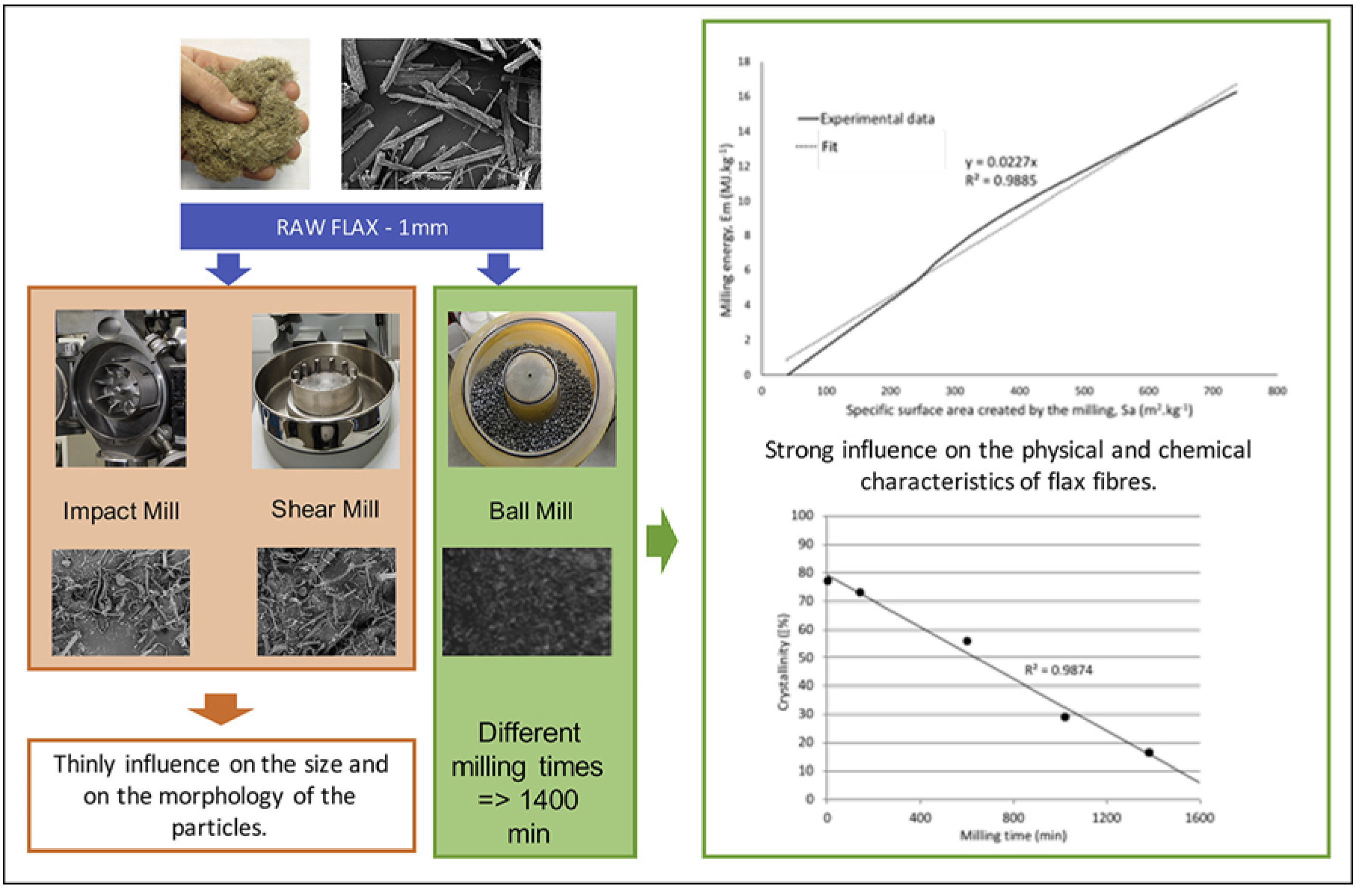

Figure 1: Overview of the setup and highlights of the grinding on flax fibre

RESULTS AND CONCLUSIONS

After a comparative work between different grinding modes, the ball milling was selected because of its efficiency and its ability to provide a wide range of particle size distributions. Morphological measurements carried out for milling times up to 23 hours have shown a marked decrease in the length and aspect ratio of the fibres; the diameter is less affected because of the smaller amplitude of this parameter due to the initial fineness of the fibres and the diameter of the elementary fibres, which constitutes a lower limit that is difficult to exceed.

In terms of structure and composition of the flax cell walls, major modifications have been highlighted; it appears that cellulose is mainly impacted by the process. Thus, a steady decrease in glucose level but also in the crystallinity of cellulose has been demonstrated. This modification of cellulose is favoured by a thermo-mechanical alteration highlighted by SEM imaging and corroborated by the sorption behaviour of the walls. Rising accessibility to water has been shown by DVS and ATG, caused by the increase in amorphous areas. The reinforcement capacity of the fines has been demonstrated in terms of stiffness, it remains modest compared to short flax fibres. The stiffness achieved with a 2 mm fibre volume fraction of 5.6% is only achieved with 37.4% of fines, i.e. a ratio of about 6.7. Their presence is therefore very detrimental in terms of reinforcement, especially since we have been able to show that in some composites they can reach rates of 90% in number. This low reinforcement capacity was confirmed with a panel of polymers, the mechanical performance of fines-strengthened polymers being much lower than those containing fibres, regardless of the matrix considered.

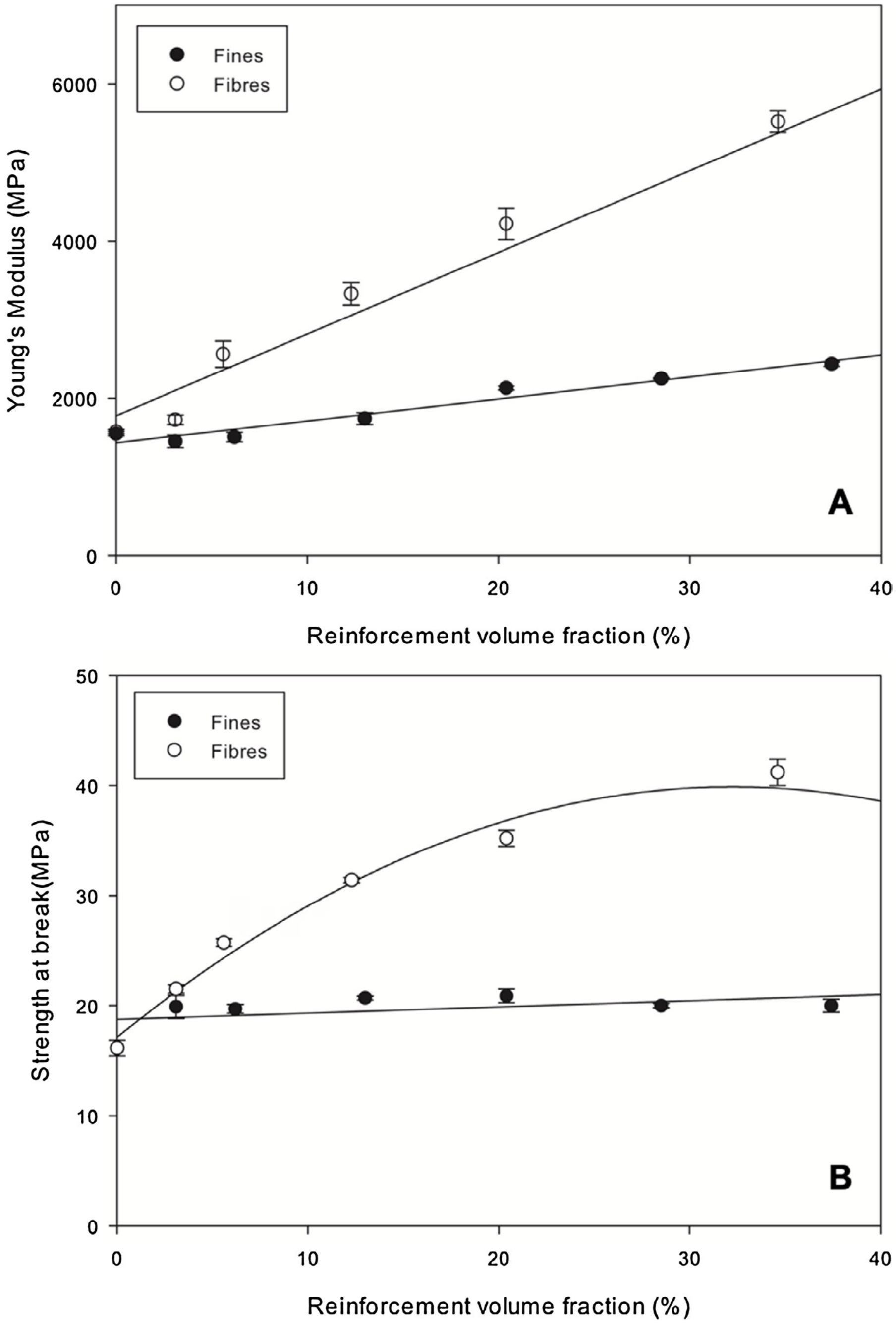

Figure 2 Young's modulus (A) and strength at break (B) of flax fines and fibres PP/PPgMA composites for a range of reinforcement volume fractions

ACKNOWLEDGMENTS

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DIOECIOUS HEMP FIBRES FOR TEXTILE OR STRUCTURAL COMPOSITES

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ABSTRACT

This work evaluates the extraction yield, the morphological properties and the tensile properties of fibres from a dioecious hemp variety. The male and female stems as well as the top and bottom part of the plants were analysed separately. The tests aim to identify the differences on properties of fibres for a potential use for textile and structural composites.

INTRODUCTION

Hemp is an ancestral natural crop once cultivated for textile applications. It has recently known a new huge interest as an environmentally friendly source for high quality fibres and literature reveals that it has a great potential for textile and structural applications [1]. In the past, hemp varieties were dioecious, which means that male and female plants grow on separate stems. The fibres extracted from male plants, finer, were intended for the finer fabrics and fibres from the female plants, coarser, for the rougher fabrics. Today, it is no longer possible to manually harvest male and female plants separately. Nevertheless, by carrying out an overall harvest of male and female plants together, previous works suggest that the fibres from dioecious varieties, considering male and female mixture, were generally finer and with a better quality than those obtained from monoecious hemp.

This work qualifies the properties of a dioecious variety of hemp, named Carmagnola. Male and female stems are then characterized separately the top and the bottom part before comparing them. After being field retted, hemp stems (≈150 cm) are cut in two parts, scutched and hackled using a laboratory scale device in order to extract long line fibres. The process involves a succession of breaking rollers, a beating system and a hackling step. The yield of fibres after the extraction process is then measured. Fineness analysis are performed on extracted fibres using a scanner and the dedicated image analysis software "FIBRESHAPE" and microstructural properties are studied by examining the stem cross-section with an optical microscope are also performed. Mechanical tests are carried out on single elementary fibres with a dedicated tensile test device from the Dia-Stron Company.

RESULTS AND CONCLUSIONS

The main difference of fineness has been observed on male top part which tends to cover less coarse fibres and therefore finer fibres than the other analysed parts and particularly the female ones. Further results will be detailed and analysed. The results from the tensile tests are shown in Figure 1.

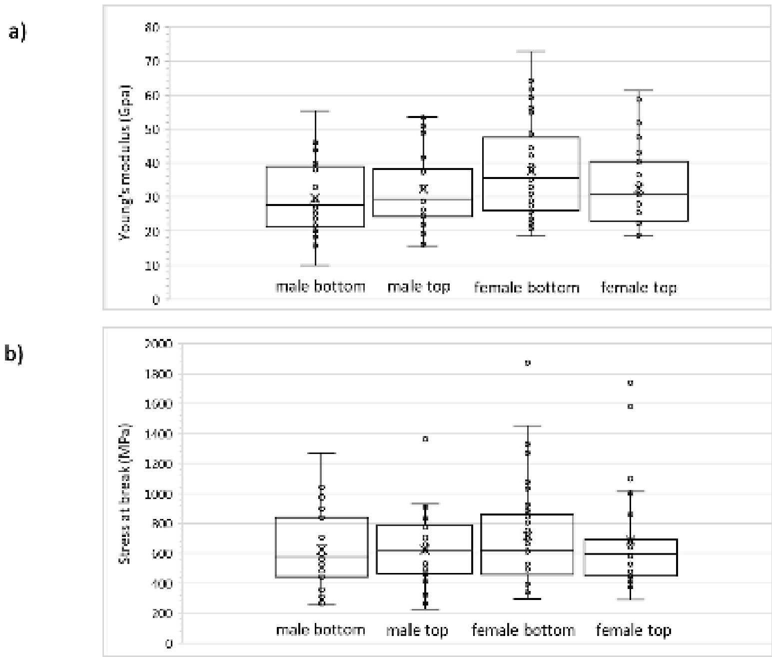

Figure 1: Young's modulus (a) and stress at break (b) of Carmagnola hemp single fibres. The crosses and the solid lines correpond to the median and the mean respectively.

Student tests have been carried out between the different batches. No significant differences are observed on tensile properties between top and bottom part. However, a significant difference of Young's Modulus behaviour appears between the male bottom sample and the female bottom sample ($p < 0{,}02$). These results will be discussed in relation to structural composite materials applications but it globally shows that the finer fibres (male top) do not really show a lower mechanical potential than the other ones studied in this work.
All the presented results (fineness, tensile properties, microstructure of fibres) will be compared to results obtained from another dioecious variety (Tiborszallasi) and a fibre dedicated variety (Santhica 27) all extracted using the same equipment and to results from the literature [2,3].

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by the Agence de l'Eau de Seine et Normandie.

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NOVEL LOW TWIST BAST FIBRE YARNS FROM DISORDERD LINES FOR HIGH-PERFORMANCE COMPOSITE APPLICATIONS

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ABSTRACT

As part of a research project (NF-CompPlus), novel yarn structures made of bast staple fibres from the European disordered line are being developed for use in high-performance composite materials. The results have shown that the produced flax yarns from relatively inexpensive flax tow lead to comparable properties in a composite as compared with a high-quality flax roving made from long scutched fibre bundles available at the market.

INTRODUCTION

Currently, high-quality long flax, which is suitable for structural and higher loaded components, is very expensive. The high price of these high-quality flax rovings and textile products is often the limiting factor for the use in many potential applications yet. The aim of the research project NF-CompPlus is to process flax and hemp fibre bundles with lower costs from disordered lines into yarns with nearly unidirectional oriented fibres by an alternative spinning process. The high orientation of the fibres in the composite leads to excellent mechanical properties. Poor impregnability of yarns with a high twist in combination with a reduction in mechanical properties is well-documented (Baets et al., 2011, Shah et al. 2013, Goutianos & Peijs, 2003). Compared to these yarns, the wettability of the fibres with the matrix is better for the developed yarns, and the mechanical properties of the fibres can be transferred more effectively to the polymer matrix in the composite.

RESULTS AND CONCLUSIONS

So far, it has been shown that flax tow can be processed into high-quality unidirectional (UD) staple fibre yarns. The yarns with a fineness of about 200 tex were further industrially processed into fabrics and subsequently transformed in combination with thermosetting matrices to composite plates for material analysis by a vacuum infusion and a resin injection process in an autoclave.

The reinforcing effect of the yarns was tested using UD reinforced specimens produced by a laboratory pultrusion process. It has already been shown for flax with a fibre mass fraction of 40% that the alternative unidirectional flax yarn leads to comparable composite properties compared with a commercial long-flax roving. For UD fibre-reinforced composites a bending modulus up to 25 GPa, bending strength of 299 MPa and impact strength of 60 kJ/m² was achieved. These values are multiple higher as compared, e.g., with injection moulded bast fibre-reinforced thermoplastics (Riedel et al., 2005). The developed bast fibre fabrics are used to produce composite prototypes for vehicle construction. For this purpose, a hybrid composite material made of bast and glass fabrics was also developed for a leaf spring element of a bogie of a narrow-gauge railway with improved damping properties. The hybrid composites produced from the quasi-UD flax and glass fabrics exhibited, for example, bending strength of 361 MPa and impact strength of 125 kJ/m². The first prototype of a flax fibre-reinforced leaf spring is shown in Fig. 1.

In the overall consideration, we can conclude that the novel yarn structures are intended to give bio-based composites new price segments that are not achievable with previously available bast fibre yarns. The yarns developed may be used for the production of semi-finished products such as woven fabrics and non-crimp fabrics and can thus also be used for products subject to higher stresses that were previously made from more expensive long flax, such as skis, helmets, furniture, automotive body components for outdoor use, boat building, skateboards, surfboards and so on. The yarn itself can also be used for the production of winded components such as bicycle frames or construction rods.

Fig.1 Leaf spring element of a bogie of a narrow-gauge railway made from the developed flax yarn (quasi-UD fabric) and an epoxy matrix (length 1170 mm, width 90 mm).

ACKNOWLEDGMENTS

Project: Innovative yarn structures and their competitiveness as part of the project fibre-reinforced composites for structural applications based on a novel, low-twist bast fibre yarns (NF-CompPlus). The research project is carried out in the framework of the industrial collective research programme. The project is supported by the Federal Ministry of Food and Agriculture (BMEL) based on a resolution of the German Bundestag (funding no. 22026215, 22014817 & 22015417).

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PHYSICAL AND THERMAL PROPERTIES OF NONWOVEN MATERIALS BASED ON RAW PALM FIBRE FOR INSULATION APPLICATIONS

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ABSTRACT

Currently the *Washingtonia* palm tree occupies the first rank of plants used in Morocco to adorn gardens and streets due to the beauty of these circular leaves which generates in each campaign large quantities of waste. In this context, our project aims to recover this waste through the development of eco-friendly nonwoven textile materials for building application. This work was focused on the petiole part of the palm tree to test the feasibility of this nonwoven in its raw state, as well as to evaluate its properties for use as insulating material in building sector. Three types of nonwovens have been developed using a needled nonwoven manufacturing unit by mixing natural cotton, natural wool and synthetic polyester fibres with staple palm fibre in a ratio of 30:70. Palm fibres and nonwoven materials developed have been characterized in terms of physical and thermal properties.

INTRODUCTION

Nowadays the interest in improving insulation has been increased due to the development in building practices, the need for improved thermal comfort and energy savings. For this reason, the production of nonwoven fabrics based on synthetic fibers and polymers is noticeable in the construction and automotive industries. However, synthetic fibers raise more and more environmental problems. Production energy and the emission of harmful compounds are major drawbacks as well as the unavailability of fossil resources in the coming years. The use of natural fibers including palm fibers is a more environmentally friendly alternative. Substituting synthetic fibers with biodegradable fibers from renewable resources contributes to the protection of the environment. Moreover, given their interesting specific properties, natural fibers are widely used as reinforcement of composite materials (Sajid, 2020). The objective of this work is to valorize this waste through the development of eco-friendly nonwoven textile materials for the insulation. Three types of fibers were mixed with palm fiber to make nonwoven textile materials. The green palm waste Washingtonia (petiole part) was harvested in the region of Casablanca, Morocco. The wool, cotton and polyester fibers used are part of the industrial waste.

The Surface density (g/cm²) and the thickness of nonwovens was determined according to the NF EN ISO 9073-1/2 standard. The porosity of the nonwovens ε was estimated according to the method of Ghorbani et al., (2016). The air permeability was determined according to the French standard EN ISO 9073-15 with an AIR TRONIC. The mechanical properties of nonwovens are determined in the width direction of the nonwovens according to ISO 13934-1 using a reference length of 20 cm. The thermal conductivity λ of nonwovens was determined in accordance with EN 12667 using the heated plate apparatus λ-Meter EP500e. An average of five samples cut from each needle-punched fabric has been calculated.

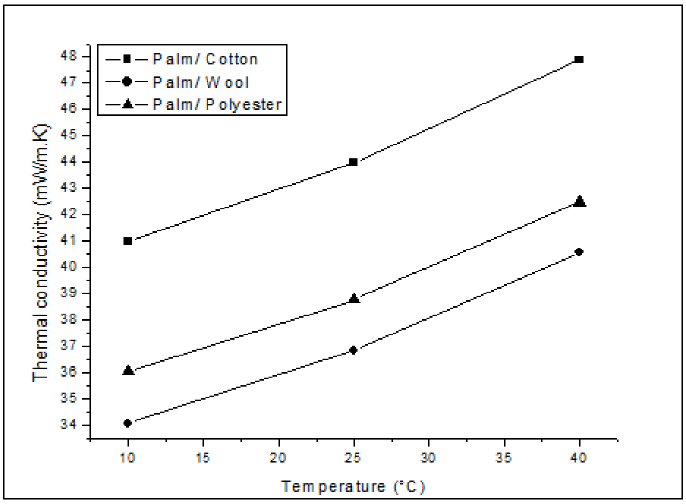
RESULTS AND CONCLUSIONS

Table 1 indicate that the nonwoven Palm / Wool is characterized by their high porosity (89.51 %) compared to other nonwovens (82.11 % for Palm/ Cotton and 83.30 % for Palm/ Polyester). In addition, the nonwovens are characterized by their air permeability. The maximum value is related to the Palm/ Wool nonwoven (1.66 m3.m-2.s-1) while the Palm/ Cotton nonwoven represents the minimum value (0.30 m3.m-2.s-1). Also, the air permeability of Palm / Polyester can go up to 1.36 m3.m-2.s-1.

Table 1. Physical Properties of nonwoven materials products

Sample	Thickness (mm)	Areal density (g/m^2)	Density (Kg/m^3)	Porosity (%)	Air permeability (m^3.m^{-2}.s^{-1})	Strength (N)	Elongation (%)
Palm/ Wool	3,98	414,60	104,17	89,51	1,66	18,40	32,53
Palm/ Cotton	4,35	773,04	177,66	82,11	0,30	56,3	35,1
Palm/ Polyester	3,53	585,40	165,78	83,30	1,36	162,3	70,7

Fig 1 shows that the Palm/Wool nonwoven fabric has a thermal conductivity lower than that of Palm/ Polyester and Palm/ Cotton, because the wool traps almost 80% air in its own volume. Imprisoning air slows the thermal conductivity of the material. All produced nonwovens have a thermal conductivity below 60 mW/m.K (El Wazna, 2019). Produced nonwovens can therefore be used in thermal insulation for automotive and building applications.



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MECHANICAL EVALUATION OF THE STABILITY OF MERCERIZED SISAL FIBERS ON ALKALINE ENVIRONMENT

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ABSTRACT
This work aims at evaluating the stability of natural and mercerized sisal fibers exposed to an alkaline environment. Three different concentrations of NaOH solution (1, 5 and 10wt.%) were used in the mercerization treatment. For the durability evaluation, fibers were exposed to 1N NaOH solution for 7, 14, 21 and 28 days. After the aging process, direct tensile tests were performed to assess the influence of the treatment on the durability of the fibers in terms of mechanical strength.

INTRODUCTION
In recent years, sisal fibers have been studied as an alternative to the use of synthetic fibers due to its attractive mechanical properties (Castoldi, 2019). Besides that, these fibers are naturally abundant, have a low density, and also are non-hazardous and non-abrasive (Yan, 2016). However, their great potential as an alternative to reinforcement in cement-based matrices is confronted with their susceptibility to degradation by alkaline attack (Gram, 1983). As cement-based matrices are alkaline in nature, it is important to enhance sisal fiber's alkaline resistance to make them suitable for use as reinforcement in cementitious composites. Several treatments were proposed by previous studies (Ferreira, 2015). However, mercerization is considered a simple and cost-effective alternative among all other surface treatments proposed in the literature (Ganapathy, 2019).
In order to evaluate the effectiveness of the mercerization on the long-term durability of sisal fibers, a test methodology was conducted based on recommendations of ASTM D6942. Fibers were previously treated through immersion on 1, 5 and 10wt.% NaOH solution for 1 hour, then neutralized with 1wt.% acetic acid solution and air-dried. For the durability test, natural and mercerized fibers with 50 mm length were soaked into a strongly alkaline solution (1N NaOH) during different exposure time intervals: 7, 14, 21 and 28 days. After the exposure time was reached, fibers were thoroughly washed with distilled water, air-dried and prepared for the direct tensile strength test.
The direct tensile test was conducted using an MTS-810 testing machine with a 100 N load cell following recommendations of ASTM C1557. Fibers were glued on a stiff paper frame and then clamped on the testing machine. Before the test, both sides of the frame were cut to allow fiber deformation. A free length of 20 mm and a displacement rate of 0.1 mm/min were adopted. An LVDT was attached to the arrangement to record the displacement. To obtain the tensile stresses, the area of each tested fiber was measured. For each fiber type (natural, 1% treated, 5% treated, 10% treated), and each time interval, 10 fibers were tested. More details of the test setup can be found in (Castoldi, 2019).

RESULTS AND CONCLUSIONS
The results from the direct tensile tests are shown in Table 1. To evaluate the effect of the alkaline exposure on fiber strength, the Stability Ratio (SR) was obtained as defined in Eq. 1. Higher ratios of SR means that the fibers have greater stability in an alkaline environment. From Fig.1 it is clear that there is a significant mechanical property degradation in the case of the non-treated fiber. After 28 days a decrease of 66% in

the tensile strength is observed, which can be attributed to the degradation of the fiber structure. As the degradation proceeds, the lignin and hemicellulose are gradually destroyed, followed by the deterioration of cellulose. As a consequence, there is a reduction in the tensile strength of the fibers (Wei and Meyer, 2015).

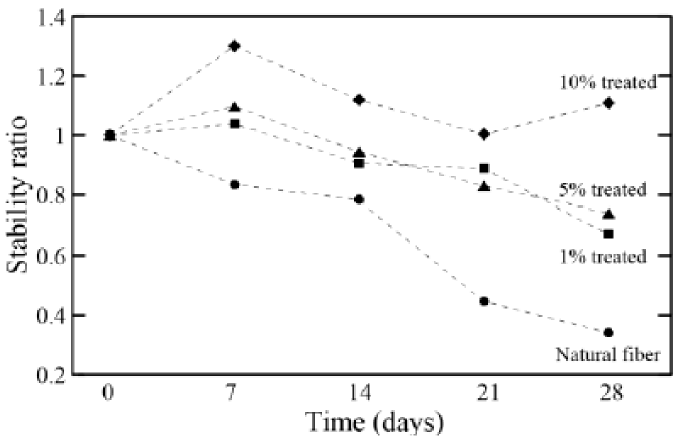
$$Stability\ Ratio = \frac{Tensile\ stength\ of\ alkali\ exposed\ fiber}{Tensile\ strength\ of\ control\ fiber}$$

(Eq. 1)

	Tensile strength (MPa)				
	0 days	7 days	14 days	21 days	28 days
Natural fiber	277.65 ± 28.84	231.54 ± 19.65	217.48 ± 28.37	123.66 ± 19.12	94.48 ± 16.78
1% treated	393.94 ± 65.28	409.33 ± 44.37	356.59 ± 25.40	349.80 ± 57.54	264.22 ± 33.92
5% treated	383.15 ± 54.73	420.32 ± 58.07	361.63 ± 86.50	317.73 ± 20.38	284.60 ± 23.84
10% treated	314.62 ± 36.82	361.15 ± 23.72	310.79 ± 49.23	278.70 ± 66.16	348.61 ± 75.74

Table 1. Average results of direct tensile tests performed on natural and mercerized sisal fibers.

On the other hand, the mercerization of sisal fibers resulted in more stable fibers. For 1 and 5% mercerized sisal fibers, after 28 days there is a decrease of approximately 30% on the tensile strength, which means that they became more resistant to the alkaline attack in comparison to the natural fiber subjected to the same conditions. The best results were achieved by the 10% treated fiber, which presented higher ratios of SR, indicating that the mercerization leads to greater stability of the fibers when subjected to an alkaline environment. Therefore, treated sisal fibers have potential use in cementitious composites in terms of improved durability in alkaline conditions.



ACKNOWLEDGMENTS

Funding: This work was supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES (Brazilian National Science Foundations).

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EXTRACTION OPTIMIZATION OF RUBIA TINCTORUM FOR TEXTILE APPLICATIONS: TOWARDS A MORE ECO-SUSTAINABLE DYEING PROCESS

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ABSTRACT

The aim of this work was to design and optimize the extraction process (based on the experimental design - DOE) of alizarin and lucidin from R. tintorum roots (25 mg) and to develop an analytical method by high performance liquid chromatography-diode array detector (HPLC-DAD) for their quantification. DOE is a statistical tool which allows identifying and quantifying the causes of an effect within an experimental study. This approach allows us to simultaneously evaluate the effect of several variables from a small number of trials, and thus reduce the total number of experiments and obtain accurate results, saving resources and hand-on lab time. The treatment of results was subsequently carried out in the statistical program MINITAB®, version 17. The target parameters were extraction time (6-24 h), percentage of water applied in the extraction (0-100%), agitation (yes/no) and temperature (30-80 oC). Using an optimized extraction process, natural colorants - alizarin and lucidin - from R. tintorum roots were applied for wool natural dyeing.

INTRODUCTION

Natural dyes have been known since ancient times, they are dyes derived and removed from plants, invertebrates, or minerals. Most of the natural colorants are vegetable colorants, extracted from different parts of plants: roots, fruits, bark of trees, leaves and wood; there are other biological sources that produce dyes such as fungi and lichens. Archaeologists have found evidence of fabric dyeing dating from the Neolithic period. In China, dyeing with plants, barks and insects has been traced to being more than 5,000 years old. [1] The essential dyeing process has changed little over time. Typically, the dyeing material is placed in a pot of water and then the fabric to be dyed is placed in the container, which is heated and stirred until the colour is transferred. Textile fibers can be collected before spinning ("wool dyeing"), but most textiles are dyed on the yarn or in "pieces" after weaving. Many natural paints require the use of chemicals called mordants to fix the ink on textile fibers; gall tannins, salt, natural alum, vinegar, and urine ammonia were used by the first dyers. Many mordants, as well as some dyes, produce strong odours, and dyeing sites were often isolated in their own districts.

Most of the natural colorants are vegetable colorants, extracted from different parts of plants: roots, fruits, bark of trees, leaves and wood; there are other biological sources that produce dyes such as fungi and lichens. Archaeologists have found evidence of fabric dyeing dating from the Neolithic period. In China, dyeing with plants, barks and insects has been traced to being more than 5,000 years old. [1] The essential dyeing process has changed little over time. Typically, the dyeing material is placed in a pot of water and then the fabric to be dyed is placed in the container, which is heated and stirred until the color is transferred. Textile fibers can be collected before spinning ("wool dyeing"), but most textiles are dyed on the yarn or in "pieces" after weaving. Many natural paints require the use of chemicals called mordants to fix the ink on textile fibers; gall tannins, salt, natural alum, vinegar, and urine ammonia were used by the first dyers. Many mordants, as well as some dyes, produce strong odours, and dyeing sites were often isolated in their own districts.

Throughout history, people have dyed their fabrics using common and locally available materials, but rare dyes that produced bright and permanent colors like natural dyes from invertebrates, Tyrian purple and kermes carmine, have become luxury items in the ancient and medieval world. Herbal dyes such as pastel (Isatis tinctoria) and indigo were important commercial items in the economies of Asia and Europe. Throughout Asia and Africa, printed fabrics were produced using techniques to control color absorption in part-dyed fabrics. Paints like cochineal and logwood (Haematoxylum campechianum) were brought to Europe by the Spanish, and European dyes were taken by the colonizers to America.

The discovery of synthetic dyes in the middle of the 19th century triggered the decline of the large-scale market for natural dyes. Synthetic dyes, which could be produced in large quantities, and unlike natural dyes, could be used in the synthetic fibers created next. Artists from the Arts and Crafts Movement preferred pure hues and a subtle variety of natural dyes, which ripen over time but preserve their true colors, unlike the first synthetic paints, [1] and helped to ensure that ancient European techniques became dyeing and printing with natural inks were preserved. Natural dyeing techniques have also been preserved by artisans and traditional cultures around the world. At the beginning of the 21st century, the natural paint market is experiencing a resurgence in the fashion industry. [2] Western consumers have become more health-conscious about the environmental impact of synthetic dyes in the manufacturing process and there is an increasing demand for products that use natural dyes. [3]

Rubia tinctorum is a perennial plant related to lady's bedstraw and goosegrass or cleavers, which are common wild flowers in Europe. It produces an array of fast colors from its roots, ranging from pale pinks and violets, through deep reds to oranges and browns. This is uncommon, as red dyes are scarce both from natural and synthetic sources, and as such madder is considered a valuable commodity. The most significant of the madder dyes is alizarin and lucidin. [4] It has been used since ancient times as a vegetable red dye for leather, wool, cotton and silk.

RESULTS AND CONCLUSIONS

Using only 22 experiments, in the case of lucidin by viewing the Pareto graphs (Figure 1), it is possible to assess that none of the studied factors significantly influence the extraction process (since none exceeded the red dashed line). Identical behaviour was observed for alizarin (Figure 2).

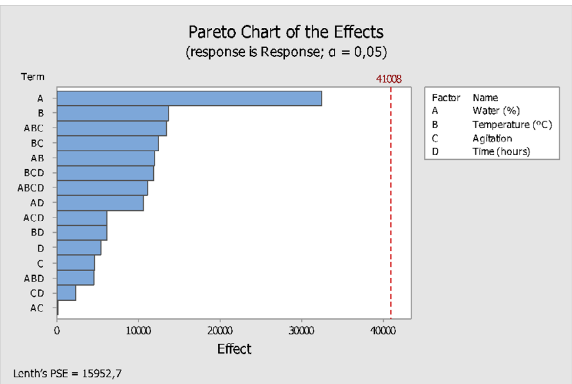


Figure 1 - Pareto chart for lucidin extraction process.

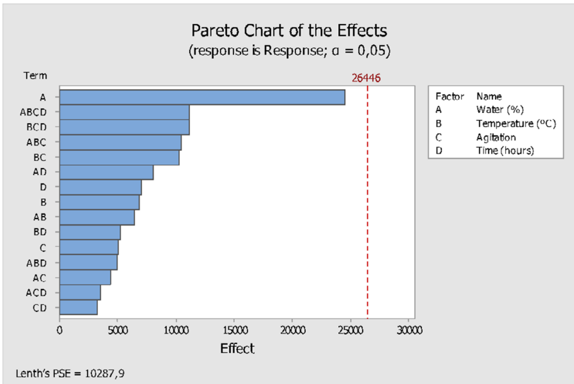


Figure 2 - Pareto chart for alizarin extraction process.

However, through the analysis of the main effects graph (Figure 3 and 4), it is possible to verify that the best conditions for the extraction of both compounds are: 0% water, temperature of 30 °C, with agitation and extraction for 24 hours, although no statistically significant differences were observed in the results.

Figure 3 - Main effects of the inputs in the lucidin extraction process.

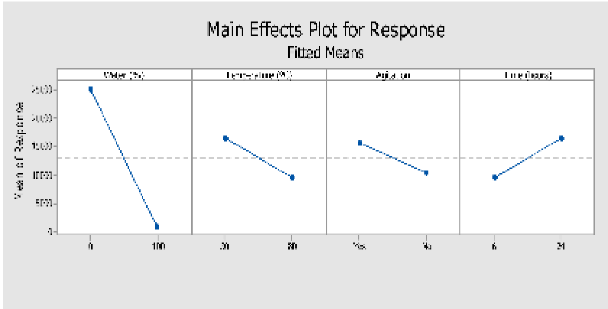


Figure 4 - Main effects of the inputs in the alizarin extraction process.

Concerning the quantification process, a HPLC 1290 Agilent infinity with quaternary pump coupled to a 1290 infinity diode array detector was set to perform chromatographic analysis. The compounds were separated with a YMC-Triart PFP (5 µm, 4.6 × 150 mm) analytical column. The HPLC–DAD worked on isocratic mode with a mobile phase of 0.1% of acetonitrile and 0.1% of trifluoroacetic acid (45:55, v/v). The mobile phase flow rate was 1 mL/min and the sampler and column temperatures were set to 4 and 30 °C, respectively, with a runtime of 25 min. A sample volume of 50 µL was injected and the analytes were detected at 254 nm (Figure 4).
Using these operation conditions, it was possible to develop an analytical method by HPLC/DAD and quantify lucidin and alizarin between 0.16 - 10.00 µg/mL.

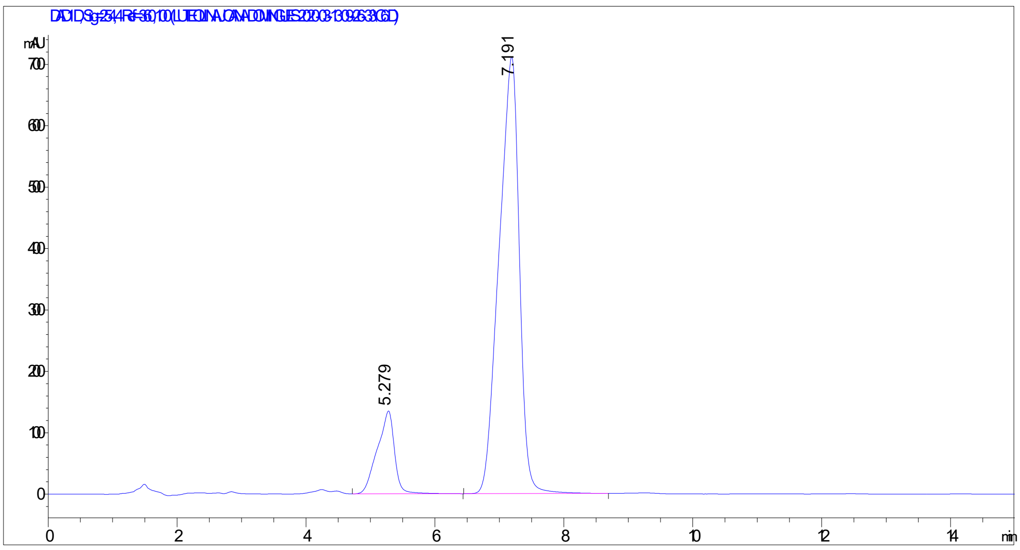
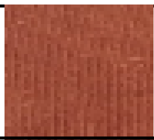
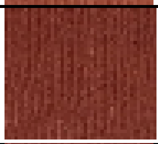
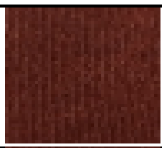
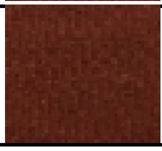


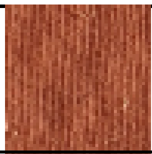
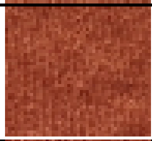
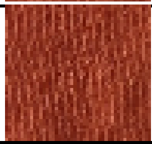
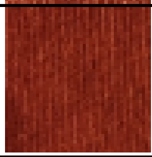
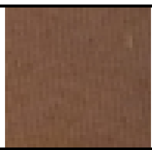
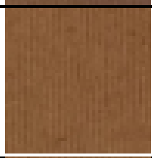
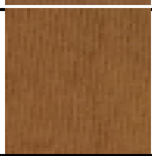
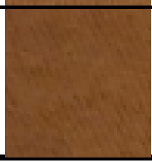
Figure 5 - Representative chromatogram of lucidin (retention time 5.27 minutes) and alizarin (retention time 7.19 minutes) at10 µg/mL.

Based on this premise, it was possible to determine that the compounds' concentrations in the optimal conditions of extraction were 371.80 µg for lucidin33.50 µg for alizarin, both for 20 mg of total extract.

NATURAL WOOL, DYEING

Using only 22 experiments, in the case of lucidin by viewing the Pareto graphs (Figure 1), it is possible to assess that none of the studied factors significantly influence the extraction process (since none exceeded the red dashed line). Identical behaviour was observed for alizarin (Figure 2).

Mordent (copper sulfate (II))	concentration g/l	Dyed Samples	K/S	L*	a*	b*
Without mordent	10%		20.58	34.54	23.13	26.42
	20%		32.66	25.59	18.91	20.38
	30%		36.66	24.06	23.10	20.87
	40%		39.34	23.34	24.13	20.84
With mordent		amostras	K/S	L*	a*	b*
	10%		23.46	27.82	17.45	17.13
	20%		34.75	25.75	18.60	21.16
	30%		37.66	26.21	18.04	23.07
	40%		30.31	30.71	16.48	25.27

Mordent (copper sulfate (II))	concentration g/l	Dyed Samples	K/S	L*	a*	b*
Without mordent	10%		8.66	43.44	20.76	24.96
	20%		11.91	39.71	19.30	24.91
	30%		16.19	37.77	23.15	28.22
	40%		23.39	33.63	25.84	29.00
With mordent		amostras	K/S	L*	a*	b*
	10%		5.95	47.32	11.38	18.13
	20%		7.77	44.97	11.99	21.21
	30%		9.74	43.61	12.63	24.16
	40%		11.75	43.46	13.18	27.56

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by Ministério da Agricultura, under grants ID Grupo Operacional 303, Operação n.º PDR2020-101-031956.

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INNOVATION AND MARKET OPORTUNITIES IN THE ORGANIC COTTON NETWORK IN BRAZIL

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ABSTRACT

The organic cotton network in Brazil presents relevant local production systems based in agroecology. This study goal is to present the principal innovative aspects in the organic cotton network in Paraiba (Brazil). These aspects were determined through data collected in technical visits, interviews, observation and annual reports analysis. The results highlight that innovation includes a great range of multi-actors organized to attend an emerging demand of natural fiber textiles in the clothing and home wear sector. Thus, the organic cotton production in Brazil presents a solid fra¬mework enabling agribusiness and textile opportunities.

INTRODUCTION

Organic cotton in Brazil is cultivated in agroecological and rainfed systems, producing organic food and fiber by smallholders (Textile Exchange, 2020). It is aiming to foster community resilience, generate income, guarantee food security, promote biome conservation and new market linkages (Barros et al., 2020). Brazil has established technical standards for organic cotton products, developing business opportunities for companies achieve the increasing customer demand for more sustainable products (Garcia et al., 2015). This study goal is to present the principal innovative aspects in the organic cotton network in Paraiba (the main producer state in Brazil), developed by multi-actors such as farmer's associations, research institutions, NGOs, fashion brands, etc. These aspects were determined through data collected in technical visits, interviews, observation and annual reports analysis (Sep, 2019/Sep, 2020).

RESULTS AND CONCLUSIONS

As the textile supply chain is long, complex and opaque, successfully translating demand for organic cotton into actual sourcing depends on the entire network taking part (Glin, 2012). Collaborative linkages facilitate the arrangement of complementary skills from different organizations motivating innovation. Thus, a network approach offers a more integrated perspective, towards knowledge and resources access among partners. The main innovations identified in the organic cotton network in Paraiba (Brazil) are summarized in Chart 1.

Organic cotton production in Brazil combines several relevant aspects in order to get international market attention including: smallholder family farmers, regenerative agriculture practices, biodiversity conservation, use of cotton crop residues in livestock feed, organic natural colored cotton, etc. Organic cotton has premium prices and comparing with the conventional cotton, still represents a small market participation. However, it is progressively developing from a niche production to well established local productive communities'.

Finally, the demand in agrotechnology conditions for organic cotton producers in Brazil concerns the development of small machinery for family holders, that must be adapted to semi-arid conditions, e.g. harvesting machine proper for polycultures.

	Innovation aspects
Collaboration	Farmers associations organized in territories developing agroecological cotton production systems with agro-food consortium. They work collaboratively, practicing sanitary protocols for insects control and using bio fertilizers recommended for organic systems.
Communication	The use of WhatsApp groups' of organic cotton producers to transmit technical knowledge between advisors and farmers.
Legal	Participatory organic certification of production systems in rural properties that work with agroecological cotton in agro-food consortium.
Management	Collective coordination to shared machineries, organize logistics and shred transports.
Research	Application of the knowledge construction methodology in Participatory Learning and Research Units. Engaging farmers in filed research and strengthening action research (production, vision, negotiation).
Agrotechnology	Itinerant mini cotton ginning machine, ensuring that the seed remains on the property for planting and use in animal feed. The development of an APP for monitoring insects. Ecological diversity, using techniques for policultives.
Production/ sales	Diversifying products, including transformation of cotton crop waste into a sub product for animal feed or pharma products. Commercialization of additional products with the organic certification, such as sesame and beans.
Training	Practices for soil and water conservation in cropping areas and rainfed methods. On-line classes and distance learning, motivating young farmers and woman into organic cotton production, especially in management functions.
Business Services	Business model with product ordering, advanced sales and expansion of market access.
Product development	EcoYarn made with organic colored cotton, fabric made with silk and organic colored cotton and jeans made with organic colored cotton.
Social aspects	Fair trade, local embedding, translocal and international connectivity, discursive resonance.

Chart 1 Identifying organic cotton innovations in the state of Paraiba (Brazil).

ACKNOWLEDGMENTS

The authors gratefully acknowledge CAPES (Coordination for the Improvement of Higher Education Personnel of Brazilian Education Ministry).

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LARGE THERMOPLASTIC MATRIX MARINE COMPOSITES BY LIQUID COMPOSITE MOULDING PROCESSES

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ABSTRACT

A significant majority of large fibre composite structures in the marine environment currently use a thermoset resin matrix. These materials have excellent durability in the sea, but are difficult to dispose of at end-of-life. After a rigorous selection process [1], methyl methacrylate and lactide monomers have been identified as potential thermoplastic matrix systems which can be manufactured using in situ polymerisation (ISP) during composite manufacture by liquid composite moulding (LCM) processes. LCM includes resin transfer moulding (RTM) for components up to about 3 m square, then Infusion under Flexible Tooling (RIFT for resins, or MIFT for monomers). The presentation will address manufacturing issues (acrylic is a “drop in” for polyester resin, but lactide requires elevated temperature processes), and end of life (acrylic is lower in the recycling hierarchy).

INTRODUCTION

With the increasing concerns over environmental issues, natural fibres and thermoplastic matrices attract increasing interest by composite engineers. As a method of Liquid Composite Moulding (LCM), Resin/Monomer Infusion under Flexible Tooling (RIFT/MIFT) has been widely used for the production of large and complex composite structures with high mechanical properties [2, 3]. Acrylic methyl methacrylate (MMA) and lactide monomers were reported to be suitable to produce thermoplastic matrix marine composites using in situ polymerisation (ISP) by LCM [1]. In this study, flax fibre reinforced thermoplastic composites were made (by MIFT via ISP) and flexural tested to guide the future production and application of large marine composite structures.

MATERIALS, SAMPLE PRODUCTION AND TESTING

The acrylic MMA resin used in this work is Elium® 188 XO catalysed with benzoyl peroxide. The L-lactide was catalysed with Tin(II) 2-ethylhexanoate. The natural fibre reinforcement was a 2x2 twill weave flax fabric with areal weight of 200 g/m2. The schematic of the MIFT for production was shown in Fig. 1. As elevated temperature is required for the process of MIFT of L-lactide monomer, polylactic acid (PLA)-flax composites were produced in the oven at 170ºC for 3 hours. The flax fibre volume fractions were ~31% for both PLA-flax and Elium®-flax composites. The mechanical properties of the sample were investigated by three-point flexural testing. The sample geometry for flexural tests is 80 x 10 x 3 mm3 (cut from the composite plate). The test span and speed in the flexural testing were 48 mm and 1.28 mm/min respectively according to ASTM D790 standard [4].

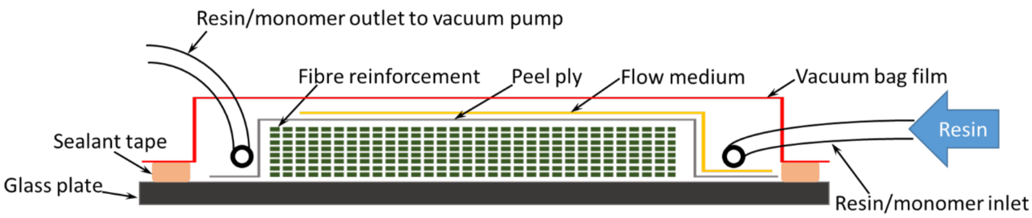

Figure 1. Schematic of the MIFT.

RESULTS AND CONCLUSIONS

The experimental results from the flexural tests and theoretical prediction (by rule-of-mixture equations [5, 6]) are shown in Table 1. Although acrylic resin (Elium®) is lower in the recycling hierarchy at end-of-life, it can be seen Elium®-flax shows better flexural properties than PLA-flax composites. In addition, except for the flexural strength of Elium®-flax, all experimental results are significantly lower than the theoretical prediction values.

Table 1 Flexural properties for PLA-flax and Elium®-flax composites.

Composite	Flexural strength			Flexural modulus		
	Experimental Mean ± SD (MPa)	Prediction (MPa)	E/P* (%)	Experimental Mean ± SD (GPa)	Prediction (GPa)	E/P* (%)
PLA-flax	56.98±9.58 (16.8%)	91.7	62.1	3.66±0.31 (8.5%)	9.86	37.1
Elium®-flax	123.73±4.96 (4.0%)	119.3	103.7	4.98±0.42 (8.4%)	9.45	52.7

*E/P represents the ratio between experimental value and prediction.

This study successfully produced flax fibre reinforced thermoplastic composites by MIFT via ISP. Further study may focus on the optimisation of ISP processes and fibre-matrix interfaces to improve the composite mechanical properties.

ACKNOWLEDGMENTS

This work was conducted within the SeaBioComp project which has received funding from Interreg 2 Seas Mers Zeeën programme 2014–2020 co-funded by the European Regional Development Fund under subsidy contract No. 2S06-006.

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MECHANICAL AND THERMAL PROPERTIES OF JUTE NANO-CLAY MODIFIED POLYESTER BIO-COMPOSITE

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ABSTRACT

This study deals with the investigation on the structural, mechanical and thermal properties of jute fiber varieties [e.g. Tossa (Corchorus olitorius) and White (Corchorus capsularis)] reinforced nano-clay polyester composites prepared by hand layup method. Jute fiber varieties were treated with NaOH and the polyester resin were modified with nano-clay and then the treated fibers and prepared composites are investigated using XRD, UTM and TGA experiments. NaOH treated fibers have better mechanical and thermal properties compared to untreated fibers. Nano-clay added polyester-jute fiber composite has higher tensile strength and thermal stability compared to pure polyester.

INTRODUCTION

Natural jute fiber is important reinforcing materials due to their high strength, good mechanical properties, eco-friendly, renewable, availability, low cost and biodegradable as compared with synthetic fiber. Properties of natural fibers depend on plant variety, age, extraction method and environment in which the plant nurtured (Babu, 2020). The mechanical and physical properties of jute are highly inconsistent and depend on its varieties. Fiber strength of Tossa jute (Corchorus olitiorius) is higher than that of White jute (Corchorus capsularis) and chemical percentage (wt.%) of compositions are different. White jute fiber is finer than that of Tossa (Roy, 2010). Both strength and fineness of jute fiber have great impact on composite properties. Nano-clay exhibits higher thermal, tensile, flexural and impact strength. Addition of nano-clay in jute fibers performs better mechanical and thermal properties (Hasan, 2018). However, the effect of nano-clay and chemical treatment on the different verities jute reinforced composite is unknown. Therefore, the aim of the study is to tune the influence of jute fiber varieties reinforcement (untreated/treated) with polyester resin (modified with nano-clay) for producing suitable bio-composite of better thermal stability and mechanical strength.

RESULTS AND CONCLUSIONS

Figure 1(a-d), 2(a-b) and 2 (c) show the tensile strength, structural and thermal stability of Tossa and White jute fiber (untreated/treated) and jute-polyester (modified with nano-clay %) composites respectively. It is seen that the tensile strength of composites prepared by untreated Tossa and White jute fiber- polyester modified with nano-clay is lower than treated one. Addition of nano-clay in polyester increases the tensile strength and thermal stability of jute reinforced composites compared to pure polyester. In case of flexural properties, the treated Tossa jute fiber reinforced composite showed higher strength compared to White jute fiber reinforced composite. Adding 1% nano-clay, flexural strength is found higher for both varieties compared to pure polyester based composite. TGA of both the jute fibers reinforced polyester- nano-clay composite showed better thermal stability compared to jute fiber pure polyester composite.

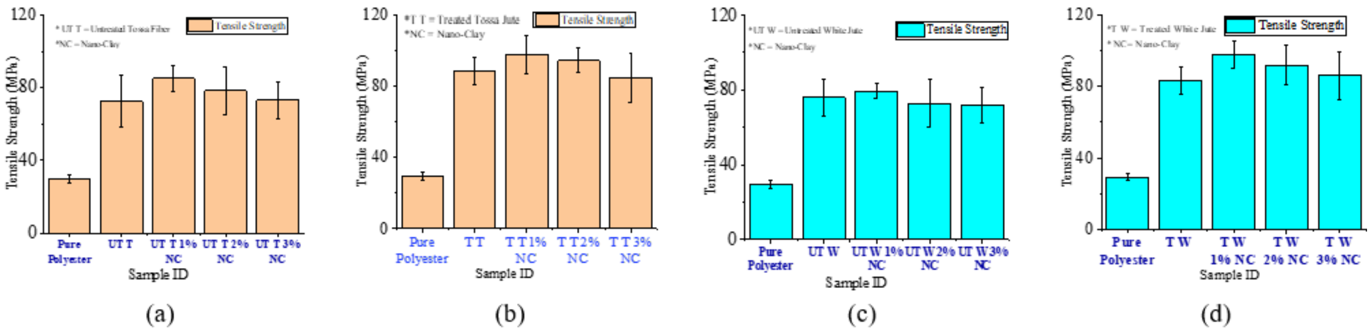

Figure 1: Tensile strength of (a) untreated Tossa, (b) treated Tossa, (c) untreated White and (d) treated White jute fiber - Polyester (modified with nano-clay %) composites

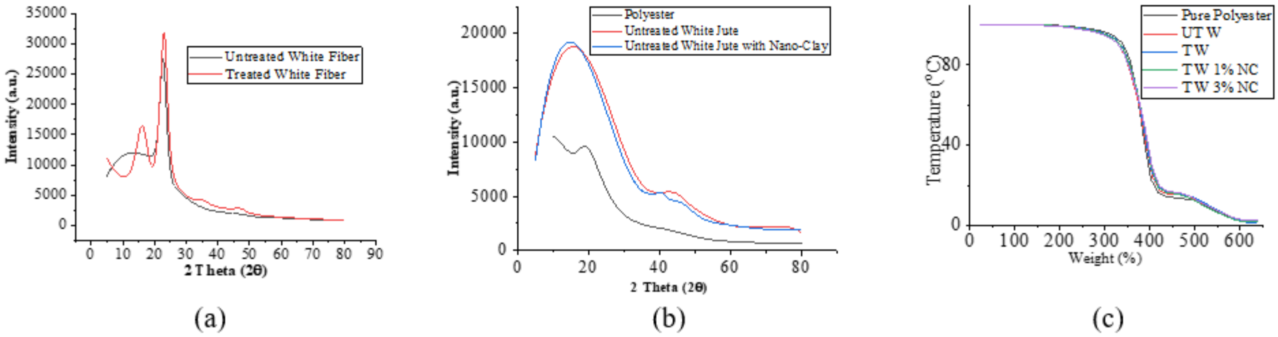

Figure 2: Structural properties of (a) Tossa and White jute fiber (untreated/treated) - (b) Polyester (modified with nano-clay %) composites (c) Thermal properties (untreated/treated white jute fiber and composite)

ACKNOWLEDGMENTS

This work was supported by Bangladesh Jute Research Institute (BJRI), Ministry of Agriculture, Dhaka-1207, Bangladesh [Innovation and Transfer of Agricultural Technology of Jute and Allied Crops] and Dhaka University of Engineering and Technology (DUET), Gazipur, Bangladesh.

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PHYSICOCHEMICAL CHARACTERIZATION OF PALM DATE TREE LEAFLET POWDERS FOR A GREEN MATERIALS MANUFACTURING

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ABSTRACT

The objective of this work is to characterize the date palm leaflets powder (DPLP) to use as reinforcement in biomaterials. The present study investigated the physical and chemical properties obtained using Fourier Transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD). Three kinds of DPLP from Deglet Noor are used named DN1, DN2 and DN3. The XRD analysis results show that the crystalline rate are respectively DN1 (42.9%), DN2 (62.12%) and DN3 (62.83%). It is noted that crystallites size results show that changing region of DPLP collected modified its size dimensions as follow; DN1 (2035.9 nm), DN2 (2026.6 nm) and DN3 (2035.9 nm), respectively. The FTIR test showed the presence of cellulose, hemicelluloses and lignin in the samples.

INTRODUCTION

The use of natural materials in industry, clothing, filters, or buildings, requires a thorough knowledge of their physical and chemical properties. The exploitation of the raw and natural materials as alternative of synthetic materials has become the popular way to overcome the environmental problem in most developing countries (Chikhi, 2020).

Natural fibers also exhibit some undesirable characteristics. High moisture absorption, low mecanical resistance and highly anisotropic properties are examples of some drawbacks associated with natural fibers (Chikhi, 2018). Knowledge of the physical and chemical properties of natural fibers is essential to understand the area in which they can be exploited and also, with which materials to get a good binder; if it is talking about composite materials. (Alhijazi, 2020) is among the recent works in this context we find this review paper was to compile and categorize research on the main types of Palm Nature Fibre Composite PNFC, while considering their physical, morphological, electrical, and thermal properties as well as FT-IR, XRD, moisture desorption.. Future studies need to focus on the acoustic properties of PNFCs, application of PNFCs as honeycomb fiber orientation, novel hybridizations and nano- fillers, experimental designs, metamodeling and RSM for the optimization of process parameters also design of experiment for variation analysis (Alhijazi, 2020).

Characterization studies of date palm tree fibers have been considerably delayed, which has prevented their exploitation in various industrial fields (Djoudi, 2019). Despite the large quantities of production whether fruit or wood compared to hemp, coir et sisal (Awad, 2020).

Among works which have aimed to investigate the physical ,chemical and thermal characterization, using the XRD analyzes, the study of (Alshabanat, 2018) who used the powder of date palm fiber (leaf) (5% by weight) from the Saudi Arabia, to prepare composites of the two types of Linear Low Density Polyethylene, LLDPE, region in order to examine the effect of these base additives and their treated on biodegradation, morphological and thermal properties of material samples under the test of burial in the ground. in contrast, (Boumediri, 2019), studied the physicochemical properties of vascular bundles and strands of fibers extracted from the spine of the date palm. The results of this XRD analysis showed that Standard Fibers have a higher crystallinity index (56.68%) compared to vascular bundles (47.82%). In addition, the crystallite size (CS) for vascular bundles and Standard Fibers was found to be 5.78nm and 5.63nm, respectively. The main groups of chemical and molecular structure were identified by FTIR analysis showing similar functional groups compared to other lignocellulosic fibers reported in the literature and EDX indicates a similar composition for the two fibers

(Ali, 2017) investigated the FTIR to characterize the date palm trees surface fibers (DPSF) as a new insulation material extracted from the date palm trees, the results obtained showed that there are strong stretch peaks at 2918.45 and 2850.6 cm-1 which may be due to the presence of an alkane functional group (C-H).

A research on the improved cellulose crystal structure of Date Palm Fruit bunch Stalk (DPFS) treated with (DPFS)- Microcrystalline Cellulose (MCC) characterized by FTIR and XRD are showed in (Alotabi, 2020). The result presented by (Beroual, 2020) noted that most of the hemicellulose and lignin were effectively removed throughout the extraction processes by FTIR XRD analy- ses showed that the prepared MCC displayed typical cellulose I, with crystallinity index ranging from 72 to 75%.

(Almotery, 2019) made a comparative study between three types of wood aimed to determine the possibility of efficiently recycling the composite. The results obtained from XRD showed two significant stretching plans in all three types of recycled Palm wood fibers, and an XRD investigation of Palm wood fibers showed the increase in tensile strength of single recycled Palm wood fibers. FTIR analysis indicates the similarity of recycled Palm wood fibers spectra with three types of Palm wood fibers, and no substantial alterations between three categories of Palm wood fibers were found.

The objective of this work is to characterize of the date palm leaflets powder. The study focuses on physical and chemical properties using a series of analyzes including FTIR and XRD applied on three kind of Deglet Noor cultivated in Biskra region of Algeria (M’khadma, Bouchagron, Lichana). this work tends to identify the cellulose content on these powders using FTIR and XRD methods.

PERPARATION OF MATERIAL

The date palm wood used in this study was obtained from the remains of the date palm, exactly the leaflets, collected in the Bsikra region of Algeria; we chose the samples of the palm variety Deglat Noor (DN) for different regions (M’khadma, Bouchagroune and Lichana).

The samples are carried out by three steps:

1 - Washed with distilled water to remove surface impurities and salt,

2 - air dried using an oven at Tp of 40°C,

3 - finally, crushed and separated into different sizes at the nanoscale using an automatic sifter.

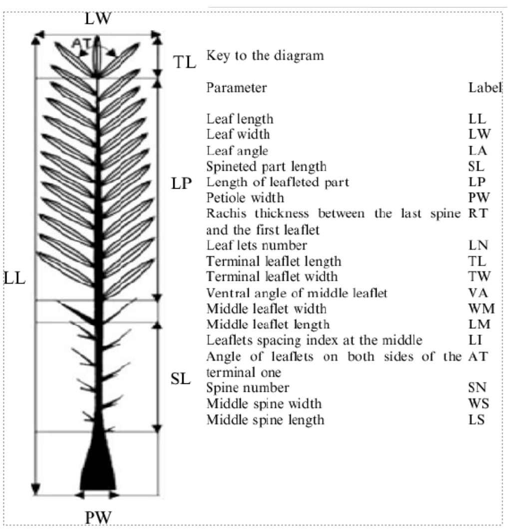

Fig.1 Date palm and different parts

Fig.2 samples studied

The phases were identified using X-ray diffraction technique (XRD, X'Pert Pro, Philips, Netherlands). The XRD analysis was operated using CuKα1 radiation tube by varying 2θ between 10 and 100°. The average crystallite size was determined by using the Scherrer equation (Eq. 1).

$$D = \frac{0.9\lambda}{\beta\cos\theta} \quad (1)$$

Where 0.9 is a dimensionless shape factor, λ the X-ray wavelength (λ_{Cu} = 0.154 nm), β (in rad) the line broadening at half the maximum intensity (full width half maximum).
Fourier transform infrared (FTIR) spectroscopy with a Bruker Senterra spectrometer was applied using exciting laser radiation wavelength of 600 nm. This identification was supported by a reference FTIR spectrum of expected phases.

RESULTS AND CONCLUSIONS

1. XRD results

Fig. 1 shows the XRD pattern of the samples of the palm variety Deglat Noor (DN) for different regions (M'khadma, Bouchagroune and Lichana) and the obtained results are summarized in Table 1.
According to Figure 1, two main and broad peaks of casi-amorphous phases were observed for all samples. In addition, the peak presented in the XRD analysis at 2θ = 21.4°, 26.58° and 26.4° corresponding to (111) and (002) Silicon Oxide - Ethylene Glycol (12/2) (JCPDS No. 98- 006-6118) that affected by the presence of a large amount of impurities existing in the biomass of the date palm (Oushabi, 2017, Alawar, 2009, Beroual, 2020).
The obtained crystallinity index (C.I.) are 48.64%, 50.78% and 46.85% for the samples of DN1, DN2 and DN3, respectively, which means that the DN2 presents a better order of cellulose crystals at the level of the axis of the fibers compared to the DN1 and DN3. Crystallinity index specifies crystalline cellulose amount in comparison to the overall amorphous material amount. This results are in line with those mentioned by (Alhijazi, 2020).
With the Scherrer equation, the crystallinity index and the crystallite size can be determined as: DN1 (42.9%, 2035.9 nm), DN2 (62.12%, 2026.6 nm) and DN3 (62.83%, 2035.9 nm), respectively, as listed in Table 1.
The results presented indicate that the crystallite size changes while changing the regions.

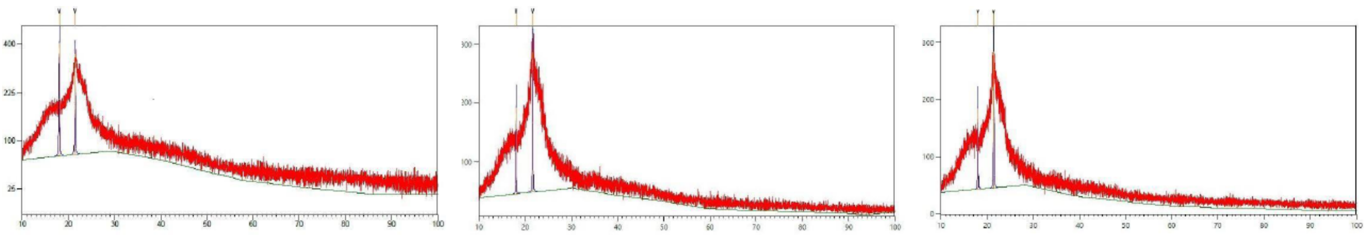

Fig.3 XRD results.

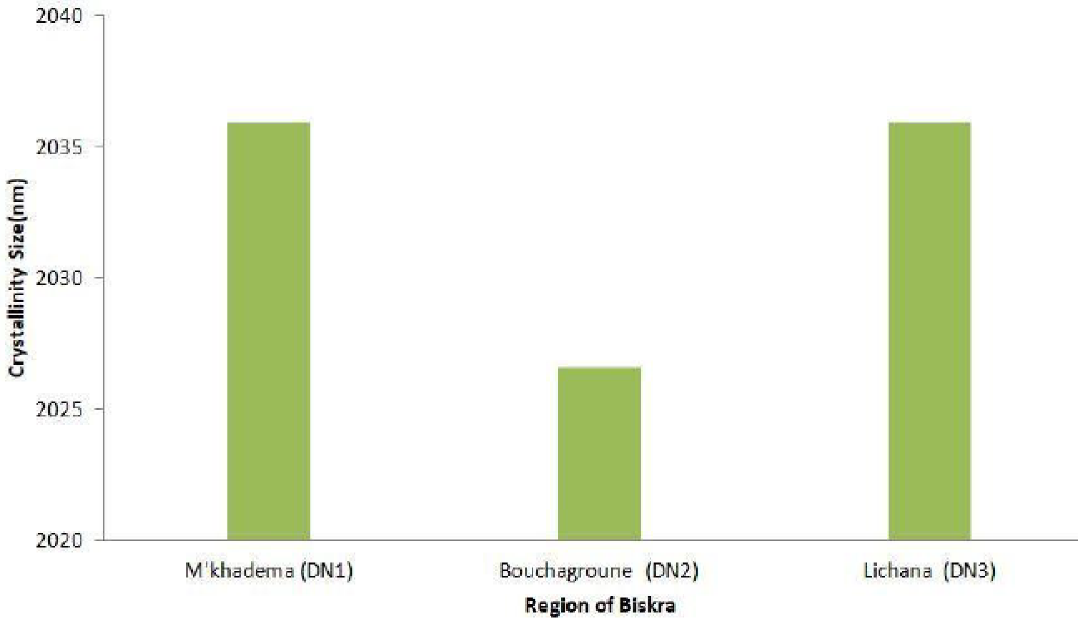

Fig. 2 Crystallinity size in different region in Biskra.

Table 1.

	Samples	Region	Peak Position (°2Theta)	Cr (%)	CI (%)	CS (nm)
01	**Deglat noor (DN1)**	M'khadema	17,99 21,4	42,9005	48,6413	42,9005
02	**Deglat noor (DN2)**	Bouchagroune	17,99 21,58	62,1252	50,7886	62,1252
03	**Deglat noor (DN3)**	Lichana	17,99 21,4	62,8314	46,85314	62,8314

*Cr: Crystallinity rate
*CI: Crystallinity Index
*CS: crystallinity Size

2. FTIR results

Fourier transform infrared (FTIR) spectroscopy is a useful tool for determining the interaction of chemicals and can give a quick and qualitative indication about the change in the chemical structure of palm wood composites. It is performed to confirm the removal of non-cellulosic materials, in addition to the identification of functional groups (Beroual, 2020)

Fourier Transformation- Infra Red (FT-IR) spectra results of samples are shown in Fig. 3. The figure indicates that there is a strong broad at 3300 cm-1 that can be identified as the characteristic features of the (FTIR) spectrum of the (-OH) stretching group on cellulose chain. Compared to the study of (Alotabi, 2020). It can be seen that, in one hand, there are medium stretching peaks at 2917 and 2849 cm-1 which might be due to the presence of Alkane (C-H) functional group (give a reference) . in Other hand, a strong broad at 1733 cm−1 can be attributed to the (C=O) group and stretching vibration of ester group in hemicellulose (Bezazi, 2014). Variable flex peak at 1609.5 cm-1 and 1321.5 cm-1 due to alkene (C = C) and alkane (-C-H) functional groups conjugated in lignin, respectively (Amroun, 2015).

A primary alcohol (C- O) functional group is obtained at 1060.7 cm-1. Similar results were obtained in the literature , which showed the presence of different stretching peaks ranged between 1700 cm-1 and 4000 cm-1 (Elseify, 2020).

This study shows that the phyico-chemical properties differ when changing the region even if a study is done on the same type of date palm.

The results of XRD analysis show that the crystalline rate are determined as follows: DN1 (42.9%), DN2

(62.12%) and DN3 (62.83%), respectively. The size of the crystallites obtained are variable with the samples collected region inducing dimensions change; DN1 (2035.9 nm), DN2 (2026.6 nm) and DN3 (2035.9 nm), respectively. FTIR showed the existence of cellulose, hemicelluloses and lignin in the samples with different rates.

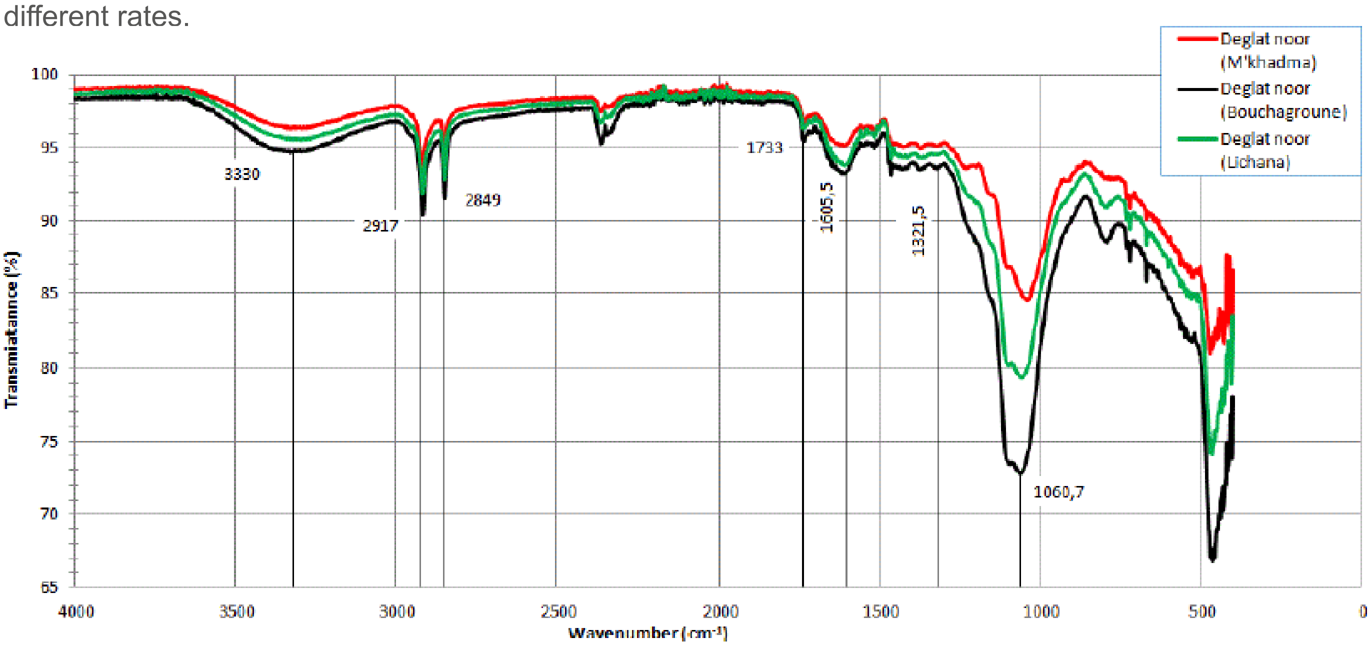

Fig.3. FTIR results

ACKNOWLEDGMENTS

Authors wish to thank the Directorate General for Scientific Research and Technological Development-DGRSDT, Algeria, for financial support.

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CHARACTERIZATION OF ACACIA CAESIA BARK FIBRES

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ABSTRACT

The stem bark of *Acacia caesia*, or *Senegalia Caesia*, richly available in the Western Ghats of Tamilnadu and Kerala, India, offers a natural fibre, which was characterized in this work, studying its chemical composition, morphology, and thermal degradation.

INTRODUCTION

Acacia caesia (AC) bark fibre (soap bark), referred to as Kari (Indu), Indumul Kodi (Tamil), Incha, Palinja (Malayalam), is a rich natural resource, highly exploited because of the presence into it of different chemicals e.g., steroids, anthraquinone, cardiac glycosides and flavonoids, of interest in Ayurveda, Siddha and other medicinal products. Some attempts to use waste by-products from AC have recently started for example to obtain cellulose nanowhiskers (Thomas et al., 2020), while the use of AC fibres remains largely unexplored.

RESULTS AND CONCLUSIONS

The fibres show much higher content in cellulose than in hemicellulose and lignin, while the density is lower than the one reported for prevalently cellulosic fibres, such as hemp or flax (Pil et al., 2016) (Table 1). The difficulties in extracting fibres by stripping oblige to consider for use fibre bundles of variable diameter, as reported in Fig. 1. Microscopic study of the fibres allows observing the bundles in the way to discern the quasi-aligned fibrils (Fig. 2a) and the internal layering of the bundle (Fig. 2b). Thermogravimetric analysis (TGA) (Fig. 3) suggests, as from the method reported by Liu et al., 2001, a degradation onset of the fibres at 308°C. These indications are obtained in view of a possible use of AC fibres in polymer composites.

Table 1. Approximate compositional properties and density

Cellulose (wt.%)	Hemicellulose (wt.%)	Lignin (wt.%)	Moisture (%)	Ash (%)	Dry density (g/cm^3)
40	23	20	12	5	1.20

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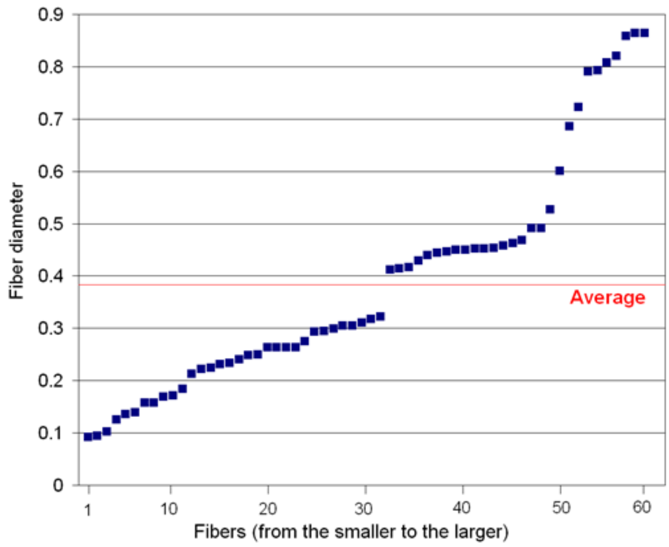

Fig.1 Mean diameter of the fibres along their length (60 fibres were measured)

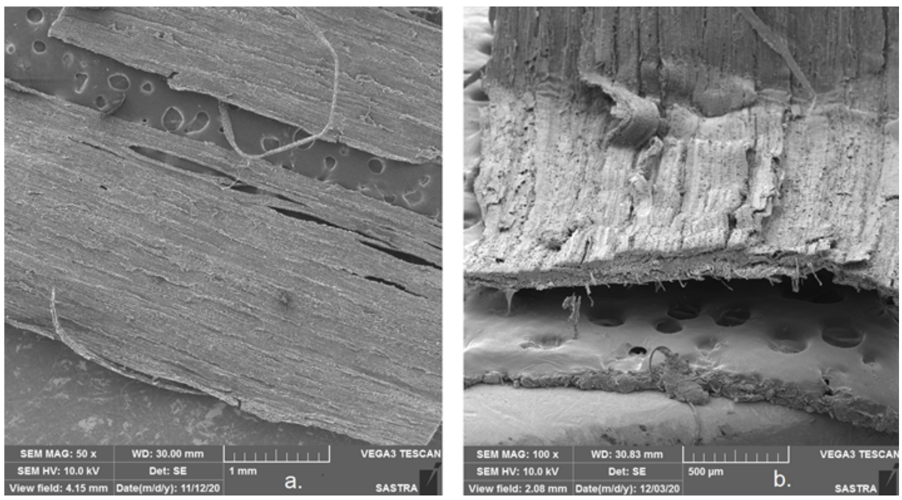

Fig. 2 SEM micrographs of: (a) Fibre surface; (b) Cross-section

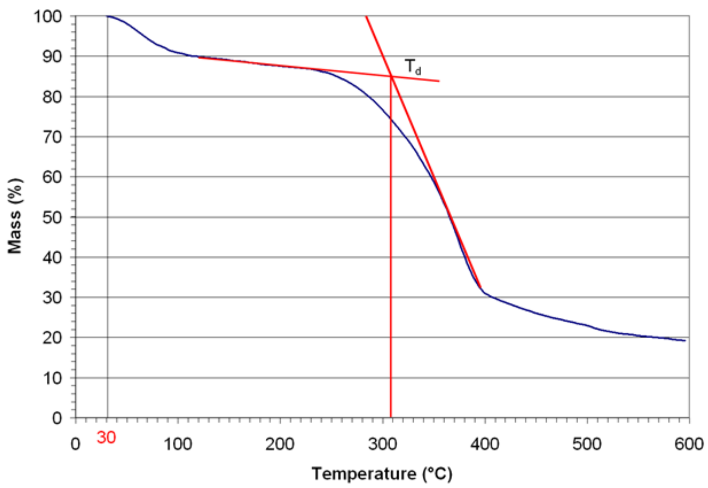

Fig.3 Typical thermogravimetric (TGA) curve in nitrogen (Td =degradation onset)

HEATED COMPRESSION MOULDING OF THERMOPLASTIC COMPOSITES REINFORCED WITH NATURAL JUTE FIBERS

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ABSTRACT
The aim of this work is to assess the possibility and viability of manufacturing thermoplastic matrix composites reinforced with jute fibres by compression moulding. The increase use of thermoplastics in composites has been a topic of interest due to the mechanical properties that thermoplastics present, as well as the possibility of recycling composites with this kind of matrixes. These targets take a step further in sustainability issues by using natural fibres to reinforce thermoplastic composites. The thermoplastic composites were produced by heated compression moulding and properties were compared with thermosetting ones from a previous work. The composites obtained were evaluated namely by tensile and flexural testing, to compare properties of the two kinds of composites studied.

INTRODUCTION
The interest of incorporating thermoplastics in fiber reinforced composites has been increasing due to improved toughness, damage tolerance and ecological properties composites with these matrixes present. Although processing thermoplastic composites has been very challenging, the shorter processing cycle times and cleaner working environments are benefits that the industry crave for [1]–[4].
The possibility of having the polymer at low viscosity before polymerization at room temperature has always been the advantage of thermosetting polymers and has always made these polymers the obvious choice for polymeric composites. In the case of thermoplastics processing, in general, is not possible at room temperature due to their high viscosity at room temperature [5]–[7].
Thermoplastic processing involves the melting of the polymer, which requires a good knowledge of thermal characteristics of the polymer. Even though the polymer is in a melted state, the high viscosity during processing may hinder a successful impregnation, leading, possibly, to a poor consolidated composite with weak mechanical properties.
Natural fibers are obviously an interesting option for composite reinforcement due to their relatively low cost when compared to synthetic ones, such as carbon or glass. The combination of these fibers with a thermoplastic matrix results in a completely sustainable material [8]–[10].
One major inconvenience of natural fibers is obviously their hydrophilic nature, which causes some difficulties in the adhesion process between fibers and matrix. Another inconvenience is the variety of fiber structure of natural fibers, which is more extent than of those seen in synthetic fibers. There are numerous combination of physical properties that have to be adjusted in order to obtain the highest potential of final composite [11]–[13].
For all the characteristics described, the incorporation of natural fibers, such as jute, is being extensively studied for large scale applications like the automotive industry. This is justified not only by the lesser cost

that natural fibers present, but also due to legislation that obliges the automotive industry to use sustainable materials [14]–[16].

RESULTS AND CONCLUSIONS

Processing parameters of the composites were tuned according to thermal properties of the thermoplastic

Table 1 – Fiber volumen fraction of composites

Matrix		Fiber volume fraction (%)
PE	Thermoplastic	40.4
PP	Thermoplastic	54.0
PVC	Thermoplastic	41.7
PMMA	Thermoplastic	46.8
Polyester [10]	Thermosetting	30.0
Epoxy [10]	Thermosetting	30.0

Table 2 – Tensile Properties of Jute reinforced composites

Matrix		Tensile Modulus (GPa)	Tensile Strength (MPa)	Specific Modulus (GPa/vf)	Specific Strength (MPa/vf)
PE	Thermoplastic	3.4 ± 0.2	62.6 ± 1.3	8.4 ± 0.5	155.0 ± 3.2
PP	Thermoplastic	3.8 ± 0.2	50.8 ± 2.2	7.0 ± 0.4	94.1 ± 4.1
PVC	Thermoplastic	3.0 ± 0.2	35.4 ± 2.4	7.2 ± 0.5	84.9 ± 5.8
PMMA	Thermoplastic	3.7 ± 0.1	56.7 ± 2.1	7.9 ± 0.2	121.2 ± 4.5
Polyester [10]	Thermosetting	7.0 ± 0.5	57.0 ± 7.2	23.3 ± 1.7	190.0 ± 24.0
Epoxy [10]	Thermosetting	6.0 ± 0.3	58.8 ± 4.8	20.0 ± 1.0	196.0 ± 16.0

Table 3 – Flexural Properties of Jute reinforced composites

Matrix		Flexural Modulus (GPa)	Flexural Strength (MPa)	Specific Flexural Modulus (GPa/vf)	Specific Flexural Strength (MPa/vf)
PE	Thermoplastic	1.8 ± 0.3	57.9 ± 7.1	4.5 ± 0.7	143.7 ± 17.6
PP	Thermoplastic	3.6 ± 0.5	55.0 ± 1.3	6.6 ± 0.9	101.9 ± 2.5
PVC	Thermoplastic	2.8 ± 0.5	48.4 ± 1.1	6.8 ± 1.2	118.0 ± 2.7
PMMA	Thermoplastic	3.9 ± 0.5	62.6 ± 5.9	8.4 ± 1.1	134.4 ± 12.6
Polyester [10]	Thermosetting	5.9 ± 0.2	91.5 ± 3.8	19.7 ± 0.7	305.0 ± 12.7
Epoxy [10]	Thermosetting	5.1 ± 0.8	86.5 ± 7.2	17.0 ± 2.7	288.3 ± 24.0

These results allow us to conclude that mechanical properties of composites with thermoplastic matrixes are compatible with engineering applications.

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INDIVIDUALIZATION OF FLAX TOWS PROMOTED BY PHYSICAL TREATMENTS: IMPACT ON MECHANICAL PROPERTIES OF A FLAX/ PLA NON-WOVEN COMPOSITE

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ABSTRACT
Physical treatments (ultrasound, microwaves and gamma irradiation) are applied to flax tows, products used in the composition of non-woven composite Flax-PLA, with the aim of increasing the specific surface area of the flax elements. The effectiveness of the treatments is evaluated by monitoring the individualization of the elementary fibers and the reduction in the size of the bundles by means of a dynamic morphological analysis.

INTRODUCTION
Technical fibers are bundles made up of elementary fibers whose cohesion is ensured by the middle lamella. In natural fiber reinforced composites, individualization is one of the important parameters to obtain good mechanical properties. It has been shown that the middle lamella is an area of weakness in composites due to lower mechanical properties of this interfacial region (Melelli, 2020). In addition, an aspect ratio (Length/Diameter) greater than 10 is considered as the minimum value for good transmission of strength during mechanical stress loading (Bourmaud, 2013). Positive impact of individualization has been observed on the mechanical properties of UD composites (Coroller, 2013).
To induce this individualization of the fiber bundles, several types of pre-treatments exist. There are chemical pre-treatments such as chelation allowing the removal of calcium ions from the pectin of the middle lamella (Li, 2009). Physical pre-treatments are also used to increase the individualization of the fibers bundles. For example, the steam explosion partially degrades the primary wall of the fibers involving a separation of the fiber bundles (Keller, 2003).
The aim of this work is to apply pre-treatments not using chemicals to preserve the ecological side of flax fibers. Then, various physical pre-treatments were applied to flax tows, a co-product of the flax processing line that would seek to be more valued.

RESULTS AND CONCLUSIONS
The pre-treatments applied are gamma irradiation at a dose of 5-7 kGy and ultrasound with an energy of 50 W/L during 30 minutes. Here, the individualization of the fibers is quantified by evaluating morphological parameters using a dynamic particle morphological analyser. Figure 1 shows the impact of ultrasound and gamma irradiation pre-treatments on the diameter of flax fibre elements.
Two populations of flax tow are clearly identified here; they can be attributed to elementary fibers around 20 µm and bundles between 40 and 150 µm. For bundles, a decrease in the density was observed for each treatment. Moreover, at the same time, the density of elementary fibers is increasing for the three pre-treatments compared to native tows.

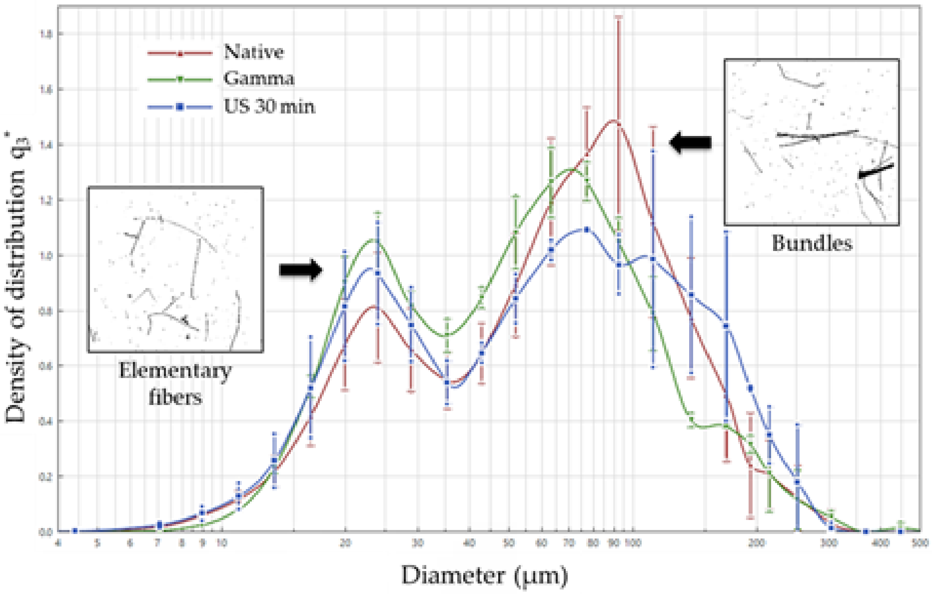

Fig.1 Evolution of density of diameter between native tows and treated tows

This study shows that the different physical treatments permit a greater individualization of tow bundles: +20% of elementary fibers with gamma irradiation compared to native tows. The gamma irradiation treatment shows the best efficiency followed by the ultrasound treatment for 30 minutes and 1 hour respectively. Mechanical properties of non-woven associated composites were assessed (24 layers, hot compression at 190°C). Moderate differences between the composites was demonstrated; but for ultrasound pre-treatment, a significant increase of the stress at break was observed.

ACKNOWLEDGMENTS

The authors would like to thank Interreg V.A CrossChannel Programme for funding this work through the FLOWER project (Grant number 23).

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CHARACTERIZATION OF RICE HUSKS AS POTENTIAL REINFORCEMENT FOR POLYLACTIC ACID COMPOSITES

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ABSTRACT

Plastic consumption has continued to grow over the years. Meanwhile, conventional petroleum-based plastics are associated with challenges like environmental unsustainability. As a result, bio-based polymers like Polylactic acid (PLA) have received much attention in past decades. PLA, being a biopolymer, can easily be reinforced with agricultural fibers to counter its expensive nature but also improve its mechanical and thermal properties. The aim of this study was to investigate the effect of Magnesium hydroxide modification on the properties of K85 and K98 rice husk varieties in Uganda for their use as reinforcement in PLA. Raw rice husks underwent pre-treatment in 4 % $Mg(OH)_2$ concentration for 1 hour at room temperature. Water absorption, Thermogravimetric analysis (TGA), Energetic density (ED) and Fuel Value Index (FVI) of rice husks were investigated. Raw rice husks exhibited higher water absorption capabilities (9.1-11.2 %) than modified rice husks (5.6-5.89 %). TGA confirmed that alkali modification of rice husks provides a higher resistance to thermal degradation than raw rice husks. Mean reactivity to char residues ratio reduced from 4.3×10^{-4} °C/min to 3×10^{-4} °C/min upon modification of K85 rice husks while modification of K98 rice husks led to increasing mean reactivity to char residues ratio by 11.4 %. Energetic density sharply reduced upon alkali modification of both K85 and K98 rice husks. The Fuel Value index of rice husks greatly depended on the amount of ash in the rice husks. As such, K85 rice husks had higher FVI compared to K98 rice husks as the former had lower ash compositions (21.2 %). The results suggest that alkali modified rice husks can be successfully used as reinforcement in PLA composites.

INTRODUCTION

Biocomposites are being used to replace conventional composites due to their superior properties (Yiga et al., 2021). Agricultural fiber reinforced plastics are composites with an agricultural fiber phase embedded in polymer matrix. Agricultural fibers act as main load bearing elements while polymer matrix acts as the load transfer medium by holding fibers together in the required orientation (Zangenberg & Brøndsted, 2015). Agricultural fiber reinforced composites find several applications in the automotive, aerospace, packaging, structural, electronics, owing to their lightweight and specific strengths which are comparable to fossil-based composites (Yiga et al., 2021). The need for materials having specific characteristics for specific purposes, while at the same time being nontoxic and environmentally friendly, is increasing, due to increasing environmental pollution (Satyanarayana et al., 2009). In order to produce fully renewable and biodegradable composites, both polymeric matrix and reinforcement must be derived from renewable resources (Narayan, 2006). As such, biopolymers like polylactic acid (PLA) are increasingly being used as matrix for biocomposites. The expensive nature of PLA can be counteracted using agricultural fibers as reinforcement (Huerta-Cardoso, et al., 2020). Moreover, their incorporation in PLA composites is sustainable and produces lightweight, non-hazardous and non-abrasive biocomposites (Chougan et al., 2020; Hegyesi et al., 2019).

Rice husks account for over 20% of paddy rice (Giddel and Jivan, 2007). Research incoporating rice husks in PLA is slowly gaining momentum because of accruing advantages such as less environmental impact and enhanced mechanical properties (Anggono et al., 2020; Běhálek et al., 2020). However, rice husks usage in PLA accounts for a small percentage of the total production of composites from PLA matrix. This research therefore aims at investigating the effect of $Mg(OH)_2$ pre-treatment on TGA properties of rice husks as reinforcement in PLA composites.

RESULTS AND CONCLUSIONS

Mean reactivity versus char residues plots for rice husks are shown in Fig. 1. Mean reactivity versus char residues plots gives an understanding of the time at which the peak temperature is reached during combustion of the fiber-reinforced plastics (Yiga et al., 2020a). For K85 rice husks, pre-treatment led to a decrease in the ratio from 4.3×10^{-4} °C/min to 3.0×10^{-4} °C/min (see Fig. 1a). This reflects that lower temperatures are required to reach peak decompositions of pre-treated K85 rice husks and therefore fiber-reinforced PLA composites developed with such pre-treated rice husks will be easier to combust than raw husks (Yiga et al., 2020b). Moreover, a lower ratio signifies low mechanical properties of developed fiber-reinforced PLA composites (Ferreira et al., 2017).

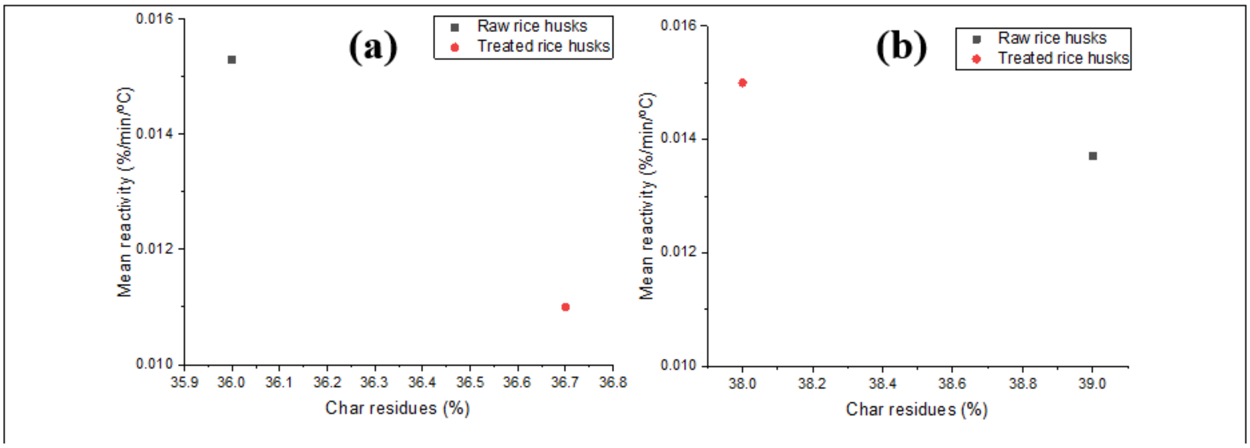

Fig. 1 Mean reactivity vs Char residues ratio for (a) K85 (b) K98 rice husks

Pre-treatment of K98 rice husks leads to an increase in Mean reactivity to char residues ratio from 3.5×10^{-4} °C/min (raw K98 rice husks) to 3.9×10^{-4} °C/min (see Fig. 1b). A higher ratio translates to higher activation energy and therefore low reaction index with oxygen/air (Farrokh et al., 2019). This is so because in conditions where the reaction with oxygen/air is low, the peak temperature reached during combustion of fiber-reinforced plastics is always at maximum. Inclusion of pre-treated K98 rice husks in PLA matrix would therefore lead to an increasing ratio and therefore higher activation energy would be required to onset degradation of such fiber-reinforced PLA composites. As such, PLA composites developed with such pre-treated rice husks would enhance their flame retardancy.

ACKNOWLEDGMENTS

The authors gratefully acknowledge funding by the Volkswagen Foundation (Grant no. 96655 entitled "Enhanced flame retardancy of bio-composite plastics developed with rice husks and clay fillers").

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ENVIRONMENTAL AND MECHANICAL PERFORMANCE ANALYSES OF 3D PRINTED BIOCOMPOSITES

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ABSTRACT

This work compares mechanical properties and environmental impacts of two 3D printable composites: carbon fiber reinforced polyamide (Carbon PA) and bio-based hemp fiber reinforced polylactide (Hemp PLA). Mechanical tests show that synthetic composite allows maximizing strength and stiffness with respect to bio-based composite. However, from the environmental point of view, hemp fiber reinforced PLA results in noticeably lower impacts. The aim of this research is to demonstrate that sustainability must be considered of equal importance to mechanical properties if more eco-friendlier products have to be produced.

INTRODUCTION

In recent years, three-dimensional (3D) printing technology is gaining rapid development in many industrial fields since it allows to (i) manufacture strong and lightweight structures; (ii) perform a tool-free process; (iii) make more flexible production planning; (iv) achieve significant cost and time-to-market reductions; (v) reduce production waste and (vi) build complex geometries. Although it was firstly developed as a method to rapidly realize prototypes, nowadays, 3D printing is a consolidated method exploited to manufacture complex and performant end-use products. Different materials can be used in 3D printing. Among others, composites, also called advanced materials, are well known for their extraordinary specific resistance and stiffness properties. One of the most performant 3D printable material is carbon fiber reinforced polyamide [1]. It presents very interesting mechanical properties, but different studies demonstrate its high environmental impacts. More in detail, carbon fibers are associated to high environmental load, mainly owing to the use of fossil resources and energy-intensive production processes [2]. A valid alternative can be natural fibers and bio-based resins, even if they typically result in lower mechanical characteristics [3]. Switching from carbon to natural fiber composites could represent a turning point for sustainability of manufacturing industry [4]. A method to compare the environmental loads of carbon and bio-based composite is Life Cycle Assessment. In this work, a comparative analysis between two different 3D printed composites, carbon fiber reinforced polyamide (Carbon PA) and bio-based hemp fiber reinforced polylactide (Hemp PLA), has been conducted in order to define which one represents the best compromise between environmental sustainability and mechanical performances.

RESULTS AND CONCLUSIONS

Tensile tests were performed according with the ASTM D3039M on at least three tensile specimens per 3D printed material (Carbon PA and Hemp PLA), in order to compare stress vs. strain curves shown in Figure 1.

(a)  (b)

Fig.1 Example of Carbon PA (a) and Hemp PLA (b) tensile specimens

Figure 2 shows the tensile behaviour of both reinforces 3D printed polymeric materials.

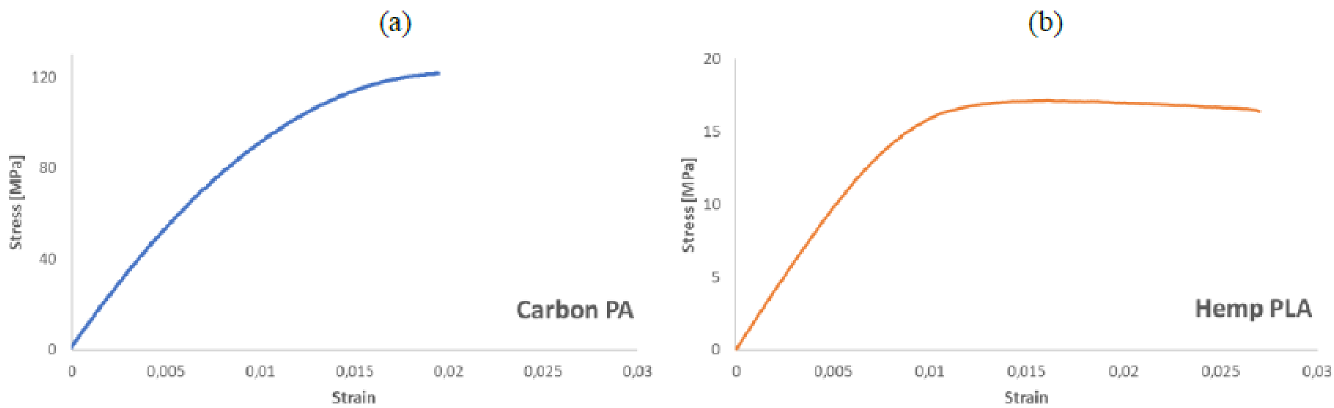

Fig.2 Tensile test results for Carbon PA (a) and Hemp PLA (b)

Table 1 summarizes main mechanical properties of the two tested materials.

Table 1 Uniaxial tension test results

	σ_{max} [MPa]	$\varepsilon_{\sigma max}$ [%]	E [GPa]
Carbon PA	126,3	2,0	13,5
Hemp PLA	17,2	1,6	2,04

This study shows that the mechanical properties of Carbon PA are considerably greater than those of Hemp PLA, but according to what emerged from the environmental impact analysis, the situation is the opposite as Hemp PLA is considerably more environmentally sustainable.
The Life Cycle Assessment (LCA) has been used to compare the impacts of the two materials. Analyses have been conducted by following the ISO 14040 – 14044 standards. Simapro software and Ecoinvent 3.1 database have been exploited to quantify environmental loads of 3D printed Carbon PA and Hemp PLA. Both raw materials production and 3D printing processes have been considered in this analysis while use phase and disposal were treated out of the system boundaries. Results demonstrate that the manufacturing of carbon fibers is significantly less sustainable than hemp fibers. In addition, owing to the lower extrusion temperature, 3D printing of PLA is less impacting than PA.

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PROPERTY CHANGES IN PLANT FIBRES DURING THE PROCESSING OF BIOBASED COMPOSITES

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ABSTRACT

Over the past decades, the use of plant fibre reinforced composites has increased significantly due to their many attractive attributes such as high specific strength and modulus, wide availability, low cost and high environmental credibility compared to their synthetic counterparts. In bio-based composites, the fibre is the key component of the composite to obtain performing properties. This is due to the sensitivity of the constituent plant fibres to mechanical stress (pressure), temperature, water and other parameters. Here, a synthesis of literature on the impact of composites processing steps on plant fibre cell wall structure and properties is addressed. Mechanical, morphological and hygroscopic properties of plant fibres are considered in conjunction with process times, temperature and shear rate.

INTRODUCTION

To produce bio-based composites, the plant fibres are processed with thermoplastic or thermoset matrices by extrusion, injection, compression moulding, and also by the emerging process of fused deposition moulding (3D printing), amongst various other techniques. During these material transformation processes, the plant fibres are subject to thermomechanical stresses that are not benign to the integrity of plant fibre cell walls (Bourmaud et al., 2018). Their very specific architecture and structure can be significantly altered by the mechanical stresses involved in conventional composites tools. These structural modifications have a significant impact on the dimensions of the fibres, and therefore on their aspect ratio (length/diameter) which strongly conditions their reinforcement ability. Similarly, lengths of synthetic fibres are drastically affected by shear rate and process parameters (Bourmaud et al., 2018). In addition, structural modifications of the constituent polymers, induced by thermomechanical stresses, will have an impact on their architecture, degree of crystallinity, chain length, but also on inter-polymer bonds and on the overall parietal structure of plant fibres (Placet, 2009). These different impacts, whether morphological or structural, will modify the mechanical behaviour of the reinforcing fibres (Gourier et al., 2014). They can also have a major influence on the water absorption capacity of the principally hydrophilic non-cellulosic cell wall polymers, which will have consequences on the quality of multi-scale interfaces (polymer-fibre, fibre-fibre or between layers of a fibre) and therefore on the performance and durability of the resulting composites (Hill et al., 2009).

RESULTS AND CONCLUSIONS

Given the thermal sensitivity of plant fibres, the choice of matrix is essential. The thermoplastic family offers a wide range of materials with shaping temperatures suitable for plant fibres, whether or not the polymers are compostable. Process time is also a major factor; from a morphological or mechanical point of view, it plays a key role in the evolution of fibre properties. A temperature indication is only useful if the exposure time is specified. There are processes by induction, fibre placement or electric field that can significantly reduce the thermal exposure times of the fibres (Fig.1).

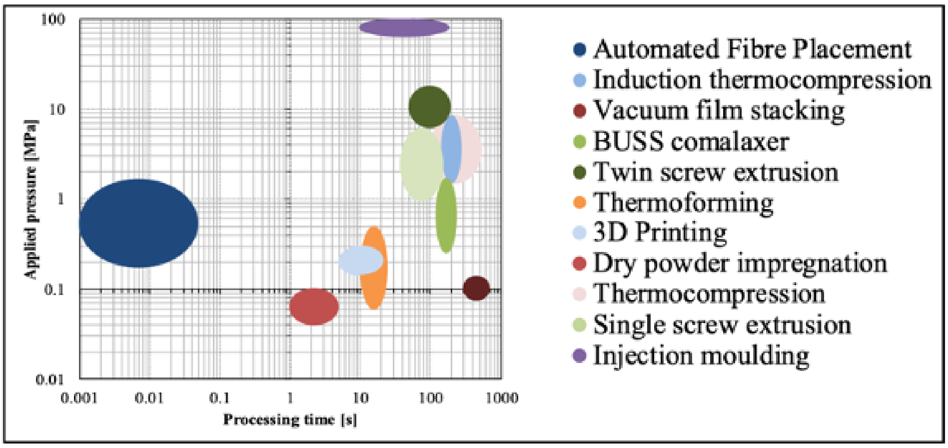

Figure 1: Results of specific air permeability, tensile and tear strength test.

The nature of parietal constituents differs and so does their behaviour on thermal exposure. Local hardness or stiffness tests generally show an increase in mechanical performances for lignified walls while mechanical performance decreases with thermal exposure for gelatinous fibres. This is explained in the literature by a cross-linking of the xylane and lignin compounds with a heating stage. It is therefore possible, depending on the temperatures considered, to select fibres that will have a more stable mechanical behaviour.

From a morphological point of view, plant fibres evolve considerably in length and diameter, especially when high shear injection or extrusion processes are used. The decrease in length can quickly reach 90% for fibrous elements a few mm long but given their assembly in bundles in the plant, their diameter also decreases which allows their shape factor (L/D) to evolve.

ACKNOWLEDGMENTS

The authors would like to thank Interreg V.A CrossChannel Programme for funding this work through the FLOWER project (Grant number 23).

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EVALUATING LONG-TERM DURABILITY OF COMPRESSION MOULDED FLAX/PLA POP BIOCOMPOSITE PLATES: MOVING TOWARDS CIRCULARITY

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ABSTRACT

In this study, the fatigue life of a newly patented sandwich biocomposite material developed with flax fibre reinforced poly-(lactic) (PLA) face sheets and soft cork as core material has been investigated. This work compares the fatigue strength of two different types of sandwich laminates with different layups: **Sample A** [40% flax and 60% PLA with areal density of 400g/m2 on both surface without any paper and cork] and **Sample C** [Film PLA/Non-woven flax PLA/paper/ Non-woven flax PLA/cork]s. It is observed from the experimental results that the presence of cork in the core has considerable effect on the fatigue behaviour of the sandwich panels. The fatigue tests performed, allowed to identify significant differences on the fatigue strength of the flax fibre based biocomposites which can be useful for many lightweight applications.

Keywords: Biocomposites, mechanical properties, long-term durability, sustainability

IN-DEPTH ANALYSIS OF THE FLAX FIBRE INTRICATE MICROSTRUCTURE IN RELATIONSHIP WITH ITS MECHANICAL BEHAVIOUR

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ABSTRACT

This work investigates the relationships between the complex flax fibre microstructure and its mechanical behaviour under tensile testing. X-ray microtomography swept across the submicronic scales broadly defined the intricate shape of the flax fibre and its main internal porosity, the lumen. Defects are quantified using polarized light microscopy. The tensile test results reveal a complex mechanical behaviour that is further implemented and investigated through a finite element model.

INTRODUCTION

Strongly linked to industrial development in the biocomposite field, plant fibres, and especially flax when advanced composites are targeted, require a deep understanding of the relationships between their submicronic structure and mechanical properties. Flax individual fibres are organized in bundles that are extracted from the stems by a mechanical process, and those fibre elements can be used for composite reinforcement (Bourmaud, Beaugrand et al. 2018). They exhibit an intricate and hierarchical structure leading to a complex mechanical response to external stresses, up to failure (Beaugrand, Guessasma et al. 2017). In this study, the relationships between the flax fibre structure and tensile performance is investigated. Some of the key links that are revealed in this work are the sub-micronic porosity, the main internal porosity being the central lumen (Charlet, Jernot et al. 2010), and process-induced defects of the fibre microstructure. These are correlated to the tensile response of flax fibre using an original approach that combines experimental and numerical work conducted at the sub-micronic scale. In particular, a mechanical model is developed based on the finite element approach where the geometry of the fibre is embedded in the model using X-ray micro-tomography data at a voxel size as small as 150 nm. The model takes into account the experimentally determined structure and tensile behaviour of a high quality fibre batch.

The flax fibres defects are quantified by polarized light microscopy (Figure 1.a). Moreover, X-ray microtomography at the fibre scale reveals the central lumen intricate shape (Figure 1.b). Tensile testing experiments are carried out up to the fracture point using a 2N load cell. Finally, a finite element model endorsing this experimental work and based on tomographic images is presented, using the Comsol software.

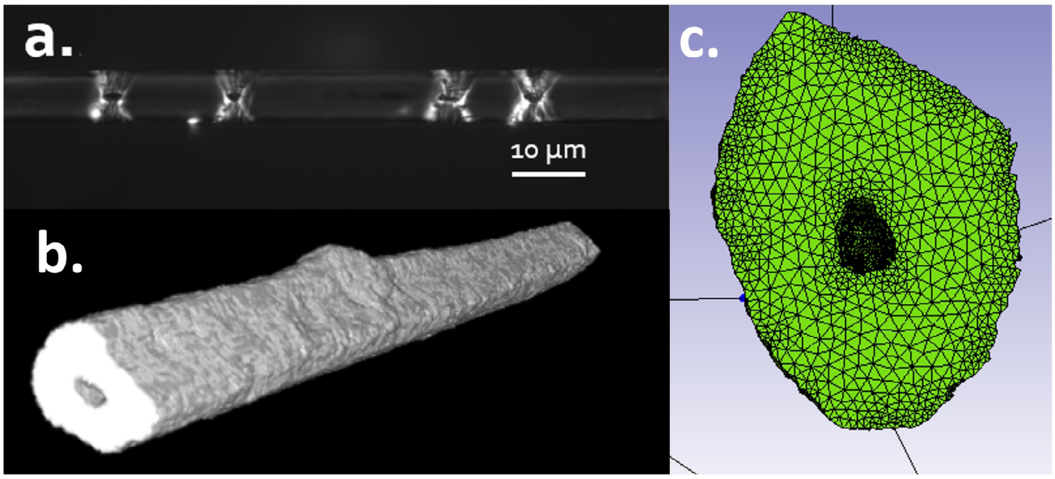

Figure 1 Polarized light revealing the local cellulose structural misalignment (a), 3D reconstruction of a unitary flax fibre from x-ray microtomography data (b) and meshing of a fibre for finite element analysis (c)

RESULTS AND CONCLUSIONS

The microstructural characterisation highlights the intricate shape of the flax fibre lumen. Indeed, X-ray tomography captures central cavities of different sizes and shapes depending of the fibre, with mean porosity content varying from 0.4 to 7.2%, in agreement with literature data (Charlet, Jernot et al. 2010, Aslan, Chinga-Carrasco et al. 2011). Variations of lumen size, fibre cross-sectional areas and aspect ratio were reported along the fibres. Numerous defects were quantified along the flax fibres and influence the tensile behaviour in a complex way that is further explored by utilising the finite element analysis (FEA) method. The finite element model spots a large spectrum of deformation modes inherent to the rich sub-micronic organisation of the fibre. The role of the defects and lumen is predicted to be central in guiding the tensile performance of flax fibre. In particular, differences in tensile response obtained experimentally are examined through differences between mechanical parameters associated to the constitutive laws at the elasticity stage. This work concludes on a better understanding of the tensile behaviour of unitary fibres if the submicronic structure of the fibre is fully considered. It opens the way to a more thriving investigation of the mechanical behaviour of flax at the bundle scale.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by the INTERREG VA FCE Program, FLOWER project, Grant Number 23

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DURABILITY OF BIODEGRADABLE NON-WOVEN COMPOSITES REINFORCED WITH FLAX FIBRES: A STUDY OF MECHANICAL PROPERTIES AND HARSH AGEING

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ABSTRACT

Here, the evolution of mechanical properties of a range of biobased composites is addressed during a garden compost stage. Composite materials are made with 30% -vol of flax non-woven and four different thermoplastic matrices: i. poly-(lactid) (PLA), ii. poly-(butylene-succinate) (PBS), iii. poly-(hydroxyalkanoate) (PHA) and iv. poly-(propylene) (PP). SEM observations, weight monitoring and tomography analysis are then conducted to understand the degradation mechanisms as well as their impact in structural and mechanical properties. Finally, atomic force microscopy is used to confirm some hypotheses on fibres degradation.

INTRODUCTION

Thanks to their good environmental analysis, plant fibres progressively appears as reinforcement in the composite area, especially in the transport sector [1]. Among them, flax fibres are commonly used due to their high specific mechanical properties [2]. In the automotive industry, they are mainly used as reinforcement in non-woven poly-(propylene) (PP)/flax composites. Using thermoplastic matrices expands end-of-life options, especially allowing recycling. Substituting polyolefin thermoplastic by biodegradable polymers should open up more end-of-life scenario as well as reducing the environmental impact of the composite [3]. However, the question of the mechanical properties of such a biodegradable composite and its durability should be tackled.

The degradation behavior of polymers is complex but well studied. Two main mechanisms are competing, which are surface erosion and bulk degradation [4]. PLA undergoes mainly a bulk erosion where PHA is subjected to surface erosion. Flax fibres can impact this degradation behavior depends on many factors including the fiber volume fraction [5], the preform architecture[5], the composite and interface quality, as well as the compost environment.

RESULTS AND CONCLUSIONS

The results from the tensile tests are shown in Tab. 1. Higher stiffness is observed for PLA/flax and PHA/flax composite, mainly due to the high stiffness of these matrices which are 3.79 ± 0.14 GPa and 4.39 ± 0.34 Gpa, respectively.

Tab. 1 Tensile mechanical properties of non-woven composites reinforced by 30% of flax fibres.

Materials	Tangent module [GPa]	Strength [MPa]	Strain at maximum stress [%]
PLA/Flax	13.16 ± 1.32	90.4 ± 7.8	1.0 ± 0.1
PHA/Flax	10.27 ± 1.52	82.4 ± 4.1	1.5 ± 0.2
PBS/Flax	7.271 ± 1.230	67.5 ± 5.3	1.4 ± 0.3
PP/Flax	8.22 ± 0.67	58.4 ± 2.1	1.2 ± 0.1

Regarding the ageing response, a loss weight of the composite is observed, whatever the matrix considered; among pure matrices, only virgin PHA exhibits a mass evolution. Thus, fibres appear to highly contribute to polymer erosion. Looking at the porosity level, obtained through tomography, all formulations present a debonding inside the composite between flax and matrix, except for PBS/Flax. This phenomenon induces an important drop in strength at an early stage, especially for PLA/flax composite (Fig.1). A smooth decrease of strength is also noted, probably due to the structural and mechanical deterioration of flax fibres during the ageing.
This hypothesis is confirmed by mechanically testing degraded flax fibres (125 days) at the microscale, using AFM investigations in Peakforce mode. It was observed that mechanical properties of flax are reduced during the first step of ageing, followed by a structural evolution leading to a progressive erosion of flax cell walls from the lumen. This can explain, at composite scale, the progressive loss of mechanical properties, as observed for PBS/Flax (Fig.1).

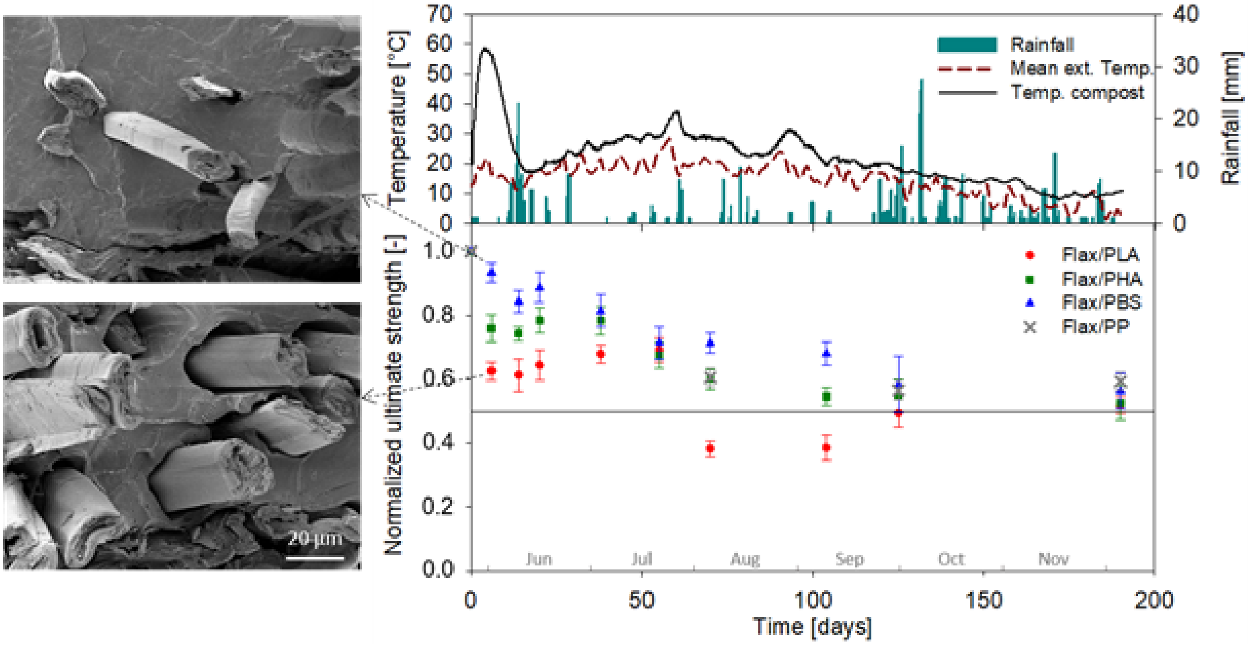

Fig. 1 Relative evolution of strength for different non-woven composites reinforced by 30% in volume of flax fibres, during harsh ageing in garden compost. Its temperature evolution is represented above. SEM pictures highlight the presence or not of debonding between fibres and PBS (up left)/PLA (down left).

During a garden compost ageing, a degradation of the fibre-matrix interface and also of the flax cell walls is observed. This phenomenon impacts the composite mechanical properties; however, the level of degradation due to the compost ageing are comparable between biodegradable polymer and PP. This demonstrates that biodegradable polymers can be considered as potential contenders to substitute commonly used polyolefin polymer.

ACKNOWLEDGMENTS

Authors thank Région Bretagne and Interreg V.A Cross-Channel Programme for funding this work through our project, FLOWER: Flax composites, LOW weight, End of life and Recycling (http://flower-project.eu).

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IMAGING AND MODELLING FLOW IN POROUS NATURAL MATERIALS: FROM SAWN TIMBER TO FLAX TEXTILE PREFORMS

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ABSTRACT
The efficient impregnation of timber and natural fibre reinforcements with fluids, ranging from preservatives to polymers, is necessary to produce biocomposites with robust performance. However, both timber and natural fibre reinforcements, have morphological, structural, and biochemical specificities that make modelling fluid flow a complex exercise. This talk will present insights from our various collaborative projects on fluid flow in sawn timber and flax fibre textiles. We demonstrate the utility and effectiveness of multi-scale imaging and visualization experiments, such as with in-situ X-ray CT scans, as well as semi-empirical mathematical modelling.

SUMMARY OF WORK
The impregnation of timber and plant fibre textiles with fluids is an active research area, in part to improve industrial technology and derived products, but also to enrich scientific understanding of the physical process [1].
Being naturally hierarchical, heterogeneous materials with complexities in cell geometry, porosity distribution, and the presence of valve-like bordered pits on cell walls that provide the primary path for fluid exchange through the wood, liquid transport in timber has been difficult to model [1,2]. We use X-ray CT to image Sitka spruce at mm-resolution both in the absence and presence of fluid flow (Figure 1). Detailed measurements of saturations obtained for two different fluids (water, ethyl acetate) show enhanced transport in the least porous regions of the timber, occurring at the interface of late- and early-wood. 3D-reconstruction of the flow alongside spontaneous imbibition experiments offer novel, visual insights. The flow measurements allow the physics of liquid transport in timber to be understood and modelled at an unprecedented scale. As Darcy-based models prove inadequate, a new model is developed and verified (to be accurate to within 3% of the experimental observations at all times). The model incorporates micro-scale cell morphometry data, including statistical representation of the variability in the timber pore space, obtained from high-resolution μ-CT scans of the timber. This work also provides insights on how fluid flow in timber ‘material’ may change from when the tree is living to when a product is produced from its wood. The employed imagining techniques and the developed model are relevant to the advancement of biocomposites, and for fundamental insights on fluid flow in porous media in general.

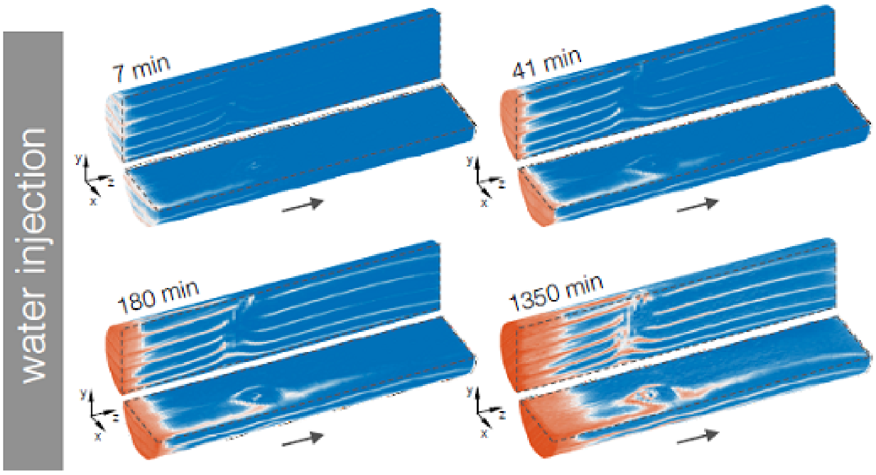

Figure 1. 3D-reconstruction of the timber sample in terms of liquid saturation at different times. Voxel size: (0.5×0.5×2)mm3.

Plant fibre reinforcements also have specificities that influence, if not govern, the mould filling stage during liquid composite moulding of plant fibre composites [3]. The effects of dual-scale flow, resin absorption, (subsequent) fibre swelling, capillarity, and time-dependent saturated and unsaturated permeability that are specific to plant fibre reinforcements require measurement of a range of parameters and properties and modified, if not more advanced, models.

Through this talk, we aim to bring the three scientific communities – wood science community, flow modelling community, and composites science community – together to explore and bring together insights through in-situ imaging and visualisation of flow and parametric modelling of the flow, in timber and flax fibre textiles. The results we share are from two different projects: one with colleagues from Imperial College London (Dr Henry Burridge, Dr Ronny Pini, Dr Saurabh Shah) on flow in softwood, and one with colleagues from the University of South Brittany (Dr Alain Bourmaud, Prof Christophe Baley, Mr Delphin Pantaloni) on flow in flax textiles.

ACKNOWLEDGMENTS

I thank the Leverhulme Trust (Project: Natural Materials Innovation) and the INTERREG IV Cross Channel programme (FLOWER) for funding aspects of this work. I thank my co-authors in the specific projects and published papers for the work in this talk.

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A NEW LIGHT FLAX REINFORCEMENT FOR AUTOMOTIVE PARTS.

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ABSTRACT
The present study is in part of the FLOWER project (EU INTERREG FMA fundings). It mainly focuses in the development of an innovative and eco-friendly headliner, flax fibre reinforced and devoted to automotive interior parts. A special attention has paid to take into account the eco-design in order to improve the recyclability and the end of life of the product.

INTRODUCTION
The global warming issue and new regulatory constraints are pushing car manufacturers to develop lighter vehicles with lower environmental impact (European parliament, 2000). Today, developments in the automotive sector mainly focus on three topics: the weight reduction of mass of vehicles, the use of recycled or bio sourced or biodegradable raw materials, the reduction and upgrade of waste and end-of-life products. Plant fibers are already used in many automotive applications such as door panels, load floors, seat back etc… They are appreciated for their ecological character and their low density (compared to petroleum-based fibers) which make it possible to lighten parts (Mérotte et al., 2016).
The study presented in this paper is set in this context as its aim is to develop an innovative flax reinforcement to be part of automotive headliner. The work was mainly focused in the development of an ultra-light flax reinforcement compatible with the manufacturing processes of headliners and automotive specifications.
The project was carried out by two partners, each specialized in its own sector: EcoTechnilin whose core business is to design and sell natural fiber reinforcements (flax, hemp, kenaff etc…) and Howa-Tramico, tiers 1, specialized in the production of automotive headliners. The objective of EcoTechnilin in the FLOWER project is to develop a new machine able to produce the ultralight innovative flax reinforcement whereas Howa-Tramico studies, analyzes and measures the physico-chemical characteristics of the final product by integrating this new bio-based reinforcement into the composite part. The main parameters taken into account are mechanical properties (flexion and cohesion), resistance to climatic cycles (from -20 ° C to 100 ° C) and emissions of VOCs, formaldehyde and odors.

RESULTS AND CONCLUSIONS
The production line has been built and different process parameters and different qualities of flax tows have been tested. Results shows that the ultralight flax reinforcement (100g/m²) made from high quality of scutched tows depicts the best properties.
It was shown that the flax reinforcement in the composite significantly contributes to the overall performance of the headliner. It influences the physico-chemical results of the final product in particular its stiffness (3 points bending test : slope from 1,2 to 1,8 mm = 4N/mm), the global cohesion of the different layers of the composite (≥ 10 x weight per unit area in kg/m²), the shore A hardness (>50 shore A), the ageing in climatic cycles (-20°C / 45°C + 95% RH / 100°C), as well as VOC emissions, odor and horizontal combustibility (< 100mm/min).

ACKNOWLEDGMENTS
The authors wish to acknowledge the funding provided by the INTERREG IV Cross Channel programme through the FLOWER project (Grant number 23).

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PRODUCTION OF RECYCLED POLYPROPYLENE REINFORCED WITH BAMBOO FIBERS

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ABSTRACT

The paper presents a comparative study of recycled polypropylene composites reinforced with long bamboo fibers. This study aims to align the surface modification of vegetable fibers with the polymeric matrix, searching for chemical compatibility between the phases of the composite. The prepared samples have long fibers with the equivalent size of the culm internodes (approximately 200 mm), oriented toward the stress direction. The esterification was made by fibers alkalinization, followed by its acetylation. To characterize the mechanical properties of the material, analysis as XRD, FTIR, SEM, and tensile tests were performed. As for crystallinity, the alkalization resulted in an increase for fibers, while acetylation afforded a light loss. These factors are observed directly in the cristallinity index of the final composites. Finally, the tensile tests revealed that samples with fibers showed higher values of tensile stress at rupture when compared with samples without fibers.

INTRODUCTION

The production of recycled materials with better performance and efficiency, when compared to non-recycled materials, requires good chemical interaction or the appearance of new phases, giving rise to blends or composites. Polymers and their variations have wide applicability for use due to their range of properties, which can be influenced by conditions of synthesis and processing, selection of materials and also parameters such pressure and temperature. The increasing demand around the polymer allows their expansion in various sectors of society, thus enabling the development of structural composites for engineering and also for other areas, such as environmental and medicinal[1,3].

Recycled polypropylene (PPr) is a polyolefin provided from waste and discarded polypropylene (PP) materials. The technique of recycling polymeric materials helps in controlling its disposal, whereas PP is not easily degraded in the environment. One of the disadvantages of the recycling process refers to the resulting mechanical properties, after recycling cycles, present themselves lower that the primary materials[3]. Fibers may be incorporated inside them, in the directions of greater mechanical stress, to compensate the degradation effects that occur in the recycling process. Bamboo has advantages as directional reinforcement of composite materials because its bundles of fibers are oriented in the direction of the culm and have high values of elasticity modulus and maximum stress at rupture[2-4]. Recycled composites reinforced with biodegradable vegetable fibers are, therefore, an excellent alternative to the production of polymers from virgin raw materials, whereas the mechanical properties of those are compensated.

RESULTS AND CONCLUSIONS

These tests showed the maximum stress at rupture, elasticity modulus and specific deformation of the specimens. The measurements of the mechanical properties for the maximum stress at rupture and elasticity modulus are shown in Table 1.

Specimen	Material A		Material B		Material C	
	σ (MPa)	E (MPa)	σ (MPa)	E (MPa)	σ (MPa)	E (MPa)
1	11	1325	38	3725	27	6098
2	9	1555	41	3451	26	6294
3	11	1575	23	3640	35	8293
4	6	1153	27	3039	49	7577
H5	9	1578	31	3113	44	6206
Average	9.2	1437.2	32	3393.6	36.2	6893.6
Standard Deviation	2.0	191.1	7.5	307.1	10.2	986.2

Table 1. Maximum stress at rupture and elasticity modulus of materials.

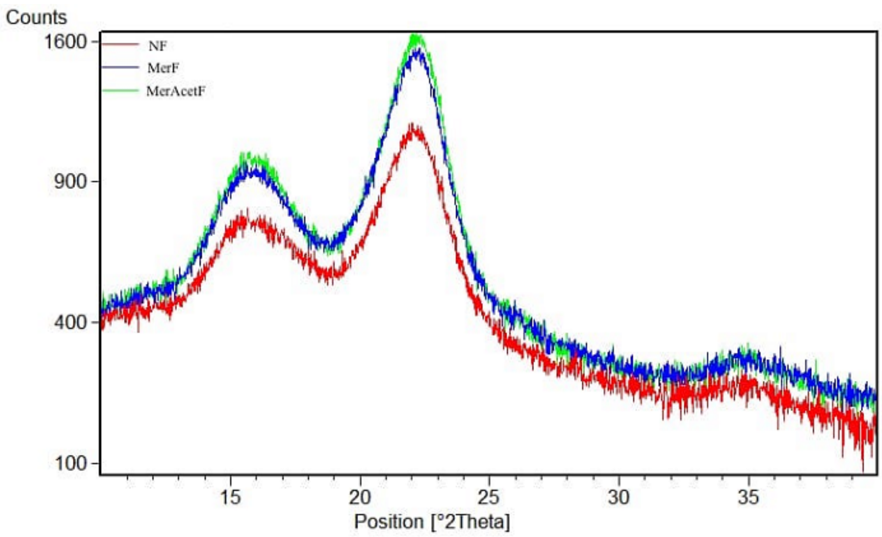

Figure 1. X-ray diffraction (XDR) of natural and treated fibers.

This study shows that the character of the composites unidirectional reinforced was demonstrated, showing that composites produced with the completely treated fibers obtained a gain in maximum stress at rupture and in elasticity modulus values. Thus, resulting in a material with high mechanical strength when compared to their respective matrix.

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STRUCTURAL BEHAVIOUR OF FLAX FABRIC-REINFORCED EPOXY PIPES

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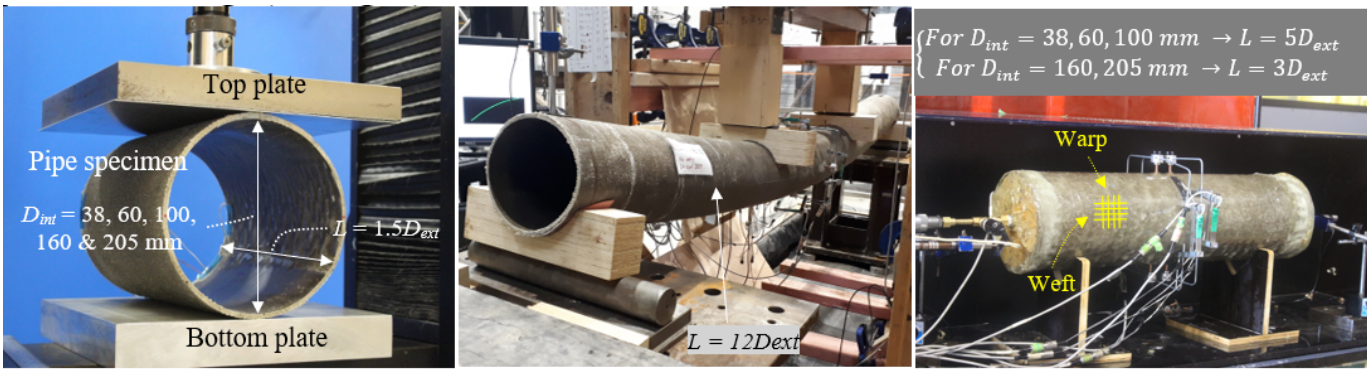
ABSTRACT

Flax fabric-reinforced epoxy (FFRE) was used to manufacture pipes with varying diameters and fabric layers. Lateral compression, bending and internal pressure tests were conducted on the pipe specimens, and the results were compared with the available data in the literature for counterpart natural and synthetic fibre composite pipes. FFRE pipes showed larger specific energy absorbed and deformation capabilities when compared to counterpart natural fibre composite pipes and showed comparable specific energy absorbed and bending strength but larger deformation capability when compared to synthetic fibre composite pipes. The internal pressure associated with pipe leakage and pipe burst exceeded the typical pipe pressure range for domestic use and for water distribution use, demonstrating a substantial potential for FFRE pipe application.

INTRODUCTION

Flax fibre is renewable, biodegradable, has a short life cycle, is readily available in many countries, and the manufacture of flax fibre causes minimal carbon footprint with lower cost when compared to counterpart synthetic and natural fibres (Eyvazinejad Firouzsalari et al. 2020; Firouzsalari et al. 2020). Flax fibre has shown great potential to replace synthetic fibres in composites for applications in which a high strength-to-weight ratio and further weight reduction of the composite component is required.

Plain-woven flax fabric having a mass per unit area of 550 g/m2 and a two-part epoxy resin and extra slow hardener was used to manufacture ninety-nine pipe specimens with varying internal diameters, varying numbers of fabric layers and varying lengths using a wet/hand layup technique. The pipe specimens were tested for lateral compression, bending, and internal pressure loadings (see Fig. 1).

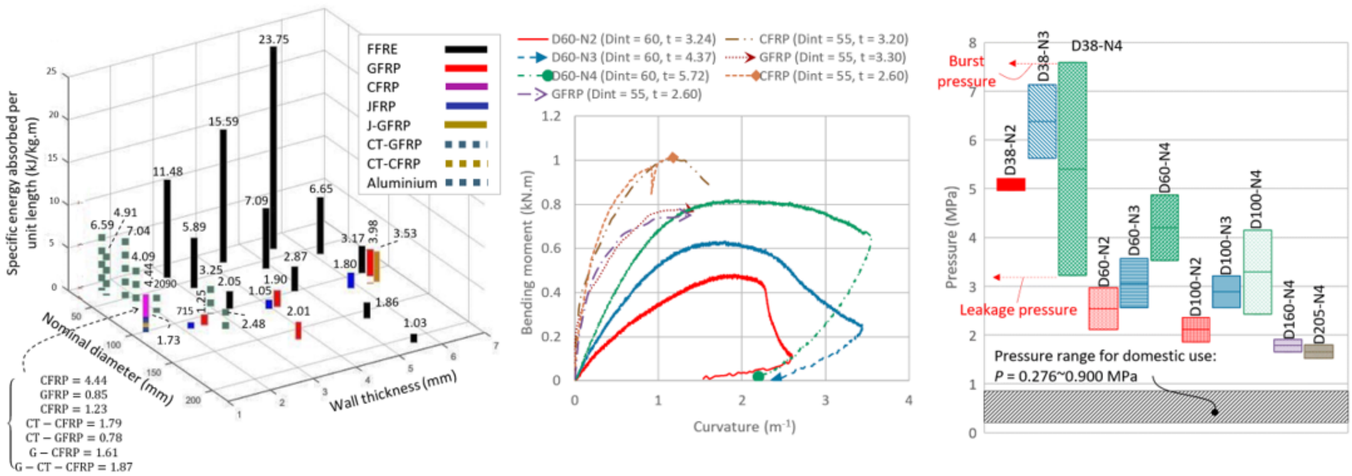


(a) Lateral compression test setup (b) Bending test set-up (c) Internal pressure test set-up

Fig. 1. Details of test setup for pipe lateral compression, pipe bending, and pipe internal pressure tests (where Dint indicates pipe internal diameter, Dext indicates pipe external diameter, and L indicates pipe length).

RESULTS AND CONCLUSIONS

In Fig. 2a the specific energy absorbed (SEA, energy absorbed per unit mass) of FFRE pipes obtained from lateral compression tests and in Fig. 2b the bending moment-curvature relationships of FFRE pipes obtained from bending tests were compared to that for natural or synthetic fibre composite pipes with similar diameters and fabric layers/thicknesses. The SEA of FFRE pipes was superior to that for Kenaf fibre-reinforced polymer (FRP) and jute FRP pipes and was comparable to that for Glass FRP (GFRP), aluminium, and hybrid composites of jute, cotton, glass and carbon fibre pipes. The curvature associated with maximum pipe bending moment for FFRE pipes was significantly larger than for GFRP and Carbon FRP (CFRP) pipes, and FFRE pipes showed comparable maximum bending moment to GFRP and CFRP pipes. The internal pressure values associated with pipe leakage and pipe bursting were obtained from internal pressure tests and in Fig. 2c are compared to pipe pressure range for domestic uses based on the current practice, with the results showing that the leakage and burst pressure of FFRE pipes was significantly higher than the pipe pressure range for domestic applications.



(a) Specific energy absorbed characteristics

(b) Bending moment-curvature relationships

(c) Leakage and burst pressure vs. pressure range for pipe domestic use

FFRE pipes that are manufactured using the hand lay-up technique showed comparable structural performance characteristics to synthetic fibre composite pipes and proved to be effective for pipe domestic use. The manufacture of FFRE pipes is presumed to be more economically efficient than conventional pipes in developing countries where flax is grown locally and wet/hand layup technique could be applied domestically.

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NATURAL FIBER REINFORCED POLYMER COMPOSITES FOR SMALL/MEDIUM WIND TURBINE BLADES: A LCA STUDY

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ABSTRACT

The demand for wind energy is increasing due to the advantages of renewability and electricity generation without using any resources except wind, where the rotor blade is the main component made of composite materials – glass fibre reinforced polymer composites (GFRP) and carbon fibre reinforced polymer composites (CFRP). The wind industry will soon experience an issue with - the End-of-life (EoL) disposal of this large quantity decommissioned blades, as there is a lack of eco-friendly and suitable recycling system. Hence, the current study aims to develop a wind turbine blade made of natural fibre composites (NFCs) with bio-based and/or recyclable polymer matrix system. The environmental impact of the proposed NFC blades and existing synthetic fibre blades (GFRP) is investigated through a Life Cycle Assessment (LCA) study.

INTRODUCTION

Composite materials are versatile materials that, now, widely employed in almost every sector of technology and engineering application, for instance, automotive, aircraft, building and construction sector (Gay, 2014). But the composites made of synthetic fibers (glass, carbon) and non-recyclable petroleum-based polymer matrices are not sustainable for the environment. Moreover, the EoL disposal and/or ecofriendly recycling of these composites is limited, and sometimes costly (Jensen, 2018; Liu, 2017). Recently, a trend of using NFCs and bio-based or recyclable polymer matrices has been observed for a paradigm shift of the composite industry to produce sustainable, carbon-negative, and fully recyclable composite with a vision to achieve sustainability through circular economy model (Dahiya, 2020; Shogren, 2019). Moreover, due to the UN sustainability development goals (SDGs), plus the EU and international strict derivatives and legislations, the industry may require shifting towards bio-based materials and bioeconomy (Dahiya, 2020; Shogren, 2019).

The present study aims to examine the feasibility of using NFCs in small to medium wind turbine rotor blades, including the environmental impact of such blades against GFRP blades by LCA methodology (La Rosa, 2013).

RESULTS AND CONCLUSIONS

A simplified fatigue design of wind turbine blades based on glass fibre epoxy composite (GFRP) and flax fibre epoxy composite (NFC) is shown in Fig. 1, which is based on the model of (Mikkelsen, 2016). Using the same model, the deflection at the tip of the blade was calculated. For the NFC blade, the deflection was higher than the GFRP blade, and therefore, NFC blade was scaled in order to have the same deflection as the GFRP blade (deflection design). As can be seen from Fig. 1, the deflection design increases the blade weight.

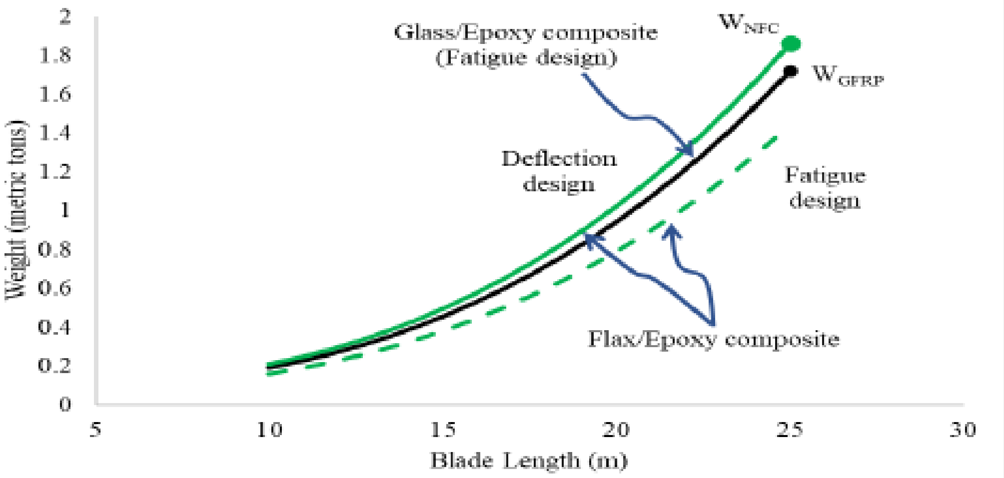

Fig.1 Simplified fatigue and deflection design of wind turbine blades based on the model of Mikkelsen, 2016.

Knowing the weight of the GFRP and NFC blades and the volume fractions of the composites, the weight of the fibres and the resin in the blades can be calculated. With these inputs, an LCA study will be performed to analyse the environmental impacts of the two different blades. It is expected that due to the renewable nature of flax fibres, NFCs might exhibit lower environmental impact than synthetic fibre composites (GFRPs) blade.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by NTNU for the PhD work of Subrata Chandra Das (Project no. 649420).

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INVESTIGATION OF THERMAL CHARACTERISTICS OF THE POLYURETHANE COMPOSITES REINFORCED WITH THE FIBERS OBTAINED FROM AGRICULTURAL WASTES

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ABSTRACT

In this study, the utilization of wastes that come into prominence due to sustainability has been emphasized and the use of corn tassel fibers from agricultural wastes in the composites has been examined. In the composites whose matrix is flexible polyurethane foam, fiber reinforcement ratio is 5% by weight. In addition, some of the fibers were subjected to surface modification with 10% NaOH for 15 minutes, at room temperature. Thermal conductivity coefficients and TGA / DTA graphs of the composites obtained from untreated and treated fibers were analyzed.

INTRODUCTION

Nowadays, with understanding the importance of sustainability, the focus has been on researching new strategies for the provision and utilization of the existing green resources primarily, in order to reduce raw material costs, develop environmentally safe formulations, accelerate degradation after use and add value to a waste material (Chris-Okafor, 2017). At this point, especially in the countries where the agricultural sector is developed, it was thought that large amounts of agricultural wastes, most of which are not managed and used adequately, can be used for different applications and various studies have been started. Improved mechanical, thermal and acoustic properties can be achieved by using these wastes as reinforcements in the production of industrial materials.

MATERIALS AND METHOD

In this study, the composites were synthesized by incorporating corn tassel fibers from agricultural wastes into the polyurethane foam representing the polymer group with a wide application area. The chemical composition of corn tassel fibers, cut in a length of ~ 0.2-0.3 cm, consists of 42% cellulose, 13% lignin, 4.2% ash and 41% other materials (Yilmaz, 2013). Some of the fibers were treated with 10% NaOH for 15 minutes at room temperature. Some of them have not been processed in any way. In the two-stage polyurethane foam synthesis, 5% by weight of the fibers was added at the end of the first step and untreated and treated fiber reinforced polyurethane composites were obtained. The abbreviations CF-PU5 and TCF-PU5 are used for untreated and treated 5% fiber reinforced composites, respectively. The thermal conductivity values of these composites were determined and TGA / DTA graphs formed as a result of thermogravimetric analysis were examined.

RESULTS AND CONCLUSIONS

The thermal conductivity coefficients of PU and the composites obtained as a result of the analysis are given in Table 1. It is seen that the coefficients (λ) of CF-PU5 and TCF-PU5 composites are at levels that make it possible to provide insulation. It is known that these values are greatly influenced by pore sizes and structures (Wu, 1999; Tan, 2011).

Table.1 Thermal conductivity values

Materials	λ (mW/m.K)	a (mm^2/s)	b ($W.s^{1/2}/m^2.K$)	r ($W^{-1}.K.m^2 \times 10^{-3}$)	h (mm)	Qm (W/m^2)
CF-PU5	50.57±1.68	1.28±0.27	45.20±5.51	328.37±10.01	16.59±0.04	179.73±16.99
TCF-PU5	51.97±0.95	1.33±0.33	45.83±6.22	282.47±4.68	14.67±0.05	156.13±30.29
PU	50.63±2.41	3.38±0.50	27.70±2.91	355.53±15.99	17.98±0.02	190.83±4.54

TGA / DTA curves of PU and the composites are given in Figure 1. The addition of corn tassel fibers to PU foam could not achieve superior thermal properties. However, thermal properties of the composites obtained by alkali treated fibers could be improved.

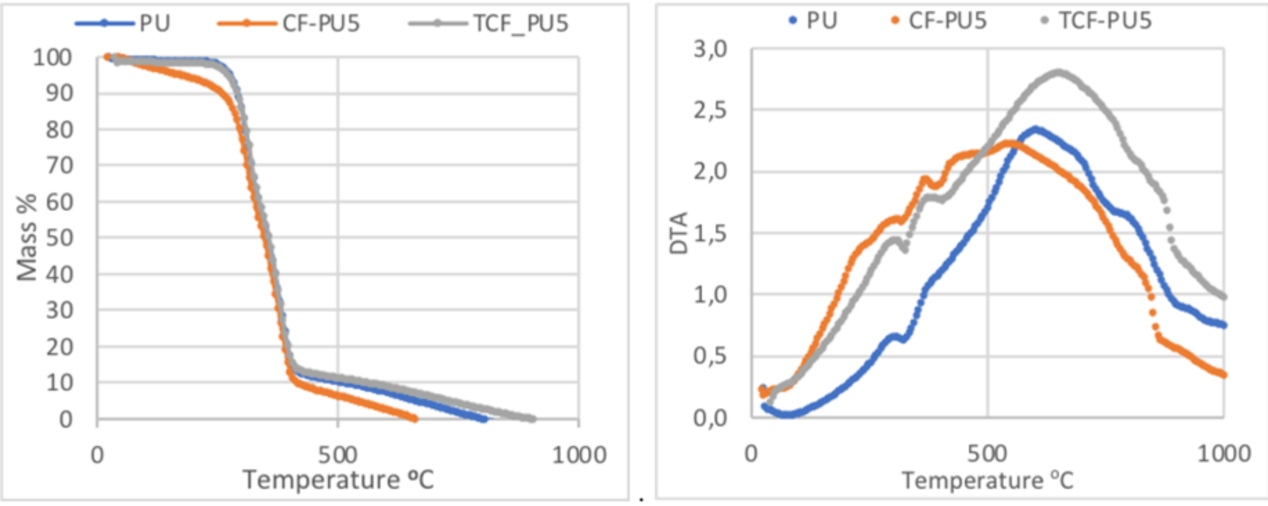

Fig.1 TGA and DTA curves

In this study, it has been determined that low cost composites can be obtained by using less petrochemicals and creating less environmental damage owing to the use of agricultural wastes without obtaining low properties. The mechanical and sound absorption tests of these composites should be performed.

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QUANTIFICATION AND PROPAGATION OF UNCERTAINTY ON VEGETAL FIBERS' PROPERTIES ON MECHANICAL BEHAVIOR OF INJECTION-MOLDED SHORT-VEGETAL-FIBER-REINFORCED COMPOSITES

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ABSTRACT

This work investigates the impact of variability of vegetal fibers' geometrical properties and complex fibers' orientation on the mechanical behavior of injection molded short-vegetal-fiber-reinforced thermoplastics (SVFRT). Tensile specimens are cut in injection molded plates of 30% short-vegetal-fiber-reinforced polypropylene. Microstructure of specimens is analyzed using 3D micro-computed tomographic in order to quantify the uncertainty on fibers parameters. Some of them are inherent to fibers (length, cross-section) but others are process-dependent (orientation. Then, tensile tests on those specimens highlight well-known anisotropic behavior of the material but also the impact of fibers properties' uncertainty and distribution of orientation on the mechanical properties of the composite. Further analyses reveal preponderant sources of variability on macroscopic behavior of SVFRT.

INTRODUCTION

The injection-molded process allows manufacturing parts with more or less complex geometry. Concerning short-fiber-reinforced polypropylene, usually glass fibers are used. One of the main advantages of glass fibers is the low variability of geometrical and mechanical properties. However, the microstructure of injected parts is complex because of process-induced distributions of fibers orientation. Recently, environmental concerns and regulations encourage industrials to increase the use of vegetal fibers in composite. However, the use of vegetal fibers is still limited because of highly variable properties (fiber length, mechanical properties…) (Charlet, 2010) and the lack of precise models for their mechanical behavior (Bos, 2006). Indeed, to the already known complex behavior of the thermoplastic matrix (viscoelasticity, viscoplasticity, strain rate sensitivity, …) and the complex fiber orientation, induced by the injection-molded process, is added vegetal fibers variable properties (Notta-Cuvier, 2016) which lead to an even more complex and uncertain composite behavior.

In the present work, plates of 30 wt.% vegetal fibers reinforced polypropylene have been injection-molded with the same injection parameters. A total of 65 tensile specimens were cut in different zones of the injected plates with four cutting angles regarding injection flow direction. The center of volume of interest of each tensile specimen was scanned using micro computed tomography (micro-CT). From the scans three probability density functions are extracted for fiber length, fiber orientation and fiber section. A number of 40 specimens were then used in tensile tests. Then, an uncertainty propagation is made to better understand the impact of the measured variabilities on the composite behavior.

RESULTS AND CONCLUSIONS

The results of tensile tests for a cutting angle of 0° are plotted in the Fig. 2. As the five tensile specimens have been cut in the same plate with the same cutting angle, the dispersion of the results directly comes from microstructural variabilities, as proven by the micro-CT campaign.

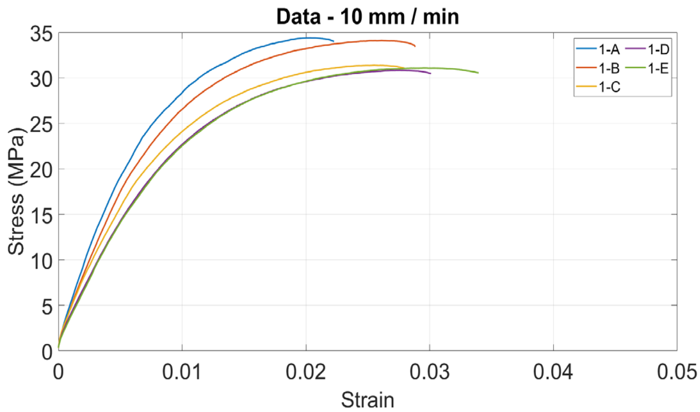

Figure 1 – Tensile results

Figure 2 reveals that the injection-molded process leads to 1/ distribution of fiber orientation in the specimen instead of aligned fibers 2/ different distributions according to the localization in the plate.

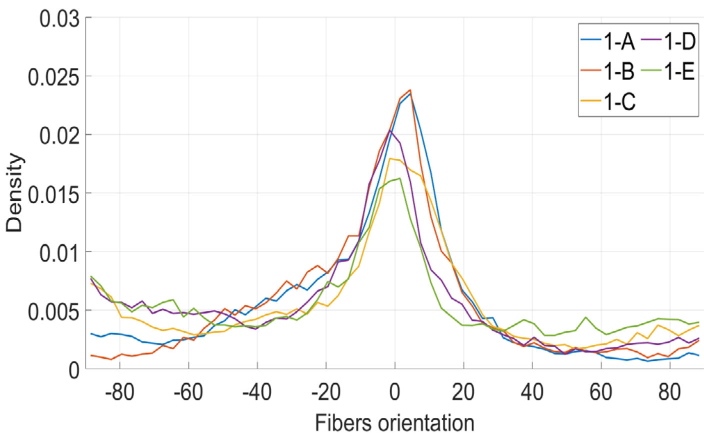

Figure 2 – Fibers' orientation

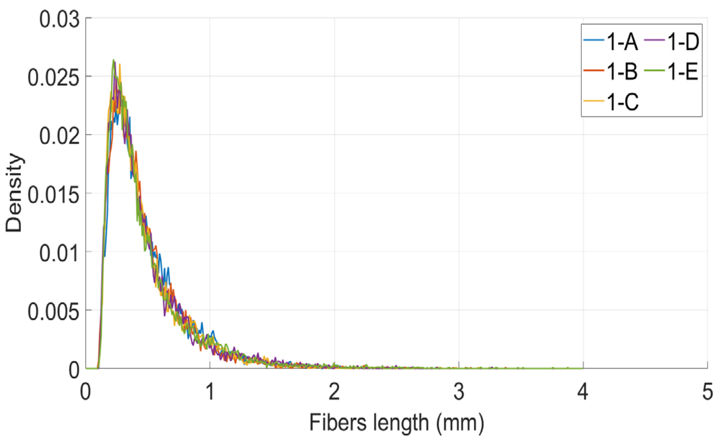

Figure 3 – Fibers' length

Although vegetal fibers present variable geometrical properties the injection-molded process induces fibers breakage. It can be seen from figure 3 that the distributions are very similar from a specimen to another. Therefore, the dispersion observed in figure 1 seems more related to fibers' orientation than fibers' geometrical properties. Further uncertainty quantification (fibers' cross-section) and propagation researches are performed in order to found out the weight of each variable parameter on the composite's behavior.

ACKNOWLEDGMENTS

The authors gratefully acknowledge support from International Campus on Security and Transport Intermodality (CISIT), the European Community, the French Ministry of Higher Education and Research and the Hauts de France Regional Council. The authors also acknowledge Novares for their support.

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MULTIFUNCTIONALITY AND CHARACTERISTICS OF WOOL FIBRE-REINFORCED THERMOPLASTIC POLYMERS FOR INJECTION MOULDING & ADDITIVE MANUFACTURING

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ABSTRACT
The authors will present the state of the art in research and development in thermoplastic wool fibre-reinforced composites. Wool and horn's structural property relationships as keratinous, natural composites are summarised. This comparison's main objective is to show keratinous composites' potential for biomimetic composite and highlight the unique circumstances that need to be taken into account in developing and producing wool fibre-reinforced composites. The published papers in the field of wool fibre-reinforced thermoplastics are critically evaluated and classified according to the thermoplastic material and processing technique based on comprehensive literature research (see Figure 1). The achieved properties, depending on the processing methods and constituent components, are compared and used to describe the micromechanics and the fibre/matrix interaction of wool and hair fibre-reinforced composites. The opportunities and limitations of adhesion promotion to improve mechanical properties are discussed by analysing literature studies. In addition to mechanical considerations, properties such as combustibility and bio-degradation of wool fibre-reinforced composites are critically evaluated. Also, difficulties and the current state regarding the life cycle assessment of wool and residues from the wool production cycle are described. In addition to the literature research analysis, own results for injection moulded and 3D-printed wool/polymer composites are presented. With the help of existing data, suitable products, and possible market segments for wool fibre-reinforced thermoplastic polymers are identified. The current state of research on wool/polymer composites is critically evaluated, and finally, ideas for necessary future research and development work are presented.

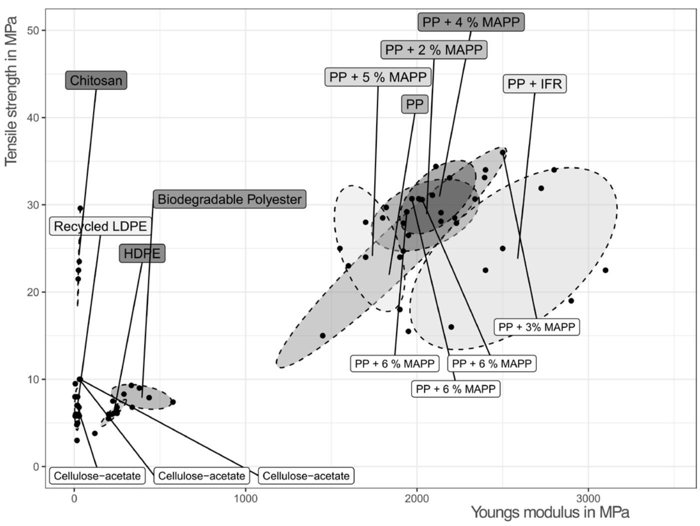

Figure 1: Matrix-dependent tensile properties of wool fibre reinforced thermoplastic composites collected from literature.

ACKNOWLEDGMENTS

This research took place within the framework of Project Bioeconomy. We acknowledge the funding agencies for the possibility to work on the shown topics within the cross-border project „Bioeconomy – Green Chemistry“ (https://edr.eu/project/bio-oekonomie-gruene-chemie), funded within the programme 'INTERREG V A-Germany – Netherlands' by the European Fond for Regional Development (EFRE) co-financed by the land Lower-Saxony, the Dutch ministry of economics and the Dutch provinces Drenthe, Flevoland, Fryslân, Gelderland, Groningen, Noord-Brabant and Overijssel.

ASSESSMENT OF THE LOW VELOCITY AND BALLISTIC IMPACT RESISTANCE OF HYBRID FLAX/BASALT SANDWICH STRUCTURES WITH AN AGGLOMERATED CORK CORE

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ABSTRACT

The main drawbacks that afflict sandwich structures are the massive exploitation of synthetic materials in their production and their proneness to impact damage. For this reason, the present work aims to propose new bio-based sandwich structures with an agglomerated cork core and flax/basalt hybrid skins and to study their critical point, namely, their impact response considering low velocity and ballistic impact conditions.

INTRODUCTION

Sandwich structures are largely employed in many industrial fields, such as transportations and buildings, for structural and semi-structural purposes thanks to the combination of a high flexural stiffness with a low weight due to their peculiar design. The typical structure that characterizes these composites and provides them with a high stiffness-to-weight ratio, is also responsible for their susceptibility to impact events that can drastically compromise their structural integrity and stability leading to a collapse of their load bearing capabilities and residual mechanical properties (Chai and Zhu, 2011).

Another problem associated with these structures is the massive exploitation of synthetic and non-biodegradable materials such as the polymeric foams used as cores and the fibers employed in skin reinforcement. In order to meet the more restrictive regulations promulgated all over the world to counteract the thoughtless pollution of air, water and soil, it is necessary to find valid alternatives to these traditional materials replacing them with bio-based ones to reduce the carbon footprint of the production process and to ease the disposal phase. Agglomerated cork proved to be an appealing eco-friendly solution as core material thanks to its biodegradability, lightness, thermal insulation and the outstanding dimensional recovery (Knapic et al., 2016). Concerning the replacement of the most common-used glass fibers, some studies assessed the feasibility of vegetable fibers such as flax, hemp and jute (Faruk et al., 2012) hoping to exploit their lightness and biodegradability. Despite these attractive features, they are not able to guarantee the mechanical performances achievable with glass fibers. Other studies focused on the more performing basalt fibers (Fiore et al., 2015) characterized by mechanical properties comparable with E-glass ones, but also by an improved eco-friendliness thanks to a reduced consumption of energy and chemicals in the production process and to an easier recyclability and recovery of the fibers. Despite all the advantages, basalt fibers are not able to solve the non-biodegradability issues therefore a good compromise is hybridization that allows to overcome the drawbacks of the single type of fibers exploiting their synergistic effect. In light of the two main drawbacks connected with the use of sandwich structures, the aim of the present work is to propose bio-based sandwich composites with an agglomerated cork core and flax/basalt hybrid skins and to assess their Achille's heel, i.e. their impact resistance, in both low and high velocity impact conditions.

RESULTS AND CONCLUSIONS

In order to obtain a thorough understanding of the impact behavior of the proposed sandwich structures, the experimental campaign of low velocity impacts with a CAI (Compression After Impact) support and ballistic impacts was carried out not only on the overall sandwich structures but also on the sole skins and cores. At first, three types of agglomerated cork with different densities were considered and their impact response was compared with the one of three more traditional polyvinyl chloride (PVC) foams with the same density used as benchmark. Based on the results obtained, two agglomerated corks and one PVC foam were selected to produce the final sandwich composites. Skins were produced with a polypropylene matrix with (PPC) and without (PP) a maleic anhydride coupling agent to investigate the effect of this parameter on the impact response of the structure.

In all impact conditions, the sole agglomerated cork was characterized by the outbreak of an intergranular fracture at cork granules/polymeric binder interface which hindered the full exploitation of cork energy absorbing and damping capabilities. The integration of agglomerated cork between the two skins in the complete sandwich structures, allowed to prevent the premature detachment of cork plugs highlighting its improved impact resistance and damage tolerance with respect to the stiffer PVC foam structures characterized by a stronger localization of the damage as shown in Figure 1. A positive effect of the integration of agglomerated cork in the overall structures can be observed even in ballistic impacts where a ballistic limit comparable with the one of PVC foam structures was obtained. Concerning the effect of coupling agent, even if an improved fiber/matrix interface is useful to increase the quasi-static performances of a composite, it plays a negative role on its low velocity impact response due to the hindering of some energy dissipation mechanisms such as matrix plasticization, leading to a decrease of the perforation threshold of the composite and to a more brittle response.

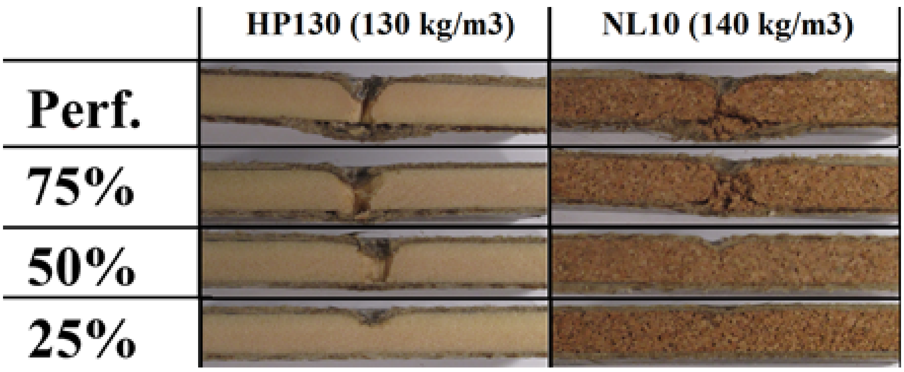

Figure 1 Damage progression as a function of impact energy in PP-HP130 and PP-NL10 sandwich composites

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THE INFLUENCE OF NATURAL RESINS ON PLA MELT SPUN MULTIFILAMENTS YARNS MECHANICAL PROPERTIES

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ABSTRACT
One of way to providing new functionalities for a textile product is insertion of natural ingredients into the process of its manufacture. Natural resins as Myrrh or Pine(Rosin) has long been used in medicine as an antibacterial and antifungal material. Polylactide (PLA) is a synthetic biopolymer obtained from renewable resources and due its biodegradability, is also widely used in medicine. In this research were developed and characterized multifilament yarns from modified biodegradable PLA granules with ethanolic myrrh and rosin extracts. Tensile tests were applied to determine, mechanical properties of PLA/myrrh and PLA/rosin multifilament yarns. The results showed that it is possible to form PLA melt-spun multifilament yarns with natural resins extract. The highest concentration of natural extract has a no significant influence on the mechanical of the melt-spun yarns.

INTRODUCTION
Melt spinning is the most economical and widely used spinning process in the textile industry. One reason is that the production of polymer yarns doesn't require solvents. In the process of melt spinning, it is possible to use additives and form multicomponent yarns with various functionalities. The yarns formed in this way are ideal for use in medicine field [1,2].

PLA is an aliphatic polyester, synthesized from natural resources (most often from corn). PLA polymer is biocompatible and biodegradable also has a good mechanical characteristic and are widely used for medical application [3].

Natural resins are myrrh and pine. Myrrh is an aromatic gum resin obtained from a small tree found in northeast tropical Arabian and the Indian. It is consists of alcohol-soluble resins (25–40%), volatile oils (3–8%) and a water-soluble gum (30–60%) and for long time used as a natural medicine and as antibacterial material for wound dressing [4,5]. Rosin is a natural product of pine resin. It is insoluble in water and soluble in most organic solvents. Rosin composed of 10–20% of neutral compounds and 80–90% of resin acids. Rosin derivates have an antibacterial against E. coli, S. aureus and B. subitilis. Moustafa and co-authors to determinate that rosin and PLA / PBAT polymer film excels antibacterial effect. Characterize by antifungal effect against V. mali. Also it is nontoxic, due such properties rosin also has a great potential to be used in a medical field [6-9].

The aim of the research is to be developed and investigated pure PLA multifilament yarns and yarns saturated with different natural resins extract. The investigated how changed the physical and mechanical properties using different natural resin extracts.

MATERIALS AND METHODS
The multifilament yarns were spun from granules of PLA 6100D (Nature Works, USA). Myrrh resin was imported from India and rosin was imported from Germany. Myrrh ethanolic extract was prepared [10]

used fine powder of myrrh. For the extraction of raw myrrh distilled 96% ethanol was used. Myrrh ethanolic extract was produced for 12 h in a round bottom flask at boiling point of ethanol (approximately at 78ºC). After, that Myrrh ethanolic extract was filtered to remove the undissolved solid particles (sand and ground myrrh). For rosin extraction was used 80% ethanol. Rosin was stirring and dissolving. After 6 hours extract was filtered. The PLA granules were modified by the spraying with natural resin extract. The multifilament yarns were formed by COLLIN® CMF 100 (Dr. Collin Gmbh, Germany) laboratory melt spinning equipment in Kaunas University of Technology, Faculty of Mechanical Engineering and Design. Mechanical properties of the PLA multifilament yarns were measured using universal tensile testing machine Zwick/Roell BDO-FBO.5TH (Zwick GmbH & Co. KG, Germany) and testXpert® program. The length between clamps was 250 mm and the tension speed was 500 mm/min. Tensile test was performed until all multifilament yarn completely break. The number of tests with a package was 35. Experiments was carried out in a standard atmosphere at the temperature - 20 ± 2 °C and relative humidity – 65 ± 4%.

RESULTS AND CONCLUSIONS

The linear density and other characteristics of the extruded samples are given in the Table 1. It was estimated that is possible to melt spun multifilament yarns with natural (myrrh and pine) resin. Addition of the highest myrrh ethanolic extract to multifilament yarns had no significant influence of linear density and mechanical properties as breaking tenacity and strain comparing with original (without modification) PLA multifilament yarns. When PLA pallets modified with rosin ethanolic extract, formed multifilament yarns linear density decrease approximately 5%. The highest rosin ethanolic extract had no influence for mechanical properties comparing with pure PLA multifilament yarns. When PLA modified with highest natural resin extracts mechanical properties at break no significant influence

Table 1. Mechanical characteristics of pure PLA and PLA with natural resin multifilament yarns

Samples	Drawing ratio	Linear density, tex	Breaking Tenacity (cN/tex)	Elongation at break, %
PLA	2.53	39.5 ± 0.7	3.2 ± 0.4	64.6 ± 4.7
PLA + 7.5% Myrrh resin		38.3 ± 0.3	2.8 ± 0.1	63.3 ± 4.9

Samples	Drawing ratio	Linear density, tex	Breaking Tenacity (cN/tex)	Elongation at break, %
PLA	2.75	51.7 ± 0.2	2.6 ± 0.4	145.1 ± 9.4
PLA + 10% Rosin		49.4 ± 0.9	1.9 ± 0.3	144.9 ± 12

ACKNOWLEDGMENTS

Acknowledgement: E.A. and E.B. would like to acknowledge the contribution of the COST Action CA16122. E.B. would like to thank Research Council of Lithuania for funding PhD studies.

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THE BAMBOO CULM AS A NATURAL COMPOSITE TUBE

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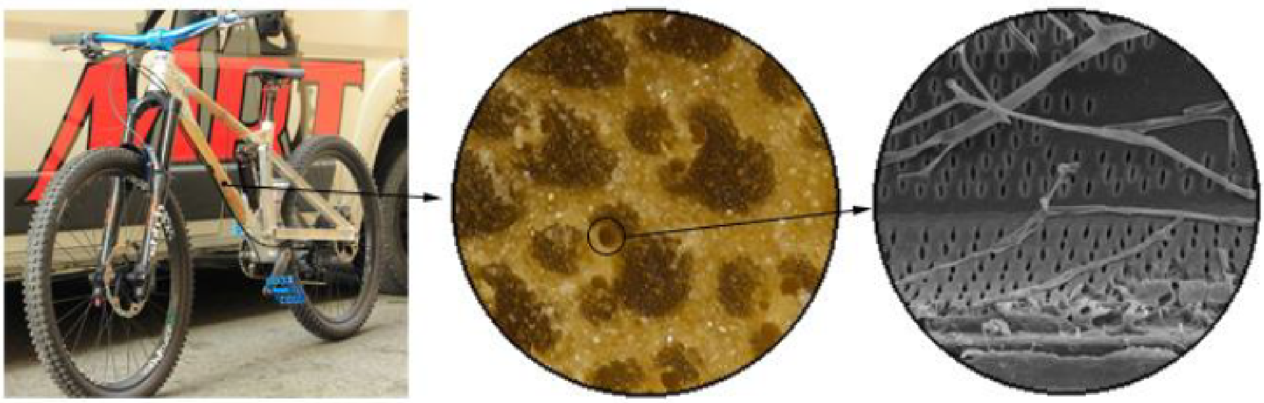
ABSTRACT
In this study, the analysis of the fiber distribution of three types of bamboo (Phyllostachys aurea, Arundinaria amabilis, Dendrocalamus strictus) is presented. Fibers distribution was observed by SEM and related with their contribution into the mechanical properties and epidermis stability of this biobased composite.

INTRODUCTION
The culm of the bamboo has been traditionally used for the construction of different type of structures as bridges and houses. Recently, new applications have been developed related with small structure fabrications as bicycle frames (Fig. 1) and others based in bamboo laminates and related with the reduction of plastic consume (Jiao 2016), as brushes, bowl or kitchen equipment. This composite shows very specific fiber distributions (Correal 2020) that optimize its thickness with the resistance to biotic and abiotic adversities (Liese 1985).
In this study, the distribution of the fibers in the culm and the influence in the mechanical properties for three types of bamboo will be shown P.a., A.a. and D.s. (Phyllostachys aurea, Arundinaria amabilis, Dendrocalamus strictus).

RESULTS AND CONCLUSIONS
Appearance and particle size
The samples were observed using a microscope (those samples that were obvious to contain larger particles) and an electron microscope. Electron microscopy confirmed the presence of nanoparticles in samples dissolved for a longer time - 10 or more hours as seen in Fig 1. For regenerated cellulose fibers, the nanoparticles are observed in the form of crystals after 10 hours of maturation, while for cotton material up to 24 hours.



a b c

Figure 1. Macro and micro images of bamboo: a) Enduro bamboocycle, Morphology of bamboo analysed by b) optical microscopy and by c) SEM.

RESULTS AND CONCLUSIONS

Bamboo can be envisaged as a natural composite based on fibers that are arranged longitudinally in the internodes and transversely in the nodes (Ximena 2002), where the lignin acts as a matrix. The success of nature is the optimization of its resources consuming the minimum raw material possible for the development of a product, such as plants or fruits. In the case of bamboo, its morphology is a design in which nature has created a fully optimized composite in terms of fibers and resin distribution.

All bamboo types have similar external appearance and are composed by the same molecules, but morphological analysis reveals differences in the distribution and proportion of components. For example, the external morphology can protect from the attack of external agents generating a closed epidermis as in the case of P.a. Or in the case of D.s. bamboo, morphology shows more nutrient storage zones.

The distribution of fibers in the inner improve the mechanical properties and are responsible of the plant protection against the force of the wind (A.a.). In fact, bamboo shows fiber accumulation in the parts of the plant that requires higher mechanical resistance. In consequence, the weight/resistance ratio of bamboo is very suitable to develop lightweight structures as commercial bicicles replacing carbon fiber (CF) composites. The same frame has been design and manufactured with bamboo culm (Fig. 1). Results indicate that mechanical resistance of both commercial and bamboos structures is similar. In fact, the flexural strength of bamboo (A.a.) is around 6690 ± 2450 MPa which is more than enough for the construction of a bicycle frame.

Thus, with the same resources and only varying the distribution of the fibers, the nature is able to satisfy the different needs that the plant has, depending on its origin. Natural resources as bamboo are interesting not only for a more sustainable future, but also, and more important, lead us to learn about eco-design for more optimized designs in terms of raw material consumption. Bio-inspired composites offer a sustainable future for composites.

ACKNOWLEDGMENTS

The authors would like to thank the University of the Basque Country (GIU18/216 Research Group). They also appreciate the technical and human support provided by SGIker Macrobehavior-Meso structure-Nanotechnology (UPV/EHU, MINECO, GV/EJ, FEDER, and ESF).

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INTERACTIONS OF PULP FIBERS WITH JET COOKED CATIONIC STARCHES

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INTRODUCTION

One of the key challenges in paper production is to optimize the use of any resources in the process. In this context, cationic starch is of utmost interest as it is among the most used additives in the process. In addition, the preparation of starch slurries involves the use of energy intense processes, which typically involve steam jet cooking. Here, we explore four industrially relevant cationic starch samples that vary in source, cationization method and degree of substitution. These starches were treated in a steam jet cooking process at different temperatures and ionic strengths, comparable to industrially employed starch cooking procedures. The resulting starch solutions were further explored towards their interaction behavior with pulp fibers and were correlated to the conditions during the steam-jet cooking. For some starch grades, a cooking temperature of 115°C was sufficient to maximize starch retention on the fibers. The results form the basis to develop better processes for starch use in an industrial setup.

RESULTS AND CONCLUSIONS

The starches obtained from different cooking conditions (3.5-7 wt%, 115-135°C) were exposed to pulp fibers and allowed to adsorb for different times. Figure 1 (left) shows a comparison of the behavior of the different starches cooked at 125°C and 3.5 wt% starch concentration. We also investigated the behavior of the starches at different temperatures (Figure 1, right). It can be clearly seen that the dry cationized potato starch shows the best retention on the pulp fibers at 115°C while the corn starch requires 130°C for maximum retention during cooking.

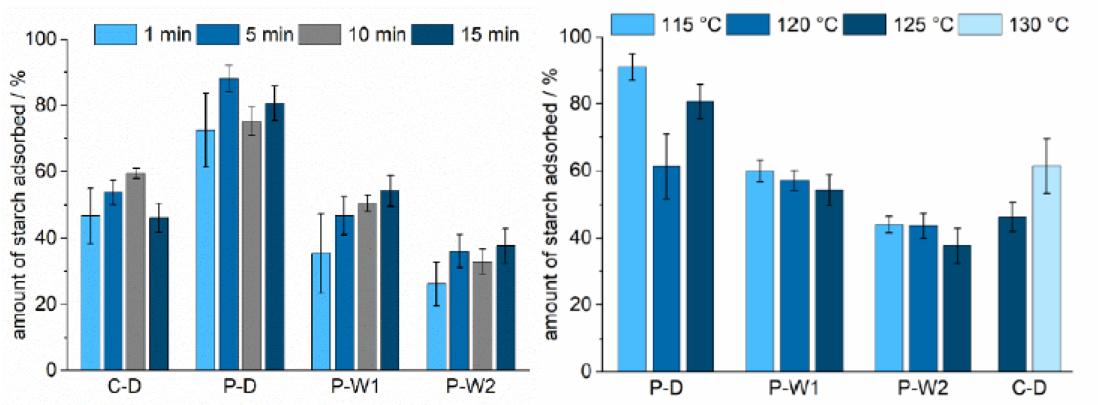

Figure 1. Left: Cationic starch retention as a function of adsorption time at a cooking temperature of 125°C and 3.5 wt% dry weight content. Right: Cationic starch retention at an adsorption time of 15 min. C-D: dry-cationized corn starch, P-D: dry-cationized potato starch, P-W1: wet-cationized potato starch, P-W2 wet-cationized potato starch with higher DS).

We further correlated the results with amylose contents and could show that preferential adsorption of amylose took place during the experiments. We could show that there is a large potential in industry to use similar procedures to optimize the cooking processes which can lead to energy savings as well as raw material reduction during starch processing.

ACKNOWLEDGMENTS

This research was funded by the Austrian Research Promotion Agency (Österrreichische Forschungs-förderungsgesellschaft, FFG), grant number 868292, and by companies of the Austrian pulp and paper industry.

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TOWARDS DLP-BASED ADDITIVE MANUFACTURING ROUTE TO PROCESS POLYMERIC COMPOSITES WITH HIGH NATURAL FIBRE LOADS

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ABSTRACT

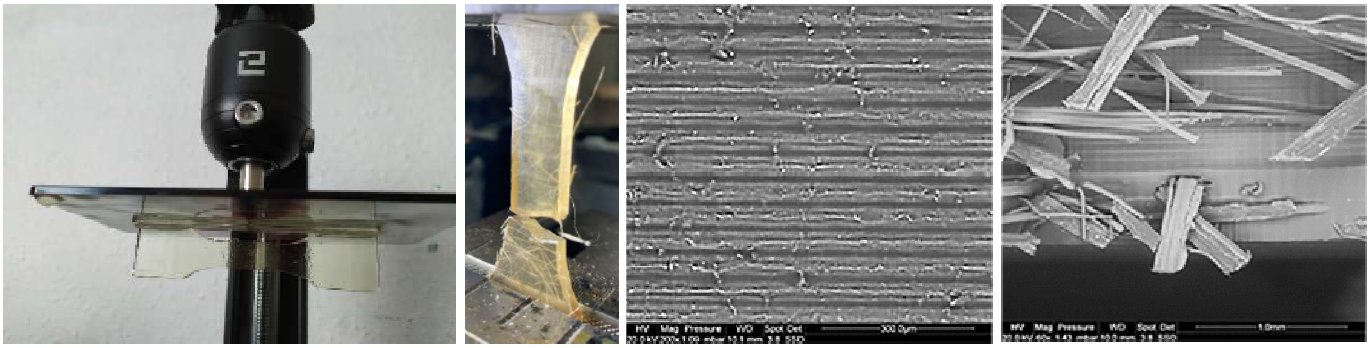
In this work we shed more light on a relatively recent additive manufacturing technology called Digital Light processing or DLP, which works under the same rational as stereolithography. The motivation behind the current development is related to the difficulty to process long natural fibres within polymeric matrices using fused deposition modelling technology (FDM) especially under a high load. We investigate through this work the potential of reaching high mechanical performance with DLP process for polymeric composites with large natural fibre load.

INTRODUCTION

Additive manufacturing (AM) is recognised as one of the key technologies of the future. Based on digitalised models and assuming a layer-by-layer manufacturing process, this technology allows the processing of wide varieties of materials without a strong dependence to tooling. In addition, AM ring handles a larger degree of complexity and customisation of products under a ground cost. Among the available AM techniques, DLP is one of the recent technologies that combines a fast material processing and high accuracy. DLP is similar to stereolithography but instead of using a laser that scans the surface of a photosensitive resin in the liquid state, it is a digital screen, which projects an image of the layer (Lovo, 2017). DLP process is often associated with an expensive resin cost and a limited material spectrum (Gibson, 2014). In this work, we explore the modification of photosensitive resins known as PLA-like (Polylactic acid) or ABS-like (Acrylonitrile butadiene styrene) and conventional resins reinforced with natural fillers such as hemp or natural fibers extracted from bullrush (Typha latifolia). This technology bypasses the difficulty of dealing with long natural fibres by forming solid patterns from a liquid state of a photo-sensitive resin.

RESULTS AND CONCLUSIONS

3D printing is carried out using a 3D printer allowing a build volume of 120x68x155 mm^3 (Fig. 1a). The resolution of the print is proportional to the pixel size of the LED display, which is 47µm for 2K resolution or 2560 × 1440 pixels. The polymerisation process via the LED screen is carried out with UV light with a wavelength of 405 nm and an exposure time varying between 7 and 20 seconds. Tensile specimens of dimensions 80 × 10 × 4 mm3 are processed with and without UV post-curing for different types of resins and natural fibre loads. The printing time for one specimen is typically 20 minutes, equivalent to the printing time for an FDM printer (Gibson, 2014) but with a resolution eight times larger (400/50). Post-curing is performed for some specimens using a UV lamp for 15 minutes to finalize the polymerization. With optical observation of the specimens (Fig. 1b), the building direction cannot be retreived although this one is aligned with the width of the specimen (Fig. 1a). SEM micrographs show, however, the layering of the structure of the prints with a typical thickness of 50 µm (Fig. 1c). The tensile tests carried out with a speed of 5 mm / min. until failure confirm a significant influence of the exposure time on mechanical properties. Stiffness and mechanical strength improve and the elongation at break decreases as the exposure time increases. The incorporation of natural fibres in photosensitive PLA does not change the stiffness. On the other hand, it negatively affects the mechanical strength and elongation because of the weak properties of the interfaces which can be read from the SEM micrographs (Fig. 1d). This study concludes on a proven potential for incorporating large loads of natural fibres in composite materials using DLP process. This process eliminates the rheological constraints inherent to other additive manufacturing processes that use heat to obtain a melt and avoid fibre degradation during processing. This is the case, for example, with the FDM process. The DLP process partially solves the fibre clustering problem, but this requires adaptation of the exposure time to UV light. Finally, the use of natural fillers proves to be an alternative to obtain resins with an acceptable cost / performance ratio.



a) b) c) d)

Fig.1 (a) Tensile specimen after printing using DLP process (b) Natural fibre-based composite after tensile testing, (c)-(d) SEM micrographies showing (c) layring structure of printed speciemens and (d) interfacial decohesion in natural fibre printed composite.

ACKNOWLEDGMENTS

The authors thank the electron microscopy platform of the LaSIE laboratory at La Rochelle University for carrying out the SEM observations.

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IMPACT OF LONG-TERM WEATHERING ON THE PROPERTIES OF A DIGESTATE BASED BIOCOMPOSITE

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ABSTRACT

The effects of weathering of a bio composite made from digestae and biobased thermoset is investigated. Therefor the samples were alternately exposed to UV radiation and moisture for various length of time. Afterwards the material strength and water absorption is tested. A longer weathering does not lead to a further decrease of the strength.

INTRODUCTION

Natural plant fibers are increasingly used as reinforcements in composite plastics due to their good specific properties and their ecological advantages, compared to synthetic fibers [1]. Biogas digestate is a plant based agricultural residue that is usable as an alternative fiber source. The material consists largely of lignocellulose [2]. Natural fiber composites have the major disadvantage that they are hygroscopic. The swelling of the fiber causes a degradation of the composite [3]. Fiber treatments and a complete enclosure with the polymer matrix help to prevent water absorption. Plastics do not have an unlimited shelf life. Environmental influences cause irreversible changes in their properties. The aging of fiber-reinforced composite a dominated by the aging of the polymer [4,5]. To use natural fibers in outdoor applications, knowledge about their durability is necessary.
In this work, biocomposites are artificially weathered and tested afterwards. The fiber is a nonwoven made from digestate and pulp. The matrix is a vegetable oil-based epoxy system. The material is produced by hot pressing (100°C, 6 MPa). The samples are alternately exposed to UV radiation (8 hours) and moist air (4 hours) over test periods of 500, 1000 and 1500 hours. Due to the test machine, the exposure is only from one side. In addition, an untreated, dry and dark stored sample is used as reference. To assess the influence of material aging, the flexural strength and the water absorption after 1 and 10 minutes are tested.

RESULTS AND CONCLUSIONS

The results of the flexural tests are shown in figure 1. Bleaching of the samples was already evident after 200 hours, which indicates a change in the composite.

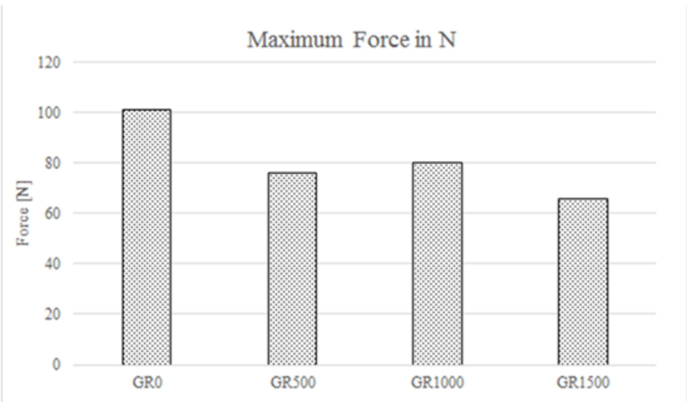

Fig.1 Tensile test results after different time of weathering

After a treatment period of 500h with UV radiation and humidity, a decrease in strength of about 20N can be seen. Further treatment, does not lead to a further decrease in the maximum breaking strength. The oscillation of the measurement can explain by the inhomogeneity of the biomaterial. The weathering of the sample do not lead to a change of fracture appearance.

ACKNOWLEDGMENTS

The Authors thank the company Q-Lab GmbH for testing and the Federal Ministry for Economic Affairs and Energy for founding this project.

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COMPOSITES WITH NATURAL POLYMERS FOR NETS INTENDED TO REPAIR PARIETAL DEFECTS

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ABSTRACT

The paper presents the physical-mechanical, morphological, and biocompatibility characteristics of the functional textile compositions, designed to repair parietal defects, made by thermo-welding technology, from textile structures based on natural polymers (PLA) and synthetic polymers (PP, PA). The textile structures, which make up the I and II layers of the composites, are made by spun-bonding (PLA) and knitting technology (PP, PA). EVA type membranes are used for binding the base layers. The functionalization operation of the composites is carried out with Hydrolyzed Collagen and Lactoferrin.

INTRODUCTION

The treatment of hernia using surgical nets is now the standard procedure in most countries and is widely accepted as superior to primary care repair by suturing. Composite meshes aim to prove an additional surface that can be safely placed in contact with the viscera, while the peritoneal mesothelial cells grow on the surface of the mesh.

Composite structures consisting of 2 layers welded through the thermo-adhesive membrane (Fig. 1). Layer I – consists of textile structures made of PA, PP made on a knitting machine of the Jaquard RJSC type and characterized by : mass - 39-107g/m2 , breaking strength - 107,96-198,89 N in a horizontal direction and 202,24-250,5 N in a vertical direction, thickness: 0,46-0,64 mm, burst resistance-189,3-270,4 kPa, burst deformation-29,5-33.1mm, contraction-1,9-3,1 %, modulus of elasticity-0,51-10,9 MPa, horizontal direction and 3,73-33,69 MPa vertical direction, anisotropy-0,156-0,475. Layer II — non-woven fabrics made by PLA spun-bonding technology with a mass of 20g/m2. Thermo-adhesive membrane based on EVA (Ethylene-vinyl acetate) with a mass of 20 g/m2.

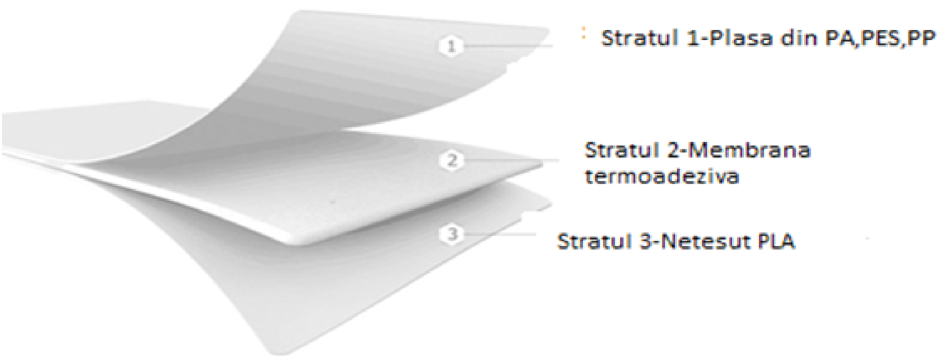

Fig. 1. Composite structures

Thermo welding was carried out on Presse Adesivatrici GMP Giemmepi equipment for which the following working parameters were used: T = 100°C, pressure = 1,4 bar, feed rate: 5,6 m/min.

RESULTS AND CONCLUSIONS

The physical-mechanical characterization of the composite structures highlights the following aspects: mass - 88,0 to 127,0 g/m2 places them in the category of high-mass mesh (>60 g/m2); breaking strength: 84,0-202.31N in the horizontal direction and 171,11-254,52 N in the vertical direction, thickness: 0,49-0,69mm, deformation resistance 213,1-273,7kPa, deformation-21,31-27,37mm, Young's modulus-18,31-64,94 MPa (horizontal direction) and 10,72-64.94MPa (vertical direction), values that place them in the category of meshes with high modulus of elasticity (>10,95MPa, specific to abdominal fascia), which ensures a strong mechanical reinforcement of the abdominal wall, anisotropy: has very good values: 0.05-0.78. The PA- and PLA-containing composite is hydrophilic and the PP- and PLA-containing composite has contact angle values <100 degrees. The pH value has been determined following SR EN 1903071/2006 using distilled water with pH = 6,922 at a temperature of 27,4° and is within the range of 6,53-6,94.

The analysis of SEM images highlights the existence of active substances on the surface of composite structures in the form of agglomerations with various dimensions or discontinuous membrane (Fig.2). Elemental composition analysis (EDAX) shows the presence of elements like carbon (57-82%), oxygen -11%, and silicon-39%.

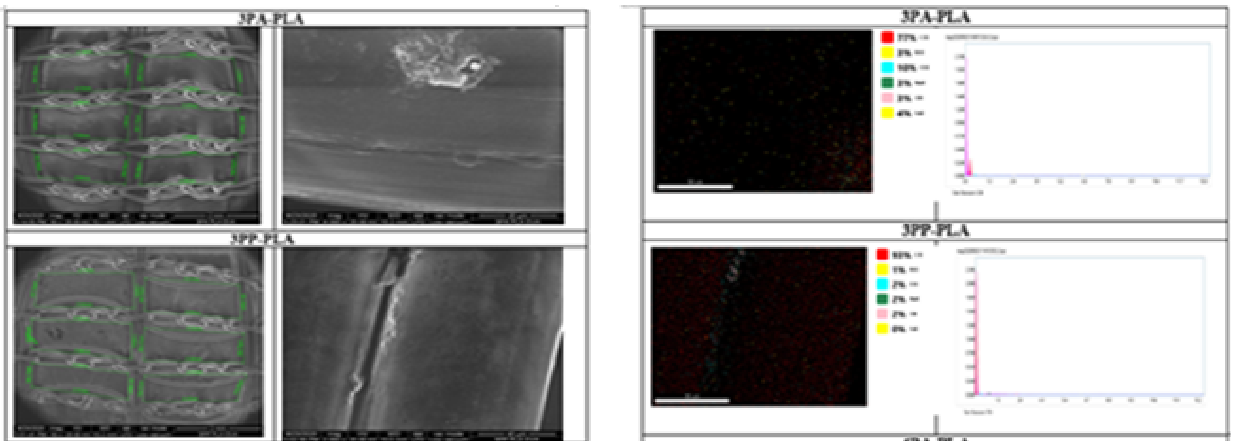

Fig 2 IMAGES SEM and EDAX

The biocompatibility expressed by the MTT and LDH presents good values for both structures. The complex characterization of the composite structures made by heat welding showed that they have properties appropriate to the field of use. The selection will be made after determining the biological characteristics (cytotoxicity, genotoxicity, sensitivity, etc.).

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by the Ministry of Education and Research, Bucharest, Romania, under Program **European and International Cooperation –sub-program 3.2- Horizon 2020, project type ERANET, title: Advanced textiles for parietal defects, PariTex**

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FEASIBILITY STUDY TO WASTE INCORPORATION FROM THE WEAVING INDUSTRY FOR OUTSOLES COMPOSITES

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ABSTRACT

The higher amount of solid waste of textile industries is mainly derived from woven fabrication and cutting stage, these processes generate some residues: bristles (spinning waste), bushings (yarn waste from weaving) and flaps (cutting process). This research focused on added value to solid waste from weaving production to this end, the work aimed to develop textile-polymer composites in a formulation ready to use, applied to footwear outsole. Results pointed out the mechanical properties decay in comparison with neat matrix, even so, briquette have the highest potential for application and aesthetic aspect should be considered.

INTRODUCTION

Solid waste management is carried out in accordance with the legal regulations from countries. Textile industry requires more planning and involvement from creation department to avoid the residues generation and correctly dispose. Each produced fabric, 15-20% of solid waste is generated, however this problem is not attributed by manufacturing companies, due to the cost is diluted in comparison with final price of clothes (Rissanen, 2013).

Poly (vinyl chloride) (PVC) is a plastic commodity, widely employed in the industry, due to the great versatility of formulation; mechanical properties, such as abrasion resistance and, low price (Wu, 2016). Study about flexible PVC composite is usually applied to developing thin films to food package (Thitiwongsawet, 2017) while laminated fabric waste reused and inserted as load to PVC composites in a footwear sole formulation and it demonstrated application potential (Dreger, 2018). In this research, cotton yarns and fabrics residues were received and cut to better dispersing into matrix, after the samples were processed with PVC formulation into two roll machine, until the completely plasticizing and preliminary mechanical test were carry out.

RESULTS AND CONCLUSIONS

In this work, mechanical properties (tensile strength, Young's modulus and elongation at break) were evaluated and measured the hardness Shore A of PVC/textile waste composites Untreated textile waste was incorporated into 2.5 and 5.0 wt % in PVC compound. The mixing was carried out in a two-roll mill at 150 and 160 °C and subsequently compressed in an electrically heated hydraulic compress at 150 bars at 150 °C for 3 min. The samples were cut according to the ASTM D412 for the mechanical tests. Fig. 1 shows the PVC/textile waste composites sheets produced.

and coffee (IBGE, 2020). The latest IPEA Organic Waste Report reveals that only sugarcane produces 201,418,487 million/ton of waste, followed by soybean (41,862,129), corn (29,432,678), orange (8,825,276), wheat (3,033,315) and rice (2,530,355) (IPEA, 2012). It is possible to observe a high incidence of these terms in network analysis (Fig 1).

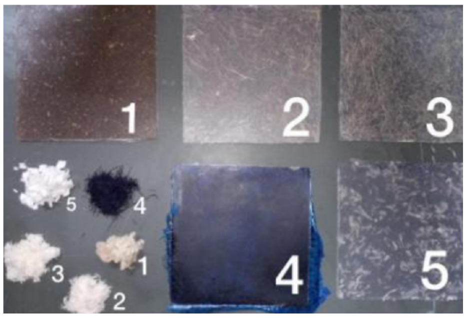

Fig.1 Composite board with textile waste and textile waste.
(1) Briquette waste, (2) Selvedge waste, (3) Starch waste, (4) Waste jeans with indigo tiger and
(5) Textile waste in use for over ten years in a domestic environment.

The composites showed a decrease in the elongation and tensile values and an increase in the Young's modulus values. The addition of the textile waste into the PVC did not display a significant change on the hardness Shore A. Except the domestic waste, all composites with 2.5 wt% of textile waste may have suitable applicability in the footwear industry (Table 1).

	Maximum Load (N)	Tensile Stress at Maximum Load (MPa)	Tensile Strain at Break (%)	Young`s Modulus (MPa)	Hardness (Shore A)
PVC neat	145.90±9.68	7.02±0.29	389.67±35.20	3.67±0.36	63.00±0.71
PVC2.5 Briquette	101.66 ±10.42	5.32±0.66	233.15±42.92	4.42±0.78	62.86±1.95
PVC5 Briquette	84.52±18.03	4.11±0.89	192.30±46.83	4.33±0.39	66.43±2.64
PVC2.5 Starched Raw	84.19±4.41	4.48±0.12	209.50±26.33	5.19±0.42	64.00±2.31
PVC5 Starched Raw	80.54±6.27	4.11±0.34	161.19±19.45	7.64±1.52	69.14±6.52
PVC2.5 Selvedge	106.35±10.13	5.07±0.68	193.30±26.23	6.66±2.00	59.29±2.98
PVC5 Selvedge	80.54±6.27	4.11±0.34	161.19±19.45	7.64±1.52	68.14±2.85
PVC2.5 Starched Indian	102.09±6.19	4.64±0.35	213.94±24.53	4.91±0.63	62.71±2.98
PVC5 Starched Indian	87.12±7.66	4.25±0.26	180.64±26.04	7.39±1.56	66.00±4.24
PVC2.5 Domestic	89.57±7.26	3.91±0.39	175.25±25.36	4.49±1.12	61.86±3.39
PVC5 Domestic	79.21±8.22	3.73±0.39	185.57±25.68	4.54±0.68	64.71±4.92

Table 1 Mechanical properties of PVC/textile waste composites.

This study shows that there are substantial differences on the mechanical properties using differently types of fibers from the textile industry. Further tests should be performed in order to analyze other mechanical properties suitable for footwear applications.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by FAPEMIG, CAPES and CEDRO Textile.

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DEFECT AND VARIABILITY REDUCTION IN NATURAL FIBERS FOR STRUCTURAL COMPOSITE APPLICATIONS

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ABSTRACT

This research aims to improve natural fiber quality and reduce variability in mechanical properties by elucidating the cause and eliminating the fiber damage occurring through various steps in natural fiber extraction process. In this regard, various conditions of enzymatic retting and subsequent fracturing of the retted flax stems under compression between the rollers of a lab scale flax decorticator has been investigated with the aim to generate a mechanical model for the stem and to optimize roller design.

INTRODUCTION

Natural plant fibers in addition to being low cost and lightweight, offer a renewable and carbon negative resource for reinforcement in polymer composites (Wambua, 2003). About 3 ton of CO2 per ton of composite can be sequestered with the substitution of glass fibers with hemp fibers in polymer composite (Pervaiz, 2003). However, compared to synthetic fibers, natural fiber shows high variability in mechanical properties such as tensile strength and stiffness (Baley, 2020), making them less favorable for structural composite applications at industrial scale.

Studies show that the currently used commercial flax fiber extraction process significantly degrades the natural fiber quality and causes a large number of defects like kink bands leading to high variability in mechanical properties (Zeng, 2015). This is a mechanized version of a traditional process being used for hundreds of years, originally designed for textile use of these fibers and has not been optimized for production of high-quality natural fibers for composite application. The paper proposed to evaluate the fiber damage occurring during current extraction processes and optimize the extraction process to minimize this damage. An experimental set-up was created to reproduce the fracture events during compression of a single retted flax stem while rolling between the flat rollers of a commercial extraction equipment. Samples taken from the middle of a single flax stem were compressed between the two plates of a Texture Analyzer with 30kg (~295N) load cell capacity to a maximum force of 8kg (~78.5N). Trigger force of 30g (~0.3N) and a slow test speed of 0.05mm/sec was chosen to monitor the fracture events through recording high quality video using a camcorder.

RESULTS AND CONCLUSIONS

The force- compression curves for single compression-decompression cycle of flax stem samples with (S1) and without bast-fibers (X1) are compared in Figure 1a. Within region 1, both stem samples follow a similar force-compression profile, but S1 exhibits higher stiffness and breaking force than X1. Figure 1b shows events which correspond with various points in Figure 1a. Initial fracturing of the woody core (xylem) occurs in region I during events 2 & 3 and event 4 onwards compression of the fractured plant structure occurs in region II, where minor fracture events maybe observed (Figure 1b). The results are comparable to those experienced from our lab scale rolling decorticator.

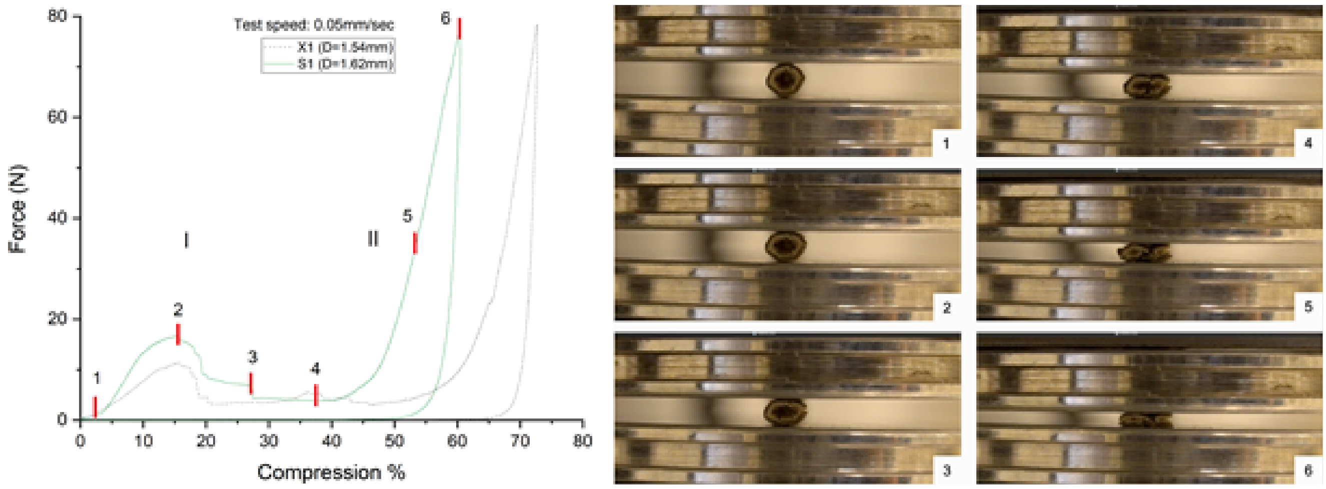

Figure 1 (a) Comparison of force-compression profile for stem without bast fibers (woody core only, X1) and with bast fibers (S1) under compression cycle (b) Visual observation of events occurring at various points during compression

Future work will evaluate the fracture modes and flexural properties of flax stems and the material parameters from both compression and flexural tests will be used to develop a mechanical model of the stem. We believe translating the single stem model to a bundle of stems will help determine the optimal process conditions required to extract fibers with minimal damage and variability.

ACKNOWLEDGMENTS

The authors acknowledge the financial and technical support from the University of Michigan College of Engineering, MSE Van Vlack Laboratory and Ford Motor Company Research & Advanced Engineering for this work.

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UTILIZATION OF DECORTICATED FIQUE FIBRES FROM COLOMBIA IN SPECIALTY PAPER PRODUCTS

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ABSTRACT

This work evaluates the paper making potentials of decorticated fique fibers from Colombia. Fique fibers were cooked using Soda and Soda-AQ pulping process and fully bleached using three stage elemental chlorine free (ECF) bleaching sequence. Morphological and physical properties of fique pulp were compared against abaca and sisal pulp obtained through similar pulping and bleaching operations. Fique fibers have shorter fiber length and lower mechanical strength than abaca but longer fiber length and higher mechanical strength than sisal. However, average fiber width of fique is higher than average fiber width of abaca and sisal which can adversely affect the permeability of paper.

INTRODUCTION

Long and thin fibers of abaca are the raw material of choice in several specialty paper products such as tea bag, coffee filter, sausage casing, plug wraps in cigarette. However, market prices of abaca fiber have risen sharply over the years due to strong demand from the specialty paper and currently trade at all time high of USD 2500 / ton (FAO, 2019). Confronted with high demand and limited supply of abaca fibers, specialty paper manufacturers have used other well-known long length cellulosic fibers such as sisal, jute, hemp, softwood etc., but generally at the detriment of desired properties in the final paper products(Hurter, 2001). Further, high fluctuations in market prices and production of alternative fibers present huge challenge to the industry in managing their supply chain of raw materials. Fique fibers are extracted from the leaves of fique plant and grown in countries such as Colombia, Venezuela, and Ecuador. Although, previous research have shown fique fibers having similar chemical and morphological properties as other leaf based fibers such as Abaca and Sisal, traditional usage of fique fibers mainly include low value products such as making coffee sacks, ropes, bags, and handcrafts(Ovalle-Serrano et al., 2018). Developing fique fibers as raw materials for specialty papers will not only provide cost saving opportunities in the formulation of furnish but also open new revenue streams for millions of small indigenous farmers in the producing countries.

Decorticated fique, abaca, and sisal fibers were cooked in a tumbling bomb digester using Soda and Soda-AQ pulping process. Obtained pulps were characterized in terms of yield, kappa number and pulp viscosity. Soda and Soda-AQ cooked pulps were bleached using (D0-Ep-D1) bleaching sequence to achieve ISO brightness over 85%. Handsheets of basis weight 40 g/m2 were prepared using bleached and unbleached pulps at different PFI refining levels following Tappi standard TAPPI T205 sp-02 (2006). A fiber quality analyzer (FQA – OpTest Equipment Inc.) was used to measure the morphological properties such as fiber length, width, coarseness, and fines content. Tensile strength, tear strength, zero span tensile strength and air permeability of handsheets made with fique pulp were measured and values were compared against that of abaca and sisal pulp.

RESULTS AND CONCLUSIONS

Table 1 shows the morphological properties and figure 1 shows the tear strength of paper. Comparing properties of fique pulp against two high value specialty pulp shows that fique has shorter fiber length and lower tear strength than abaca but longer fiber length and higher tear strength than sisal pulp. However, fiber diameter of fique was higher than both abaca and sisal which can adversely affect the permeability of paper.

Properties	Fique	Abaca	Sisal
Length weighted fines (%) (0.025 - 0.2 mm)	0.5	2.7	0.4
Mean fiber length (mm) (> 0.2 mm)	2.0	2.7	1.9
Length weighted average fiber length (mm) (> 0.2 mm)	2.7	3.8	2.4
Fiber width (µm) (W = 7...60 µm)	26.0	19.9	19.5

Table 1 comparison of morphological properties

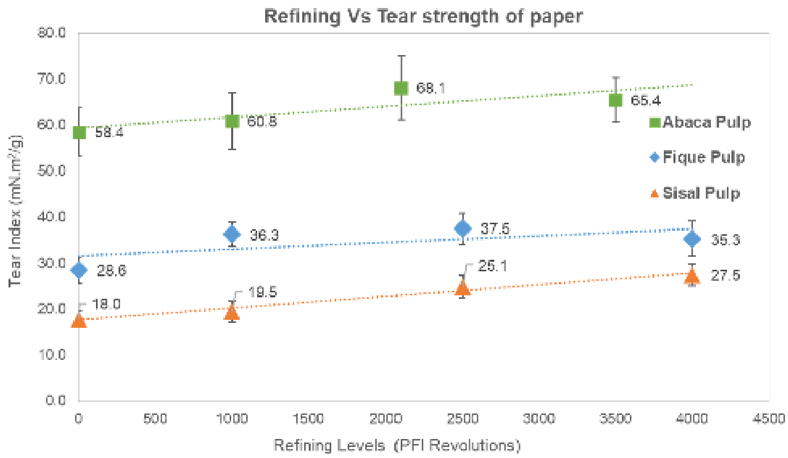

Fig.1 Tear strength of pulps at different refining levels

Results from this study shows that decorticated fique fibers from the Colombia can be utilized in specialty paper applications as a cost-effective raw material. Further characterizations are required to analyze air permeability of the paper which is another property equally important for specialty paper products such as tea bags, coffee filters, sausage casing and plug wraps.

ACKNOWLEDGMENTS

The authors acknowledge the funding by Compania de Empaques, Antioquia, Colombia to support this research efforts.

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MECHANICAL AND ACOUSTIC PERFORMANCE OF PLANTAIN (musa paradisiacal) FIBRE REINFORCED EPOXY BIO-COMPOSITE

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ABSTRACT

Natural fibre reinforced polymer bio-composites are becoming attractive materials for ` structural applications owing to their mechanical and acoustic properties. Research has projected that they could possibly replace synthetic fibre reinforced composites due to their low influence on human health and environmental friendliness. Though, researches have been devoted to studying their mechanical properties, with little emphasis on quantifying the sound diminution behaviours. This research is aims to examine the void content, impact, hardness and acoustic properties of plantain (Musa paradisiacal) fibre reinforced bio-composites (PFB). Biocomposite with 5, 10, 15 and 20 (Wt. %) fibre content were fabricated. Impact, hardness and void content increases as fibre content increases. The sound absorption coefficient shows improvement. Results suggest that of plantain (Musa paradisiacal) fibre reinforced bio-composites could be less costly, feasible and ecologically superior alternatives to synthetic fibre composites for acoustic applications in areas like building architecture and automotive industries.

INTRODUCTION

Sound absorber is referred to the technique of the absorbing sound being in to the material. It can be classified into three types of sound absorbers, which are rigid absorbers, surface absorbers and Helmholtz resonators (Ismail, et al 2019). Asbestos was the initial substance to be used as sound insulating or sound proofing material. Asbestos is also known to be fibrous materials that are not readily burnt and corroded. It is readily deformed with other constituents and is widely regarded as a good electrical insulator. A microscope particles emitted from asbestos content creates health challenges when inhaled over a period of time and this particles will cause small growth deformation which is called cancer (Bernstein, et al 2005). This health considerations, has limited the application of asbestos in acoustic applications. Fibre reinforced composite have vast properties like acoustic, dielectric, thermal, impact etc. which makes them more fascinating in different industries, economical and development of any country. Synthetic fibre have been known to have Similar behavior, characteristics and dangerous properties as asbestos content, especially synthetic fibre inhalation, can cause lung damage and growth development called cancer (Wei-Chung, et al 2009). Natural fibre are commonly being used as replacement for synthetic and wood-based fibres materials for acoustic absorption applications

Recently researcher has begun investigations into natural fibres reinforced bio-composite for acoustic application as sound absorption materials. Researchers like, Ersoy and Küçük (2009) reported, that tea leaf fibres composites has better acoustic properties than polyester and polypropylene composites nonwoven fibres. Whereas Zulkifli et al. (2008) studied the acoustic properties of multi-layer coir fibres and establish that the sound absorption coefficients were equal to commonly produced rock wool and synthetic fibres (Zulkifli, et al 2008). Also, Yang, et al (2003) reported that composite boards made from rice straw/wood particle have acoustic properties better than other wood-based materials. Yang et al. (2004) also reported similar result with rice straws and wood particles board composite. He however, noted that in the 500 Hz to 8000 Hz frequency range, rice straw composite boards have better sound absorption properties compared to fibre board, particleboard and plywood composite. This study, analyzed the mechanical and acoustic performance of plantain (Musa paradisiacal) fibre reinforced epoxy bio-composite (PFB).

RESULTS AND CONCLUSIONS

Impact and Hardness Behaviour

The PFB impact strength is described in Fig. 1, as the resistance presented during the application of high speed stress. As revealed in Fig. 1, the increase in impact strength was observed as fiber contents increases, which can be attributed to the reinforcing influence of plantain fiber on the matrix phase as we previously reported (Imoisili et al 2020).

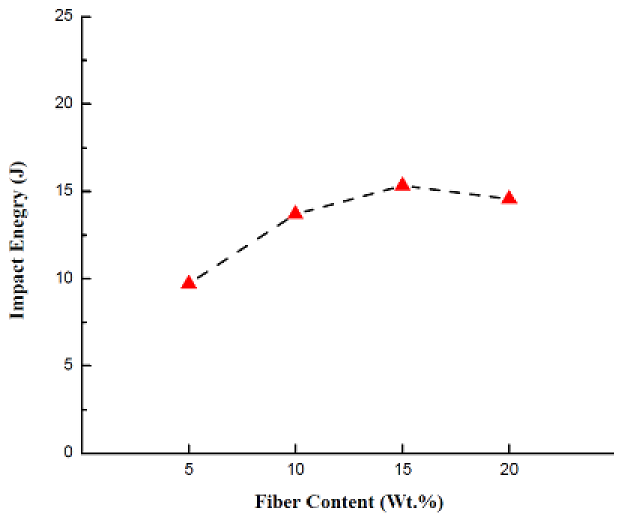

Fig. 1 Effect of fiber content on Impact Strength of bio-composite

Hardness behaviour of PFB are presented in Fig 2 is an average Vickers hardness of ten measurements for every sample. It can be understood that increase of the Plantain Fiber in the bio-composite resulted in improvement up to 28%. This upsurge of the composite hardness is a consequence of the stiffing influence of the fiber on the polymer matrix (Mohan and Rajmohan 2017).

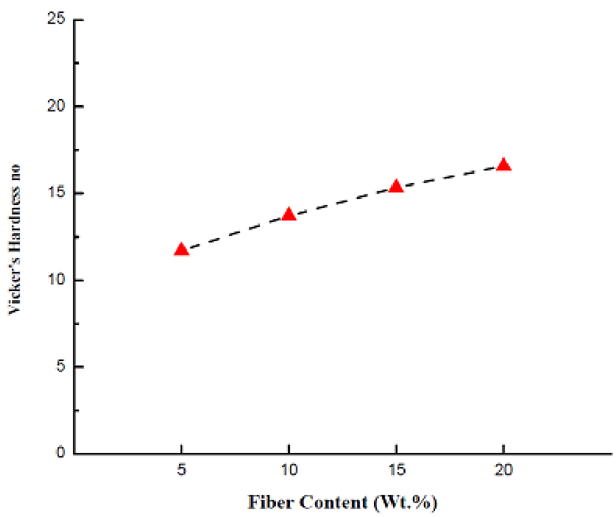

Fig. 2 Effect of fiber content on hardness of bio-composite

SEM Morphology of Fractured Bio-composite Samples

Firmly crammed bonding at the interface of fibre/matrix as shown in Fig 3, was responsible for the improved impact strength of the bio-composites as few fibre pull out was observed. These observations further underscore the prominence of fibre/matrix adhesion on the mechanical property of reinforced polymer composite. The presence of voids was observed on the fracture surface, with rough fibres surface which effortlessly traps air and this feature tends to increase sound absorption properties of the bio-composite.

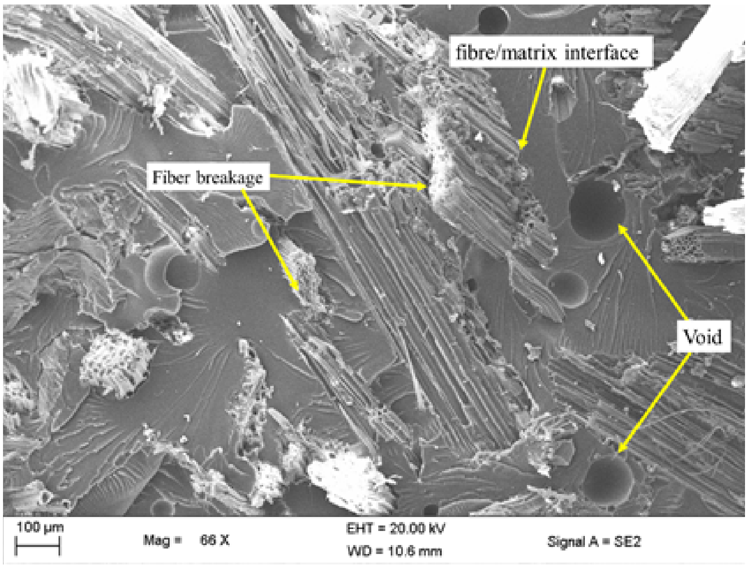

Fig. 3 SEM micrograph of fracture surface of bio-composite sample

Void Content.

PFB void content is shown in Table 2. Highest volume of void material (6.57%) was observed in sample BC4, while the lowermost volume of void (2.37%) was in sample BC1. The existence of void content is due to the inefficiency of the polymeric phase to dislodge trapped air within the bio-composites and presence of moisture during fabrication (Imoisili et al 2018). Besides that, incomplete wetting of fibres by the matrix is also responsible for void increase in the bio-composite (Yahaya et al 2015; Ismail, et al 2019). The increases in void content will results in reduce mechanical properties of composites (Imoisili et al 2020).

Table 2 Void content of biocomposite

Sample	Void content (%)
BC1	2.37
BC2	3.63
BC3	4.21
BC4	6.57

Acoustic Properties

The sound absorption coefficients of PFB are illustrated in Figure 3. Markiewicz, et al. (2012), define sound absorption as the ratio of the acoustical wave energy that is absorbed by the composites to the total energy incident to the sample. Research has indicated that for natural fibre polymer composites, sound absorption coefficient increase with frequency (Albuquerque et al 2000). It was observed form Fig 3, that as fibre content increases, there was a corresponding intensification in sound absorption coefficient. At higher fibre content, the plantain fibres were further compressed inside the epoxy matrix thus causes the size and volume of the air void fractions to reduce within the composites, resulting in a reduction in sound coefficient. The fluctuating behavior at 2000 - 4000 Hz might be due to the specific characteristic of natural fibres reinforced composite that tends to absorb and reflect sound at that frequency (Markiewicz, et al. 2012). Another aspect that could affect the variability was the different size of the fibre width, the irregular texture and the crumpled nature of the plantain fibre. Generally, it was found that PFB of 15 wt. percent appears to higher sound coefficient than other composites.

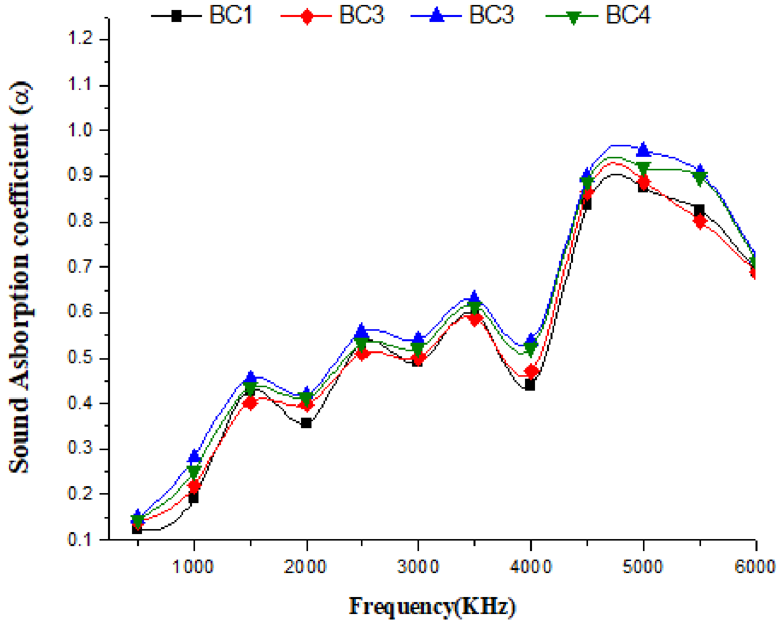

Fig.4 Sound coefficient of PFB at different fibre content (wt. %)

The study shows that the impact, hardness and void content of PFB increases as fibre content increases. However, for sound absorption coefficient it was observed that there was increase as fibre content increases from 5 wt% to 15 wt% and reduces at 20wt %. Surface morphology by SEM shows fibre breakage, the rigid nature of the plantain fibre/matrix and the dispersal of the fibres in the polymer matrix. These structures and the fibre dispersion are believed to be the main causes for the improved sound absorption. The fabricated PFB shows excellent acoustic properties and potentials as an environmentally safe and sustainable product that can be used as sound absorbing material for both building architecture and automotive industries.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support from URC of University of Johannesburg, and NRF of South Africa

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DEVELOPMENT AND CHARACTERISATION OF FLEXIBLE AND WEARABLE STRAIN SENSING FABRICS FOR COMPOSITE APPLICATIONS

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ABSTRACT
This study presents a fabrication of 2D twill weave natural sisal fabrics including sensor yarns in the weft and warp directions. The resulting samples are characterized in terms of sensitivity, dynamic durability and reliability with a cyclic loading-unloading to evaluate a real-time monitoring of sisal yarns inside the fabrics. Knowledge on the behavior of the sensor yarns allow to evaluate the local mechanical behaviors of sisal natural fibers inside the fabrics. These fabrics were used as reinforcement for green composite application.

INTRODUCTION
The "green composites" are in the advancement processing technology and the increasing environmental security, which replace some existing components made with oil dependent resource by natural fibres to become the 3rd generation of composite material [1]. These materials are often based on natural reinforcement fibrous fabrics (2D and 3D) [2]. However, a lack of knowledge concerning the use of natural fibres as fibrous reinforcement can reduce and limit their use in some areas, where the high performance is required, due to the ageing, fatigue behavior and their failure mode inside the structural composite materials or during the weaving process of the fibrous reinforcement. Then, to go beyond these limits, fibrous reinforcement must have been more investigated with additional research works. One of the possible ways is the monitoring of the structure by inclusion of devices as strain gauge transcription of physical deformations to electrical signals [3], electronic components, etc., Among the strain gauges (or strain sensors), intelligent fibrous components can be an interesting devices to evaluate mechanical strain due to its relative resistance changes ($\Delta R/R0$) measurement during its deformation inside the composite applications.

RESULTS AND CONCLUSIONS
The initial sisal yarn was dipped into a PVA solution. Then, the resulting PVA-coated sisal core yarn sample was ligated by two copper connector wires and spaced for d=30 mm. These connectors were used as electrodes for electrical conductivity and electromechanical test. In order to make a good contact between substrate specimens and electrodes, the end of sample was coated with PEDOT:PSS layers and then dried after every PEDOT:PSS cycle layer. This strain sensor yarn is characterized in terms of the electromechanical properties before its integration into the fabric structures. The 2D twill fabric including strain sensor yarn are produced as shown in Fig.1. The mechanical properties of fabric samples were investigated simultaneously with the electrical responses of the sensor yarns. As shown in Fig. 2-a, mechanical stretching curves are plotted. Then, the electromechanical properties of the yarn strain sensors are eval-

uated. The linearity of these sensors is measured to determine the sensitivity of these sensors inside the fabrics (Fig. 2-b), by computing the gauge factor (K) as:

$\Delta R/R0 = K*\varepsilon$, where the $\Delta R/R0$ is the relative resistance changes and ε the relative elongation.

It was found a Gauge Factor values K□2.636 and K□4.750 for the sensor alone and the sensor inserted inside the fabrics, respectively between 0%-4% strain. The sensor yarn inserted into the fabric shows a high sensitivity, suggest that the sisal yarn inside the fabrics is mechanically affected by the weaving process.

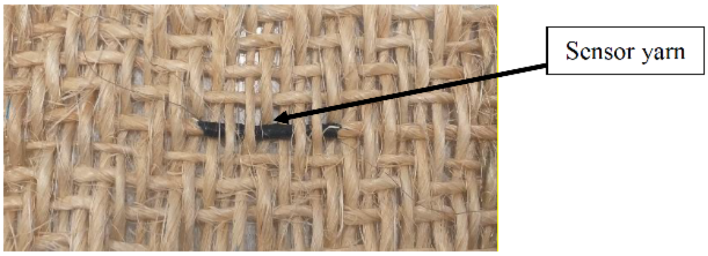

Fig. 1: Yarn strain sensor inserted inside the 2D fabrics

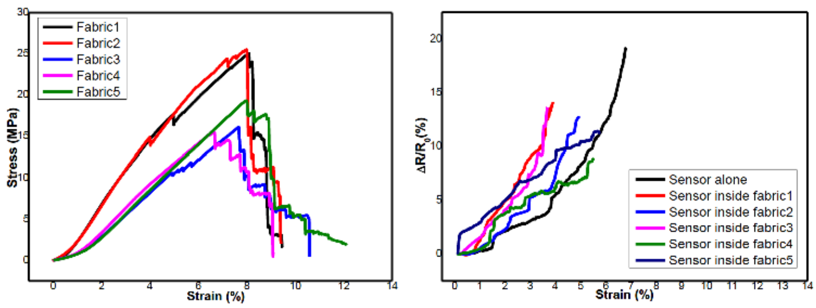

Fig.1: Curves of (a) mechanical stretch of fabrics and (b) electro-mechanical response of sensor yarns inside the fabrics

The intelligent fibrous components developed by the inclusion of strain sensor yarns can be an interesting devices to evaluate mechanical strain due to its relative resistance changes ($\Delta R/R0$) measurement during its deformation inside the composite applications.

ACKNOWLEDGMENTS

We would like to thank PHC Toubkal/19/83 - Campus France: 41511ZF and CNRST Maroc agencies for financial support to conduct this research work.

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ANALYSIS OF SORGHUM STALK FIBRES FOR USE IN THE PRODUCTION OF LOW-COST HOUSING BRICKS

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ABSTRACT
Research into low-cost housing solutions, especially for low and middle income countries, has grown in recent years. Greater use of natural materials, both mineral and bio-based, offers opportunities for more affordable and sustainable materials and products. In this study, fibres extracted from sorghum stalks were investigated as potential additives in low-cost brick production. Analysis of the sorghum fibres included microstructural examination and tensile strength testing. Sorghum stalk fibres were shown to be a promising natural fibre for further studies due to their comparable tensile strength to fibres currently used in housing bricks.

INTRODUCTION
Synthetic and natural fibres are widely used in composite construction products to enhance mechanical properties. Natural fibres can offer low cost solutions for a variety of applications but are also more prone to decay (Ismojo et al., 2017). Stalks from sorghum, one of the most cultivated cereal crops in Africa, is considered a waste material. Fibres can be extracted by peeling them off the inner layer of a sorghum stalk, however these fibres are short, as they are interrupted by the internodes along the stalk. The aim of this abstract is to present and analyse the results of the preliminary tests conducted on sorghum stalk fibres to use in the production low-cost soil bricks.

METHODOLOGY
A total of 30 individual sorghum fibres were tested to determine tensile strength. Fibre diameters were measured using an optical microscope along with the length of the internodes. Tensile test was performed on a gauge length of 20 mm at a speed of 0.2 mm/min at room temperature. In addition, the porosity of the fibres was determined by the use of mercury inclusion porosimetry (MIP). Furthermore, morphology was examined under a scanning electron microscope (SEM).

RESULTS AND CONCLUSIONS
Straight fibre lengths were between 300-500 mm with fibre diameters varying from 190-350 μm. Fibre internode length varied between 0.2 and 0.5 mm. A cross-sectional view of a single sorghum fibre is shown in Fig. 1a and consists of multiple microtubes of sizes ranging between 5 and 15 μm that form a honeycomb-like frame around three larger sized cells. The diameter of the larger cells ranged between 90 to 100 μm, while the smaller tubes were around 35 μm. Smaller pores (Fig. 1b) were observed on the side of the fibre and ranged between 0.7 to 2 μm. Smaller pore sizes investigated by MIP showed pores as small as 0.1 μm. This porous structure contributes to the high water absorbency of the fibres. Pre-treatment of the fibres before use was adopted, a process in which fibres were submerged in water for 24 hours after extraction, and then the surfaces were cleaned, by gentle brushing, to remove materials such as wax shown in Fig 1 c.
The tensile stress-strain curve of a typical fibre, is shown in Fig 2. Stress-strain responses were found to be

linear initially followed by a nonlinear phase with decreasing stiffness until fracture. Failure at maximum load was brittle. These results are consistent with past literature (Kim & Netravali, 2010) where a brittle failure is anticipated, while the elongation in sorghum fibres was lower than other recorded natural fibres.

The individual fibre tensile strengths varied from 24 MPa - 167 MPa, with a mean of 44 MPa and a standard deviation of 26 MPa. Despite the low and variable tensile strength of the sorghum fibres under study, in comparison to literature (Akubueze et al., 2019; Kumar et al., 2019), they have potential for reinforcement in low strength bricks for us in low-cost housing ; Salih et al (2020) found that fibres with much lower tensile strength (<16 MPa) were suitable to produce soil bricks with compressive strength higher than 2 MPa. Treating the fibres with sodium hydroxide is the next step in the research, as it is expected to improve other natural fibres' properties (Kim & Netravali, 2010; Meon et al., 2012). Further tests are also planned to understand the sorghum fibre behaviour in a soil clay matrix.

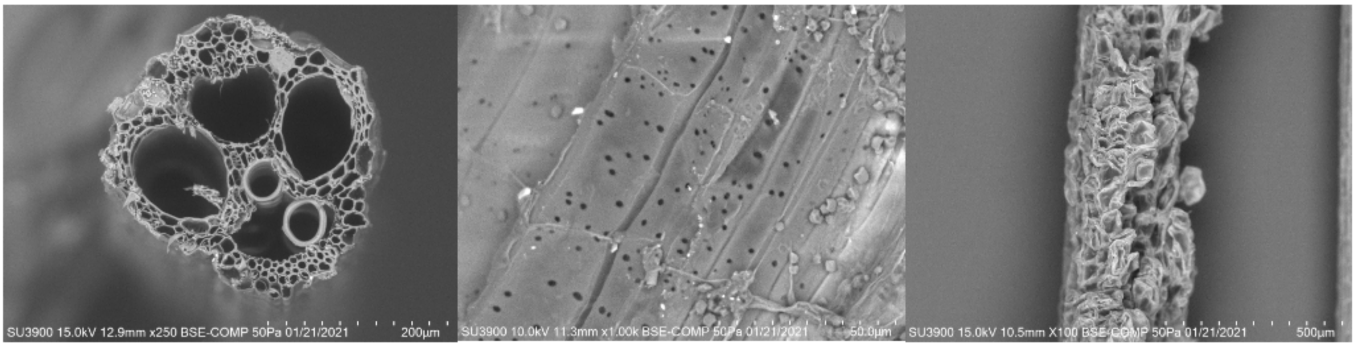

Fig 1 SEM image of a single sorghum fibre: a) Cross section b) side c) wax on surface of the fibre

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by the Schulmberger foundation's Faculty for the Future fellowship and the help of all the technical staff at the University of Bath.

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A STUDY ON THE PROPERTIES OF PLANTAIN PSEUDO-STEM FIBRES, PLANTAIN BUNCH FIBRES AND RICE HUSK FOR CONSTRUCTION APPLICATION

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ABSTRACT
In the past decade, the substitution of conventional composite materials with natural fibres such as agricultural by-products have become common in production of sustainable construction materials. The purpose of this study is to assess the properties of plantain pseudo-stem fibres, plantain bunch fibres and rice husk as source of reinforcing elements for composite materials especially for construction application. Experiments conducted revealed that the fibres and the husk have different lengths and diameter, and their surface texture was rough which is likely to improve bond with matrix. It was also found that the specific weight, water absorption, tensile strength and stress-strain properties of the fibres and the rice husk are within acceptable parameters for natural fibre application. The study therefore concludes that the plantain pseudo-stem fibres, plantain bunch fibres and rice husk possess properties that are suitable for use as reinforcement in composite materials for construction application.

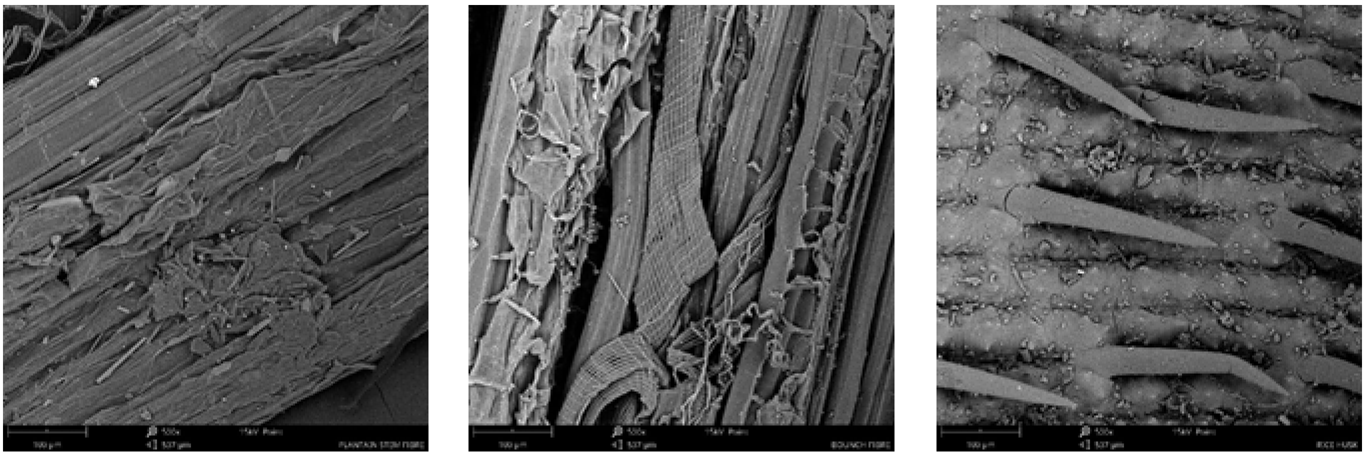
INTRODUCTION
The use of conventional building materials such as cement and steel rods has globally contributed to environmental issues, resulting in increased greenhouse gas emission due to the release of CO2 in the atmosphere. Some of the materials can be substituted with natural fibres especially in composite. According to Bonnet-Masimbert et al. (2020), a number of studies used natural fibres such as bagasse, hemp, coir, flax and pineapple as reinforcement and have shown a great potential as building material. The use of natural fibres as building material also helps in reducing the energy footprint of buildings thereby contributing to sustainable construction application. Recent advances in the application of natural fibres as reinforcement in composite materials are applicable in aerospace parts, automotive components, sporting equipment and building construction (Ighalo et al., 2020).

A number of natural fibres properties have been investigated, including oil palm, coconut, bagasse, raffia fiber, cassava, ambarella, Cocos Nucifera and oil palm broom fibres (Danso, 2017; Stanislasa et al., 2020; Prakash & Kavitha, 2020; Danso et al., 2017; Momoh et al., 2020). However, there are other natural fibres that have potential for composite materials such as plantain pseudo-stem, plantain bunch and rice husk which their properties have not yet be investigated. This study, therefore, seeks to assess the properties of plantain pseudo-stem fibres, plantain bunch fibres and rice husk as source of reinforcing elements for composite materials especially for construction application.

The fibres and husk used in this study are plantain pseudo-stem fibres, plantain bunch fibres and rice husk. These fibres were sourced from different locations in Ghana. The properties of the fibres and the husk were determined through laboratory experimental testing. The various analysis and tests conducted on the fibres and the husk are scanning electron microscope (SEM) analysis, energy dispersive spectrometer (EDS) analysis, length and diameter test, specific weight test, water absorption test and tensile strength test.

RESULTS AND CONCLUSIONS

The result obtained from the SEM analysis is shown in the Fig. 1, and their surface texture was rough which is likely to improve bond with matrix. The physical and mechanical properties of the fibres and the husk are presented in the Table 1. The plantain pseudo-stem fibres were characterized as long lengths because the fibres can take the entire height of the plantain tree which can grow even beyond 4m. The mean lengths of the plantain bunch fibres and the rice husk were 391.33 and 8.94mm respectively. The fibres and the husk recorded mean specific weight of 0.35, 0.48 and 0.67g/cm3 respectively for plantain pseudo-stem fibres, plantain bunch and rice husk. The difference between the specific weight of the fibres and the husk was found to be positive and significant (t=5.381 and p=0.016). The result shows mean absorption rate of 245, 174 and 58% respectively for plantain pseudo-stem fibres, plantain bunch fibres and rice husk, with t-test result of t=2.917 and p=0.048 suggesting that the difference between them are positive and significant. The mean tensile strengths recorded are 59.9, 77.1 and 101.6N/mm2 respectively for plantain pseudo-stem fibres, plantain bunch fibres and rice husk, and the difference between them are positive and significant (t=6.574 and p=0.022). it was also observed that the plantain bunch fibres had the highest strain, followed by the plantain pseudo-stem fibres, while the rice husk had the least strain. The study therefore concludes that the plantain pseudo-stem fibres, plantain bunch fibres and rice husk possess properties that are suitable for use as reinforcement in composite materials for construction application.



(a) Plantain pseudo-stem (b) Plantain bunch (c) Rice husk

Fig. 1. SEM images of the fibres and the husk

Table 1: Properties of fibres and husk

Fibre/husk	Length (mm)	Diameter (mm)	Specific weight (g/cm^3)	Water absorption (%)	Tensile strength (N/mm^2)
Plantain pseudo-stem	Long	0.65 ±0.36	0.35±0.043	245 ±37.03	59.9 ±10.62
Plantain bunch	391.33 ±80.8	0.52 ±0.21	0.48±0.051	174 ±29.38	77.1 ±12.76
Rice husk	8.94 ±0.9	1.90 ±0.44	0.67 ±0.089	58 ±6.12	101.6 ±20.02
t-value	-	2.326	5.381	2.917	6.574
p-value	-	0.0128	0.016	0.048	0.022

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BEHAVIOR IMPROVEMENT OF CONCRETE GEOPOLYMERS USING WET PRESERVATION HEMP

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ABSTRACT

This paper evaluates a geopolymer concrete with hemp fibres as natural aggregates prepared with an inorganic binder. The hemp tested was used in two states of conservation: 1) fresh and 2) preserved in moist conditions for six months. The results show different behaviour between them. It is highlighted that wet preservation hemp samples increased their mechanical properties.

INTRODUCTION

The use of technologies based on geopolymer compounds activated with alkalis and strengthened with natural fibres [1] is one of the most promising alternative solutions today for the future in the building industry and in civil engineering and infrastructure [2]. In addition these compounds are generally considered to be beneficial from an environmental point of view in that it significantly reduces CO2 emissions calculated in terms of the ecological footprint left by a product [3]. In this paper it was studied the influence of the state of preservation on formulations of geopolymer hempcrete it was present the results of the comparative assessments carried out by analysing morphology, pore size distribution and physical and mechanical properties. It was prepared 32 test samples of geopolymer hempcrete in two groups. Each group was made up of 16 test samples manufactured with hemp preserved in the two different ways (fresh “F” and wet-preserved for six months “W”).

RESULTS AND CONCLUSIONS

It was observed that the fibres, for the wet-preserved samples (W), compared to those stored fresh (F), the percentage of cellulose increased (4%) whereas there was a slight reduction in the percentage of lignin (12%) and of hemicellulose (13%). The microphotographs reveal the progressive thickening of the hemp fibres when the fresh hemp (F) is compared to the wet-preserved hemp (W). In Figure 1, it was showed a geopolymer concrete made with wet stored hemp (W), the thickening of the hemp fibres is highlighted with green arrows. The EDX analyses of samples F1 (Images A-B) and W1 (Images C-D) confirm the appropriate composition of the geopolymer concretes made of sodium silicate and soil with phyllosilicates. The large pores in all the images are also highlighted, varying in size from 100 μm and above and visibly connected. The wet-preserved samples (W) compared to those made with fresh hemp (F) indicated the percentage of pores within the macropore radius range of (r) 1000-100 μm is half that of those prepared with fresh hemp (F). In relation to the mechanical results there were manifested in substantial differences between F and W samples with respective values of 17 % and 28% in the case of resistance to compression and of 32% and 42% in the case of resistance to bending. It was highlighted that the MPa value was higher in all the geopolymer concretes made with the hemp that was wet-preserved for six months (F) than in those made with fresh hemp (W). (See Figure 2).

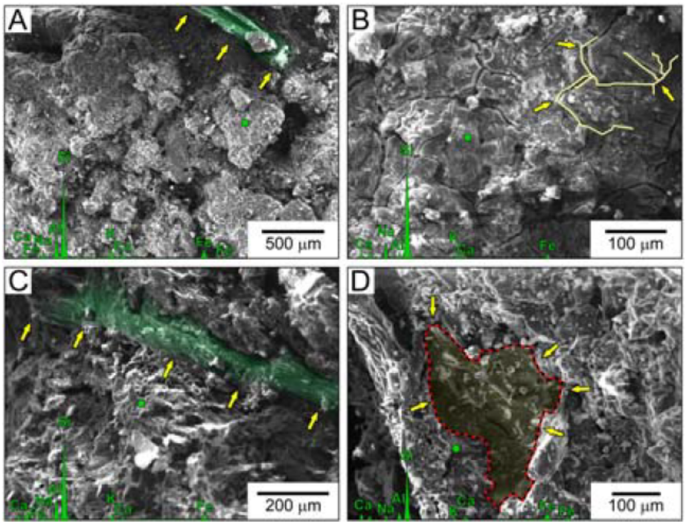

Fig. 1. SEM images including EDX analyses

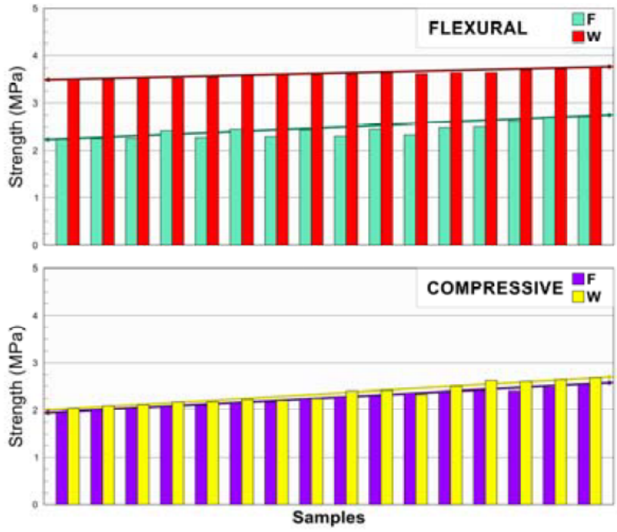

Fig. 2. Tensile test results

The main reason for the improvement in the mechanical properties of the different mixtures is the increase in the percentage of cellulose in the wet-preserved hemp (W) compared to the fresh hemp (F). The enhanced structural arrangement of the fibres improves these properties. These results were confirmed in the study conducted by [4] in which it was argued that the cellulose nanocrystals in the wet-preserved hemp (W) make it more resistant to bending and to uniaxial compression, in this way achieving the main objective of wet preservation of hemp.

Finally, it can be said that wet preservation of the hemp is equivalent to other pre-treatments conducted to improve the conditions of the hemp fibres, the fact that these treatments are no longer required would reduce hemp production costs and therefore the cost of the final building materials. With this system the fibre can be used all year round in favourable conditions. In future complementary studies, it would also be useful to determine the optimum level of storage for achieving the results observed and compare them with the maximum storage time.

ACKNOWLEDGMENTS

This work was supported by REMINE Project, H2020-MSCA-RISE-2014, Project MAT2016- 75889-R and Research groups HUM-629 and RNM 0179.

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CEMENT-BASED MORTARS REINFORCED WITH AZOREAN NATURAL FIBRES EXTRACTED FROM GREEN WASTE – TOWARDS SUSTAINABILITY IN CONSTRUCTION

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ABSTRACT

Nowadays, there is an urgent need to develop and design environmentally friendly materials from natural resources, which in turn is one of the great challenges of the present time. In this paper, two types of endogenous natural fibres (Hedychium gardnerianum, Ananas comosus (L.) Merr., 'Cayenne') are investigated as potential substitutes for conventionally studied alternatives such as sisal. Several formulations were prepared and characterized with regards to consistency by spreading EN 1015-3; apparent density at 7 and 28 days of curing (EN 1015-10); mechanical resistance at 7 and 28 days of curing (EN 1015-11) and morphology (scanning electronic microscopy). In addition, for comparison purposes, sisal and polypropylene commercial fibres were used. The different fibre´s role in the cement-based mortar was tested and compared in order to identify their use based on their origin and their mechanical and physical characteristics.

INTRODUCTION

The construction industry, along with the materials industries which support it, is one of the main global exploiters of natural resources [1]. Significant improvements have to be made towards a more sustainable and ecologically responsible industry in this sector. With the current technological advancements, one of the many possible alternatives may comprise the development of new environmentally friendly materials using different raw materials sources. This need to turn to alternatives with low environmental footprint brought, once again, attention to natural fibers [2]. In this context, cellulosic fibres, extracted from sustainable plants or even green waste, are a promising alternative to substitute conventional reinforcement materials [3]. The final fibre properties will depend on the plant species, specific characteristics, the preparation and processing methods for fibre extraction, among other important factors. In this sense, there is a lack of fundamental knowledge regarding alternative raw material sources for cellulosic fibres extraction and their suitability to be used in the development of reinforced composites.

This work studies the suitability of natural cellulosic fibre, extracted from two local Azorean endogenous species (Hedychium gardnerianum, a local plant invader, abundantly present in forest green waste, and pineapple leaves obtained as waste from local production of pineapple fruit (Ananas comosus (L.) Merr., 'Cayenne' variety), as alternatives for reinforcement of cement-based mortars.

RESULTS AND CONCLUSIONS

The stems from Hedychium gardnerianum and the leaves from Ananas comosus (L.) Merr., 'Cayenne' variety, were dried, cut and sieve in order to obtain fibres with mean length of 12 and 6 mm (Fig 1). Several formulations were prepared (Table 1) in order to study the effect and the role of these fibres on the properties of the cement-based mortar.

Table 1 Compositions tested.

#		Cement:Sand ration	Sisal %vol/m³	*H. gardnerianum* %vol/m³	*Ananas comosus* % vol/m³	PP % vol/m³	Plasticizer
1	Ref.	1:3	0	0	0		
2	PP_007	1:3	0	0	0	0.1	
3	PP_01	1:3	0	0	0	0.15	
4	PP_015	1:3	0	0	0	0.25	
5	SS_01	1:3	0.1	0	0	0	
6	SS_015	1:3	0.15	0	0	0	
7	SS_025	1:3	0.25	0	0	0	
8	HG_01	1:3	0	0.1	0	0	
9	HG_015	1:3	0	0.15	0	0	
10	HG_025	1:3	0	0.25	0	0	
11	AA_01	1:3	0	0	0.1	0	
12	AA_015	1:3	0	0	0.15	0	
13	AA_025	1:3	0	0	0.25	0	

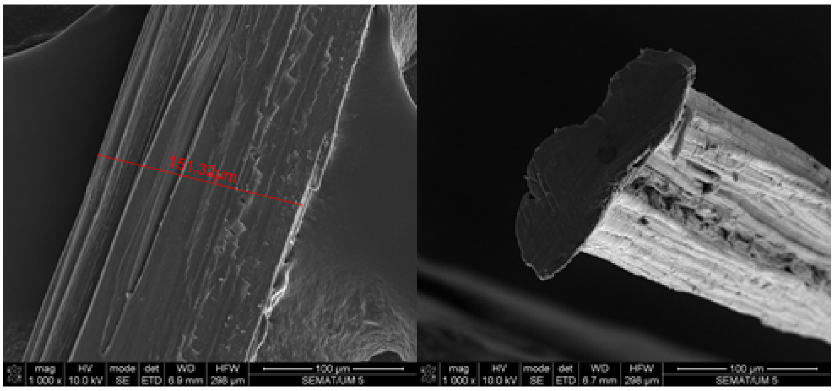

Fig.1 Morphologic SEM imagens of Hedychium gardnerianum fibres.

The results obtained, regarding consistency by spreading suggest substantial differences on the properties of the different compositions analyzed. The fiber's characteristic hydrophilicity/hydrophobicity is one of the factors that influences the workability of the mortars because it directly affects the amount of free water in the mixture. Consequently, the mechanical properties are also expected to show differences depending on the type and amount of fibre used.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by Governo Regional dos Açores, through project Eco-compósitos Inteligentes - ACORES-01-0247-FEDER-000015.

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NEW LIGNOCELLULOSIC PARTICLEBOARD BASED ON CARDOON (CYNARA CARDUNCULUS L.) AND CITRIC ACID

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ABSTRACT

In the present work, a totally biosourced particleboard was produced using cardoon particles (a no added value by-product from the Portuguese cheese making industry), bound with an adhesive based on a cardoon leaves extract and citric acid. The extract was combined citric acid as crosslinking agent. The effect of the content of citric acid (0-100 % on extract weight, dry basis) and the pressing temperature influence was evaluated by Automatic Bonding Evaluation System (ABES). The better formulations were used to produce the bioadhesive and the cardoon- based particleboards.

INTRODUCTION

In Portugal, cardoon plants are cultivated mostly for the value of the flowers, used in the cheese industry. The stalks, branches and leaves are a by-product with no added value. Recent works shows that it is possible the valorization of the cardoom byproducts by the combination of these particles with starch-based binder in the production of low-density particleboards appropriate for interior furniture[1]. Some studies have shown that citric acid is a good cross-linking agent, in the formulation of bio-based adhesives mainly with carbohydrates such as starch [2] or sucrose [3]. Cardoon leaves extract (CLE) was mixed with different percentage of citric acid (25-50-75-100%) by mechanical stirring. The effect of citric acid content and press temperature (120-160 oC) on adhesive performance was evaluated by ABES . The methodology used was the same described in previous works[4]. Particleboards were produced using dried particles of cardoon stalks, blended with a bioadhesive based on the CLE and citric acid (10% mass of resin solids/ mass of dry cardoon stalks fibers) in a laboratory glue blender. One layer 210 x 210 mm x 8 and 15 mm particleboards at 160 oC of press temperature for 20 min were produced.

RESULTS AND CONCLUSIONS

The effect of press times (30-180 s) and temperature effect (120 - 160 oC) on the mechanical cure were analyzed by ABES (Figure 1). The cardoon leaves extract was used as adhesive alone, in the form of aqueous solutions (self-condensation reaction), and in combination with different percentage of citric acid. The behavior of the adhesives under the pressing conditions studied, showed that the influence of citric acid as a crosslinking agent increases with time and temperature. Based on the obtained results, the use of more than 50 % (on extract weight, dry basis) of citric acid did not imply an improvement in the adhesive properties under the pressing conditions studied.

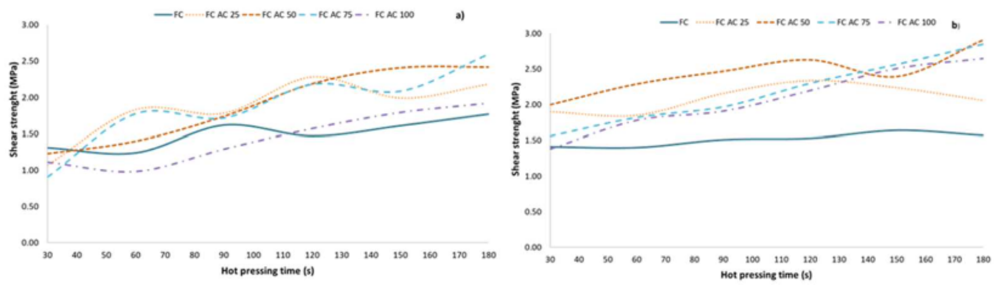

Fig 1 Development of shear strength as a function of hot-pressing time of CLE solutions alone (FC) and with citric acid (25-50-75-100 (% on extract weight, in dry basis)) at a) 120oC and b) 160oC.

Table 1 shows the influence of the citric acid percentage used in the bioadhesive formulation on the physico-chemical properties of the produced particleboards.

Table 1 Results for 21 x 21 cm Cardoon stalks particleboards bonded with CLE and citric acid.

Citric acid (% on extract weight)	Thickness	Density (kg/m^3)	IB strength (MPa)
50	8	515 ± 8.0	0.20 ± 0.01
75	8	545 ± 4.0	0.18 ± 0.01
75	15	615 ± 9.0	0.22 ± 0.02
100	8	535 ± 18	0.19 ± 0.03

Values are presented as mean ±standard deviation (n=6); IB=Internal Bond; Particleboard dimensions 21 x 21cm

The possibility of the use of the same agricultural or forestry industry byproduct as raw material and as component of the bio-adhesive is a very interesting route to produce sustainable and low toxicity products with an interesting applicability in food packaging (Fig.2).

ACKNOWLEDGMENTS

The authors wish to thank EuroResinas – Indústrias Químicas and project INNOSURF under PT2020 for the support with data, equipment, and materials. This work was financially supported by: Base Funding - UIDB/00511/2020 of the Laboratory for Process Engineering, Environment, Biotechnology and Energy – LEPABE - funded by national funds through the FCT/MCTES (PIDDAC).

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THERMAL ANALYSIS OF PRE-CAST CONCRETE WALL WITH SANDWICHED RICE BALES

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ABSTRACT

Heat transfer analysis of the precast concrete sandwich wall panels insulated with rice straw bales has been performed using finite element analysis (FEA). The heat transfer behaviour of insulated wall panels was modelled under different conditions like cold and hot exterior environments. Precast concrete wall panels consist of two wythes of concrete separated by the layer of rice straw bales. The results indicate that rice straw bales can be used as an alternative for synthetic insulation materials used in practice and has benefits due to their low environmental impact and sustainability. The effect of straw bales orientation and density is also investigated. Numerical investigations prove the thermal efficacy of rice straw fibres comparable to conventional insulations used in building constructions.

INTRODUCTION

After harvest, bales are compact masses of leftover rice straw. Straw bale construction offers high comfort and helps homeowners and building managers to minimize heating and cooling energy usage by around 80 per cent (Marques et al., 2020). Rice Straw bale act as an efficient thermal bridge because fibers mainly consist of gaseous phase and solid skeleton due to which the heat transfer via the solid phase is negligible and hence pose high thermal resistance (Vėjelienė, 2012).

The current work analyses the temperature drop and heat flux distribution along the width of the precast panel after the time interval of 24 hours. The dimensions of the panel are taken following the Precast concrete institute (PCI) guide for precast panels. The thickness of concrete wythes is 3″ with rice straw insulation of 2″ thickness sandwiched in between two wythes (Fig.1) (Seeber et al., 1997; Yu et al., 2020). The study performed to measure the thermal conductivity of rice straw bales concludes that it depends on mainly three parameters, packing density, temperature and orientation of fibers w.r.t direction of heat flow (Sabapathy & Gedupudi, 2019). The effect of these parameters on heat transfer in the precast wall is investigated. In the first part, FEA thermal analysis (Fig 2.) of four different precast panels was conducted with room temperature (25°C) on one side and cold temperature (5°C) in another side while in the second part, the outside temperature is 50°C and room temperature is kept the same.

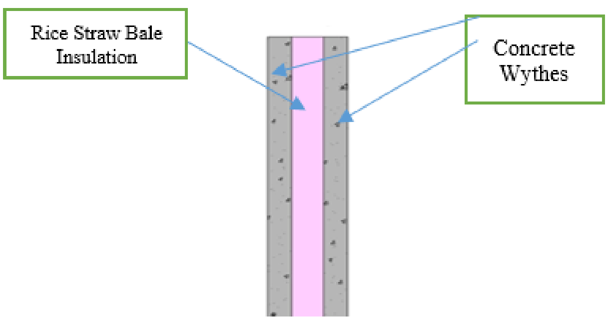


Fig 1. Cross Section of Precast Panel with rice straw bale thermal insulation

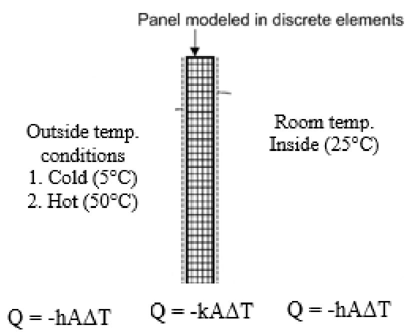
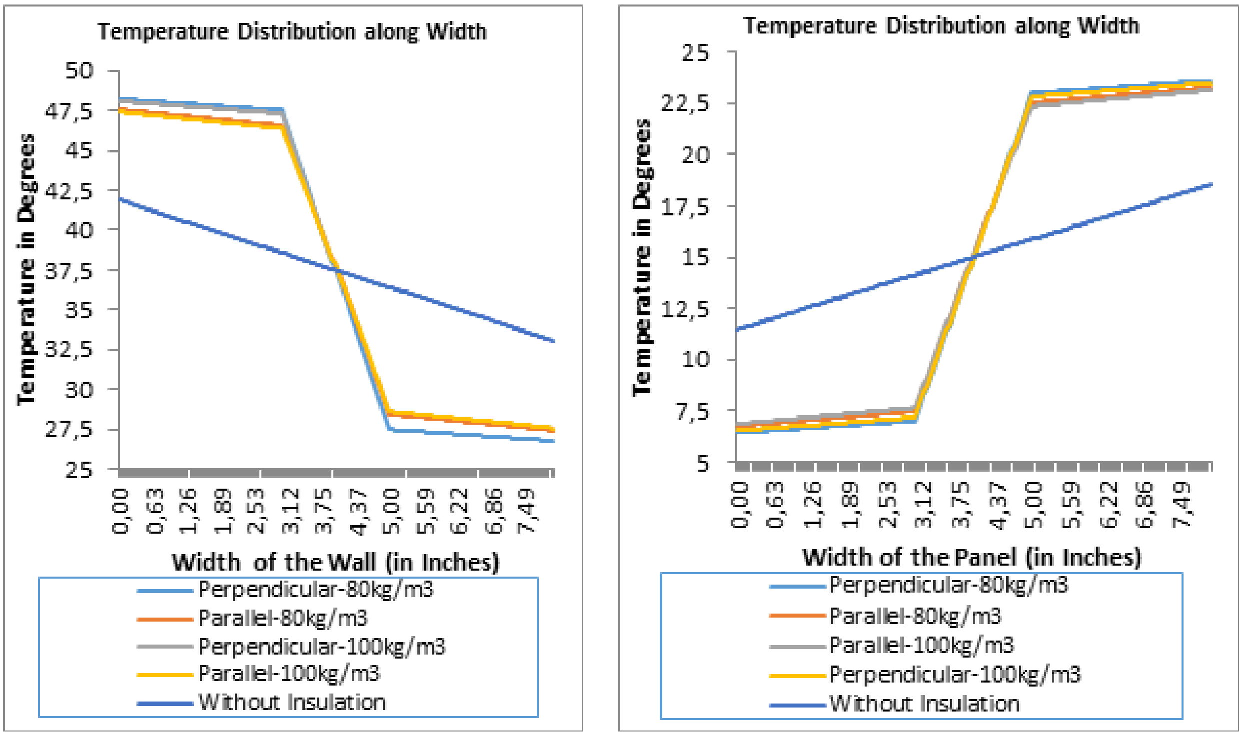


Fig 2. FEM Model

Perpendicular (across the heat flow) and parallel (along the heat flow) fibre orientations were investigated. Further, two different fibre densities of 80 kg/m3 and 100 kg/m3 are analysed for each fibre orientation.

RESULTS

The results of analysis commercial FEA package ABAQUS are illustrated in Fig. 3 (a), and Fig. 3 (b) for cold and hot external environments respectively. Thickness of wall panel is 8 inches with exterior and interior environmental boundary conditions imposed on the left hand side and right hand side respectively. The thermal performance of the panel is also compared with the solid precast panel without any insulation as the benchmark case. In both the figures, it is evident that rice straw bales as an insulation helps to maintain the temperature on the interior side somewhere around the room temperature (25ºC). it can also be noticed that the thermal performance of the fiber insulation increased with the increase in the packing density. Moreover, the perpendicular direction of the fibers in the direction of heat flow provide a better thermal barrier as compared to the parallel orientation. The results show that that rice straw bales can act as an efficient thermal insulation and their thermal resistance appears at par with commonly used insulation materials such as XPS (extruded polystyrene) foam.



a) $T_{in} = 25°C$, $T_{out} = 50°C$ b) $T_{in} = 25°C$, $T_{out} = 5°C$

Fig 3: Temperature distribution in the precast concrete wall along the width

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CELLULOSIC FABRICS REINFORCED CEMENTITOUS MATRIX (FRCM): LIGAMENTS, TREATMENTS AND EMPLOYMENT

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ABSTRACT

The application of Fabric-Reinforced Cementitious Matrix (FRCM) systems have a great growth applications' opportunity, due to the improvement of tensile and flexural strength properties in relation to cementitious composites employing disperse fiber reinforcing. This study aimed to develop a review about cellulosic textile materials (fabric, nonwoven and yarns) employed for reinforcing cementitious composites, in order to scrutinizing the durability performance. Five features were evaluated: applications, fiber origin, textile ligaments, pre-treatments and addition process to matrix. Results are technically promising for employment of cellulosic fabrics and yarns as reinforcement of FRCM, mainly in plain woven, a range of materials, fiber coatings and mineral additions.

INTRODUCTION

The purpose of adding fibres to cementitious materials is to increase properties, mainly for enhancing ductility and post-cracking behavior. Vegetal fibers are attractive owing to the features: cheapness, lightness and biodegradability, make them alternatives in relation to synthetic fibers; in addition, the concern regarding environment have become these fiber an alternative to reducing the energy expenditure and the emission of green-house gases (GHG) (Ferrara, 2019). On other hand, the interfacial bond between the fiber-matrix interface is relatively weak, influenced by the hydrophilicity of plant fibers. In order to overcome this deficiency, some pre-treatments and matrix additions are usually used (Ferrara, 2021). High alkalinity of matrix reduces the degree of cellulosic polymerization and provides reduction in tensile strength (Ferrara, 2019).

Cement, mortar or concrete composites reinforced with cellulosic fabric have a great growth applications' opportunity, due to the improvement of tensile and flexural strength properties in relation to cementitious composites employing disperse fiber reinforcing (Boulos, 2018). Thus, this study aimed to develop a review about cellulosic textile materials (fabric, nonwoven and yarns) employed for reinforcing cementitious composites, in order to scrutinizing the durability performance, identifying the main aspects: (i) applications, (ii) fiber origin, (iii) textile ligaments, (iv) pre-treatments of yarns and (v) addition process to matrix.

RESULTS AND CONCLUSIONS

According to analyzed literature, textile materials reinforced cementitious composites articles covered the main issues: strengthening and rehabilitation of masonry walls (**Figure 1a**) (de Carvalho Bello, 2019); environmental exposures degradation (as heat, salt, or alkaline exposure) (Boulos, 2018); addition to reducing porosity (as nanoclay and nano-SiO2 particles employing); comparing different origin of cellulosic fibers, textile ligaments (**Figure 1b**); and pre-treatment or covered textiles in order to reduce the hydrophilicity (Mercedes, 2018).

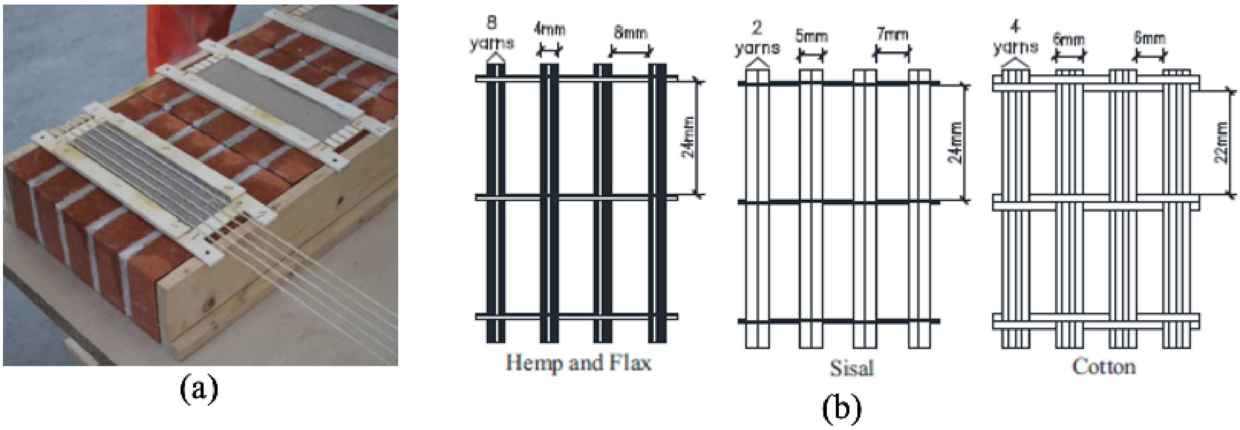

Fig.1 (a) Sisal yarns embedded in natural mortar on a masonry wall to realize single lap shear tests (de Carvalho Bello, 2019; (b) Hemp, flax, sisal and cotton fabric (on the right, respectively) and ligaments used (on the left) (Mercedes, 2018).

Many natural fibers have been employed for applications as reinforcement of composites. The most studied are sisal, hemp, date palm, jute, cotton and flax. In addition, textile ligaments and pre-treatments are conditions tested together as in studies to evaluate the performance of pure or impregnated threads and fabrics (mainly plain woven). De Carvalho Bello (2019) report pure and impregnated sisal yarns by water-based adhesive, which are embedded into a natural lime mortar to reinforce a masonry wall (**Figure 1a**). The obtained samples were tested by single lab shear and presented the maximum tensile strength at 169.5 MPa; this value was about 29% lower than yarns were impregnated alone, evidencing uneven load distribution (de Carvalho Bello, 2019). Mercedes (2018) evaluated inorganic resins (epoxy or polyester) on different fabric ligaments (**Figure 1b**) and cellulosic materials (hemp, flax, sisal and cotton). The resin coating increased the tensile strength and stiffness in almost all tested fibers (except for sisal, in which an excessive sectional area of yarns caused mortar debonding failure). Coated-hemp reached the highest tensile strength at 554.25 MPa (increased 92% with epoxy resin) and coated-cotton presented the greatest gain avoiding multicracking failure (Mercedes, 2018).
Results are technically promising for employment of cellulosic fabrics and yarns as reinforcement of FRCM, mainly for plain woven, a range of materials, fiber coatings and mineral additions.

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DURABILITY OF GEOPOLYMER COMPOSITES REINFORCED WITH SISAL FIBERS

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ABSTRACT

In this study, two metakaolin-based geopolymer mixes were produced: one with a lab-manufactured sodium solution, and another with a commercial one. They were reinforced with 10% of aligned, continuous, and pre-treated sisal fibers. The composites behaviour in the inelastic phase, i.e., cracking mechanisms, strength, and ductility, were studied through flexural tests. Both types of composites were exposed to accelerated degradation methods (10, 20, and 30 wetting/drying cycles), prior to testing, to study its long-term durability. Both composites presented minor degradations up to 30 cycles, reaching flexural strengths up to 35 MPa, suggesting an improved efficiency of this technology when compared to similar studies with cementitious matrices.

INTRODUCTION

Natural fibers have been widely studied as reinforcements in brittle materials in recent years (Silva, 2010). Its potential high mechanical capacity and renewable availability stand out in its use (Silva, 2009). Within the scope of sustainability, geopolymers appear as compatible admixtures since cementitious materials are responsible for at least 1% of the CO2 release worldwide per year. Thus, the combination of the two technologies presents green-friendly and mechanical advantages, with potential efficient applications as (1) reinforcement layers in pre-existing structures and (2) thin structural elements. Despite showing great capacity when reinforcing cementitious matrices, it is known that the issue of long-term durability of this type of element reinforced with natural fibers must be considered (Silva, 2010). Previous studies carried out accelerated aging tests, using cementitious matrices with partial pozzolanic substitutions, in which the composites demonstrated drastic losses in strength and deformation capacity after 10 wetting and drying cycles (Silva, 2010). It is known that metakaolin based geopolymers generally present great durability (Trindade, 2017), due to their chemical characteristics, being less susceptible to attacks by sulfates and other degrading agents (Alcamand, 2018). For this reason, the aim of this study was to mechanically characterize two types of geopolymer composites reinforced with 10% sisal fibers, under usual conditions and after being exposed to 10, 20 and 30 accelerated aging cycles. The characterization was made through 4-point flexural tests. Two GP matrices were used, one with a commercial solution of sodium hydroxide + sodium silicate water glass (M1) and another with a solution produced in the laboratory (M2), comprising the mixing of NaOH in pellets, with deionized water and hydrophilic fumed silica.

RESULTS AND CONCLUSIONS

Figure 1 show the results obtained under usual conditions and after the composites were subjected to 10, 20 and 30 wetting/drying cycles. Table 1 presents the average values calculated for each group of samples tested, showing the strength obtained at first crack (σ1st), maximum strength (σmax) and displacement (δ) correspondent to maximum strength. Previous results indicated 36 MPa and 27 MPa, as compressive strength of M1 and M2 matrices, respectively.

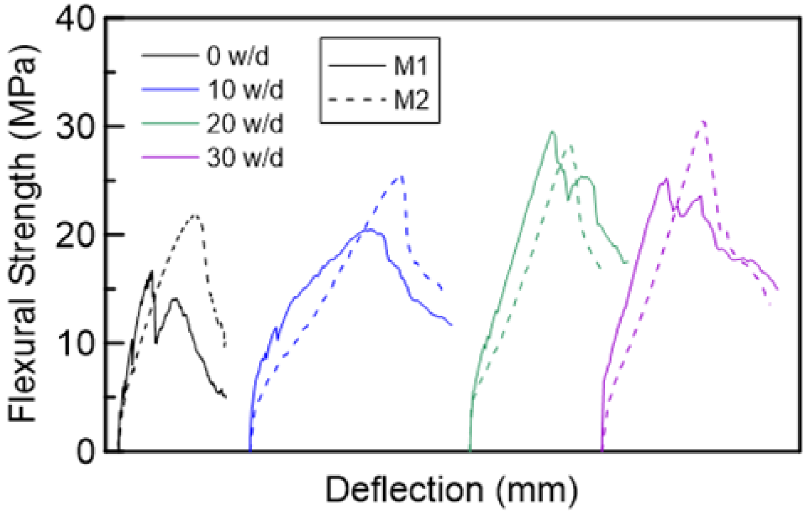

Fig.1. Flexural tests results

From the results presented, it can be stated that none of the two geopolymer matrices showed degradation signs in all studied cycles, this statement being reinforced by the consistent values found in the first crack strength. It was also possible to observe a gradual increase in maximum resistance, probably related to changes in the fiber-matrix interface with the incorporation and loss of systemic water. Thus, metakaolin-based geopolymer materials demonstrate greater mechanical suitability in conditions of accelerated degradation when incorporated with natural fibers, when compared to similar results of conventional binders (cement based).

w/d cycles	M1			M2		
	σ_{1st} (MPa)	σ_{max} (MPa)	δ (mm)	σ_{1st} (MPa)	σ_{max} (MPa)	δ (mm)
0	6.46	16.71	24.45	4.51	21.84	24.31
10	6.98	20.54	45.07	4.32	25.79	43.78
20	6.20	22.96	36.74	4.59	28.49	30.01
30	6.67	25.22	41.22	4.63	30.62	38.22

Table 1. Flexural tests results

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding provided by the CNPq/PIBIC program, for granting the Scientific Initiation scholarship to the undergraduate student Fernanda de Campos Tavares. This research was carried out at the Structures and Materials Laboratory (LEM-DEC) at PUC-Rio.

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EFFECT OF NANOFIBRILLATED CELLULOSE ON SHRINKAGE OF CEMENT PASTE

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ABSTRACT

The aim of the present work was to evaluate the effect of the addition of low percentages (0.025 and 0.05wt.%) of nanofibrillated cellulose (NFC) to cement pastes on their total and autogenous shrinkage behaviours. Cement pastes with two different water-to-cement ratios of 0.35 and 0.40 were investigated. Results show that the water content in the matrix affects the way the NFC influences the evolution of shrinkage deformations. The use of 0.025wt.% of NFC was capable of decrease the autogenous deformation by 20% at the cement paste's age of 28 days.

INTRODUCTION

The volumetric deformation of cementitious materials known as shrinkage is basically related to the movement of water in such porous materials (Bažant, 1975). This phenomenon is well known, and several approaches have been used to mitigate it (Yang et al., 2019). While considerable work has been performed e.g., on effects of superabsorbent polymers or shrinkage reducing admixtures, the use of nanocellulose in cementitious systems is still rare (Stephenson, 2011) and there are gaps in the understanding the interaction of this material with cement hydrates. The motivation for using nanofibrillated cellulose (NFC) comes from its intrinsic properties such as high specific area, water retention capacity and good mechanical properties (Dufresne, 2013). These features make nanocellulose a promising admixture for enhancing volumetric stability of cement paste.

In the present study, cement pastes were doped with NFC at contents of 0.025 and 0.05wt.% and their behaviour with respect to total and autogenous shrinkage was evaluated. Two cement-to-water ratios of 0.35 and 0.40 were employed. Prior to the addition of cement, the water and NFC gel were mixed for 5 minutes at 600 rpm to homogenize the suspension. Then the cement was added and mixed for 1 min at 140 rpm and 4 min at 285 rpm. Prisms with dimensions of 160 x 20 x 20 mm³ were casted, demoulded after 24 hours and kept in an environmentally controlled room (temperature of 21 ºC and RH of 50%) for 28 days. For the autogenous shrinkage investigation, the specimens were sealed with an aluminium foil to prevent water evaporation. Automatic readings were performed continuously by a dial gauge every 30 min.

RESULTS AND CONCLUSIONS

The volumetric de Figure 1 presents the results of the shrinkage tests showing that the NFC differently affects the shrinkage behaviour depending on the w/c. The addition of NFC at any percentage did not influence the total deformations of cement pastes with a w/c of 0.35 and even a slight increase was observed for the specimens with w/c of 0.40. This trend changes when only autogenous deformations are considered, including an expansion effect at the first 48 hours. The addition of 0.025% NFC caused a decrease in the autogenous deformation of the cement paste with w/c of 0.35 by 20 %.

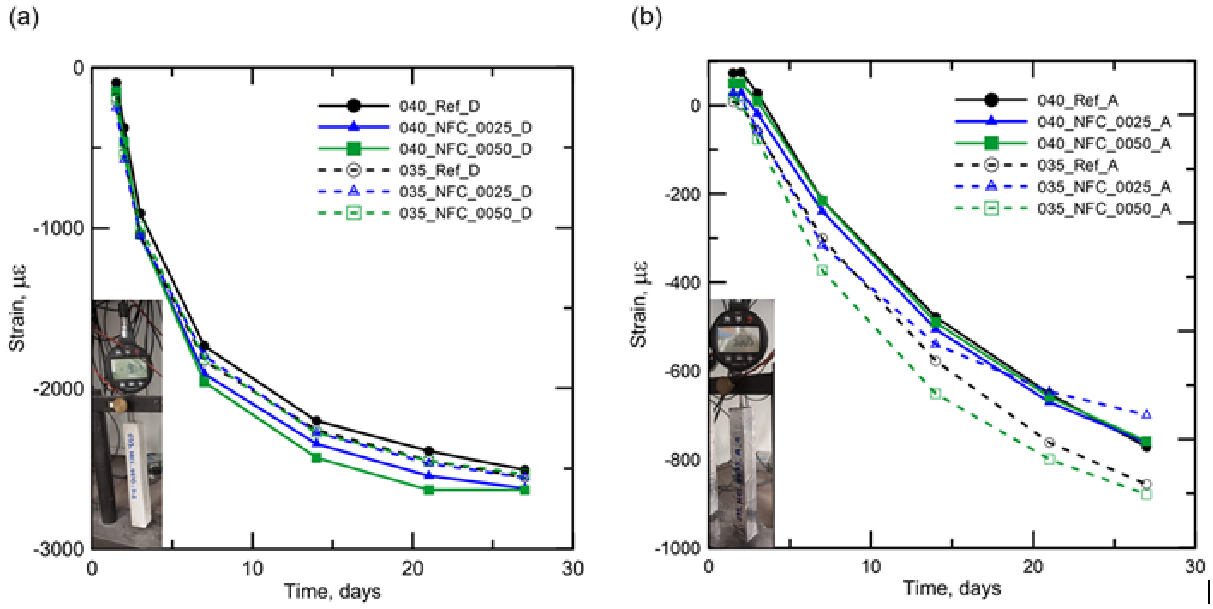

Fig.1 Results from (a) total and (b) autogenous shrinkage.

The present study shows that the inclusion of NFC imparts different effects regarding the type of shrinkage i.e., total and autogenous, and the water-to-cement ratio. The results suggest that this difference is related to the intrinsic characteristics of the nanofibrils such as hygroscopicity and hydrophilicity and how they interact with the available water within the matrix, like already observed elsewhere (Hisseine et al., 2020).

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by the Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES (Brazilian National Science Foundations). enormous potential of ZnO nanostructures in engineering the interfacial layer and thereby optimizing the mechanical properties of natural fibre-reinforced biocomposites.

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4D PRINTED CONTINUOUS FLAX-FIBER REINFORCED BIOCOMPOSITES FOR ARTIFICIAL REEF

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ABSTRACT

The problem of depletion of biotic resources in coastal and littoral zones is now accepted by the scientific community. To remedy this, artificial reefs supposed to promote the dynamics of repopulation have been developed in coastal areas. However, the latter are often made up of concrete blocks, ship hulls or used tires. These are by no means sustainable solutions. Previous work has underlined the potential of natural fibre to be used as actuation agent in hygromorph biocomposite due to their hygroscopic behavior. Indeed, morphing ability of hygromorph biocomposite is controlled by the hygroscopic stress state induced by fibre swelling within the polymer matrix. The Morph-Reef project, aims to develop a new concept of artificial 4D printed reef with hygromorph biocomposite while having a controlled lifespan and positive effect on marine microorganism colonization. This first work focuses on the understanding of the effect of various biopolymer having different stiffness (PLA, PBS and PBAT) on flax fibre swelling and consequently on morphing potential. Thus, hygroscopic (sorption and hygro-expansion), tensile mechanical properties and colonization properties of continuous flax fibre biocomposites will be investigated

INTRODUCTION

The problem of depletion of biotic resources in coastal and littoral zones is now accepted by the scientific community. To remedy this, artificial reefs supposed to promote the dynamics of repopulation have been developed in coastal areas. However, the latter are often made up concrete blocks, ship hulls or used tires (Sherman and Spieler 2006). These are by no means sustainable solutions. The Morph-Reef project aims to develop a new concept of biologically artificial reef that are both deployable and having a controlled lifespan and a positive effect on marine micro-organism colonization. Deploying structures made with pine cone inspired hygromorph biocomposites (HBC) has been recently proposed (A. Le Duigou et Castro 2015).

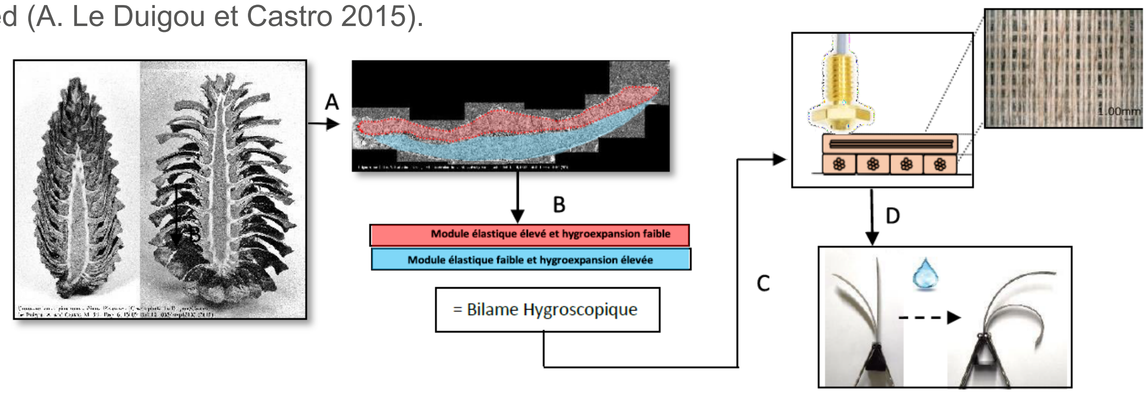

Fig.1 A Microstructure of pine cone scale, B Actuation principle with a bilayer microstructure, C Architectured hygromorph biocomposite made with 4D printing, D Moisture induced bending deployment of hygromorph biocomposites

Their actuation is induced by hygroscopic loading applied to an asymmetric architecture during moisture variation. Natural fibers represent the major component of HBC since their swelling behavior governs the composite deployment. As a matter of fact the fiber selection appears as a determining factor in order to maximize the hygroscopic response of the HBC under moisture gradient. Significant differences were observed in the actuation esponse (speed rate and curvature) of HBC depending on the used natural reinforcements (A. Le Duigou et al. 2017). This variation was related to the specific morphology, the microstructure and the biochemical composition of each fiber (flax, jute, kenaf and coir). A reef with an optimal shape have to include cavities to shelter fauna and flora while having higher surface roughness to increase adhesion potential (Pioch 2008). The current shaping ability of thermoplastic biocomposites is still limited by conventional manufacturing process (thermocompression…). 4D printing of biocomposites are a great opportunity for hygromorph biocomposites to allow complex shapes with tailored properties to be manufactured (A. Le Duigou, Chabaud, et al. 2020). A recent review (A. Le Duigou, Correa, et al. 2020) has pointed out that 4D printed continuous natural fibre biocomposite overcome mechanical and actuation properties of short fibres biocomposite. In addition, biocomposite materials can offer a controlled lifetime in water environment thanks to the component selection (Fibre and matrix). Biopolymer such as PLA or PHA have evidenced different degradation kinetic in seawater (Deroiné et al. 2014). The addition of flax can accelerate the moisture uptake and the degradation rate (A. Le Duigou, Bourmaud, et Baley 2015). Due to higher lignin content, jute fibres has evidenced a reduced moisture-induced degradation compared to flax fibres (Antoine Le Duigou et al. 2017). This first work focuses on the understanding of the effect of various biopolymer having different stiffness (PLA, PBS and PBAT) on flax fibre swelling and consequently on morphing potential. Thus, hygroscopic (sorption and hygro-expansion), tensile mechanical properties and colonization properties of continuous flax fibre biocomposites will be investigated.

RESULTS AND DISCUSSIONS

The mechanical, hygroscopic and actuating properties of the hygromorphic biocomposites PLA/cFF and PBS/cFF are gathered in Table 1.

Table 1 Mechanical, hygroscopic and actuation properties of PLA/cFF and PBS/cFF hygromorphic biocomposites

Materials	EL (GPa)	ET (MPa)	m= Ep/Ea	$\beta_T.\Delta C$ (%)	Responsivenes s (mm^{-1})	Reactivity (10^{-4} mm^{-1} min^{-1})
PLA/cFF	14.1 ± 3.6	2.0 ± 0.1	7.05	1.26 ± 0.5	0.0275 ± 0.002	1.2±0.4
PBS/cFF	10.3 ± 0.7	0.43 ± 0.04	24	3.8 ± 0.4	0.0547 ± 0.003	7.2±0.9

Substitution of the PLA matrix with PBS reduces longitudinal and transverse stiffness by 30% and 75 % respectively due to the high contribution of the matrix in composites having moderate fibre content. Interestingly, the anisotropic ratio and hygroscopic strains are drastically improved compared to PLA/cFF counterparts. Then, PBS/cFF shows a 250% increase in hygroscopic strain compared to PLA/cFF biocomposites. Free flax fibres can exhibit a radial hygroscopic expansion of about 21 ± 3% (A. le Duigou et al. 2017), thus a low stiffness matrix such as PBS seems to reduce the constraining effect on the flax fibres during the sorption, which allows a higher hygroexpansion of fibres and actuation of biocomposites.

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MODELLING AND OPTIMIZATION OF TENSILE STRENGTH OF PLANTAIN (Musa Paradisiacal) FIBRE/MWCNT HYBRID NANOCOMPOSITE USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT

Agricultural wastes from plantain pseudostem has become a major source of natural fibre in composite manufacturing for industrial application. In this paper, a fiber reinforced hybrid nanocomposite was fabricated using plantain (Musa paradisiacal) fibre and multiwall carbon nanotube (MWCNT) in epoxy resin. Chemical treatment of the fiber surface using 0,05% potassium permanganate (KMnO4)-acetone solution was used to reinforce the adhesion interface between the fiber and the matrix. Response surface methodology (RSM) based on the Box – Behnken design (BBD), was utilized in the experimental design to optimize the influence of three variable parameters, namely: MWCNT size, KMnO4 Treatment time and fiber content on the tensile strength of the hybrid nanocomposite. In the sample preparation, three level were used for MWCNT content (0.5, 1, 2%), KMnO4 Treatment time (1, 3, 5 mins) and fibre content (10, 20, 30 wt. %). Analysis of variance (ANOVA) shows that MWCNT content, fiber content and KMnO4 Treatment time, significantly effects the tensile strength of the hybrid nanocomposite as proven by scanning electron microscopy (SEM) micrographs. The expected findings were in near alignment with the experimental results with the value of R2 = 0.9985. The optimal operational condition for ultimate tensile strength for the hybrid nanocomposite was observed as MWCNT concentration 1.29 (%), KMnO4 Treatment time 3.14 (mins), and a fibre content 13.41 (wt. %). The optimum tensile strength of plantain (Musa paradisiacal) fiber/MWCNT hybrid nanocomposite was increase by 65% over pristine epoxy-resin system. This current research has demonstrated that RSM via the BBD technique is an effective way of achieving optimal values for mechanical properties over the least amount of time, reducing production costs and saving resources.

INTRODUCTION

Harvest seasons are also characterized by huge amounts of agricultural waste materials, which have been used as a main source of natural fiber (Kumar, 2020). Exploration is proceeding to producing composite polymers, using the most environmentally sustainable agro-waste fibers as reinforcement and conventional polymers as matrix (Imoisili et al 2018). Natural fibres (NF) are not only biodegradable and renewable, but have other unique benefits over synthetic fibres, such as high stiffness, safe processing, relatively cheap, light weight and high power (Imoisili et al 2018; Mohammed et al 2015). Natural fiber reinforced polymer composite (NFRC), has established a broad variety of applications in the building and manufacturing sectors such as, doorways and window covers, roofing fabrics, railings, furniture and their packaging, machine housings and other electrical parts. They are also found, in a range of industrial uses, including automobile in areas such as headliner panels, boot-lines, door plates, noise insulation sheets, main engine shield, exhaust insulation, interior insulation, firewall, wheel-box and roof shield (Mohammed et al 2015;

Medupin et al 2013). Plantain fibers as a viable natural fiber source in polymer composite for different applications have been researched, and documented by a variety of researchers (Onifade et al 2020; Chukwunyelu et al 2020).

In attempt to increase the functional performance of NFRC, a chemical alteration of the fiber surface or the amalgamation of numerous separate forms of fibers into a single matrix resulting in the formation of hybrid composites has been suggested (Jawaid et al 2010). These hybrid composites are the complete calculated components of which one type of fiber benefit can be substituted for by what is deficient in the other. As such, consistency of properties and efficiency may be accomplished by correct material selection (Dhakal et al 2013). Work has shown that synthetic fibres hybridization with natural or other synthetic fibres in polymer matrix may have an assertive impact on the physical, mechanical, and thermal properties of polymer composites. Work has shown that synthetic fibres hybridization with natural or other synthetic fibres in polymer matrix may have an assertive influence on the mechanical, thermal and physical properties of the materials (Mane et al 2015; Athjayamani et al 2010). Several experiments have been performed to modify the matrix using nanoparticles. These lead to the development of carbon nanotube-based polymer nanocomposites, with a complete range of desirable properties for advanced industrial and technological applications (Imoisili et al 2020; Nabinejad et al 2017). Carbon nanotubes (CNT), is one of the most desirable polymer nanocomposite fillers owing to its exceptional high strength (Ayatollahi et al 2011). The special properties and structures of CNT render it suitable as a reinforcement medium for the hybrid epoxy matrix (Rajamohan and Matthew 2019; Rajmohan et al 2015).

RSM, is an essential statistical technique for optimizing complicated processes and has the capacity to evaluate correlations between responses and independent variables, and to also identify the effect of independent variables on responses, either through independent variable or by process combinations (Mohammed et al 2015). The Relatively smaller number of experimental tests used to evaluate and communicate with many parameters are the major strength of RSM. This is therefore less time-consuming and time-consuming than other approaches that are supposed to refine the method (Aimi et al 2014; Hashmi et al 2012).

Research findings indicate that the usage of potassium permanganate ($KMnO_4$) in the treatment of plantain fiber is very successful due to its beneficial impact on mechanical properties (Imoisili et al 2018; Khan et al 2006). When fabricating a fibre reinforced hybrid nanocomposite, there are a variety of factors that influence the tensile strength of the composite. The design of the experiment is also an important tool for optimizing the final response of the composite. In this current research, potassium permanganate treated plantain (Musa paradisiacal) fibre and Multiwall carbon nanotube (MWCNT) hybrid nanocomposite was fabricated. The statistical model and precision of parametric optimization utilizing RSM to quantify the effect of fiber content, MWCNT concentration and $KMnO_4$ treatment time and their interactions on tensile strength were investigated. The results obtained were compared with experimental data for the investigation of accuracy and also for the computation of possible errors.

RESULTS AND CONCLUSIONS

Table 2, shows the experimental results and predicted responses following the tensile experiments and the BBD formulation. The residual values were determined between the experimental outcome and the predicted response. Table 2 indicates that the maximum tensile strength of the hybrid nanocomposite obtained was 45.74Mpa for composites with a concentration of 1% MWCNT, fibre content of 10 wt. % and $KMnO_4$ Treatment time of 1mins. However the minimum tensile strength was recorded at 19.45Mpa for composite with 20 wt. % fibre content and 5mins $KMnO_4$ Treatment time with no MWCNT content. This clearly indicates that the addition of MWCNT has effectively improved the tensile strength of the nanocomposite due to its toughness and high tensile properties, as a result of which the stress can be efficiently transferred from the polymer matrix to the MWCNT and thus, increases the composite strength. Comparable findings have been recorded for hybrid composites (Imoisili et al 2020).

Table 2: Experimental and predicted tensile strengths for hybrid nanocomposite.

Run Std	Run No	$KMnO_4$ Treatment (mins)	Fibre Content (wt. %)	MWCNT Conc. (%)	Tensile strength (Mpa)		Residual
					Experiment	Predicted	
2	1	1	20	2	38.04	37.90	0.1388
15	2	3	20	1	42.91	42.92	-0.0220
11	3	1	30	1	36.62	36.11	0.5138
12	4	5	30	1	33.56	33.38	0.1837
4	5	5	20	2	36.52	36.05	0.4688
17	6	3	20	1	42.89	42.92	-0.0320
13	7	3	20	1	42.93	42.92	0.0080
14	8	3	20	1	42.89	42.92	0.0580
9	9	1	10	1	45.74	45.92	-0.1837
16	10	3	20	1	42.91	42.92	-0.0120
5	11	3	10	0	30.16	29.51	0.6525
3	12	5	20	0	19.45	19.59	-0.1388
8	13	3	30	2	34.62	35.27	-0.6525
1	14	1	20	0	22.45	22.92	-0.4687
10	15	5	10	1	42.96	43.47	-0.5138
6	16	3	10	2	42.66	42.62	0.0450
7	17	3	30	0	16.89	16.93	-0.0450

ANOVA analysis of tensile strength

The ANOVA quadratic models for tensile intensity of the three selected variables are seen in Eq (1) by adding multiple regression analysis to the responses.

Tensile strength = 30.41381 +27.13575A +3.11463B -0.371225C +0.185000AB +0.130750AC -0.003500BC -11.22225A2 -0.646188 B2 0.006172C2 (1)

Where A, B, and C are coded variables for MWCNT Concentration (A), KMnO4 Treatment time (B) and Fibre Content (C).

This quadratic equation has been used to produce tensile strength predictions for each variable. Table 3, presents the results of the ANOVA tensile strength analysis. The ANOVA table displays the mean square (MS) and the sum of the squares (SS) of each parameter in which the F-ratio and the P-value are defined as the mean square error and the ratio of the respective mean square effect. Table 3, shows an F-value = 520.59, which indicates significant quadratic effect. The substantial relationship between the tensile strength and the variables was measured on the basis of their p-values. P-values of less than 0.050 are deemed to be important, which is expressed in model terms by A, B, AB, AC, and BC. As shown from lists the statistical data obtained for the analysis of tensile strength variance in Table 3, regression coefficient (R2) of 0.9985, argue that the model is capable of representing the relationship among significant model terms. The closest the R2 value is to 1, the greater the accuracy of empiric model data to predict the response (Pavani et al 2016). Similarly, the adjusted R2 of 0.9966 was very similar to 1. It suggests that the analytical process was quite accurate. R2 and R2 adjusted were both in strong agreement (Stamenkovi´c et al 2018). The coefficient of variance (C.V.) means consistency of the real and expected construct, and must be less than 10% (Hassana et al 2019). Reliability of the experiment performed in this analysis was reported at a small C.V of 1.45 %. Adequate precision, which accuracy assess the ratio of signal to noise was more than 4. The ratio for this analysis was 71.914, suggesting acceptable signal. The design space was navigated using this model.

Table 3: Results of ANOVA for acquired quadratic model.

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	1294.48	9	143.83	520.59	< 0.0001	significant
A-MWCNT concentration	494.39	1	494.39	1789.43	< 0.0001	
B-Treatment time	13.42	1	13.42	48.56	0.0002	
C-Fibre content	198.30	1	198.30	717.75	< 0.0001	
AB	0.5476	1	0.5476	1.98	0.2020	
AC	6.84	1	6.84	24.75	0.0016	
BC	0.0196	1	0.0196	0.0709	0.7976	
A^2	530.27	1	530.27	1919.27	< 0.0001	
B^2	28.13	1	28.13	101.82	< 0.0001	
C^2	1.60	1	1.60	5.81	0.0468	
Residual	1.93	7	0.2763			
Lack of Fit	1.93	3	0.6430	506.28	< 0.0001	significant
Pure Error	0.0051	4	0.0013			
Cor Total	1296.41	16				
$R^2 = 0.9985$			Adjusted $R^2 = 0.9966$			
Predicted $R^2 =$ 0.9762			Adequate Precision = 71.9075			
C.V. % = 1.45			mean.= 36.13			

Analysis of residual plots of hybrid nanocomposites

Fig. 1(a) points out the association between the distribution of standard probability and the internal residues of tensile strength. All residual points indicate a probable curve closer to the line fitting the model data. As demonstrated in figure. 1(a), the normality did not show any obvious problems with residual value (Wu et al 2012). Fig. 1(b) indicates the correlation between experimental and residual runs for tensile strength behaviour. The data point was reliably close to '0,' suggesting constant variance of the experimental tests results, thus It was recommended that for such study no transformation reaction are needed (Chowdhury et al 2016). Fig. 1(c) indicates the association between current and expected tensile strength values. Points are the variance of the actual values from the predicted or modified values. Both scatter points were accurately distributed along the axis, suggesting a high levy of consistency between the experimental and the expected values. The closest the data points are to the reference line, the better the precision of the model (Qiu et al 2013). All the fundamental analyses were strongly related, indicating the feasibility of the chosen empirical model. Fig. 1(d) indicates the association between the studentized residues and the expected tensile strength reactions. As exhibited in this graph, the studentized residues were uniformly dispersed around the "0" plot at a constant scale, indicating the suitability of the model Hassana et al 2019).

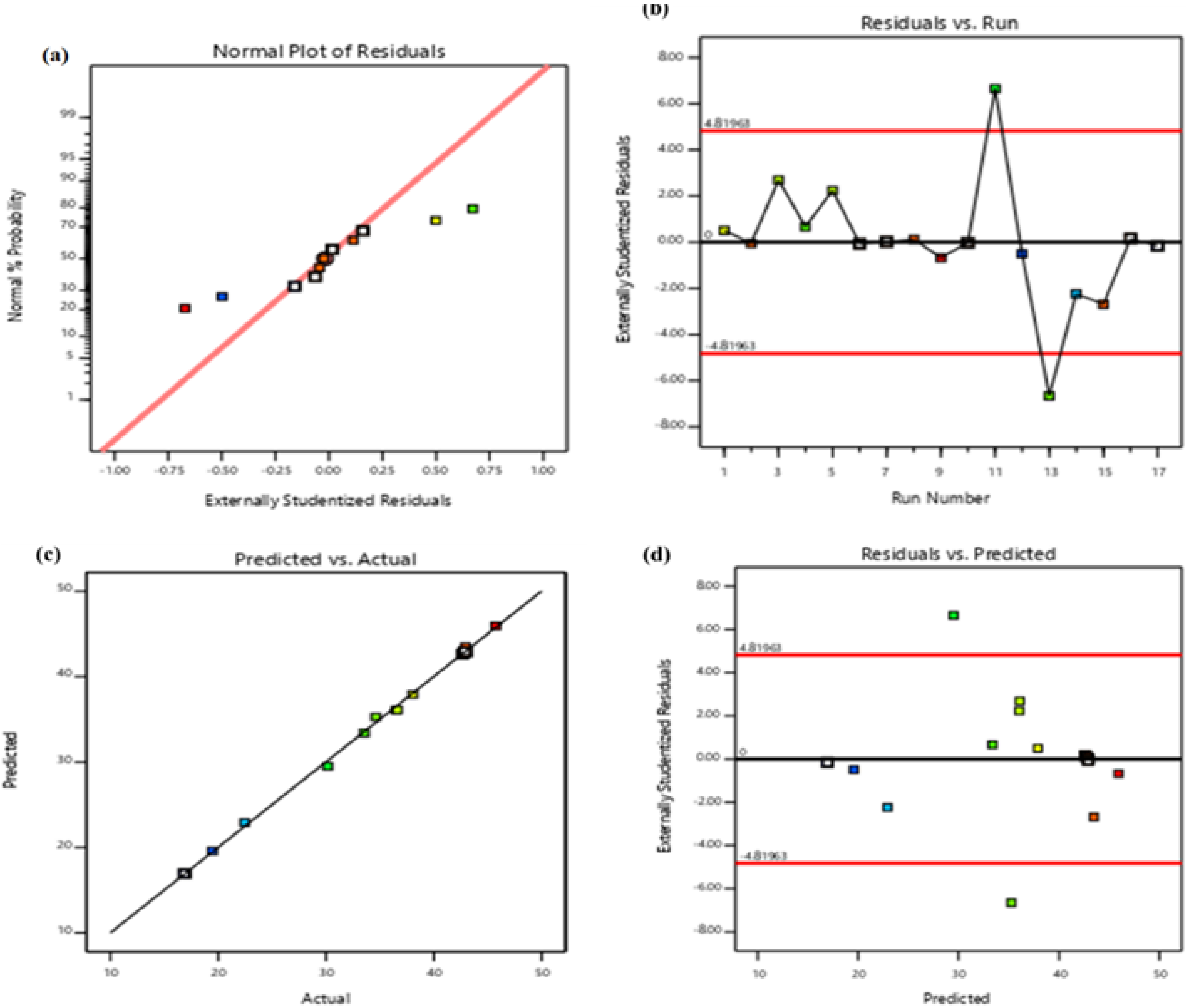

Fig. 1 Plot of (a) normal probability vs residual (b) residual vs run number (c) predicted vs actual values (d) externally studentized residuals vs predicted response following tensile strength.

The perturbation plot in Fig. 2, provide the relationship for all process variables at the core of the tensile strength response. This plot also divulges the reaction of a single variable in motion from the reference point chosen, while all other factors remain constant (Qiu et al 2013). In this analysis, the reference point was positioned at the center of the design space, this was also the zero-coded level of each element. The tensile strength was shown to improve with an increase in MWCNT concentration (A) owing to improved toughness of multiwall carbon nanotube and bonding with epoxy matrix. Apparently from the plot, here was an improvement in the tensile strength as $KMnO_4$ Treatment time (B) increases, owing to the elimination of waxes, cellulose and other impurities from the fiber surface. However, an improvement in the fiber content (C) resulted in a decline in the tensile power, which can be due to a reduction in the wetting of fiber and a reduction in the coupling of fiber / matrix. As demonstrated in Table 3, tensile strength was most influenced by MWCNT concentration ($F = 1789.43$ $p < 0.0001$) and fibre content ($F = 717.75$ $p < 0.0001$).

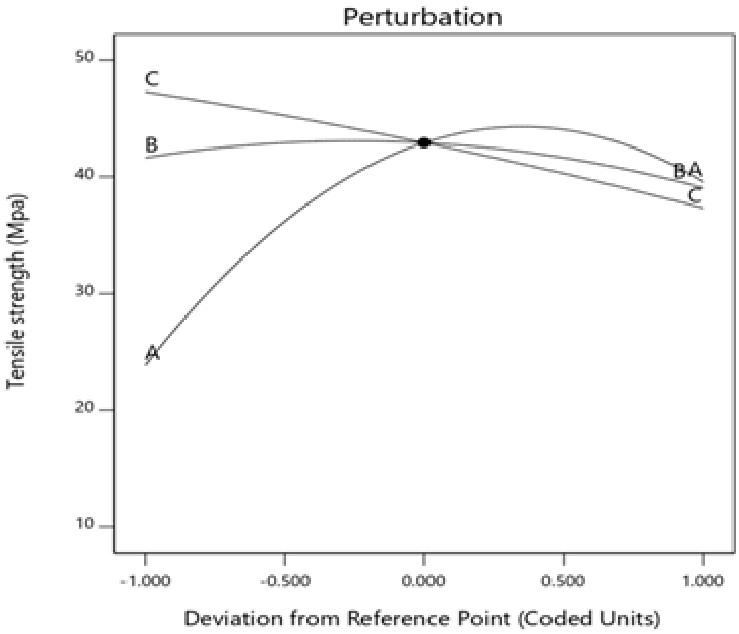

Fig. 2 Effect perturbation plot of hybrid nanocomposite following tensile test.

Surface response contour plots of hybrid nanocomposite tensile strength

Fig. 3 displays 3D surface and 2D contour effects of the input parameters on the tensile strength behaviour. 3D map of the terrain in Fig. 3(a) indicates the impact on tensile strength of the concentration of MWCNT (percent) and KMnO4 Treatment period (mins). From the profile view of the 3D surface map, it can be calculated that the rise in the concentration of MWCNT from 0 to 1.5 %, improves the tensile strength of the hybrid nanocomposite and decreases marginally as the concentration rises to 2 per cent. This decline could be attributed to weak nanotube distribution, solvent impact or particle agglomeration in the nano-composite matrix. Similar results has been reported for hybrid nanocomposite (Rajamohan et al 2019; Zakaria et al 2017; Zhou et al 2007). KMnO4 Treatment period has also improved the tensile strength due to greater interlocking of the fiber in the epoxy matrix (Imoisili et al 2017). From Fig 3(b) optimum treatment period was found to be 3min. Fig. 4 demonstrates the outline of the effect of the concentration of MWCNT (%) and the fiber quality (wt. %) on the tensile strength. As clearly shown in Fig. 4 (a), 3D plot confirms that as fiber content increases from 10% to 30% there has been a relative decline in the tensile strength of the nanocomposite, this could be ascribed to weak wetting of the fiber in the matrix (Hassana et al 2019). The plot of the 2D contour Fig. 4(b) indicates that the tensile strength value was the maximum at 10% and the lowest at 30% with respect to the fiber length material (wt. percent). From Fig. 5, Silhouette view for effect of treatment time vs fibre content, Fig.5 (a), 3D surface plot endorses that treatment time (mins) effects the tensile strength of the hybrid nanocomposite, as increase of treatment time from 1 to 3mins increase the tensile strength but decrease as treatment time increases to 5mins, this may be as a results of fibre degradation due to excessive oxidation at prolong treatment time (Zhou et al 2007). Fig. 5(b), indicates that the value of tensile strength was highest at 3mins and lowest value at 5mins treatment time with respect to fiber length content (wt. %).

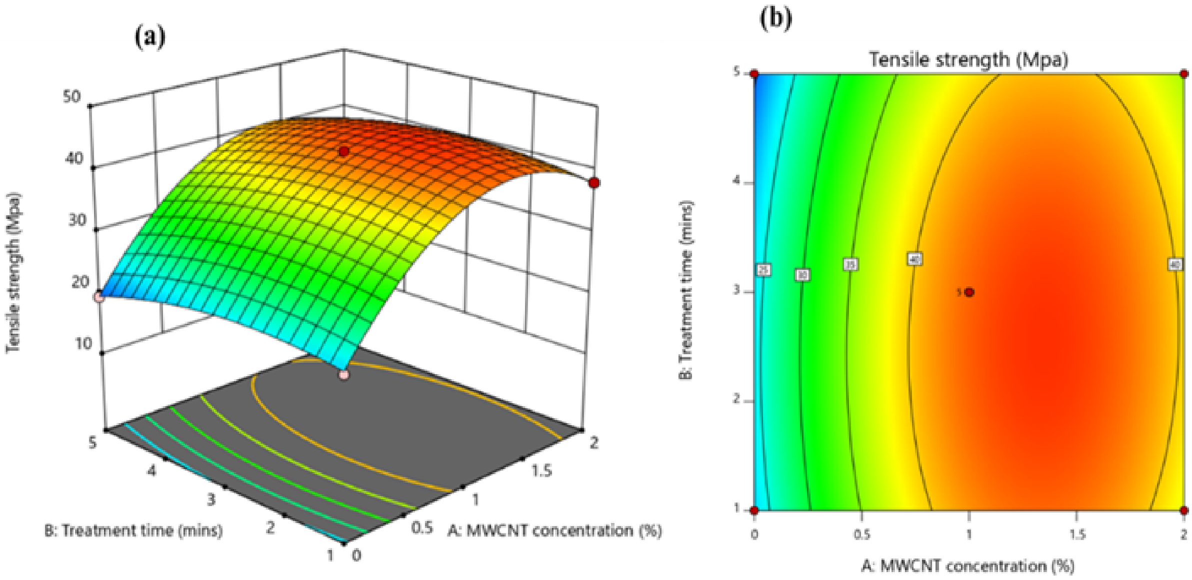

Fig. 3. Surface plot of MWCNT concentration vs Treatment time on tensile strength (a) 3D (b) 2D

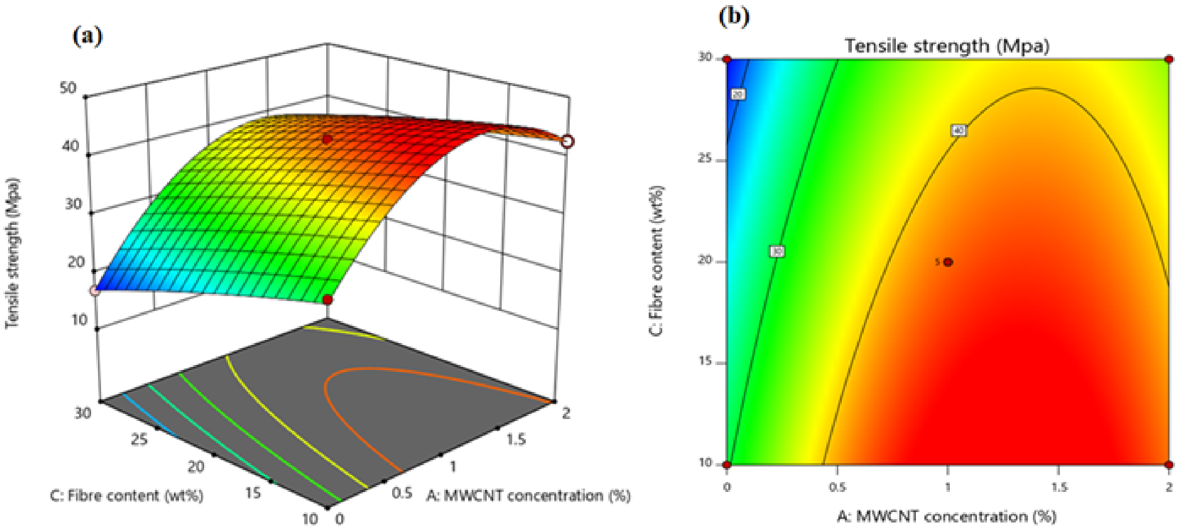

Fig. 4. Surface plot of MWCNT concentration vs Fibre content on tensile strength (a) 3D (b) 2D

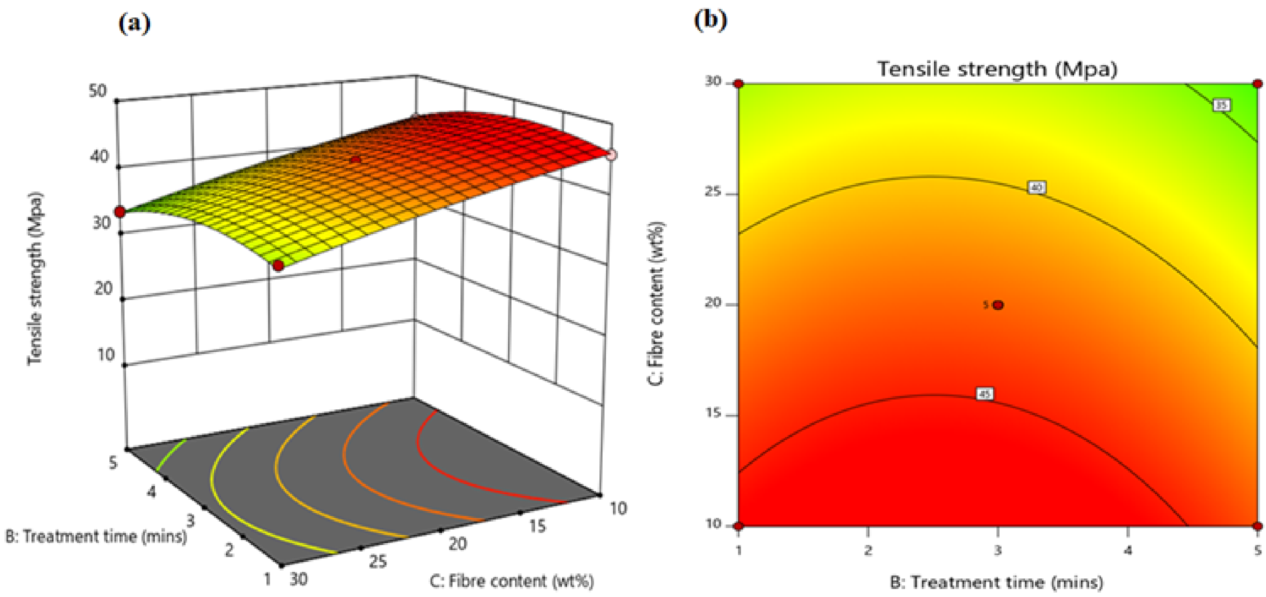

Fig. 5. Surface plot of Treatment time vs Fibre content on tensile strength (a) 3D (b) 2D

Confirmation and optimization test of hybrid nanocomposites

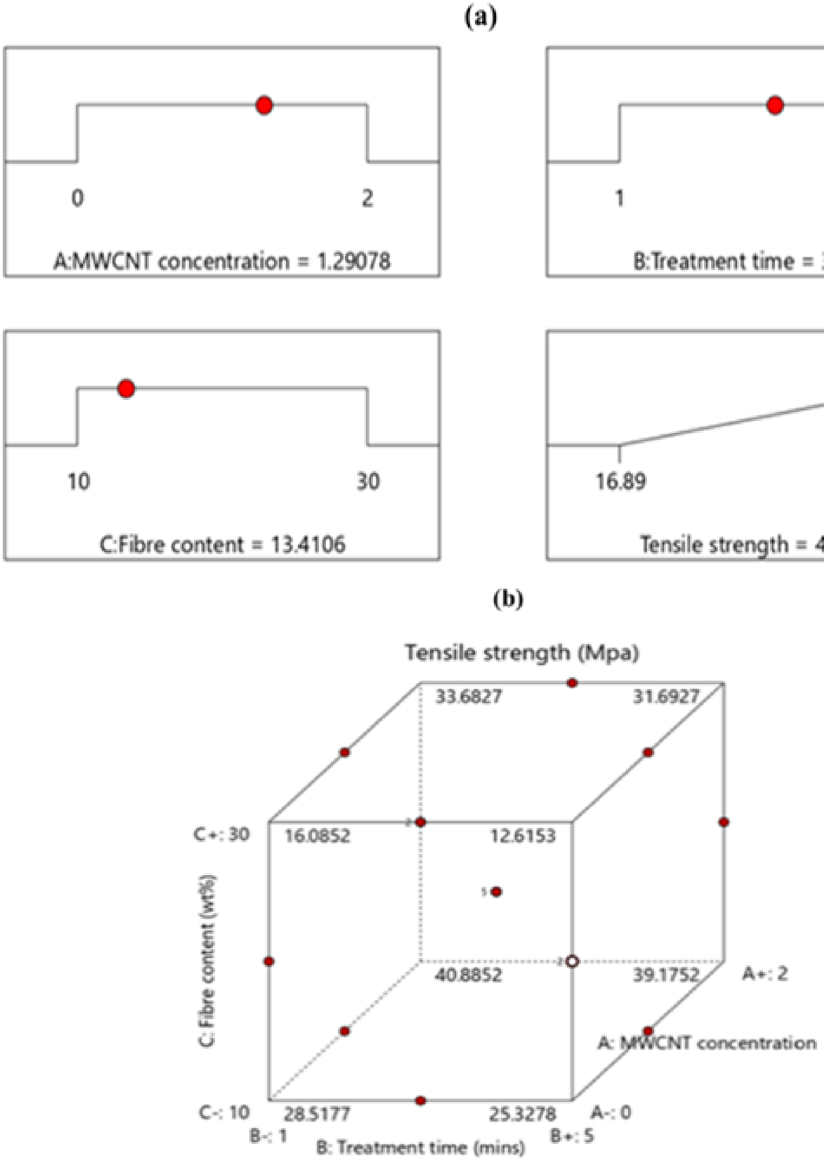

Fig. 6. Plot of numerical optimization for MWCNT concentration (%), $KMnO_4$ Treatment time (Mins) and fibre content (%).(a) ramp and (b) cube

After researching the variable parameters affected the tensile strength of the plantain fiber and MWCNT hybrid nanocomposite, an optimal parameter for tensile strength was identified. For tensile strength optimization, optimum value was set between 16.93 and 45.74 MPa obtained from Table 2. The cube and the optimization ramp are display in Fig. 6 (a-b). The optimal operational condition for ultimate tensile strength for the hybrid nanocomposite as observed from Fig. 6 (a), were a MWCNT concentration (A) of 1.29 (%), a KMnO4 Treatment time (B) of 3.14 (mins) and a fibre content (C) of 13.41 (wt.%). From the BBD results in Fig 6 (a), tensile strength was predicted to be 46.93 MPa. In order to validate the feasibility of the statistical experimental analysis, tensile experiments were carried out under optimal conditions. Five samples each were tested for both pristine and reinforced composites and a mean tensile strength of 27.58Mpa was reported for pristine epoxy and 45.62 MPa for hybrid nanocomposite. The findings revealed that the percentage variance between the observed and the expected values was 2.8 % indicating that the adequacy of the model was appropriate for about 97 % of the projected period. Reasonable agreement was achieved between the expected and the experimental findings, the validation of the concept and the affirmation of the optimum point.

SEM Micrograph of untreated, optimum treated fiber and fracture surface of hybrid nanocomposite are exhibited in Fig. 7. Untreated fiber surface are shown in Fig. 7a, was coated in impurities and waxes (Patra et al 2012). However, the micrograph of KMnO4-acetone treated plantain fiber as seen in Fig. 7b, shows that the standardized roughness of the fiber was obtained elimination of lignin, waxy content and other surface impurities from the fiber surface (Patra et al 2012; Khan et al 2006). The SEM image from Fig.7 (c) clearly shows that MWCNT has been well spread in matrix and successful integrated into plantain fiber hybrid nanocomposites. The micrograph also indicates good interfacial bond between fiber, MWCNT and matrix.

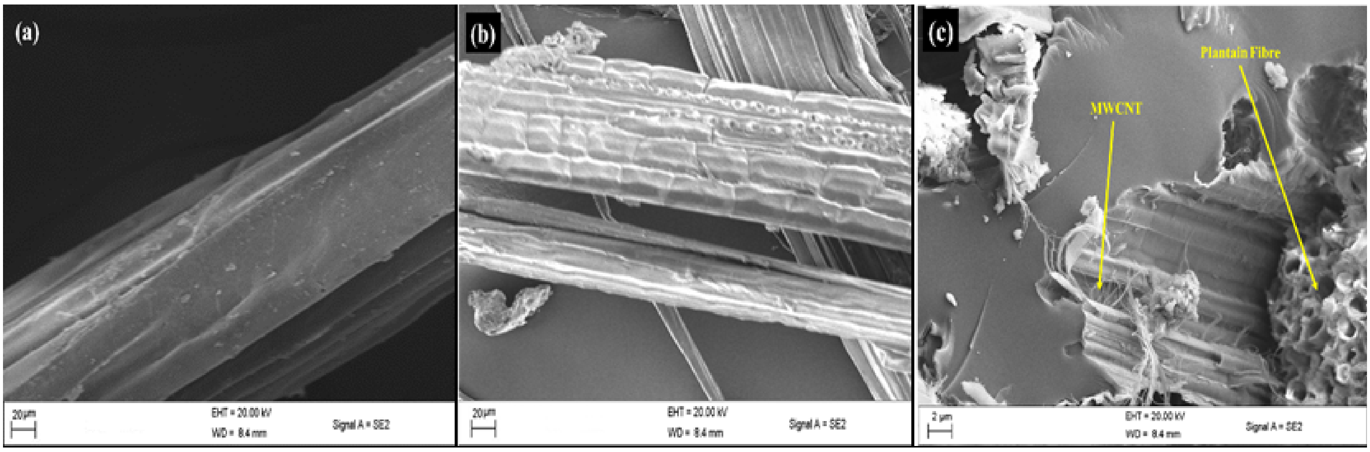

Fig. 7. SEM micrograph (a) untreated fibre (b) treated fibre (c) fracture surface of hybrid nanocomposite

The effect of MWCNT concentration, KMnO4 Treatment time and fibre content on the tensile strength of Plantain (Musa paradisiac) fibre/MWCNT hybrid nanocomposite has been evaluated using RSM via BBD. Determine optimum parameters are a MWCNT concentration of 1.29 (%), KMnO4 Treatment time of 3.14 (mins) and a fibre content of 13.41 (wt. %). 46.93 Mpa predicted tensile strength was close to the 45.62 Mpa experimental value. The optimum tensile strength of plantain (Musa paradisiacal) fiber/MWCNT hybrid nanocomposite was increase by 65% over pristine epoxy. The current research has demonstrated that RSM via the BBD technique is an effective way of achieving optimal values for mechanical properties over the least amount of time, reducing production costs and saving resources.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding from URC and GES of University of Johannesburg, and NRF of South Africa.

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SPONGE GOURD-EPOXY COMPOSITES: EFFECT OF HORNIFICATION ON THE CRYSTALLINITY OF THE FIBERS AND ON THE DYNAMIC MECHANICAL BEHAVIOR OF THE COMPOSITE

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ABSTRACT

A study was carried out to compare the effect of the greener hornification treatment with the usual mercerization and acetylation treatments on the crystallinity index (CI) of sponge gourd fibers and on the dynamic mechanical behavior of epoxy composites. Regarding CI, the results showed an increase of 13% for the hornified fibers, in relation to the untreated fiber. This value, however, was lower than that obtained by the mercerization and acetylation treatments (33% and 24%, respectively). A similar trend was obtained when the dynamic mechanical properties were evaluated. However, the use of a chemical-free treatment proved to be efficient in increasing the crystallinity of the fibers and, consequently, the thermal stability not only of the fibers but also of the composites.

INTRODUCTION

The dry vascular system of the fruit of sponge gourd (Luffa cylindrica) has as single characteristic a 3D array of fibers, forming a natural mat. This material has proven to be suitable for applications where weak fiber/matrix interfaces deflect cracks and increase the toughness of composites (Boynard, 2000). However, for applications where tensile strength is of primary interest, the strength of the fiber/matrix interface must be increased to guarantee a suitable load transfer. The common way to increase the strength of the interface is through chemical treatments on the surface of fibers. The chemicals used, however, jeopardize the green approach of using lignocellulosic fibers as reinforcements. Therefore, a green approach to treat the fibers could have many advantages. Although not specifically being a surface treatment, hornification can reduce the hydrophilic character of lignocellulosic materials (Diniz 2004). Therefore, the effects of hornification were compared to that of mercerization and acetylation surface treatments.

Composites with a nominal volume fraction of fibers (Vf) of 20% were manufactured by compression molding. The epoxy matrix was formulated using the diglycidyl ether of bisphenol A (DGEBA) resin and a primary cycloaliphatic polyamine based on isophorone diamine (IPDA) as hardener. The amount of hardener was 20.9 phr (parts per hundred parts of resin). Mercerized, acetylated and hornified fibers were used. The treatments were performed as described by Quinayá (2020). X-ray diffraction analysis was performed using CuKα radiation (λ = 1.5418 Å), operating voltage of 40 kV, current of 30 mA, and steps of 0.02°.s-1. The test was performed from 2θ = 5° to 70°. The crystallinity index was calculated by peak deconvolution. DMA tests of the resins and of the composites were performed using a heating rate of 3 °C/min under nitrogen flow (20 mL/min) from 0°C to 180°C. The three-point bending configuration was used with specimens 19.5 mm long, 6.5 mm wide and 3 mm thick.

RESULTS AND CONCLUSIONS

The results of the CI are listed in Table 1. It can be seen that hornification is less effective than traditional treatments, but also produces an increase in the CI value. This occurs due to the removal of extractives in the process of humidification and drying of the fibers and, mainly, to the contraction of the cell walls (Diniz 2004).

Table 1 Crystallinity index (CI) of sponge gourd fibers.

	Untreated	Hornified	Acetylated	Mercerized
CI, %	50.6	57.3	62.7	67.2

Table 2 shows the variation of the glass transition temperature (Tg), determined from the peak of tanδ curves and the value of the tanδ peak height of the epoxy matrix and of the composites with untreated and treated fibers. It can be observed that the fibers, even without treatment, already caused small increase in Tg of the composite, and that the hornified fibers provided similar results when compared to mercerized ones. It can also be observed that the tanδ peak was reduced in height, which can be associated to restrictions of molecular chain mobility (Nair 2001). From these results, it is clear that the hornification provided results similar to those of chemical-based surface treatments with the great advantage of being a greener approach. The slightly better behavior of untreated fiber composites compared to treated fiber compounds was attributed to the low volume fraction of the fibers used. In fact, the Vf used (20%) is expected to be less than the critical volume fraction when sponge gourd fibers are used due to the low Young´s modulus of these fibers.

Composite/Fibers	Epoxy matrix	Untreated	Hornified	Acetylated	Mercerized
Tg, °C	77.5	79.8	81.0	76.0	79.5
Tanδ peak height	1.135	0.535	0.651	0.620	0.664

RESULTS AND CONCLUSIONS

The authors gratefully acknowledge the funding by Brazilian Agencies CNPq (Grant number: 307363/2018-0) and CAPES (Finance Code 001).

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MODELLING OF A FIBERWOOD MANUFACTURING PROCESS

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ABSTRACT

A model of a fiberwood panel manufacturing process is being developed. This model is developed to reproduce the evolution of unmeasurable variables within the mat (pressure, temperatures), in order to reproduce the operation of the process. For this, the main process (pressing) is modeled in detail to evaluate how energy and matter is transported through the process. Preliminary results demonstrate the possibility of simulating reproduce internal variables throughout the pressing process.

INTRODUCTION

This work focuses on developing a model from partial differential equations of the fiberwood pressing process to reproduce the evolution of internal variables of the process (pressures, temperature) throughout the pressing process (Ismail, 2012, Kavazović et al., 2012). These models would be used to develop computer simulators of the processes, using "Digital Twin" techniques.

A simplified representation of the cross-sectional structure of the press is given in Figure 1 (Pereira, 2006). The adhesive-treated wood-furnish mat is conveyed through the press between two endless steel belts. Heat and pressure have to be transferred from the press into the moving mat. The pressing force is exerted from closed frames onto the press beams and heating platens. The mix of fiberwood obtained by crashing wood and glue is pressed continuously at high temperatures so the glue reacts uniting the fibers and high densities are obtained at the lateral sides of the panel. To have estimators of internal variables, to improve the quality of the product and reduce the energy consumption it is fundamental to have detailed models of the process that reproduce the relations between variables, that are obtained by adapting models of the fiberwood process (Ismail, 2012, Kavazović et al., 2012).

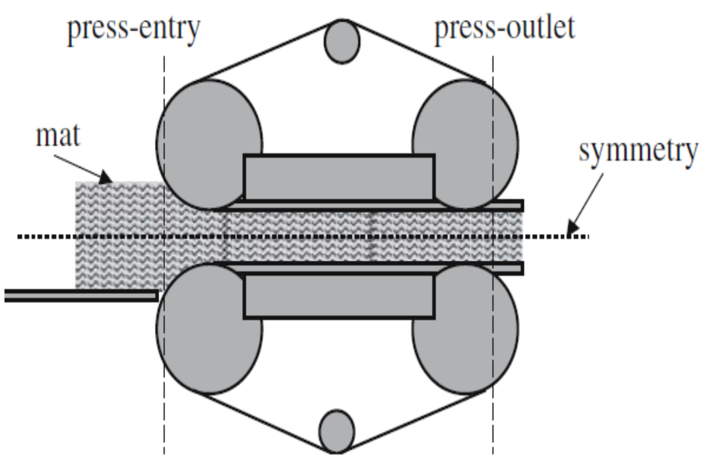

Figure 1: Panel pressing process (Pereira et al, 2006)

RESULTS AND CONCLUSIONS

A model was developed and written in the Matlab software using directly the equations. Some simulations results are now presented, with the mat divided uniformly into a grid of 4000 points (20x20x10). Figures 2 show the evolution of Temperature and Pressure through the press, at different depths. Initially all the layers have the same density but as the pressing proceeds, the density in the peak area increases much faster in comparison with the core region. The results are consistent with the information available from lab measurements and the operator's knowledge. They make possible to see the possibility of predicting distribution of internal variables throughout the pressed mat in different operating conditions (mat speed, applied pressures and temperatures, etc.)

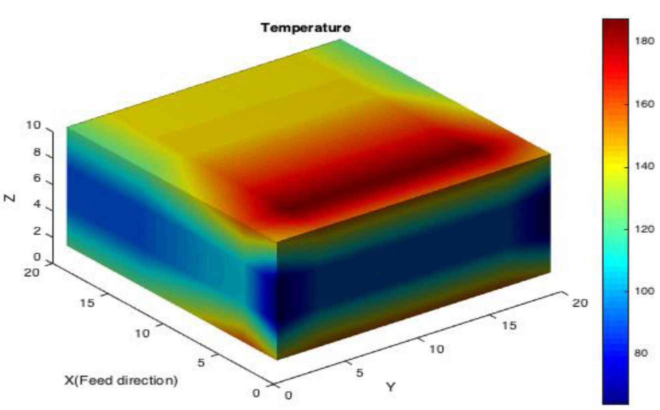

Figure 2: 3D results of temperature distribution using the developed models

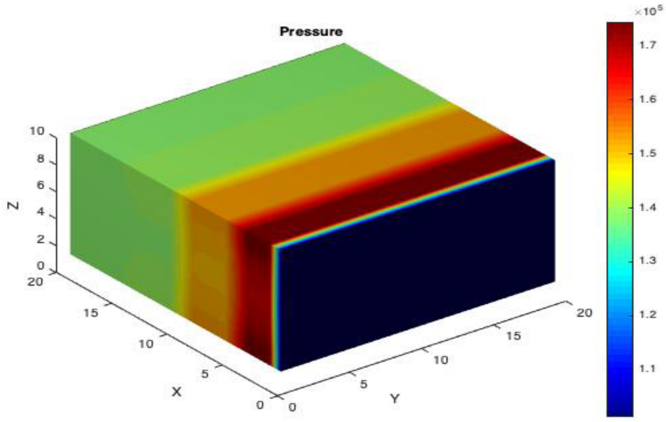

Figure 3: 3D results of pressure distribution using the developed models

ACKNOWLEDGMENTS

Funded by Junta de Castilla y León (CLU-2017-09, VA232P18, UIC 225) and EU-FEDER.

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MECHANICAL AND HYGROSCOPIC PROPERTIES OF MOLDED PULP PRODUCTS USING DIFFERENT WOOD BASED CELLULOSE FIBERS

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ABSTRACT

In this study, we compared the use of cellulose fibers extracted from both softwood and hardwood to produce Molded Pulp Products with optimized mechanical and hygroscopic properties. As there are several methods of fibers extraction used in the paper industry, we compared recycled and virgin fibers, softwood and hardwood, as well as bleached and unbleached kraft method and bleached chemi-thermo-mechanical method in order to compare their properties and obtain the method that gives optimized properties. We observed that improved mechanical after sorption analysis and water immersion were obtained with the use of bleached chemi-thermo-mechanical pulp when compared with the other fibers' extraction methods tested.

INTRODUCTION

As plastic packaging is getting more controversial, industrials are studying other processes to produce more environmentally friendly products. Wood cellulose fibers have been used for paper and pulp industry (Biermann 1996; Bajpai 2018) and have a high amount of processing possibilities in order to make the desired product. Molded Pulp Products (MPP) process is used to make 3D products such as egg trays and household appliances protections (Keyes 1890, 1903). In order to obtain products with the appropriate packaging properties, we need to compare the mechanical and water barrier properties of MPP samples as cellulose is a hygroscopic material whose properties are modified when in contact with water and humidity. In order to properly compare the wood cellulose fibers used in the pulp and paper industry, we made MPP with the different fibers and used a shouldered testing bar shaped punch cutter to obtain testing samples with the same shape and size as described in NF EN ISO 527-2 with the specimen type 5A (AFNOR 2012). For sorption analysis, the testing samples were put in climatic chambers with saturated salts to maintain a specific relative humidity. These samples were kept in the environment until equilibrium was reached and tensile tests were performed at a testing speed of 1mm/min. Tensile strength and strain as well as Young Modulus were studied to compare the results of all cellulose fibers analyzed.

RESULTS AND CONCLUSIONS

Table 1 shows the saturated salts used to obtain the desired water activity as well as Young Modulus for all samples tested after equilibrium is reached. The results from tensile tests and water uptake following sorption analysis in Figure 1. We can observe that using BCTMP allows us to obtain a higher Young Modulus for all water activities when compared to all the other materials tested.

Table 1 Saturated salts used to obtain specific water activity (a_w) and tensile test results

Samples	a_w (saturated salt)	0.10 (KOH)	0.33 ($MgCl_2$)	0.55 ($Mg(NO_3)_2$)	0.75 (NaCl)	0.98 (K_2SO_4)
R-NPM	Recycled NewsPapers and Magazines	770	812	880	674	279
R-CBB	Recycled CardBoard Box	923	1 161	1 097	759	411
BCTMP	Bleached Chemi-Thermo-Mechanical Pulp	1 390	1 200	1 197	1 143	561
BSKP	Bleached Softwood Kraft Pulp	464	485	524	340	180
BHKP	Bleached Hardwood Kraft Pulp	343	409	399	332	156
USKP	Unbleached Softwood Kraft Pulp	619	813	591	595	268

When recycled, cellulose fibers are cut and become shorter thus lowering their mechanical properties. BCTMP process keeps most of wood molecules such as lignin, pectin and hemicellulose, maintaining their mechanical properties. As for kraft fibers, the kraft process removes all wood molecules but cellulose fibers, modifying their structure and reducing their mechanical properties with a reduced fibers cohesion.

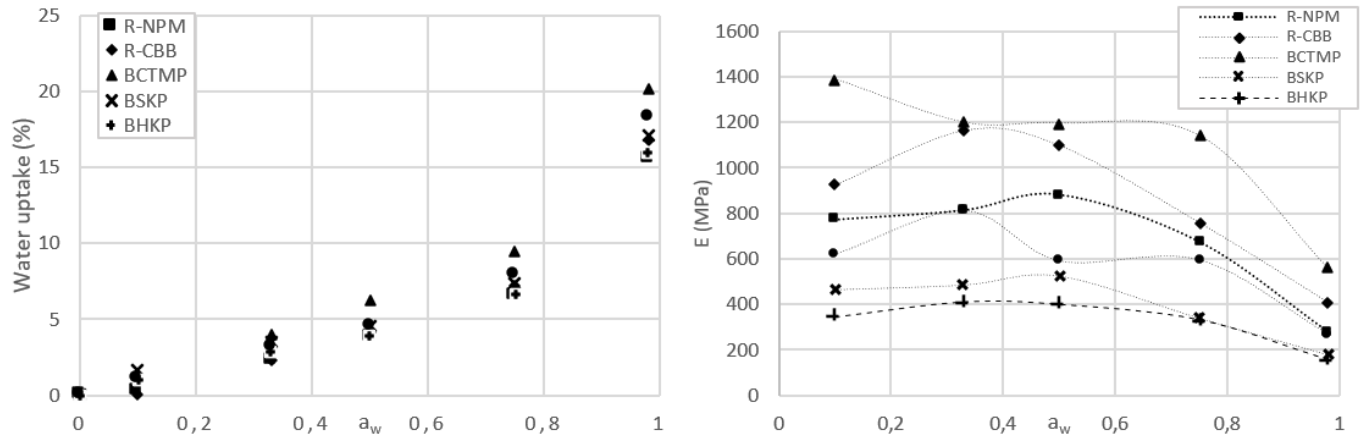

Fig.1 Water uptake following sorption analysis (left) and tensile test results (right)

This study shows the importance to analyze the water uptake of cellulose fibers on the mechanical properties of Molded Pulp Products. Each type of cellulose fiber tested show a specific behavior that needed to be understood to use the appropriate material for optimized product properties.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by French National Association for Research and Technology (ANRT) for funding Claire Dislaire's PhD thesis with a CIFRE fellowship in partnership with Ecofeutre and the Dupuy de Lôme Research Institute of the South Brittany University (France).

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HIGH-STRENGTH BIOCOMPOSITES - A COMPARISON OF LIGNOCELLULOSE MICROFIBRILS AND FIBERS

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ABSTRACT

This work describes mechanically released microfibrils from kraft spruce fibers, containing different residual lignin contents. Effect of lignin content on the structure and composition of the corresponding microfibrils is elaborated. Cellulosic films from fibers or microfibrils of same density were prepared for comparison. Hot-pressed microfibril films were also prepared for mechanical performance. Structure, mechanical properties, and water/moisture interactions are discussed.

INTRODUCTION

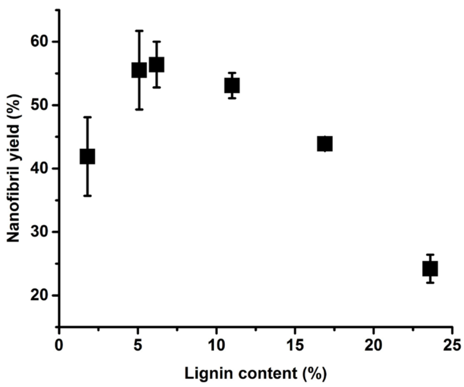
Kraft fibers are industrially predominant fibers in the pulp and paper industry. Unbleached fibers are of particular interest due to their high production yield, shorter chemical treatment and suppressed moisture sensitivity. Microfibrillated lignocellulose (MFLC), obtained from fibrillation of fibers, has emerged as an important building block for materials production.

Lignin contains charges1 and makes the fibrillation easy, while lignin itself is intermixed with cellulose fibrils and cements them together2, impeding the fibrillation. The optimum lignin content, at which these two competing factors are balanced is investigated. A series of kraft pulp fibres with different lignin content was prepared from spruce, and was then mechanically beaten and homogenized into MFLC with different lignin contents. Thereafter, the nano-sized fibrils' fraction and width of fibrils were analyzed.

Lignin-rich fibers/fibrils at the conditions of heat and moisture can be plasticized. Therefore, in this study, moist hot-pressing was used to make dense cellulosic films for mechanical performance. Films made from MFLC are typically much stronger and more ductile (larger strain to failure) than wood fiber films, although densities are seldom similar in the literature, which makes comparisons difficult. Here, the effect of fibrous reinforcement dimensions (microscale diameter fibers or nanoscale fibrils) on mechanical properties, and deformation mechanisms are discussed.

RESULTS AND CONCLUSIONS

Plot of nanofibril yield or mass fraction of nanosized fibrils (width<100nm), a measure of "ease of fiber fibrillation", against lignin content (2-24%) is shown in Fig. 1.



MFLC suspensions with a middle range lignin content (5-11%) showed higher nanofibril yields than bleached sample due to a higher charge level. While at very high lignin content, the binding effect from high lignin content impeded fibrillation. The large fibrils of MFLC-K2 and MFLC-K65 showed a width of 0.2-0.8 μm, while the width of MFLC-K114 fibrils was typically 1–2 μm.
Wood fiber and MFLC film structures of same density (25% porosity) followed almost the same tensile curves, but fiber films failed at lower strains due to smaller pores/structural defects. Therefore, modulus revealed to be more relevant to density and composition, rather than geometry of constituent particulates. Modulus and strength of hot-pressed fiber films increase up to an optimum residual lignin (11-17%) and then decrease. Enhanced stress transfer is related to lignin binding effects. Decreased mechanical properties of very high-lignin films were due to large structural defects related to fiber bundles.
Despite the wide distribution of fibrils' width, by utilizing lignin/hemicellulose plasticity, MFLC hot-pressed into dense films, competing with literature cellulose nanofibril films. Hot-pressed MFLC due to low porosity (5-13%) showed high mechanical properties (Modulus up to 20 GPa and ultimate tensile strength up to 260 MPa). Hot-pressed high-lignin MFLC showed very high wet-strength, related to lignin effects on limited swelling and moisture-durable inter-fibril bonding.
The hot-pressed unbleached kraft fiber films showed mechanical properties (10-13 GPa modulus, 80-150 MPa strength) much higher than high-density hardboards, and even typical load-bearing "semi-structural" plastic composites (modulus of 5−12 GPa and strength of 50−150 MPa)3. These hot-pressed unbleached kraft fibers films are industrially relevant, recyclable, and made "green", hence have great potential and promise as future materials.

ACKNOWLEDGMENTS

The authors acknowledge the funding by Swedish Foundation for Strategic Research and STFI association of interested parties, and Pär A. Lindén for experimental help.

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VALORISATION OF INVASIVE PLANTS FROM MACARONESIA AS FILLER MATERIALS IN THE PRODUCTION OF NATURAL FIBRE COMPOSITES BY ROTATIONAL MOULDING

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ABSTRACT

This paper compares the mechanical properties of different natural fibre composites produced by rotational moulding, as a way of waste valorisation from campaigns to control invasive plant species in Macaronesia. Rotomoulded parts produced with polymeric matrices (polyethylene) and filled with up to 20 % by weight of cellulosic fibres obtained from *Arundo donax L., Pennisetum setaceum* and *Ricinus communis* plants are characterised in terms of tensile, flexural and impact strength.

INTRODUCTION

Invasive species are a real thread to the preservation of ecosystems, being their presence especially dangerous in areas with high biodiversity such as the Macaronesian archipielagos: Madeira, Azores and the Canary Islands. Some plant species such as giant reed *(Arundo donax L.)*, fountain grass *(Pennisetum setaceum)* or castor oil plant *(Ricinus communis)* have spread without any control in these three archipielagos affecting natural ecosystems and endangering some of the endemisms found in this region. The Macoronesian region, despite representing only 0.2% of the of the European Union's territory, hosts over a quarter of the plant species of community interest listed in Annex II of the Habitats Directive (92/43/EEC) [1].

Several campaigns are undertaken every year to control the spread of these specimens on the Islands, but these do not appear to be fully effective in controlling and eradicating these invasive species, mainly due to the lack of regularity in this work. As a way of increasing the effectiveness of these control strategies, it has been proposed to use the plant waste from these campaigns to obtain natural fibres for their use in composites production.

RESULTS AND CONCLUSIONS

Inv2mac and ecoFIBRAS projects aim at achieving a better environmental state of preservation of natural ecosystems by studying the distribution of different invasive plant species in Macaronesia, performing their biological, chemical and physical characterization and trying to valorize them to obtain composite materials, with the final objective of supporting periodic actions of ecosystems cleaning. In particular, this work deals with the use of cellulosic fibres obtained from *Arundo donax L.* (AD), *Pennisetum setaceum* (PS) and *Ricinus communis* (RC) for the production of polymer matrix composites by rotational moulding. As a summary of the biodistribution study, it can be concluded that giant reed can be found in the three archipelagos, as well as castor oil plant, although this last is only found in anthropized spaces. Fountain grass can only be considered as dangerous in the Canary Islands, although some first populations have been found in Madeira.

Some mechanical devices and procedures have been developed for the extraction of cellulosic fibres from these plants, also characterizing them in terms of infrared spectrum, scanning electron microscopy, thermogravimetric analysis and chemical composition determination.

Segregation and agglomeration of filler and reinforcing materials have been recurrent problems in the production of composites by rotomoulding [2]. After preparing and characterising different formulations of rotational moulding composites with fibre contents from 5 to 10 % (wt), the possibility of increasing the amount of filler material to 20 % (wt) by grinding and sieving the natural fibres was assessed. Cellulosic fibres of each plant species were ground and sieved, separating them in four particle sizes of fibres of each species (untreated and alkaline treated), using them as fillers of PE matrix (Matrix Revolve N461) to produce sample parts (cube shape) by rotomoulding these blends into a 120 x 120 x 120 mm aluminium mould. Test specimens were obtained from each face of the cubes and then tested for tensile, flexural and impact properties.

Table 1. Mechanical properties of rotomoulded composites (PE matrix and 20 % fibre). A, B, C, D refers to different fibre sizes distribution.

COMPOSITE	DENSITY (g/cm^3)	IMPACT Strength (kJ/m^2)	TENSILE (MPa)			FLEXURAL (MPa)			SHRINKAGE %
			Ultimate strength	E	Yield strength	Ultimate strength	E_f	Yield strength	
R.PE.	**0,901**	**17,6** ± 1,1	**16,1** ± 0,1	**395,4** ± 71,2	**7,2** ± 1,3	**18,7** ± 2,1	**661,2** ± 120,7	**9,0** ± 1,7	**3,83**
R.PE.AD.20.A	**0,720**	**8,5** ±1,67	**12,2** ±0,16	**382,7** ±46,08	**3,7** ±0,72	**12,4** ±1,14	**637,1** ±72,05	**6,2** ±0,95	**1,80**
R.PE.AD.20.B	**0,654**	**4,6** ±0,69	**7,9** ±0,82	**314,9** ±30,09	**5,0** ±0,69	**10,9** ±1,08	**515,1** ±44,52	**6,3** ±0,75	**1,52**
R.PE.AD.20.C	**0,562**	**2,6** ±0,88	**4,7** ±0,80	**217,5** ±36,25	**2,1** ±0,75	**6,3** ±3,24	**336,1** ±143,15	**3,1** ±1,22	**1,73**
R.PE.AD.20.D	**0,589**	**1,7** ±0,64	**3,9** ±2,03	**179,0** ±89,12	**1,6** ±0,74	**5,2** ±4,14	**219,8** ±166,18	**2,8** ±2,26	**2,47**
R.PE.ADt.20.A	**0,785**	**9,5** ±1,39	**12,9** 0,37	**430,4** ±21,56	**5,3** ±1,64	**14,3** ±1,41	**721,8** ±78,66	**6,9** ±0,98	**2,01**
R.PE.ADt.20.B	**0,731**	**7,0** ±1,44	**9,9** ±0,74	**392,4** ±6,29	**5,7** ±0,64	**13,2** ±1,14	**677,8** ±127,12	**7,6** ±0,09	**1,67**
R.PE.ADt.20.C	**0,569**	**2,7** ±0,61	**5,1** ±1,16	**229,7** ±46,17	**3,4** ±0,72	**6,9** ±2,28	**389,3** ±103,67	**3,9** ±1,24	**1,61**
R.PE.ADt.20.D	**0,613**	**2,5** ±1,09	**4,8** ±1,92	**224,8** ±96,90	**2,6** ±1,07	**5,9** ±3,19	**263,6** ±143,59	**3,2** ±1,80	**2,41**
R.PE.PS.20.A	**0,515**	**3,3** ±0,57	**5,5** ±0,32	**249,5** ±31,85	**1,7** ±0,21	**5,9** ±0,68	**268,1** ±36,16	**3,4** ±0,64	**2,09**
R.PE.PS.20.B	**0,527**	**2,5** ±0,62	**5,2** ±0,46	**224,1** ±34,39	**2,7** ±0,91	**5,0** ±0,10	**266,4** ±13,29	**2,8** ±0,20	**2,06**
R.PE.PS.20.C	**0,527**	**1,8** ±0,36	**3,8** ±0,48	**202,7** ±36,86	**1,5** ±0,34	**4,3** ±1,84	**214,2** ±58,77	**2,5** ±1,06	**2,18**
R.PE.PS.20.D	**0,496**	**1,2** ±0,62	**1,6** ±1,35	**81,2** ±51,93	**0,5** ±0,33	**1,8** ±1,40	**74,1** ±64,55	**1,1** ±0,77	**3,26**
R.PE.PSt.20.A	**0,755**	**8,1** ±1,11	**11,6** ±0,41	**389,4** ±30,97	**4,5** ±1,31	**13,2** ±1,44	**583,4** ±42,37	**6,7** ±1,33	**1,77**
R.PE.PSt.20.B	**0,775**	**8,4** ±1,13	**11,9** ±0,58	**424,6** ±43,45	**6,1** ±1,03	**14,4** ±1,67	**681,4** ±95,69	**7,3** ±0,70	**1,69**
R.PE.PSt.20.C	**0,707**	**5,3** ±1,62	**9,0** ±0,75	**344,1** ±14,00	**4,1** ±0,92	**11,9** ±1,82	**621,3** ±103,76	**5,9** ±0,31	**1,65**
R.PE.PSt.20.D	**0,633**	**3,8** ±0,32	**6,8** ±0,57	**264,1** ±26,07	**4,0** ±1,26	**8,5** ±1,43	**457,0** ±16,70	**4,3** ±0,32	**1,56**
R.PE.RC.20.A	**0,595**	**3,6** ±1,19	**7,6** ±1,15	**266,9** ±25,29	**1,6** ±0,35	**6,7** ±3,88	**226,0** ±131,17	**3,5** ±2,38	**2,66**
R.PE.RC.20.B	**0,524**	**1,9** ±0,28	**4,2** ±0,54	**210,6** ±32,46	**1,5** ±0,28	**4,5** ±1,04	**206,0** ±52,22	**2,2** ±0,26	**2,22**
R.PE.RC.20.C	**0,503**	**1,4** ±0,48	**2,6** ±0,61	**146,5** ±55,23	**1,1** ±0,25	**3,7** ±1,95	**169,9** ±71,89	**1,7** ±0,71	**2,42**
R.PE.RC.20.D	**0,514**	**1,3** ±0,5	**1,8** ±1,48	**105,3** ±70,40	**0,8** ±0,48	**2,0** ±0,99	**84,8** ±47,22	**0,9** ±0,66	**2,86**
R.PE.RCt.20.A	**0,729**	**6,6** ±0,69	**11,4** ±0,33	**373,8** ±28,84	**3,6** ±1,31	**12,6** ±1,91	**563,1** ±105,99	**6,0** ±1,37	**2,37**
R.PE.RCt.20.B	**0,526**	**2,3** ±0,58	**3,9** ±0,48	**192,5** ±28,63	**2,2** ±0,61	**5,3** ±1,91	**252,6** ±72,35	**2,3** ±0,31	**2,15**
R.PE.RCt.20.C	**0,408**	**0,9** ±0,35	**1,6** ±0,81	**65,5** ±26,93	**0,6** ±0,18	**1,6** ±0,71	**84,4** ±49,88	**1,0** ±0,55	**2,05**
R.PE.RCt.20.D	**0,462**	**1,1** ±0,55	**2,0** ±1,46	**96,2** ±65,40	**0,7** ±0,40	**2,6** ±1,79	**97,8** ±64,60	**1,3** ±0,91	**2,38**

This study is a first approach to the valorisation of residues obtained from periodic campaigns of control of invasive species, performed by public authorities, usually at local level. It is important to highlight that the main objective of this research does not focus on an economic profitable activity, but on the reduction of wastes to be disposed from ecosystems maintenance actions and the investment of potential incomes into preservation policies.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by European Funding for Regional Development (FEDER), INTERREG MAC 2014-2020 [MAC ECOFIBRAS, grant number MAC/4.6d/040 and INV2MAC, grant number MAC2/4.6d/229].

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A REVIEW OF 3D AND 4D PRINTING OF NATURAL FIBRE BIOCOMPOSITES

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ABSTRACT

This paper proposes a critical overview of the current state of 3D printing of natural fibre-reinforced composites or biocomposites for mechanical purposes, as well as an overview of their role in 4D printing for stimuli-responsive applications.

Natural discontinuous fibre-reinforced polymers exhibit moderate mechanical properties compared to composites manufactured by conventional processes due to specific factors of the 3D printing process, such as high porosity, low fibre content, and a very low fibre-aspect ratio (L/d). Hygromorph BioComposites (HBC) are categorized into a new class of smart materials that could be used for 4D printing of shape-changing mechanisms. Fibre content, fibre orientation control, and fibre continuity are outlined in relation to known challenges in actuation performance.

INTRODUCTION

Additive manufacturing has been extensively investigated over the past decade due to its disruptive potential in the design of advanced materials and structures. Among the various additive manufacturing techniques, Fused Filament Fabrication (FFF) 3D printing is one of the most applied techniques to polymers and composites in the literature. However, most review articles on 3D printing deal with synthetic composites and do not mention the current trend of research on biocomposites while the advent of 3D and 4D printing represents a great opportunity for biocomposites to develop for the first time on the same time scale as their synthetic counterparts. A complete state-of-the-art review of the work carried out to date that also highlights recent trends on 3D and 4D printed biocomposites is thus justified.

RESULTS AND CONCLUSIONS

Polymers reinforced with discontinuous natural fibers exhibit moderate mechanical properties (Figure 1) compared to synthetics composites and biocomposites made by conventional processes due to factors specific to the 3D printing process, such as high porosity, low content of fibers and a very low fiber aspect ratio (L / d) (A. Le Duigou et al. 2016)(A. Le Duigou, Correa, et al. 2020).

An opportunity is to develop continuous natural fibre reinforced biocomposite to optimize mechanical performance (Antoine Le Duigou et al. 2019)(A. Le Duigou, Chabaud, et al. 2020).

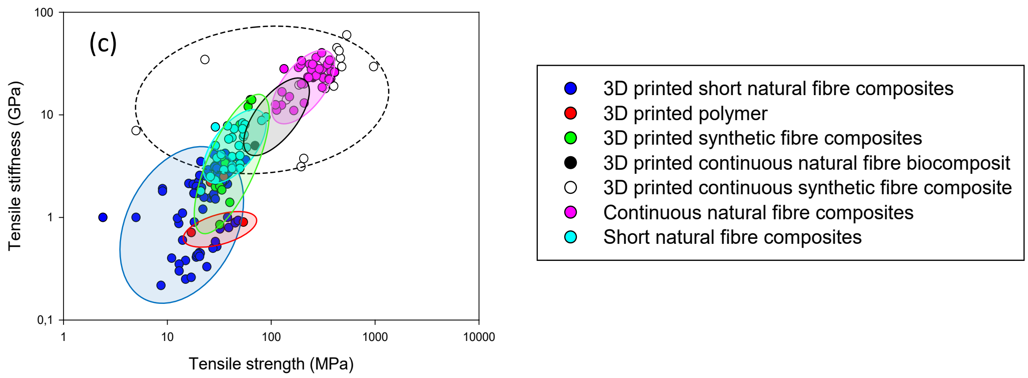

Figure 1. Literature review of tensile properties of natural fibre biocomposites made with 3D printing. Comparison between pure polymer, short natural fibre biocomposites and synthetic counterparts, continuous natural fibre biocomposites and synthetic counterparts, 3D printing versus conventional process (injection or thermocompression) (A. Le Duigou, Correa, et al. 2020)

Hygromorphic biocomposites (HBCs) are classified into a new class of smart materials that are used for 4D printing (Figure 2). Fiber content, fiber orientation control and continuity are described as the key factors for controlling actuation

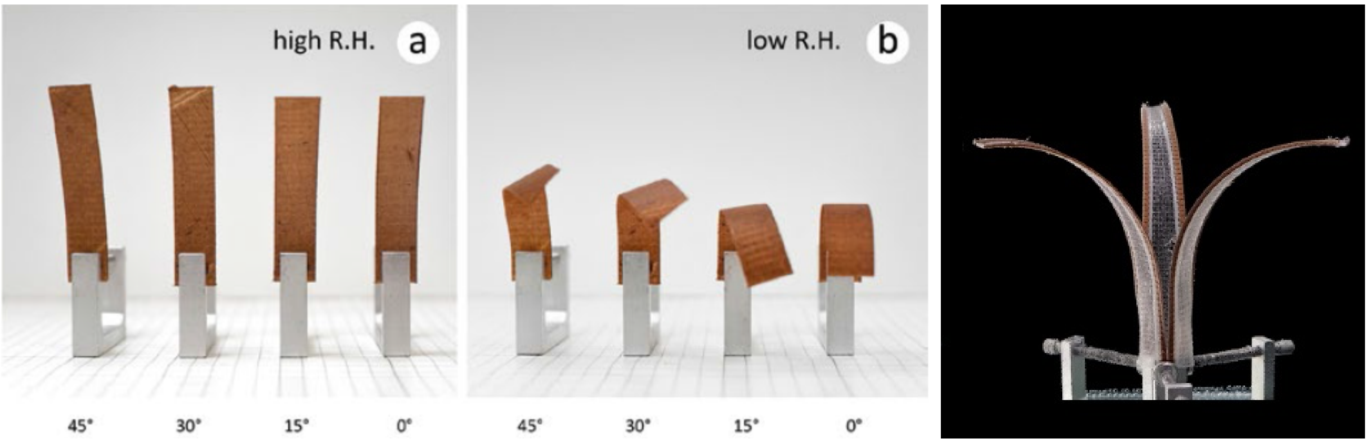

Figure 2. Example of 4D printed hygromorph biocomposites (Poppinga et al. 2020)(Correa and Menges 2017)

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MICROMECHANICAL CHARACTERIZATION OF WOOD FIBRE-REINFORCED BIOCOMPOSITES

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ABSTRACT

Wood fibre-reinforced biocomposites offer the potential of replacing conventional fossil-based short-fibre composites as a more sustainable alternative. This work deals with opportunities and challenges on the use of wood fibre-reinforced biocomposites for structural applications on the basis of micromechanical considerations. A closer focus is drawn on the characteristics and reinforcement ability of wood fibres, compared to their structural components named as cellulose nanofibrils (CNF), nanocellulose crystals (CNC). The potential of woody materials is demonstrated and evaluated using physical tensile tests of injection molded specimens. The test results show that wood fibres can serve as promising reinforcement for bioplastics.

INTRODUCTION

Wood fibres have been used as reinforcement in thermoplastics for different applications in the construction, building and automotive industry (Mallick, 2010), (Dai, 2014). In addition, increasing environmental awareness increases the attractiveness of recycled and renewable raw materials such as wood fibres and bioplastics. In this study, bioplastics are considered as thermoplastic materials derived from biomass, e.g. polylactic acid (PLA). Improving the mechanical properties of a polymer is a major reason for using fibres as reinforcement of polymeric matrix systems. Other reasons can be weight and cost reduction purposes (Neagu, 2006). The reinforcing effect through wood fibres can vary depending on several factors, e.g. production method, fibre type and quality (Chinga-Carrasco, 2011). This study focuses on a theoretical micromechanical characterization of wood fibres and experimental investigations of wood fibre-reinforced biocomposites. The purpose is to substantiate the potential of wood fibre-reinforced biocomposites with theoretical principles.

A background in micromechanics of biocomposites is provided, considering different types of wood fibres and nanofibres, based on literature. In addition, we provide data from our own research about biocomposites made of wood fibre-reinforced PLA. Five different test series, including 10 individual tests each (injection molded), were tensile tested on a Zwick Roell Proline with a load cell of 2.5 kN. We also demonstrated the potential of the biocomposites for 3D printing product prototypes by FDM (Figure 1).

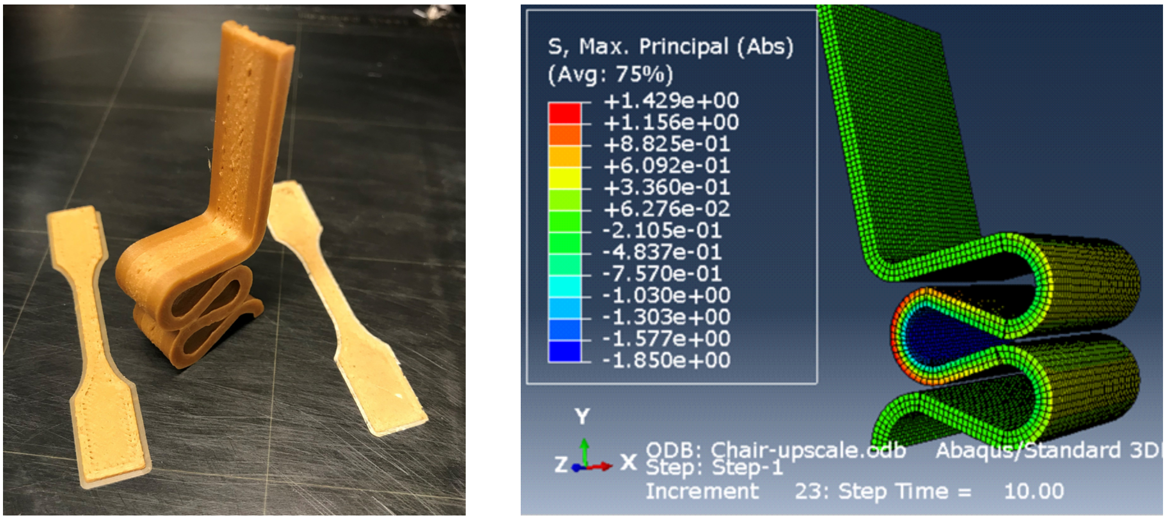

Figure 1: FDM printed miniature chair model and dogbones made from wood fibre reinforced PLA filament (left). Finite element model of the chair to demonstrate the potential of wood fibre reinforcements (right).

RESULTS AND CONCLUSIONS

Wood fibres are well established as a reinforcement for biocomposites and contribute some good properties, such as higher stiffness, strength increase, weight reduction and cost reduction. Although there are still challenges in the production of such composite materials, mainly related to the hygroscopic nature of wood fibres and their varying quality, the use of wood fibre-reinforced biocomposites appears to be a feasible alternative for a variety of applications.

The results of the tensile tests show that the addition of wood fibres can improve the mechanical properties of PLA significantly. Adding woody components can contribute to optimize the stiffnesses according to the application, e.g. 3D printing. Mechanical properties for different applications can be tailored by carefully mixing the biocomposite components.

ACKNOWLEDGMENTS

The Research Council of Norway and the companies supporting the ALLOC project (Grant no. 282310) are thanked for financial support.

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INFLUENCE OF MANUFACTURING CONDITIONS ON THE MECHANICAL PROPERTIES OF NONWOVEN FLAX/PLA COMPOSITES

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ABSTRACT

In this work, the nonwoven flax/PLA comingled fabrics are used to fabricate composite parts. The influence of the consolidation pressure and the temperature is investigated to identify the optimum parameters for the composite part's impregnation quality. The mechanical properties of the co posites in terms of interlaminar shear strength (ILSS) and impact strength are investigated to correlate them with manufacturing parameters. Furthermore, the influence of the degree of crystallinity on the impact strength of the composites is quantified.

INTRODUCTION

Natural fibers such as flax fibers are currently considered to possess good mechanical performances as reinforcement for composite materials [1]. Currently, the flax reinforcements are being used in the form of nonwoven fabrics for semi-structural applications in the automotive sector [2]. Furthermore, these nonwoven fabrics allow for highly drapable facilitating to produce parts with complex shapes [3]. In this study, the needle punched flax/PLA fabrics were used to manufacture composite plates. The needle-punched nonwovens were manufactured by CETI, France. The flax fabrics were dry-laid by carding, and the PLA nonwoven was then cross-lapped to obtain three different areal densities (See Table 1). The composites were manufactured using the compression molding technique. The fabrics were cut and dried overnight at 50°C under vacuum. The dried fabrics were immediately transferred into a preheated rectangular mold of dimensions 290x290x3mm3. A stepped consolidation cycle was adopted to ensure good impregnation and low void content [4]. In order to investigate the influence of this stepped consolidation cycle, the dwell time at every pressure step was varied from 4 min to 1 min, and the temperature was varied between 165°C to 185°C, which results in 12 test cases. The investigation of the impregnation quality of the composites was carried out in two ways. Firstly, the bulk void content was quantified based on the density measurements. Next, the interfacial void content, i.e., flax/matrix interface void content, was quantified using microscopy. The specimens were then subjected to ILSS and impact tests to characterize their mechanical performance.

RESULTS AND CONCLUSIONS

In Table 1, the tensile strength of the nonwoven flax/PLA fabrics is presented. It can be noticed that the fabrics exhibit higher strengths in the cross-direction (CD) when compared to the machine direction (MD). This difference can be directly attributed to the pulling forces during the preparation of nonwoven fabrics. On the other hand, it can also be linked to the content of flax. Considering that these nonwoven fabrics are only needle punched and not wet-laid, the interaction forces between the flax fibers and PLA is limited in the nonconsolidated state [5]. However, these differences will be reversed in composites, given that the stress transfer is ensured because of the solid PLA matrix. A quantitative relation between the manufacturing parameters along with physicochemical properties and the mechanical properties of the composite can be achieved. A correlation between the processing conditions, polymer crystallinity and the impact properties will also be presented [6].

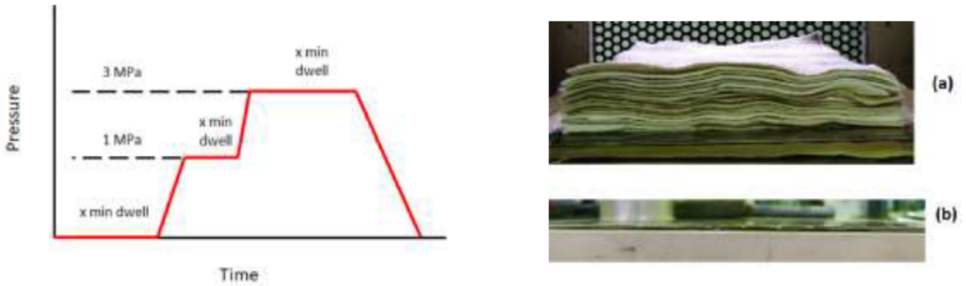

Figure 1: (left) Consolidation cycle of Flax/PLA composites; (right) Flax/PLA composite manufacturing (a) Layup of PLA and Flax/PLA nonwovens (b) composite exhibiting no warpage

Flax/PLA Composition (%)	Areal weight (g/m^2)	Strength (N/50mm)	
		MD	CD
40/60	161.7	64.0	117.9
50/50	183.2	52.0	85.9
60/40	171.7	41.2	63.9

Table 1: Properties of nonwoven flax/PLA fabric

ACKNOWLEDGMENTS

This project has received funding from the Interreg 2 Seas program 2014-2020 co-funded by the European Regional Development Fund under subsidy contract No 2S06-006.

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LINSEED FLAX: A POTENCIAL SOURCE OF FIBRE SUITABLE FOR LOAD BEARING COMPOSITES

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ABSTRACT

Linseed flax is a very popular crop grown around the world for the feed-oil production purpose. In traditional harvesting of linseed flax, the fibre rich stem parts are cut in small pieces and are left in the field, which causes significant loses of fibrous raw materials. In this present work, good quality, long and fine fibres are extracted from dew-retted stems of the linseed flax and the extracted fibres are characterized for their mechanical properties. Two different approaches, depending on the straw alignment in the bale are considered for the fibre extraction purpose; namely the scutching-hackling route and the breaking card route. It is observed that the fibres extracted through scutching-hackling route are longer and cleaner than that of the fibres extracted through breaking card route but the later has a higher production rate than the previous method. However, the linseed flax fibres extracted through both routes have very good mechanical properties which makes them suitable as reinforcement for the load bearing composites.

INTRODUCTION

The ever-growing problem associated with global waste, public's growing awareness on sustainability, environmental legislative pressures such as the European Union end-of-life vehicle act [1], landfill of waste products directives [2], as well as the growing demand for more environmentally friendly products with low impact on the environment have bolstered the interest in bio-based materials in the consumer industry [3]. Use of renewable natural fibres coming from annual plants such as flax, hemp, or nettle as reinforcement material for thermoplastic polymer composite manufacturing fits well in this picture.

At the present time, the demand for textile flax is in constant increase and the present production does not increase at the same rate. This is why, the price of the scutched or hackled flax is in constant increase and is not necessarily compatible with the needs of industries such as the automotive for example. Other sources of high performance fibres should be considered and from them, linseed flax cultivated on about 15000 ha in France but on more than 600000 ha in Canada [4] could constitute a new way to fulfil the some of the technical market needs. Indeed, linseed flax fibres are either burnt in the field or collected for very low added value applications such as heat generation. If the fibre potential was already in different works [5], the feasibility to manufacture load bearing composite materials from linseed flax straw harvested after un-perfect dew retting that follows the traditional combine machine is investigated in this work.

To reach this goal, the fibre mechanical potential as well as the fibre length should be maintained as high as possible. Two different methods fibre extractions processes were used depending on the straw alignment within the bales (as summarised by Figure 1). For randomly oriented straw, breaking rollers associated to a breaking card was used. In the case of aligned straw, a scutching/hackling device was considered. For both extraction processes, the fibres were characterised at the scale of a continuous sliver and their morphological and mechanical properties characterised to conclude on their potential to manufacture load bearing composites.

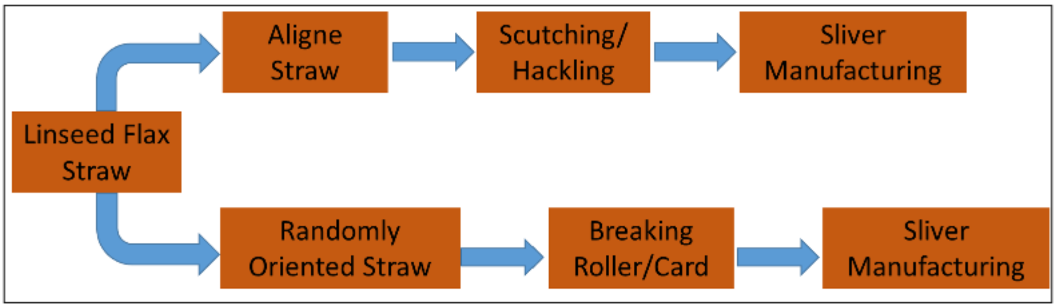

Figure 1: Long and fine fibre extraction approaches from the linseed flax straws.

RESULTS AND CONCLUSIONS

The linseed flax fibres extracted through both approaches were characterized at a scale of continuous sliver for their morphological and mechanical properties to conclude their potential to manufacture load bearing composites. It is observed that the fibres extracted through scutching-hackling route are longer and cleaner than that of the fibres extracted through breaking card route but the later has a higher production rate than the previous method. The tensile properties of linseed flax fibres extracted manually and through both approaches are reported in Table 1. The linseed flax fibres extracted through breaking card method has the lowest mechanical properties among all three samples, it can be attributed to the fibre damage occurred by the roller pins of the breaker card. However, the mechanical potential of all extracted fibres is highly sufficient to be considered as reinforcement for the load bearing composites.

Table 1: Tensile properties of the linseed flax fibres

Sample ID	Tensile strength (Mpa)	Tensile Modulus (GPa)
Manually extracted fibres	1110 ±707	46 ±29
Breaking rollers/card	880 ±297	43 ±19
Scutching/hackling	1004 ±335	44 ±13

These results will be discussed in relation to the harvesting techniques and the potential of development in France and in Europe of both fibre extraction routes.

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PROPERTIES OF BACTERIAL CELLULOSE FOR THE SCENIC ARTS

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ABSTRACT
Kombucha (a symbiotic culture of bacteria and yeast) generates material that, once dried, has the texture of paper or leather, properties that may be explored as textiles for the scenic industry. This study presents an analysis of its specific characteristics, exploring them as a non-conventional material for arts and performance. Costume Design uses surfaces as a powerful way for expression; it may apply the unique features of bacterial cellulose (BC) as assets. A qualitative methodology approach was used - review of relevant literature to deepen knowledge on the research topic as well as observation to identify material properties and possibilities used to express a multitude of narrative ideas, concepts, feelings.

INTRODUCTION
In 2009, the pioneer Suzanne Lee inspired numerous designers with experiments with Kombucha BC (Living circular, 2014). However, its capability to absorb humidity of different sorts does limit its use as conventional garments (Araújo, Gouveia & Moreira da Silva, 2015) i.e., most fibres are required to be hydrophobic for usability, which is not the case in BC. This research paper aims to recognise how these hydrophilic properties, generally seen as disadvantages, may still hold applicability (added-value even), being applied in different contexts (e.g., performance arts). For this, literature review and case-studies were used (Fig. 2. A & B) as well as observation complemented with interventionist approaches (i.e., a costume design was planned and executed in BC, for the materialisation of a specific narrative for a dance scene, alluding to concepts such as metamorphosis, transience and impermanence) (Fig. 1. A, B, C & D).This hydrophilic feature makes it interesting to a more artistic context, such as the performance field of costume design, where the evaluation, exploration and investigation of resources, for effects and possibilities is not only desirable but highly demanded. Many costume designers from the performance arts assert the difficulty of finding textures to strengthen the concept that the director or artist is trying to convey to the audience (Pinillos, 2019). The wardrobe impacts on the expression and interpretation of the artist (Stanislavski, 2009). The use of biomaterials to make artistic costumes is increasingly growing (Fossheim 2019), for instance, in the international conference of costumes: Critical Costume exhibition 2015, designers explore costume/environment dichotomies examining the performative qualities of these types of resources, encouraging alternative representation mediums, art methodologies, the role of the costume and performance, symbology (Pantouvaki, 2015).

RESULTS AND CONCLUSIONS
Results show the aesthetics and plasticity capability of BC. When the costume is dry, it displays different textures, thicknesses and opacities (Fig.1 A & B); However, when exposed to water this material loses its rigidity, the texture changes, starts to lose its red colour (natural red dye) and gains thickness; it transforms, adheres tightly to the body, showing ranges of transparency; it resembles (and feels) like skin, enabling a greater freedom of movements and comfort to the performer (Fig.1 C & D). It changes overtime and through the movements and by the elements to which is exposed. It serves symbolically to stipulated brief. It renders, additionally, a desirable and necessary visual impact and poetry.

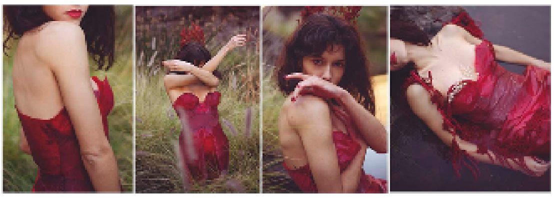
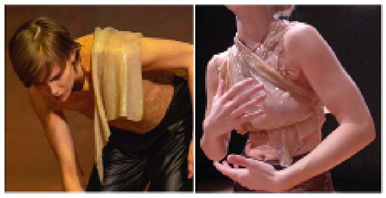

Fig.1 A, B, C, D - BC for costume design. Font: the authors (2020).
Fig.2 A,B- BC costumes. Fossheim (2019).

Although other materials may mimic skin or similar textures, BC also has the particularity of allowing for varied effects, shapes, textures and a range of thicknesses, stiffness, transparencies and colours, depending on simple variables (e.g., humidity, growing time and temperature, dyes). It enables, additionally to look like real genuine skin, stretching and adapting to the body, which is of importance for some performing arts. In this context, the humidity may be a playful element as the performer plays the part, the concept to be interpreted; the expression of a certain feeling or trait may be materialised in the form of a colour or texture, affected by moisture and the BC changing capacities. It may be considered a highly interactive and versatile material, a transformative element, exploring and evoking ephemerality or transmutation. Further studies are needed to grasp resilience through harsh movements and/or different briefings.

ACKNOWLEDGMENTS

The authors gratefully acknowledge support from FCT and CIAUD, Lisbon School of Architecture, Universidade de Lisboa.

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SORPTION BEHAVIOUR, GLASS TRANSITION AND FLOWABILITY OF POWDERED ORANGE COPRODUCT

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ABSTRACT

The aim of this study was to contribute to the valorisation of the orange juice co-product in order to offer it as a natural, versatile, high quality and stable powdered food ingredient for human nutrition. To ensure its efficient use for this purpose, the freeze-dried powdered co-product was characterised in terms of the physico-chemical aspects related to the presence of water and its ability to remain free-flowing and non-agglomerated, allowing an easy handling. The results of this study ensure the flowability and provide the tool to define the conditions for a proper storage of the powdered co-product.

INTRODUCTION

Trying to contribute 100% to the circular economy models of the agri-food industry and in the interest of contributing to a healthy and sustainable diet, the valorisation of the whole orange juice co-product for its use in human food, has been considered. In order to contribute to the feasibility of this proposal, the aim of the present study was to determine the glass transition temperature (Tg)-water content (xw)-water activity (aw) relationships of the freeze-dried powdered coproduct and its ability to remain free-flowing and non-agglomerated, allowing easy handling. For the study, the co-product obtained from the extraction of orange juice was freeze-dried and crushed to get a powder of particle size < 500 μm, which was analysed with regard to its xw, angle of repose, hygroscopicity, wettability, true density, tapped density and porosity (Uscanga et al., 2020). On the other hand, samples of the powdered co-product were equilibrated in environments with different relative humidity and their xw and Tg were measured after thermodynamic equilibrium was reached (Silva-Espinoza et al., 2020).

RESULTS AND CONCLUSIONS

Table 1 shows the powdered coproduct proximal composition. It was calculated from the experimental xw of the obtained powder and the mean orange coproduct composition (USDA, 2018). As it can be observed, this biomaterial is an important source of carbohydrates, with a contribution of 38 g of dietary fiber /100 of powdered co-product (USDA, 2018). Natural carbohydrate biopolymers from plant sources may be an appropriate alternative to the synthetic biopolymers in different uses (Mirhosseini and Amid, 2013). The composition shown in Table 1 and the density of the pure components (Choi and Okos, 1986) were used to calculate true density of the co-product (Table 1). As regards the physical properties measured (Table 1 and Figure 1), the results obtained show that this freeze-dried coproduct has good characteristics as a powdered product. However, due to its hygroscopicity (Table 1), storage at 4°C rather than at room temperature is recommended to ensure the powder flowability, which increases its critical water activity so that in environments with a relative humidity of approximately 35 %, its glassy state would be guaranteed (Figure 1).

Table 1. Orange co-product proximal composition and physical properties measured			
Water (w/w)	0.0156	**Bulk density (gcm^{-3})**	0.213 ± 0.013
Carbohydrate (w/w)	0.8948	**Porosity (%)**	83.836 ± 0.013
Protein (w/w)	0.0537		
Lipid (w/w)	0.0072	**Angle of repose (α°)**	33.3 ± 0.2
Ash (w/w)	0.0286	**Hygroscopicity (%)**	6.458 ± 0.002
True density (gcm^{-3})	1.470	**Wettability (s)**	920 ± 61

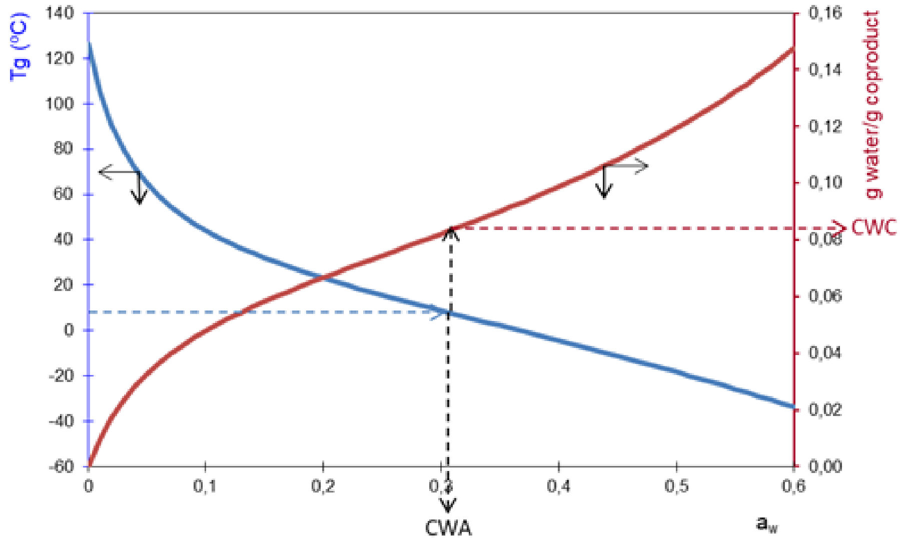

Fig.1 Glass transition temperature (Tg)-water content-water activity (aw) relationships of the freeze-dried powder coproduct. Critical water activity (CWA) and critical water content /CWC) for the glass transition at 4 ºC

ACKNOWLEDGMENTS

The authors thank the Ministerio de Economía y Competitividad for the financial support given through the Project AGL 2017-89251-R (AEI/FEDER-UE).

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EFFECT OF FIBRE TYPE ON THE STICKINESS SENSATION IMPARTED BY A FABRIC WHEN WET

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ABSTRACT

Fabric adhesion to the skin (stickiness or cling) causes wearer discomfort. We investigated the effect of fibre type on the stickiness sensation experienced when damp fabric contacts the skin, for two natural fibres (cotton and merino wool) and one synthetic fibre (polyester). The study considered both objective and subjective methods of measurement. The first consisted of measuring the mechanical parameters involved in the interaction between skin and fabric using a surrogate skin. The adhesion forces, under static and dynamic conditions, were measured. The second part of the study used subjective assessment of the fabrics, with a group of volunteers. Fabrics were pulled across the volunteers' skin, after which they indicated their perception of wet cling. We attempted to associate the mechanical properties of the different fabrics to the sensation of stickiness assessed by human volunteers, to determine if mechanical testing parameters can predict the stickiness sensation. Cotton fabrics had the highest values of adhesion forces and were perceived as stickier compared to wool or polyester fabrics, showing that an objectively measured mechanical parameter can predict the sensation of stickiness.

INTRODUCTION

In a hot environment or during exercise, perspiration, composed of water, minerals, lactate, and urea, alters the interface between clothing and skin by modifying the mechanical properties of this contact [1]. The surface tension of the water and the modification of skin characteristics with the presence of sweat causes adhesion between skin and fabric and changes the perception of the garment for the wearer [2]. 'Stickiness' is the phenomenon whereby fabric in a garment sticks to the skin causing an uncomfortable sensation of itchiness and clamminess.

In this research we worked with three equivalent (weight, thickness) fabrics made of different fibres: cotton, polyester and merino wool. We measured relevant mechanical properties of the fabrics. This involved selection of: (i) a suitable artificial skin (Lorica Soft), close to the mechanical properties of human skin to best mimic the contact between the garments and skin [3]; and (ii) an artificial perspiration solution as lubricant for both mechanical and sensorial testing [4]. Dynamic [5] and static [6] adhesion forces were measured under a range of experimental conditions. The second part of the study was pair-wise sensorial assessment with a panel of volunteers, using a body movement simulator [7].

RESULTS AND CONCLUSIONS

The results from the dynamic adhesion test (which best corresponds to the mode of assessment used with human volunteers) are shown in Figure 1 and key results of the sensorial assessment with human volunteers are summarised in Table 1.

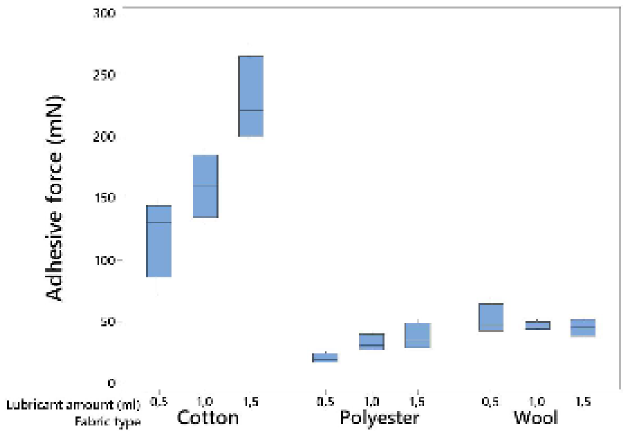

Figure 1. Dynamic adhesion forces for cotton, polyester and merino wool with three artificial perspiration (lubricant) levels.

Wool and polyester had very similar stickiness attributes behaviour when measured by both mechanical testing and human trials, and both were far less sticky than cotton. When selecting fibre types for use next-to-skin in hot or humid conditions, or when exercising, wool and polyester will be less sticky and more comfortable than cotton. If selecting between polyester and wool, then non-comfort related factors should be considered, such as odour resistance [8].

Parameter	**Wool *vs.* Cotton**	**Polyester *vs.* Cotton**	**Wool *vs.* Polyester**
Stickiness	Cotton	Cotton	No significant difference
Wetness	Cotton	Cotton	Wool
Coldness	Cotton	Cotton	No significant difference
Roughness	Wool	Polyester	No significant difference

Table 1. Fibre type given higher rating by volunteers for stickiness and related comfort parameters (statistically significant with p=0.01 or smaller).

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The authors gratefully acknowledge funding for this research from Australian Wool Innovation.

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DEVELOPMENT OF A CARE LABELLING PROCESS FOR COMPRESSION STOCKINGS BASED ON NATURAL (COTTON) FIBERS

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ABSTRACT
The aim of this work is to investigate to which extent the performance of compression socks with cotton components is deteriorated after repeated washing processes. Five compression stockings having at least one cotton constituent yarn and, two all nylon stockings as reference samples were produced under controlled commercial conditions. After analyzing the data obtained, a care labelling process for the compression socks from cotton was developed such that they can preserve their compression properties over successive laundering treatments.

INTRODUCTION
Medically functional products encompass advanced applications that cover therapeutic, bio-sensing, emergency care and rehabilitation activities. Imparting pressure therapy through compression garments is a well-established method of treatment for burn injuries, venous and lypmphatic disorder, etc. (Gupta, 2011). Core-sheath composite elastomeric yarns, mostly from nylon and polyester fibres, are employed in the compression stockings. As the stocking has to be worn almost for an entire day, skin problems such as irritation might arise. Natural fibers are, on the other hand, favored raw materials for comfortable textile products and use of cotton in compression stockings help to overcome skin problems to some extent. Since compression stockings are continuously worn, they have to be washed every day due to hygiene issues while preserving their compression properties. The literature survey reveals that the studies on the effect of washing and multiple wearing on the durability of compression socks are mainly confined to commercial products and those from synthetic fibers (Gohar, 2020; Harpa, 201; Maleki, 2011; Siddique, 2019, 2020).
This study aimed to develop a care labelling process for the compression stockings based on natural fibers, namely, cotton. Knee-high compression stockings having cotton cover yarn that could meet the requirements of Class II and III compression for patients having sensitive skin were produced. Dimensional and compression performance changes in the samples that were repeatedly hand and machine washed were observed. Accordingly, the care labelling directions for such stockings were suggested.

RESULTS AND CONCLUSIONS
A total of seven types of stockings for a fixed leg size, exhibiting compression levels of Class II and III were produced in the form of plain jersey structure in which elastic yarns are integrated in as weft inlay stitch, under controlled commercial conditions. The samples were then subjected to repeated hand and machine washing processes. After washing, the samples were flat-dried without any exposure to heat and sun light. Washed and dried samples were tested for some of their dimensional properties as well as compression performance. The pressure test results after successive washing for both the cotton and nylon samples with 475 dtex inlay yarns are given in Table 1. The nomenclature used in the table is as follows: I for inlay, G for ground, N for nylon, and C for cotton yarn, in turn. Table 1 reveals that the pressure levels for the repeatedly washed stockings are within the compression range.

Table 1 Pressure of stockings with 475 dtex inlay yarns after repeated washings

Samples	(mm Hg) as delivered to the customer	(mm Hg) After 5 hand wash	(mm Hg) After 10 hand wash	(mm Hg) After 5 machine wash	(mm Hg) After 10 machine wash
I_{475} C- G_{45} C	40	36,8	40,2	38,1	42,1
I_{475} N- G_{45} N	39,2	39,6	38,7	38,9	42

Similarly, the samples from the inlay yarns having 570 dtex elastane were also repeatedly washed and tested for their properties under discussion. The results showed that hand and machine washing processes have different effects on the properties of compression stockings from different constituent fibers. Accordingly, the most suitable care label for the compression socks with cotton components was suggested.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by ITU Scientific Research and Development Support Program under the grant number MGA-2018-41341, and they are also thankful to Variteks Ortopedi San. A.Ş. and, to A. Hachana and G. Eren for their technical assistance throughout the experimental studies.

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COMFORT-RELATED PROPERIES OF COOTON SEERSUCKER WOVEN FABRICS

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ABSTRACT
This work concerns the comfort-related properties of the seersucker woven fabrics made of cotton. The seersucker woven fabrics are characterized by an occurring the puckered and flat strips in the warp direction. Some researchers consider that due to their structure the seersucker woven fabrics are characterized by very good comfort-related properties. In the presented work the seersucker woven fabrics of different repeat of the seersucker effect and different weft yarns were investigated in the rage of heat and moisture transfer. Results showed that the structural factors significantly influence the comfort-related properties of the investigated cotton fabrics.

INTRODUCTION
Seersucker woven fabrics are characterized by an occurring the puckered and flat strips in warp direction. They are manufactured from two warp sets on loom with two loom beams [Gandhi 2012]. The seersucker woven fabrics create a 3D woven structure (fig. 1).

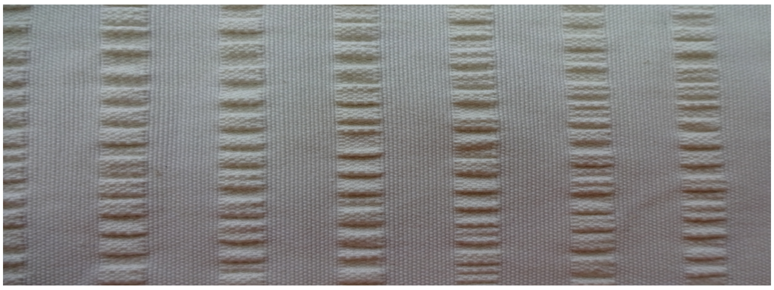


Fig. 1. Seersucker cotton woven fabric

Investigations carried out till now confirmed that the seersucker woven fabrics are characterized by excellent comfort-related properties; especially their thermal resistance is much higher than the thermal resistance of typical two-dimensional woven fabrics of basic of derivative weaves [Matusiak et al. 2016]. The aim of presented work was to analyze the comfort-related properties of the seersucker woven fabrics made of cotton. Totally, 9 variants of the seersucker woven fabric of different structure were the objects of the investigations. The fabrics were manufactured on the basis of the same warp sets made of 20 tex x 2 cotton yarn. Three variants of the seersucker woven fabrics have been investigated:

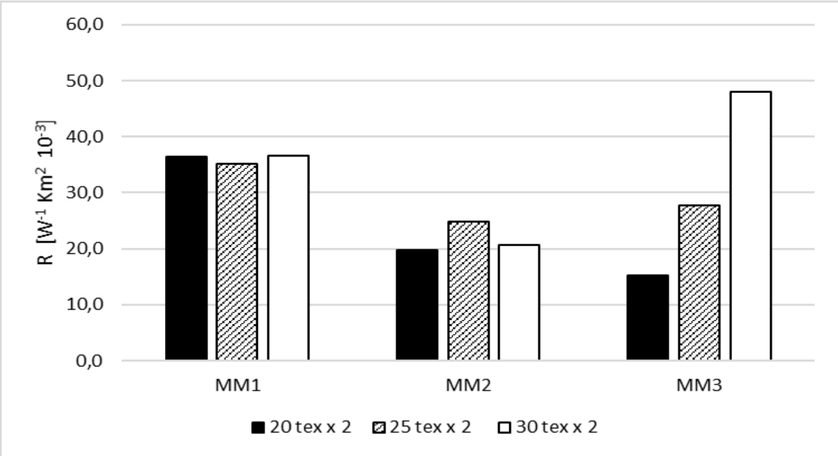
- variant MM1 – width of puckered and flat strips appropriately: 5 mm and 8 mm,
- variant MM2 – width of puckered and flat strips appropriately: 9 mm and 18 mm,
- variant MM3 – width of puckered and flat strips appropriately: 11 mm and 41 mm.

In weft 3 kinds of cotton yarns have been applied: 20 tex x 2, 25 tex x 2, 30 tex x 2.
Measurements of the comfort-related properties have been performed by using the Alambeta, Permetest and MMT (Moisture Management Tester) devices. Obtained results have been analyzed using the statistical tools available in the TIBC® STATISTICA™ version 13.3 software.

RESULTS AND CONCLUSIONS

Obtained results showed the influence of the repeat of the seersucker effect and a kind of weft yarn on the heat and moisture transport through the investigated fabrics. Figures below show the exemplary results from the Alambeta (fig. 2a) and Permetest (fig. 2b).

a)



b)

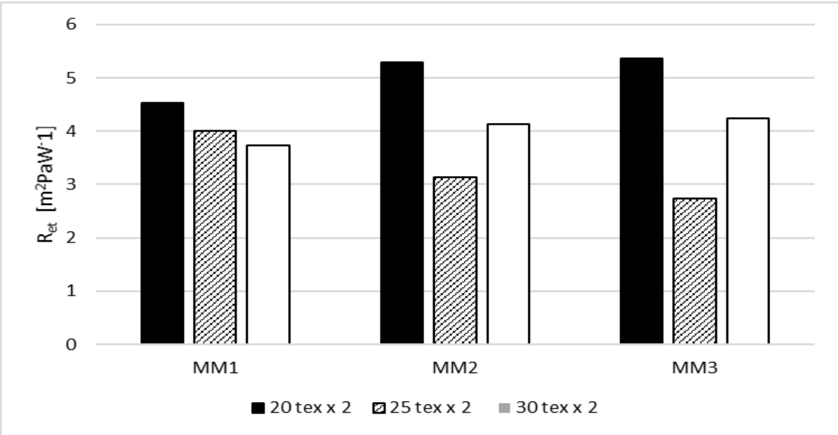


Fig. 2. Comfort-related properties of the seersucker woven fabrics made of cotton: a) thermal resistance, b) water-vapour resistance

Investigations performed by means of the MMT showed that the gray seersucker woven fabrics do not transfer the liquid moisture. In the case of the finished fabrics their ability to absorb and transfer the liquid moisture strongly depend on the seersucker effect. This study shows that both structural factors: repeat of the seersucker effect and a kind of weft yarn influence the values of parameters characterizing the fabrics from the point of view of the heat and moisture transport. Statistical analysis by means of the two-factor ANOVA confirmed that the stated influence is statistically significant at the probability level 0.95.

ACKNOWLEDGMENTS

This work is financed by National Science Centre, Poland in the frame of the project titled „Geometrical mechanical and biophysical parameterization of the three-dimensional woven structures", project No. 2016/23/B/ST8/02041

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UPCYCLING OF NATURAL FIBERS TO CREATE NEW FASHION PRODUCTS

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ABSTRACT
This paper aims to discuss how to give a new life to textile waste, creating new products and thus extending the life cycle of natural fibers. Also it is intended to create a sustainable fashion brand that is based on circular economy principles and on the upcycling of natural fiber fabrics at the end of life, for the creation of clothing and accessories. The raw materials for this project of upcycling will be industrial pre consumption waste, such as production surplus, leftovers, scraps and fabric samples that are discarded by companies. Preference will be given to natural fibers such as cotton and linen.

INTRODUCTION
The textile industry and specially the fashion industry are at the top of the ranking with the greatest environmental impact. The textile value chain starts with the raw material, goes through all the transformation processes, reaching the final product and finally the distribution, and there are countless impacts on the environment in all these stages. (Choudhury, 2014; Muthu, 2014)
Sustainability has been one of the main issues these days, in all areas. Excessive consumption in fashion and clothing has led the market to look for new ways to treat waste. To trying to solve the problems and the environmental impacts, different concepts of fashion and design have emerged. Upcycling is a concept for waste recovery processes, because it transforms waste into products, or raw materials, with better quality and higher added value. The main goal is to avoid the waste of useful materials and so, reducing the consumption of new raw materials and resources to create new products (McDonough & Braungart, 2002). Another concept that cannot be ignored when it comes to sustainability and the circular economy is the Cradle to Cradle (C2C) approach. Applying the C2C concept to the textile industry by reusing fibers for the production of new products, makes perfect sense. Fibers are an important material in the textile industry, so it is important to minimize their impact on the environment as much as possible (McDonough & Braungart, 2002)
Cotton is the most widely used natural fiber in the world. Its production should be mainly organic, however the consumption associated with the cotton cultivation has a great impact on the planet and ecosystems, from the area for cultivation, the water used for irrigation, the energy used for harvesting till the chemicals used in agriculture (Tab.1). Year by year, harvest after harvest, intensive cotton cultivation explores and abuses the ecosystems. (Bartl, 2019)

Tab. 1 - Consumption of Resources for Cotton Cultivation (Bartl, 2011)

Resource	Demand for 1 t raw cotton
Crop land	8000 – 18000km^2
Agricultural chemicals	8.3 – 13.8kg
Water	Average: 5700m^3 up to 29000m^3
Energy	36 – 55GJ

The brand developed aims to spread more sustainable habits and encourage slow fashion, with the creation of products (women's fashion clothing and accessories) mostly handmade through the use of raw material from the waste of natural fibers of local textile companies.

RESULTS AND CONCLUSIONS

Figure 1 presents a coordinate made with 100% cotton fabric collected from the waste of a local textile company. Instead of having been discarded, this fabric was upcycled to two more valuable garments, a ruffled top and a midi skirt. The transformation process was handcrafted, with the help of two domestic sewing machines.

Fig. 1 - Coordinate stitched with 100% cotton fabric

The amount of water and energy saved in this upcycling process can be calculated from the data presented in table 1. The top weighs 62 gr and the skirt 143 gr, the set makes up 205 gr. According the table 1, for the set of Figure 1, were saved between 1,169 l and 5,945 liters of water. Regarding the energy spent per 1,000kg of cotton, which varies between 36Gj and 55GJ, for the coordinate top plus skirt, were saved between 7,380KJ and 11,275KJ of energy. These are significant values for only two pieces of clothing and this is just an example of two products of the proposed brand. Comparing to a collection with hundreds of pieces, the savings will be much higher.
The communication of the entire project it's being done mostly through social media. The Instagram page started in December 2019 and currently has 1,130 followers. The first products to be promoted were linen and cotton bags, with various functions. In 2020, with the arrival of the pandemic, cotton masks washable and reusable, began to be sewn. In addition to this, various pieces were also released, such as ribbons and elastic bands for hair, shirts, tops, skirts, dresses, pants, kimonos, bags for mobile phones or glasses, coasters, coin purses, make-up discs, etc.

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DEVELOPMENT OF COTTON BASED COMPRESSION STOCKINGS FOR CLASS II COMPRESSION REQUIREMENTS

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ABSTRACT
This work focuses on the development of Class II medical compression stockings having improved tactile properties by the use of cotton components in their construction. Nine compression stockings having at least one cotton constituent yarn and, three all nylon stockings as reference samples were produced. The compression tests performed were promising for the users since the pressure exerted by the compression stockings having cotton components covered the required pressure range.

INTRODUCTION
Medical textile products are classified according to whether they are used in internal or external applications, and the external applications include compression stockings. Textile materials, structure and fabrication technology directly affect the properties and performance of the compression textiles in practical applications. Together with other parameters and settings, the adoption of yarn materials determines the properties of the compression stockings and influences their longetivity, comfortability, biocompatibility and medical efficacy of compression interventions (Oğlakcıoğlu, 2009; Liu, 2017).
Core-sheath composite elastomeric yarns, namely double cover yarns, are used to ensure fabrics with adequate medical compression function. Mostly nylon and polyester fibres are employed in the compression stockings. Natural fibers are, on the other hand, favored raw materials for comfortable textile products and are especially preferred in products which are in close contact with skin. The literature survey reveals that cotton has been used for achieving good comfort related properties in medical compression stockings, though the number of the Works is quite limited, so is the information in this aspect (Bera, 2014; Alıšauskıenė 2014; Oğlakçıoğlu, 2010).
This study aimed to design knee-high compression stockings having cotton cover yarn that could meet the requirements of Class II compression for patients having sensitive skin. For the study, the compression stockings that could fit Tendon Circumference of 23 - 25 cm, which meet moderate compression level requirements (23-32 mmHg), were designed and produced. In doing so, double cover (DC) ground yarns with 45 dtex elastane and DC inlay yarns with 285, 475 and 570 dtex elastane were employed in the form of single jersey knitted fabric structure in which elastic yarns are as laid-in stitch. The influence of positioning of the cotton component in the double cover yarn and in turn in the knitting structure on pressure performance of the stockings were studied. Pressure exerted by the stockings were tested using MST-Professional 2 Medical Stocking Tester to ensure that they meet the desired pressure level.

RESULTS AND CONCLUSIONS
The pressure test results for the samples with 475 dtex inlay yarns are given in Table 1.

Table 1 Pressure test results for samples with 475 dtex inlay yarns

Samples	(mm Hg)
I_{475} N- G_{45} N	29,6
I_{475} N- G_{45} C	29,8
I_{475} C- G_{45} N	30,6
I_{475} C- G_{45} C	29,6

The nomenclature used in the table is as follows: I for inlay yarn, N for nylon yarn, G for ground yarn and, C for cotton yarn. As may be seen from the results given, the pressure levels recorded for the stockings remained within the targeted range.

Similarly, the samples from the inlay yarns having elastane of 285 and 570 dtex also displayed satisfying pressure performance in term of Class II requirements. Accordingly, it may be concluded that the cotton based compression stockings, which offer better wearing comfort properties without compromising the required pressure values, can be developed by setting appropriate knitting variables such as yarn input tension.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by ITU Scientific Research and Development Support Program under the grant number MGA-2018-41341, and they are also thankful to Ç. Yasavul, B. C. Kütüklü, and B. Meriç for their technical assistance throughout the experimental studies.

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EFFECT OF ACIDIC ENZYME IN THE BAGGING BEHAVIOR

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ABSTRACT

The principal aim of this work is to study the effect of acidic enzyme washing parameters on the residual bagging height. To achieve this goal, six denim fabrics (twill 3/1) were washed in different conditions. Then the test of bagging is performed for five times in order to have an average. The results of these tests were analyzed. It can conclude that characteristics of matter and enzyme concentration have a very significant effect on the residual bagging height.

INTRODUCTION

Denim became the most considered style today. It is the clothing material that has proclaimed the most popular in the past three decades. At the beginning it was a work garment then it became a cloth of style. This evolution is thanks to the improvement carried out either at the level of spinning, weaving and more important at the level of finishing and washing. Washing treatments give the fabric flexibility and softness. Many studies focused on the enzymatic washing effect on the physical, mechanical and color properties of denim garments such as elongation at break, tensile strength, weight loss, stiffness, water absorption, shrinkage, color fading, and morphological values (Kan, 2015; Midha, Kumar, and Kumar, 2017; Mondal and Khan, 2014; Patra, Madhu, and Bala, 2018; Sarkar, Khalil, and Solaiman, 2014). Based on this literature survey, it has been shown that tensile strength, color shade, and stiffness decrease after cellulase treatment. The mass of fabric obtained with cellulase washing is higher than those with pre-washing. It could be explained by the shrinkage in the warp fabric direction. Otherwise, hydrolysis of the cotton denim garments caused an enhanced softness, water absorption, color fading and elongation. Else, tensile strength is decreased.

Until now, overall studies still focus on the effects of treatment in the mechanical, physical and sensorial properties but there are no studies on the effect of finishing treatment in the bagging properties. The bagging is unaesthetic and undesirable phenomenon which appears at the knee and elbow after exercising load or after use.

This paper discusses the effect of enzymatic washing parameters on the residual bagging height behavior of denim garments. For this reason, six denim fabrics with different fiber blend ratios were cut into 50cm x 100cm and sewed as tubes. These samples have the same weave (twill 3/1) but different characteristics. Firstly, these samples were desized with amylase. Then they were washed with an acidic enzyme at different conditions (enzyme concentration: 0.35,2,3; temperature: 40,50,60; time:15,45,60; and material to liquor ratio:1:5,1:8,1:10) according to a Taguchi experiment design.

The bagging deformation was investigated by an apparatus that was designed and that was integrated to the dynamometer testing (Fig.1). During a bagging test, a removable hemisphere in the upper jaw applied a load on the sample up to a certain distance with a defined speed 60 mm / min. The number of cycles was fixed at 5 cycles. After this test, the residual bagging height was measured after a relaxation time (30 min) thanks to a welded needle.

Fig.1 Fabric bagging apparatus

RESULTS AND CONCLUSIONS

The obtained results for the 18 experiments of the used Taguchi design are analyzed using MINITAB software (MINITAB 14.1). Fig.2 illustrates the main effects plot for the residual bagging height as a function of the investigated input parameters. Results show that the samples factor and the enzyme concentration have an effect on this propriety of bagging behavior. The other factors show insignificant variation, they have no effect on the bagging phenomenon. To validate this result, a study of the analysis of variance was carried out (Table 1).

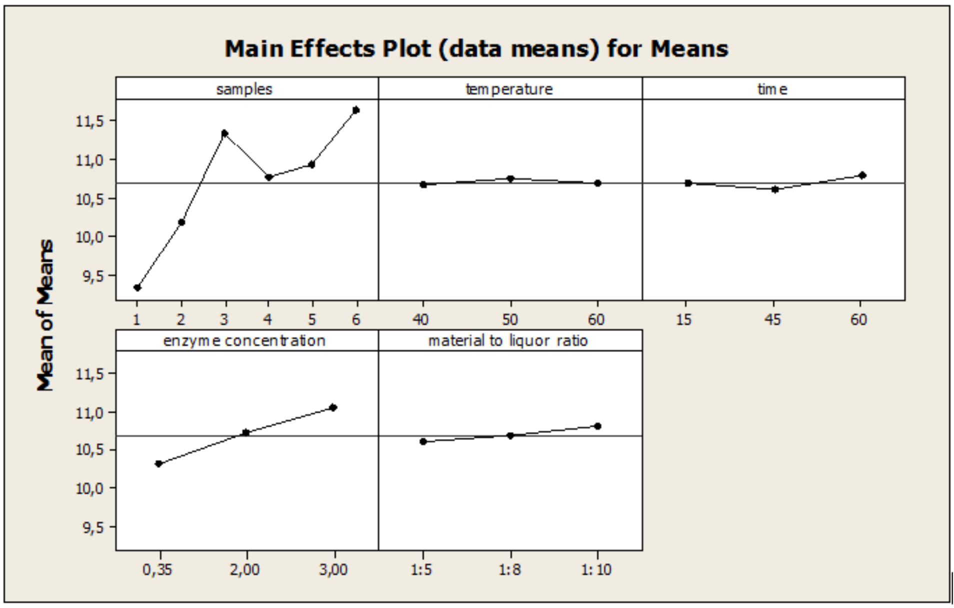

Fig.2 Main effects Plot for residual Bagging height (mm)

ANOVA results represent that sample factor and enzyme concentration have significant effects on the residual bagging height (P=0.002<0.05 for samples and 0.02 for enzyme concentration). On the other hand, the temperature, time, and material to liquor ratio do not significantly affect the residual bagging height (P>0.05).

Table 1 Analysis of Variance for Means for residual bagging height

Source	DF♪	Seq SS◊	Adj SS*	Adj MS•	F*	P♣
Samples	5	10.6648	10.6648	2.1340	32.6000	0.0020
Temperature	2	0.0252	0.0252	0.0126	0.1900	0.8321
Time	2	0.0993	0.0993	0.0497	0.7600	0.5250
Enzyme concentration	2	1.6114	1.6114	0.8057	12.3100	0.0200
Material to liquor ratio	2	0.1218	0.1218	0.0609	0.9300	0.4660
Residual Error	4	0.2617	0.2617	0.0654	-□	-
Total	17	12.7842	-	-	-	-

DF♪ : Degrees of Freedom for the model with factors, the degrees of freedom associated with each sum of squares, assuming a full model ; SS◊ : Sum of squares ; Adj SS*:adjusted sum of squares; MS● : The mean square for each component in the regression model ; F* : F-statistic value indicates whether the predictors or factors (the interaction and main effects) are significantly related to the response; P♣ : p-value is the probability used of obtaining a test statistic that is at least as extreme as the actual calculated value if the null hypothesis is true. A commonly used cut-off level for the p-value is 0.05; -□ : It means no value existed in table.

Thanks to this study we can conclude that the residual bagging height depends closely on the property of the sample and enzyme concentration. Concerning the “sample” factor, this property of bagging behavior depends enormously on the effect of sample composition. In fact, the existence of elastane fiber (elastomeric fibers) and/or polyester which have a high recovery behavior helps the fabric to return to its initial state after elimination of source of deformation.
For the enzyme concentration, it is clear that the increase in its percentage causes an increase in the residual bagging height. In fact, the enzyme damages the cellulose, on the link β1,4glycosidic of the cellulose molecule. The hydrolysis of this link breaks the molecule into several pieces, which causes a decrease in the degree of polymerization (DP) and remarkable drops in mechanical strength. This can limit the ability of a fabric to return rapidly to its initial state, which justifies the significant increase in the residual bagging height.
This study can help industrialists as well as researchers who studying this field of interest to understand the effect of acidic enzyme on the bagging behaviour after garment uses due to the internal stress, shrinkage and excessive extensions. Nowadays, the main equipment to control garment’s quality can be found in washing industries such as dynamometer device. Hence, if offered bagging process, it could be easily adopted to industrial washing due to its simplicity. It only requires a simple jaw that is integrated into the dynamometer; hence manufacturers can easily carry out the bagging tests. Moreover, after this study, it is possible to choose the best condition of this treatment that minimizes this phenomenon and gives the desired appearance.

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APPLICATIONS OF MUNJA FIBRE

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ABSTRACT
Today's world economy is affected by the shortage of various necessities of life, including shelter, food, domestic fuel, clothing, and other basic living amenities due to depletion in feedstock resources. Constant research and development are being carried out by scientists round the globe to explore and develop alternative ways to fulfil one's basic amenities. World's desperate desire to minimize its dependence on fossil fuels has strengthened the interest in producing green materials, chemicals, and fuels from renewable feedstocks. Plant wastes are emerging as excellent alternative feedstock due to their easy availability, economical cost, and renewable nature. One of the most fascinating plant which matches the above objective is Saccharum Munja Roxb, which is a weed by classification and offers tremendous potential for industrial, commercial, and agricultural, exploitation. Effectively capitalizing on the potential of biomass from hardy weeds is necessary, especially for the Second and Third World countries. This paper analyses the possible use of Saccharum munja Roxb, a perennial tropical grass to boost the economy of the country. Not only the grass is capable of fibre extraction but also the plant is used for stabilizing land, and can be added to animal feed, or form the raw material for manufacture of a variety of furniture and handicrafts. The review paper discusses S-Munja's value added applications such as paper making, chemical (Furfural) extraction, Europium/red phosphorous Extraction, carbon powder manufacturing, Bioenergy production, Manufacturing of composites, Medical applications, Application in Dye removal from water, Use in Rehabilitation of Fly Ash lagoons etc.
Keywords: Fibre, Grass, Saccharum Munja Roxb, Weed

INTRODUCTION
Saccharum munja, also known as munja is a grass found in, Australia, Africa, South America and Indian sub -continent on well drained and areas. In the Indian sub -continent it grows in the dry/arid areas and along river banks of the northern part of India. The grass is tall, panicles silky and greenish brown. Botanical identification of Munja is Species/Specie: Munja/Bengalense/Sara; Family/Famiglia: Poaceae (Grass family); Genus/Genere: SaccharumL. (sugarcane). The grass grows in excess and up to 2 to 2.5 meters in height. It is Leaf sheath shortly silky at extreme base, otherwise striate, quite smooth, pale straw, villous on margins at apex colored with long white hairs usually much longer than proper internode, uppermost sheath sometimes extending beyond the base of panicle. White flowers of Munja are of ornamental value. In India the common name of the plant is Sarkanda or Kana or Moonja. Fruiting and flowering are perennial and mostly from the months October to January. Harvesting of munja is done yearly once when the height of the plant grows up to 10 to 12 feet and the colour of leaves starts turning yellow. Saccharum munja is an extensively growing perennial grass which structures the part of tall Savannah grasses which cover around 14 million sq. km round the globe. It possesses enormous growth potential of about 180 tons/hector/year of fresh weight, of global landmass. Munja can be grown on marginal lands, and it is estimated that there is around 430–580 million hectors of marginal land available globally which can be capitalized upon. About 29% or about 96.4 million hectares are considered degraded in India S-Munja is reported to have potentials to remediate, revegetate, and restore this degraded land.

RESULTS AND CONCLUSIONS

This review clearly indicates that Saccharum Munja, is neglected and underutilized grass species not only in India but across the globe as well. It can be grown on Degraded lands and Marginal lands without disturbing or damaging the surrounding ecology. Studies conducted by scientists provide evidences for efficiencies of these grasses for mitigation, climate change, biodiversity conservation, ecosystem restoration and for reducing our dependency on fossil fuel by giving viable value-added applications like Fibre extraction, Re-inforced Composite manufacturing, Paper making, Europium extraction, Bio energy, Medicinal applications, Extraction of Furfural, Manufacturing of Micro fibrillated cellulose etc. Munja can be a game changer in manufacturing of various value-added products which can be very sustainable and efficient replacements for various products which traditionally used are chemical based and not sustainable. The economics of various processes assessed in terms of current prices in India shows that one hectare (which is the average land holding) of land generates the yield which is sufficient to give employment to the whole family ultimately increasing their income and lifting them above the poverty line.

ACKNOWLEDGMENTS

The authors are thankful to the institute for giving inspiration to publish this paper in International Conference of Natural Fibres.

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MATERIALS TOWARDS TRANSITION - CIRCULARITY IN FASHION DESIGN EDUCATION

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ABSTRACT

This paper presents an analysis on Material preferences and Design practises. The study explores which, how and why materials were applied by a specific group of fashion students (under graduation level) and their involvement and proficiency through the experience. Through a mixed methodology approach, results suggest an increased interest in natural and bio-based material development and their application in circular design projects; they highlight the challenges and advantages of such experimental processes and inform on how students perceive the playful addition of different scientific disciplines, craft and investigational methods to the creative process.

INTRODUCTION

Efforts towards a circular approach to design goods has been steadily increasing for the past decade. Decisions made at the creative stage require deeper awareness, enabling for a product to be resilient and fit to purpose, preferably maintained indefinitely in a closed-loop of utilization or safely discarded at the end of its life (Ellen MacArthur Foundation, 2012). Careful assessment of materials, production and recovery are of significance (Haffmans et al., 2018). Fashion Design education guide students to integrate informed decisions in creation, materialized in the form of clothes or fashion accessories. The implementation of natural materials is central to this discipline, for many different reasons, such as economic or environmental concerns. In order to facilitate the transition from a linear to a circular system, a new program was implemented at the undergraduate level in Fashion Design Course, imparting an in-depth understanding of circularity - associated strategies and the importance of, not only product life-cycle assessment, but also the origin of raw materials and the speeds at which these may travel their journey (Earley & Goldsworthy, 2015; Earley & Politowicz, 2013). Besides observation, a series of surveys were performed, analysed and interpreted to better evaluate primary interests, concerns and preferences. Multiple projects were examined in order to: understand if patterns would emerge; which challenges arose; the strategies and solutions adopted; the type of materials applied and if these decisions would help assisting the transition to a Circular Economy (CE). This was equally important to assess the applicability of natural/biobased materials and their dynamics to a specific context such as fashion.

RESULTS AND CONCLUSIONS

The study shows a decrease in synthetics (only 20% of the students applied it). 100% of them resourced to natural fibers, organic cotton was applied to all projects. Higher percentages of lyocell (57%), alpaca wool (53%) and hemp (37%) were observed. 63% of the sample group opted for innovative biobased materials such as bioplastics (as alternatives to leather, in some cases), mostly derived from varied waste streams, textile and non-textile residues (e.g., bacteria, algae, food, starch, paper, wood, etc.).; these were explored by not only studying resources but also by developing materials, under guidance from the tutor.

Overall outcomes confirm the pertinence of strategies implemented and indicate the desire of future designers to embrace circularity, to plan accordingly to CE framework and tenets, and counter the global production of virgin fibers. Results suggest a greater engagement from pupils (i.e., their role in the fashion paradigm and which values to prioritize). Additionally, it reveals an increased interest in learning in depth the natural and emerging material structures and their particularities; an emphasis on these materials inclination was noted. The latter occurs, in part, due to their emerging nature, unique aesthetics and properties, availability and D.I.Y. factor. The convenience to be transformed from waste to value, in a relatively approachable manner, is equally of importance. Moreover, the development of new material and unfamiliar techniques exposes ensuing challenges and opportunities in the context of fashion design field.

When guided towards a playful, yet solid, experimental-practice methodology to uncover the potential of natural and innovative materials, results also indicate students appreciate not only the discovery process and serendipity element that comes from exploring, but also the sense of unleashed creativity or originality. Through experimentation, some students also remarked that often materiality preceded the design creation, directing it.

Recognizing the dynamics between theoretical and experimental practices may be revealing and help to assess whether materials education benefits from a shift from the traditional technical and theoretical knowledge approach to an experimental-based one (with the playful component or the addition of other scientific subjects, craft and investigational methods). Additional data is needed to analyze further key aspects such as commercial success, usability aspects, acceptation by users and their perception on innovative materials.

ACKNOWLEDGMENTS

The author gratefully acknowledge support from FCT, CIAUD, REDes – Lisbon School of Architecture, Universidade de Lisboa.

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THE RECYCLING OF PRE-CONSUMER JEANS IN BRAZIL AND CHARACTERISTICS OF THE SHREDDED MATERIAL

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ABSTRACT

Jeanswear production generates a large amount of waste. In the case of 100% cotton jeans, specifically for pre-consumer scraps, the generation of waste comes from cutting processes. The present study aimed to investigate the issues on the recycling of pre-consumer jeans in Brazil; and through the recycled material from pre-consumer jeans (100% cotton, from 6 to 12 OZ, and 2x1 and 3x1 twill), the determination of the defibrated weft and warp yarn titles through laboratory tests was carried out. It is concluded that the feasibility of reinserting recycled fibers, due to variations in title, length, and tenacity, must be preceded by a characterization study, to be correctly employed in industrial or artisanal processes, enabling the production of recycled articles with reproducibility of its characteristics, thus ensuring reintegration and maintenance in the market.

INTRODUCTION

Brazil has a complete textile chain, including the production of fibers until retail sale. The country is still considered a world reference in fashion segments, among them, Jeanswear reaching textile production number of 2.03 million tons in 2018 (Abit, 2020). This production generates a large amount of waste. In the case of 100% cotton jeans, specifically for pre- consumer scraps, the generation of waste comes from cutting processes (Ribeiro and Andrade Filho 1987). However, these textile residues can be recycled or reused (Zonatti et al., 2016). In textile recycling, the material is reinserted in the production cycle, thus avoiding waste of material, reducing environmental impacts and the use of new raw materials (Abramovay et al, 2013, Castro; Amato-Neto, 2012).

The recycled fibers are produced in secondary cycle through mechanical processes, transforming the material into individual fibers (Wang, 2006) and later into a new product. Recycling is one of the agents of change for an economy with less impact towards sustainability (Todeschini et al. 2017). There is a considerable reduction of energy use, water stress and greenhouse gas emissions, provided by the mechanical recycling of cotton (Roos et al. 2016). According to Gulich (2006a), almost 100% of textiles are recyclable and can be included in the market again. Even discarded textile scraps can produce new articles (Sinditêxtil, 2014).

Mechanical recycling comprises the defibration of the material, to this process are destined scraps of fabrics (Wang, 2006). The shredding machinery can be composed of 2, 4, 6 or 8 stages, depending on the used material: the more stages, the higher the quality of the final material. The stages have rollers of varying diameter, with several needles on their surface that tear and crush the fabric scraps (Laroche, 2013).

The present study aimed: (i) to investigate the issues on the recycling of pre-consumer jeans in Brazil, based on a literature review (including analysis of sector reports), and interviews with companies of the recycling sector; (ii) through the recycled material from pre-consumer jeans (100% cotton, from 6 to 12 OZ, and 2x1 and 3x1 twill), the determination of the defibrated weft and warp yarn titles through laboratory tests was carried out.

RESULTS AND CONCLUSIONS

The most produced and consumed jeans in Brazil is 300 g/m2 (12 OZ), 3x1 twill, in which the warp yarn count is 90 Tex (6.5 Ne) and in weft, 65 Tex (9 Ne) (Dynamic, 2020). According to the supplier, the title for the waste yarns employed in this study ranges from 150 to 300 g/m2 (6 to 12 OZ). For 155 g/m2 (6.5 OZ) jeans, 2x1 twill, the weft and warp yarn titles correspond to 36 Tex (16 Ne).

In the analysis of the shredded material, it was separated into 20 specimens of warp fibers (blue) and 20 wefts fibers (white). They were weighed and measured. The length of the warp

fibers was 4.38 ± 1.38 cm (mean and standard deviation), and for weft fibers, were 2.95 ± 0.74 cm.

The yarn title was determined based on the previous results: 25 ± 7 Tex for warp and 30 ± 5 Tex for weft. Even if it is a defibrillated with a mixture of weight between 150 to 300 g/m2 (6 to 12 OZ), the loss of the titration of the recycled fibers present in the defibrate is clear in relation to the titration of the virgin fibers of the jeans.

Fibers recycled by mechanical processes are also shorter in length than virgin cotton fibers. According to Gulich (2006a), the processes and equipment usually applied for textile characterizations are not well suited to recycled fibers, due to the mixture of fibers and heterogeneity. Therefore, it is necessary to define the composition of the material and separate its components for effective characterization.

The comparison between recycled and virgin cotton yarns shows that the tenacity of the recycled yarn decreased by 26.3% (Araújo and Mello and Castro, 1986). Regarding the length of fibers, this is approximately 20% less than the original fiber, due to the cutting and defibration processes (Halimi et al. 2008). The use of fiber, the recycling process, and its intensity influence the quality of the product, but it remains viable. (Gulich, 2006b).

It is concluded that the feasibility of reinserting recycled fibers, due to variations in title, length, and tenacity, must be preceded by a characterization study, to be correctly employed in industrial or artisanal processes, enabling the production of recycled articles with reproducibility of its characteristics, thus ensuring reintegration and maintenance in the market.

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PILLOWCASE COMFORT: SENSORIAL AND MORPHOLOGICAL ANALYSIS

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ABSTRACT

Expectations for quality of fabrics enhance as a result of the increasement in people's living standard, as well the concern for aesthetics, design and fashion. Parallel to this, consumers expect improvements in the properties of fabrics by increasing the comfort feeling. The aim of this study is to carry out the analysis of pillowcases made of plain fabrics (cotton and flax), based on the sensorial evaluation of comfort regarding the touch, related to the number of threads in the fabric and analysis of SEM (Scanning Electron Microscopy), in order to understand comfort patterns in bedding linen. It is concluded that the number of threads is the most relevant factor for feeling comfortable, this factor is more relevant than the ligament of the fabric or the constituent material among the natural fibers analyzed in this study (cotton and flax).

INTRODUCTION

When choosing home textile products, the four main factors that consumers evaluate when purchasing bedding linen are: size, softness, durability and price, remaining the most important and unchanged over the years. The factors that gained the most popularity are the value added of the product and the 100% cotton fabric. Additionally, consumers are increasingly becoming aware of the importance of thread counting in fabrics in relation to the quality of the final product (Das, 2010).

Sensory evaluation plays an important role in identifying materials, in addition to determining their technical specification. In procedures for the sensory evaluation of textiles, the term "fabric handling" is commonly used (Mäkinen, et al., 2005).

Handling the tissue is defined as “total sensations being felt by human fingers during touching the tissue” (Sajjadi, et al., 2015). This parameter is associated with fabric properties, such as surface contour (roughness, smoothness), surface friction, resilience, flexibility, elasticity, compressibility, density and thermal character (Behera, et al., 2007).

The objective was to perform the sensorial test according to the Likert scale, in 4 pillowcases 100% cotton (CO) and flax (CL). All pillowcase tests were not washed for comfort tests (full products supplied by the company Trousseau – Sao Paulo - Brazil), were evaluated through touch using the Likert scale with grades from 1 to 4. In the present study, the panel of evaluators was composed of 30 individuals, 14 men and 16 women, whose ages ranged between 15 and 69 years. The research aims and the methodology to be used in the analysis were explained to each evaluator individually. Four standard samples were considered as the reference base on the Likert scale, and the touch analysis (1) Unacceptable, (2) Poor, (3) Good and (4) Excellent.

RESULTS AND CONCLUSIONS

Sensorial evaluation was performed through the touch of both hands of the evaluator. The textile article sample was rubbed against the fingers in order to notice changes in the subjective degree of softness. Fig. 1 presents the average of the tests.

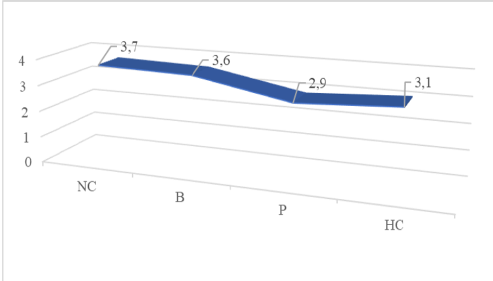

Fig 1 Average score (1- 4) by type of fabric: NC (100% CO Sateen - 200 threads); B (100% CO - 200 threads); P(100% CL– 75 threads); HC (100% CO Percale - 245 threads)

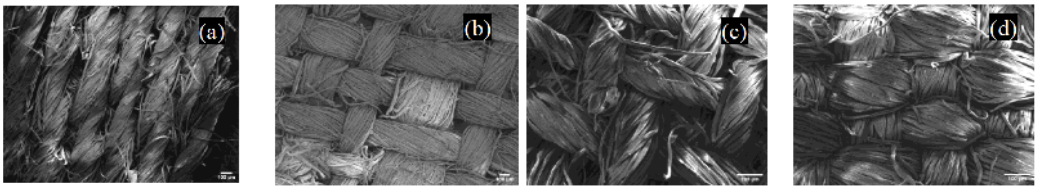

Fig.2 SEM FEG micrograph of flat fabric samples, (a) Pillow Case New Classic 100% CO – Extra Sateen (Brazil), (b) Pillow Case Bogota 100% CO – (China/Brazil), (c) Pillow Case Provenza 100% CL –(Italy), (d) Pillow Case Basic 100% CO – Extra Percale (Brazil).

The study shows that the “New Classic” and “Bogota” pillowcase fabric presents better comfort because of its thinner and satiny fabric, according to the comments of the evaluating public, respectively 3.7 and 3.6. Analyzing the structure of the fibers and the weave of the fabrics shown in the SEM (Fig. 2), it can be seen that the "New Classic" fabric presents satin interlacing, which provides shine and softness to the fabrics and threads and can be mercerized; the “ Bogota ”, has a taffeta weave and the yarn structure is similar to the" New Classic" fabric due to its shine and softness. The wefts of the fabric "Provenza" and "Hotel Collection" and its weft structure are made of taffeta. However, there is a clear linear correlation between the averages of the comfort score and the number of threads of each fabric ($y = 0.0210.x$; $r^2 = 0.9485$) We conclude that the number of threads is the most important factor relevant to the sensation of comfort. This factor is more relevant than the ligament of the fabric or the constituent material among the natural fibers analyzed in thisstudy (cotton and flax).

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by FAPEMIG, CAPES and Trousseau.

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OPPORTUNITY OF RECYCLING POLYPROPYLENE DISPOSABLE FACEMASKS INTO BIO-BASED COMPOSITES FOR CAR COMPONENTS

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ABSTRACT
This work investigates the opportunity of recycling disposable medical facemasks mainly composed of polypropylene and, in association with flax fibres, developing nonwoven mats in order to manufacture compression moulded composites. The mechanical recycling process and the nonwoven technologies are presented, discussing the conditions for properly extracting and blending the fibres. The characterisation of the final composites shows interesting results for their implementation as car components.

INTRODUCTION
Because of the fight against COVID-19, the consumption of surgical masks for healthcare personnel and the general public has increased considerably. It represents several million per day in France for a single-use product. This consumption causes an end-of-life problem and an induced environmental impact that raises questions (Aragaw, 2020). A surgical mask (as well as a N95/FFP2 mask) is a textile material essentially composed of polypropylene (PP) fibres, excluding metal nose strips and elastic/strips. Recycling initiatives (thermal) are taken to manufacture plastic parts by injection (e.g. Plaxtil company). Another possible recycling approach is mechanical. Indeed, work has been carried out on the recycling of textile waste used for the reinforcement of composites (Piribauer, 2019). However, the quality of the composite is linked to the quality of fibre extraction, its length and the quality of fibre/matrix adhesion (Vroman, 2013).
Our study here consists of using PP fibres extracted by mechanical recycling as the thermoplastic resin of a composite. The proposed composite is initially produced by intimately mixing flax-based reinforcement fibres and recycled PP (rPP) resin fibres. Such a composite obtained by themo-compression is widely used in the automotive field and has many advantages: its cost, lightness, sound and vibration absorption properties, and even its ability to be recycled (Zhang, 2019).

RESULTS AND CONCLUSIONS
This study shows the potential for mechanical extraction of fibres from the surgical masks under certain process conditions we studied and presents a specific solution for developing the nonwoven mats accordingly to the fibre quality of extracted fibres with appropriate nonwoven technologies. The mechanical properties of this composite obtained by compression moulding are similar to those obtained with flax and virgin PP fibres. Further tests should be performed shortly in order to analyse mechanical properties (tensile and flexural) as well as other properties, such as sound and vibration dumping.

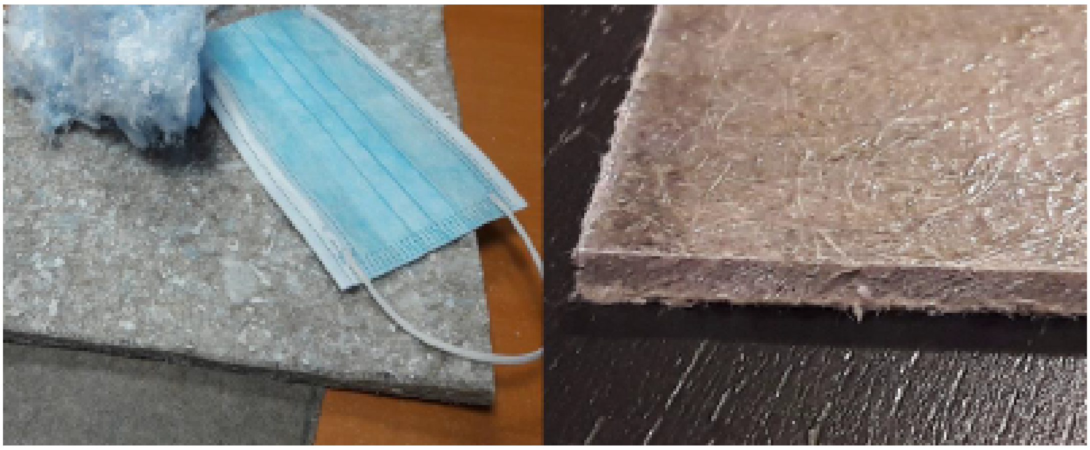

Fig.2 Facemask, polypropylene fibres after mechanical recycling, commingled rPP/flax nonwoven mat, final composite obtained by compression moulding

ACKNOWLEDGMENTS

The authors gratefully acknowledge IFTH (Institut Français Textile Habillement) for facilitating experimentations and prototyping at the CENT nonwoven platform. All their gratitude is expressed to the ENSAIT students, particularly to Eloi Facon, as well as to Mathieu Hericier, Juliette Tabouret, Margaux Tépeint and Bastien Turbot. The author also sincerely acknowledges the TIO-NT company, French mask manufacturer, for their cooperation in this study.

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WET SPINNING BI-COMPONENT FIBRES FOR ADVANCED APPLICATIONS

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ABSTRACT

Here the properties of a cellulose /PAN core shell fibre have been characterised and analysed. The fibres were spun utilizing a traditional wet spinning approach. The mechanical properties of the resultant bi-component fibres vary significantly from the properties of their single-component counterparts, with the fibre properties being influenced by various parameters.

INTRODUCTION

Bi-component fibres are a class of fibres whereby two polymers of different chemical and physical properties are extruded from the same spinneret resulting in a fibre with improved properties and functionality. The first bi-component fibre was produced in the 1960's from two nylon polymers resulting in a side-by-side fibre with self-crimping properties [1]. Many different configurations can be used for bi component spinning with side-by-side and shell-core being the most commonly utilized industrially [2]. A limitation of current commercial bi-component fibres is the requirement for melt-extruding the polymers, as such bi-component fibres are typically developed from synthetic polymers. Many natural polymers are not able to be melt spun as they are not thermoplastic in nature [3]. Here we report on a bi-component fibre which has been wet spun from cellulose acetate and polyacrylonitrile (PAN). These polymers were used due to their good processability when wet spun. We report on the effect varying the core and shell configuration, extrusion speed and dope concentration have on the properties of the fibres.

RESULTS AND CONCLUSIONS

The thermal and mechanical properties, and morphology of fibres produced using two polymers suitable for wet-spinning: cellulose acetate (CA) and polyacrylonitrile (PAN) are reported. Fibres were wet spun using CA as the core and PAN as the shell, and vice versa. The effect of extrusion speed was studied by varying the extrusion speed of the core in the CA-core fibres. The extrusion speed was found to influence the ratio of core-to-shell diameter. As the core extrusion speed was increased the core diameter increased. The extrusion speed ratio of core-to-shell was found to influence the thermal and mechanical properties of resultant fibres. The choice of polymer for the core and shell components also impacted the fibre properties. , Scanning electron microscopy (SEM) revealed there was no interfacial connection between the core and shell components, which likely lead to 'double fracture' behaviour in the stress-strain curves of the fibres.

Figure 1 shows the thermogravimetric analysis (TGA) curves of the bi-component fibres produced, as well as an SEM image of a CA-core, PAN-shell fibre. The different rates of thermal decomposition indicate the presence of two different polymers and revealed the relative mass of each polymer contained in the fibre. A higher amount of residue at the final temperature indicated a greater mass percentage of PAN in the fibre. The SEM image shows the difference in core and shell morphology, as well as the interface between core and shell. SEM images of the various fibres showed the diameter of the core to increase as core extrusion speed increased.

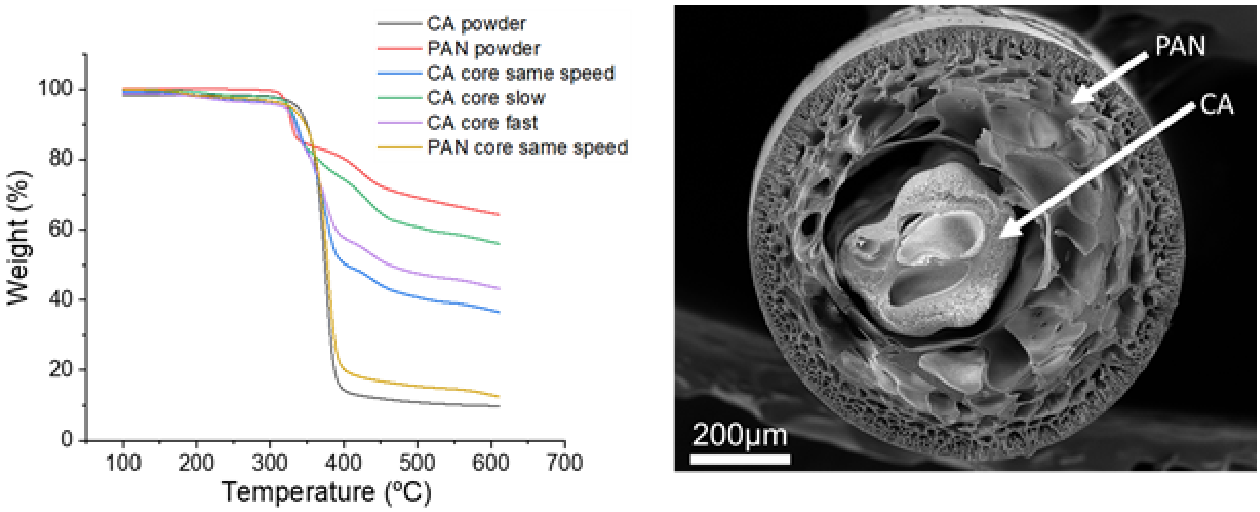

Figure 1. Thermogravimetric analysis (TGA) curves for bi-component fibres (left) and an SEM image of the CA-core, PAN shell fibre (right).

The results show that it is possible to influence the thermal and mechanical properties of wet-spun bi-component fibres through altering parameters such as core-shell configuration and extrusion speed. It was also seen that different cross-sectional morphologies arise when the core-shell configuration or extrusion speed is varied. Further work will be conducted to assess how this can be applied to renewable, regenerated cellulose fibres (RCFs).

ACKNOWLEDGMENTS

The authors acknowledge this work was performed in part at the Deakin Hub in the Victorian Node of the Australian National Fabrication Facility (ANFF) with support through an Australian Government Research Training Program Scholarship.

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THE INNOVATIVE PROTECTIVE NONWOVENS WITH ADDITION OF FEATHERS

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ABSTRACT

The aim of the research work is manufacture of innovative protective nonwovens containing wool and poultry feathers using needle punching method. One of the nonwoven component -poultry feathers- is a by-product of animal origin, arising during the poultry slaughter. The work comprises development of processing technology (grinding and fractionation) of waste in the form of poultry feathers as an addition to the production of protective nonwovens intended for covering the grassy-bean mixture on difficult terrain (new dumps, heaps, railway embankments, ski slopes etc.) where getting a good sodding is very difficult.

INTRODUCTION

Protective nonwovens are widely used in agriculture to protect the most delicate crops. The most commonly used nonwovens are petroleum-derived raw materials and therefore involve problems related to biodegradability and disposal. The technology of producing nonwovens by needle punching is known and used on an industrial scale. The advantage of this method is the possibility of introducing various types of natural, chemical, mineral and metal fibers as well as a mixture of these fibers into the fleece produced. Various types of geotextiles for the stabilization of slopes or dumps with the use of natural fibers such as cotton, jute, coir and sisal or synthetic fibers such as polyester and polypropylene are known from the literature and patents. The publication (Kumar, Das, 2018) describes a method of producing needle-punched geotextiles from nettle and poly (lactic acid) fibers to stabilize slopes and embankments. The publication (Kakonke, at al. 2020) describes an absorbent nonwoven fabric produced by needling from a mixture of cotton fibers and chicken feathers for use in modern disposable hygiene products. The paper (Seawright , Schacher, 2017) is focused on the manufacturing of nonwovens out of polypropylene and various types of poultry feathers (turkey, chicken, goose, duck) by means of dry needling method. The feathers are placed between two layers of non-woven polypropylene to form a sandwich, i.e. polypropylene - feathers - polypropylene.

So far, no nonwoven fabric has been developed using wool and waste poultry feathers. The new protective nonwoven is obtained by needle punching technique and are made of biocompatible materials such as wool and poultry feathers as by-products poultry industry. This composite material combines the characteristic of biodegradability with the ability to fertilize the soil during its biodegradation. Elaborated protective nonwovens contain only components of natural origin. Due to the content of organic matter in their composition, they are a valuable source of fertilizing ingredients for plants and soil microorganisms.

RESULTS AND CONCLUSIONS

The conversion of poultry feathers into fibrous pulp for the use as a component of nonwoven requires specific grinding conditions – fragmentation of feathers into millimeter short filaments (Fig1).The optimal parameters for grinding poultry feathers were determined as well as experimental tests with different degree of feathers fragmentation were prepared to assess their suitability for the nonwovens manufacture.

Technological trials to produce innovative protective nonwovens by needle punching method were carried out on the experimental line owned by the Institute (Fig2).

a)  b)

Fig 1. a) Feathers before grinding, b) after grinding

Fig. 2. Experimental line for the production of needle punched nonwovens.

Fig. 3. Needled nonwoven made of wool and poultry feathers.

The nonwoven fabric (Fig 3) characterizes the following useful properties: light color, surface mass approx. 150-300 g / m2, feathers content 35-45%, good adhesive properties, large water capacity. The material degrades by 70% after 2-3 months. An additional advantage is the ability to control the time of microbiological decomposition by the different content of feather fraction in relation to wool in the produced non-woven fabric. As a result of degradation, the nitrogen released from wool and feathers enriches the soil with nutrients, replacing fertilizers. The proposed solution is friendly to the environment and human health, at the same time ensuring the reduction of biomass waste in the form of feathers, deposited and polluting the environment. The invention is the subject of a patent application P. 430284 “Method for producing fluffy composite nonwoven fabric”.

ACKNOWLEDGMENTS

The investigation presented in this paper was carried within research project EkoPióro POIR.04.01.04-00-0059/17 „Development of innovative protective nonwovens with addition of feathers” . The project is co-financed by the European Union from the European Regional Development Fund under the Intelligent Development Operational Program.

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INFLUENCE OF FINISHING PROCESS ON THE THERMOPHYSIOLOGYCAL PROPERTIES OF KNITTED FABRIC MADE OF UNCONVENTIONAL CELLULOSE YARNS

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ABSTRACT

The knitted fabric thermophysiological comfort is influenced by raw material and fabric structure, including yarn spinning and finishing process. The research on raw and finished cotton, viscose and Tencel® double jersey knitted fabrics knitted from ring, rotor and air-jet spun yarns counts of 20 tex were carried out. The knitted fabric made by different yarn structures and raw material as well knitting fabric finishing process has an impact on the knitted fabric structural parameters, thus on thermal and water vapour resistance. Obtained results can serve as guidelines for further research on the knitting and finishing process in order to produce quality garments made of non-conventional yarns spun from cellulose fibres.

RESULTS AND CONCLUSIONS

The results of the basic knitted fabric parameters as well as thermal and water vapour resistance are given in Table 1. A change in all parameters of the knitted fabric structure after the finishing process is visible through fabric mass per unit area. The mass per unit area of almost all knitted samples has increased after finishing, except for samples knitted with ring spun yarn made from viscose and Tencel® fibres due to the fabric widening that occurred after the finishing process. The sample made from ring spun yarn from viscose fibres expanded by 6% and sample from Tencel® fibres expanded by 10%, with other samples shrinking from 6% to 9% after finishing process, not due to the relaxation. The thickness of all finished samples decreased from 4.6% for the cotton yarn to 30% for the ring spun yarn from Tencel® fibres.

Table 1. Basic knitted fabric properties, thermal and water vapour resistance

Fibre type	Yarn type	M, g m^{-2}	T, mm	Dh, cm^{-1}	Dv, cm^{-1}	Nl, l/cm^{-2}	S, %	Rct, $m^2C\ W^{-1}$	SD $m^2C\ W^{-1}$	CV %	Ret, $m^2Pa\ W^{-1}$	SD $m^2Pa\ W^{-1}$	CV %
COTTON	R-Ring	157	0.64	11.1	11.4	253	39	0.030	$3.0x10^{-4}$	11.3	4.71	0.32	6.8
	F-Ring	162	0.61	10.5	12.3	258	32	0.026	$4x10^{-4}$	1.5	3.78	0.43	11.4
VISCOSE	R-Ring	165	0.63	10.9	11.8	257	39	0.022	$1.8x10^{-4}$	8.3	4.03	0.19	4.6
	F-Ring	141	0.36	10.1	11.7	236	33	0.021	$6x10^{-4}$	2.7	3.18	0.17	5.5
	R-Rotor	131	0.59	8.6	12.0	206	22	0.013	$1.4x10^{-4}$	11.3	3.03	0.05	1.6
	F-Rotor	160	0.47	9.5	12.4	236	28	0.015	$3x10^{-4}$	2.1	3.27	0.38	11.9
	R-AJet	127	0.58	9.0	12.0	216	25	0.017	$8x10^{-4}$	4.8	3.06	0.04	1.2
	F-AJet	147	0.47	8.8	13.5	238	23	0.017	$8x10^{-4}$	4.6	2.88	0.11	3.8
TENCEL	R-Ring	152	0.63	10.8	11.8	255	36	0.023	$2.8x10^{-4}$	12.2	3.70	0.50	13.5
	F-Ring	139	0.44	9.4	11.7	220	26	0.019	$3x10^{-4}$	1.5	2.94	0.22	7.5
	R-Rotor	128	0.61	9.2	12.1	223	25	0.015	$1.2x10^{-4}$	7.9	3.28	0.16	4.9
	F-Rotor	161	0.51	10.3	13.0	268	36	0.014	$1.1x10^{-4}$	7.4	2.82	0.16	5.7
	R-AJet	132	0.62	9.0	12.3	221	25	0.017	$1.3x10^{-4}$	7.5	3.28	0.33	10.1
	F-AJet	156	0.49	9.3	12.8	238	33	0.017	$2x10^{-4}$	1.4	3.01	0.28	9.4

Where: R is raw knitted fabric, F is finished knitted fabric, Ring is knitted fabric made of ring yarn, Rotor is knitted fabric made of rotor yarn, AJet is knitted fabric made of air jet yarn, M is knitted fabric mass per unit area in g m-2, T is knitted fabric thickness in mm, Dh is number of loops in courses cm-1, Dv is number of loops in wales cm-1, Nl is knitted fabric number of loops per unit area in l/cm-2, S is knitted fabric shrinkage in %, Rct is knitted fabric thermal resistance in m2C W-1, Ret is knitted fabric water vapour resistance in m2Pa W-1.

Although mass per unit area and thickness of almost all fabric after finishing process increased, except knitted fabric made of viscose and Tencel® ring spun yarns, thermal and water vapour resistance of all finished knitted fabric decrease. Considering that, thermal resistance describes the thermal barrier of heat passage from the human body to the environment it can be concluded that after finishing the fabric will provide greater heat loss, i.e. worse thermal barrier property.
On the other hand, a decrease of the knitted fabric water vapour resistance indicates easier transmission of water vapour (sweat) through fabric, thus better physiological properties. It can be concluded that besides different yarn raw material and yarn structure, finishing process additionally influences on thermophysiologycal properties.

CONCLUSION
Based on conducted research it can be concluded that raw material, yarn structure and the finishing process itself cause significant differences of basic knitted fabric parameters after the finishing process, thus thermophysiological properties. For the commercial application of the knitted fabrics, the recommendation is a careful selection of knitting parameters in order to obtain a satisfactory knitting structure. Furthermore, special attention should be paid to the process of knitted fabric finishing which must be adopted to a precisely defined structure. Guidelines for processing procedures should be found in the extreme values of the obtained results when comparing raw and finished knits properties. This is a basic precondition for the quality garments production from non-conventional yarns spun from regenerated cellulose fibres.

ACKNOWLEDGMENTS
This work has been supported by the Croatian Science Foundation under the project (IP-2016-06-5278).

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PLAegg – GREEN COMPOSITE FROM EGG SHELLS AND PLA

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ABSTRACT
Based on the principles of Circular Design, this paper aims to present the development process of PLAegg, a biodegradable, compostable and recyclable composite produced from eggshells and Polylactic Acid (PLA). The material was developed within the scope of the We Won't Waste You project, a partnership between Design Studio FEUP and Matosinhos City Council, which through Oficina Design intends to reuse waste to develop new materials and products. Several experiments were performed varying the formulations and material processability. The Material Driven Design (MDD) method was used as the validation procedure, and finally, the material was applied in a new product; a Lexi lamp.

INTRODUCTION
The growing production of waste is an issue that has been attracting the whole society's attention and concern. It is therefore essential to find solutions to tackle this problem. Preserving natural capital and maximizing the value of resources are some of the Circular Economy's principles. Some Circular Design (CD) guidelines can be framed in the mentioned theme concerning material recycling. About 36.4% of the waste produced in Portugal is categorized as biowaste, including eggshells, which are locally produced in large quantities and discarded as waste (Fernandes et al. 2018).

The first step in the PLAegg's production process is the manual removal of the eggshells organic part. The eggshells were washed with water and dried in a kiln at 200ºC for 60 minutes. Afterwards, they were manually grounded using a pestle and separated by grain size using a vibratory sieve shaker (425μm, 600μm, 850μm). The particles were manually mixed with PLA (Ingeo™ 3260HP) binder previously heated to a temperature of approximately 200ºC for 10 minutes. Material's experiments were carried out to find the ideal ratio between PLA and eggshells, its behaviour in moulds with different shapes and materials, as well as to check the influence of particle size on moldability and the aesthetic properties of the material.

The MDD method (Karana et al. 2015) was applied to validate the material. This method aims to support designers in projects in which the material is the starting point. The study was carried out with 32 design and mechanical engineering students. Among the main findings, the valorisation of the material's aesthetic and translucent aspects was highlighted, which led to its application to a lighting fixture, the LEXI lamp (Leite 2020) (Fig. 1). LEXI is a compact decorative table lamp that represents the principles of Circular Design (Commission 2019), insofar as it is a simple and functional device, and is easy to produce and maintain.

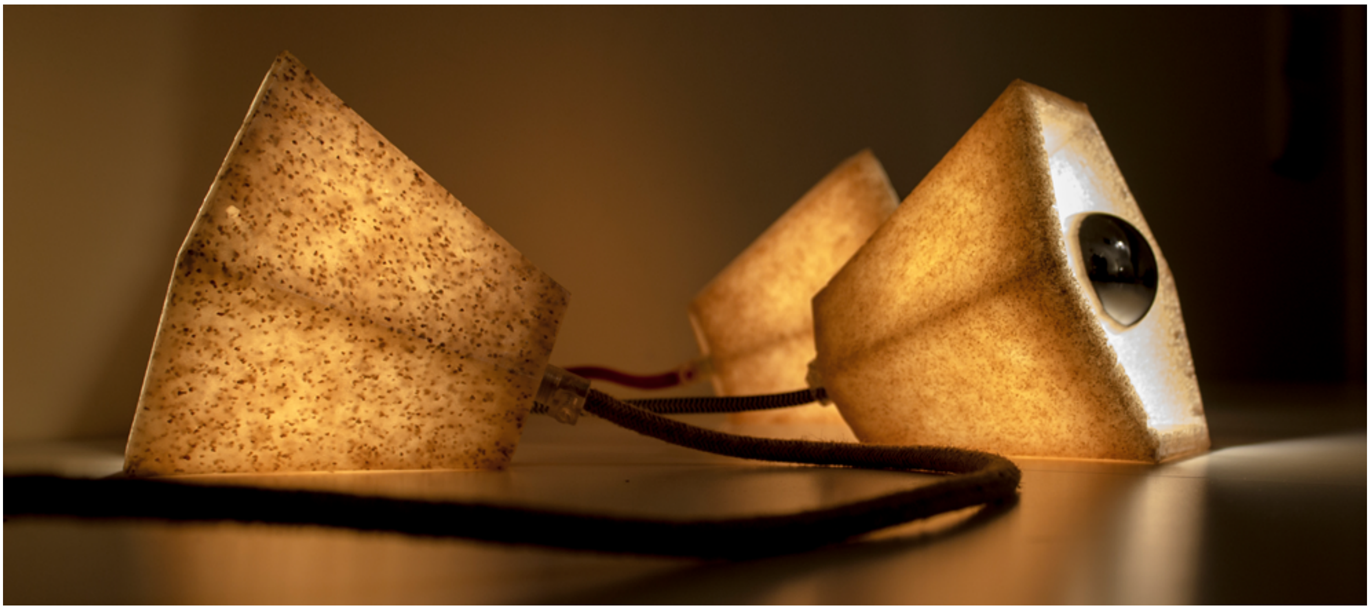

Fig.1 LEXI lamp

RESULTS AND CONCLUSIONS

As a final result, a new material was developed from eggshells and PLA. The percentage of eggshell with the best aesthetic properties of the material was 12.5%. People perceive PLAegg as a resistant, lightweight material, with a smooth surface that arouses curiosity and comfort. The most interesting material's qualities are translucency and three-dimensionality due to the eggshell particles, which opens the opportunity to apply PLAegg to objects that enhance these qualities. This practical experience has allowed evidence that it is possible to add value to food waste through engineering and design.

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HEMP FOR HIGH-VALUE TEXTILE APPLICATIONS: UPSCALING HEMP CULTIVATION FOR PROCESSING ON THE FLAX SCUTCHING LINE

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ABSTRACT

This work investigated the effective fiber yield of field-retted hemp for textile applications at (semi-)industrial scale. Using an experimental harvesting module, we collected the lower, fiber-rich part of hemp stems (USO-31, 0.25 hectare) and automatically aligned them parallel for field retting. Following successful turning and baling using flax machines, hemp was scutched on an industrial flax processing line. Results are promising: 15 % of the initial weight of straw (750 kg) was processed into long aligned fiber, in addition to 24 % of short fiber. Future research (2021) will focus on increasing fiber yield, e.g. by harvesting two stem parts, and optimising agricultural practices such as sowing density and field retting.

INTRODUCTION

Industrial hemp (Cannabis sativa L.) has great potential as a sustainable source of textile fibers within the growing European bio-based economy. Yet, to build a viable local hemp-for-textiles chain, agronomic practices and fiber processing need optimization to current industrial standards. A promising approach for flax-producing regions, such as Flanders (Belgium), may be to turn, collect and process field-retted hemp using the existing, modern equipment for flax, as has been repeatedly suggested in literature (e.g. Amaducci 2003, Amaducci & Gusovius 2010, Gusovius et al. 2016) and, seems supported by small-scale experiments (e.g. Amaducci et al. 2008 – Hemp-SYS & MultiHemp projects; Vandepitte et al. 2020).

Here we attempted to upscale hemp cultivation, harvesting and primary processing (fiber extraction). At the experimental farm of Bottelare (Belgium), a field plot of 2500 m2 was sown with cultivar USO31 the 15th of May, 2020 using an automatic seed driller (sowing density: 72.5 kg/hectare, ~ 500 seeds/m2). At mature flowering (27th July, 2020), the crop was harvested, using an experimental longitudinal harvest module, developed by a Belgian pre-starter (HempInvest). The fiber-rich, lower stem part (from ~30 to 130 cm above-ground level) was cut and laid down in swaths for field-retting (Fig. 1). During retting, swaths were turned once using a one-row flax turning machine (manufacturer: Depoortere). Straw was field-retted for 49 days, after which it was collected using a self-propelled round flax baler (manufacturer: Vlamalin), and subsequently processed on a nearby industrial flax breaking and scutching line (Depoortere/Vanhauwaert at Van de Bilt zaden en vlas, NL).

RESULTS AND CONCLUSIONS

At harvest, mean plant height was 225 cm, plant diameter at stubble height was 8.3 mm and plant density was 169 stems/m2 (= 34 % of sowing density). Hemp bales (diameter = 120 cm) weighted ~ 250 kg, which is comparable to flax bales of the same size.

Scutching processed 15.2 % of field retted straw into long hemp fiber, suitable for (semi) wet-spinning after hackling, in addition to 24.2 % of short hemp fiber. Following additional processing steps, the latter product might be implemented for non-woven applications and short-staple fiber spinning. Both long and short fiber

percentages were comparable to those commonly obtained for flax on the same scutching line (pers. comm. B. Depourcq, Van de Bilt zaden en vlas).
Yet, extrapolated long and short fiber yield were rather low: 0.46 and 0.76 tons per hectare, respectively. Our future research will therefore focus on increasing fiber yield, e.g. by harvesting two stem parts of one meter length, and optimising agricultural practices such as sowing density, cultivar choice and field retting. Furthermore, we are currently investigating the impact of hackling losses (= the next processing step) and the spinning and weaving properties of long and short fibers.

Fig. 1. Automated harvesting (left), turning (mid) and baling (right) of hemp for the flax processing line (summer 2020, Bottelare, Belgium).

ACKNOWLEDGMENTS
The authors gratefully acknowledge the funding by HOGENT (Belgium) of this research (multidisciplinary PWO-project ‘Cannabisness’). We also thank the many industrial partners of this project for excellent advice and the use of equipment, in particular HempInvest, Van de Bilt zaden en vlas, and Cretes.

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LEARNING FROM ANCIENT FLAX FIBRES

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ABSTRACT

Morphological, ultrastructural, biochemical and mechanical characterisation of ancient flax fibres, originating from Italian canvas (XVII-XVIII century) and Egyptian mortuary linen (Eleventh dynasty, ca. 2033 - 1963 BCE) was performed, using advanced microscopy techniques, such SEM, NMR, multiphoton excitation microscopy and atomic force microscopy, and compared against a modern flax yarn. Our findings reveal the impact of ageing and time, according the conditions of sample conservation but also the cultural know-how of ancient civilizations in producing high-fineness fibres, as well as the exceptional durability of flax fibres.

INTRODUCTION

Flax (Linum Usitatissimum L.) is one of the oldest domesticated plants, probably around 8,000 BCE[1], in the Fertile Crescent area[2], first for its seeds and then for its fibres[1]. Ancient Egypt laid the foundations for the cultivation of flax as a textile fibre crop with an intensive use, especially for clothing and in the fishing sector for work clothes, felucca sails and nets. The funerary uses included mummy strips, funeral linen (Fig 1.A) as well as ornaments. In Europe, starting from the Late Middle Age, flax was also widely used as a supporting tissue for paintings on canvas, especially due to the greatest homogeneity into canvas geometry. Today, flax fibres are used in high-value textiles or reinforcements in composite materials[4]. For several decades, the development of non- or micro-destructive analysis techniques has led to numerous works on the conservation of ancient textiles and optical microscopy[3,5], or vibrational techniques[6] have been used extensively. Nevertheless, conservation of mechanical performance and the ultrastructural differences between ancient and modern varieties have not been examined thus far.

RESULTS AND CONCLUSIONS

The morphological characteristics of the ancient fibres were studied by scanning electron microscopy. The investigations highlighted the fineness of the yarns used, particularly for the Egyptian samples, thus confirming the great technical mastery of this civilization. The mechanical properties of the flax cell walls were also studied by AFM in Peakforce mode. Whatever the samples considered, the mechanical performances of the fibres are close to those obtained on a contemporary yarn but evolutions could be identified in terms of crystallinity rate or biochemical composition of the walls. Specific degradation phenomena have also been highlighted on certain samples, induced by possible biological attacks.

Fig.1 Samples used in this study: Egyptian Mortuary linen, 2140-1976 BCE (a), Madonna col bambino, 1782 AD, Nicola Monti (1736-1795 AD) (b) and contemporary spool of yarn, 2019 AD (c)

The results obtained address important findings about the damage mechanisms and ageing of flax fibres and confirm the exceptional durability of these fibres. It is a strong point for the development of tomorrow's biocomposites, with high performances and environmentally friendly.

ACKNOWLEDGMENTS

The authors would like to thank Interreg V.A CrossChannel Programme for funding this work through the FLOWER project (Grant number 23).

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DEVELOPMENT AND CHARACTERIZATION OF FLAX/POLYPROPYLENE BASED MICRO-BRAIDED HYBRID YARN FOR BIOCOMPOSITES

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ABSTRACT
With the growing popularity of hybrid yarn techniques, the micro-braided yarn is becoming a good choice as intermediate materials for natural fiber based thermoplastic biocomposites, by lowing the resin flowing distance during impregnation process. This article focuses on the development and characterization of micro-braiding for biocomposites at yarn scale. Different flax/polypropylene (PP) based micro-braided yarns were manufactured by varying the yarn structure including fineness and number of flax roving, and PP braiding angle; both dry- and thermo-state tensile tests were carried out. It has been observed that the yarn structure parameters influenced the frictional damage on flax roving, the cohesive effect between PP filaments and flax rovings, cover factor, the degree of total fiber dispersion and the flax/PP impregnation distance, finally influenced the characterizations.

INTRODUCTION
The MBYs were manufactured by a tubular braiding loom (Kobayashi 2013), flax rovings were stably fed as axial or middle-end fiber, braided by 8 PP filaments wounded on carriers shown in Fig. 1. 3 fineness of raw flax roving (1000tex, 500tex and 300tex), 3 braiding angles (0°, 20° and 50°) and 3 structures depending on the number of flax rovings (1/2/3) were altered.Textile properties tests including linear density (NF G07-316 standard), yarn width (Image J software), uniformity and hairiness (Uster Tester 4 machine) were evaluated. Dry-state tensile tests were performed on conditioned single yarn according to NF EN ISO 2062 standard, tensile modulus was calculated as the slope of the curve force versus deformation, Thermo-state tensile tests were conducted using a universal tensile tester MTS and an isothermal oven (Wang, 2015). Temperature at 180°C (above the melting temperature of PP 165°C) and extension velocity as 5mm/min were determined.

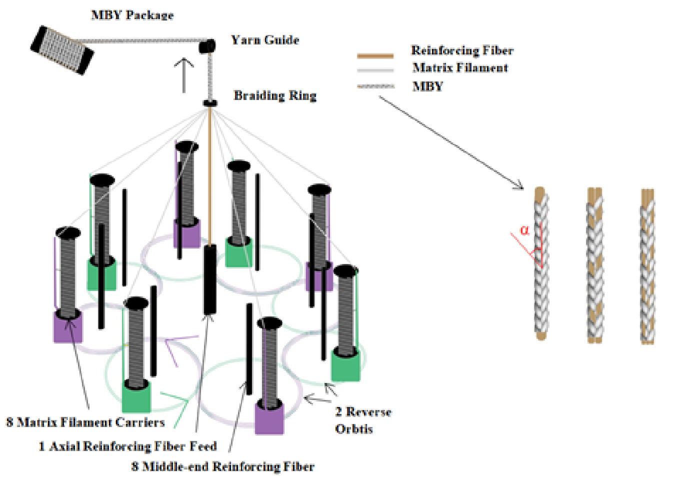

Fig.1 MBY preparation and structure

RESULTS AND CONCLUSIONS

MBY ID was nominated as fineness of flax roving-number of flax rovings-PP braiding angle. The fracture of flax roving surface treatment agent made the force versus deformation curve divided into two phases E1 and E2. The experimental results are discussed into 3 parts.

(1) Same structure, same PP braiding angle but different flax fineness: the thinner flax roving means the smaller flax mass ratio, which led to the better uniformity and the less hairiness of the MBY; the lower Fmax and deformation at Fmax, the smaller load modulus in dry-state; better impregnation and lower Fmax in thermo-state.

(2) Same structure, same flax fineness but different PP braiding angle: the larger PP braiding angle led to finer MBY morphology, better uniformity and less hairiness; greater Fmax and deformation at Fmax in dry-state; more frictional damage on flax surface in E1 phase, while greater cohesive effect in E2 phase; better impregnation effect in thermo-state. But the extreme larger braiding angle (over-covered) led to the opposite effect.

(3) Same PP braiding angle, similar linear density but different structure: the more dispersed structure led to the better uniformity; less hairiness of the MBY; less PP coverage, less frictional damage on flax surface in E1 phase, while better cohesive effect in E2 phase at dry-state. The greater degree of dispersion also led to the less impregnation distance and a longer extension of deformation in thermo-state shown as Fig. 2.

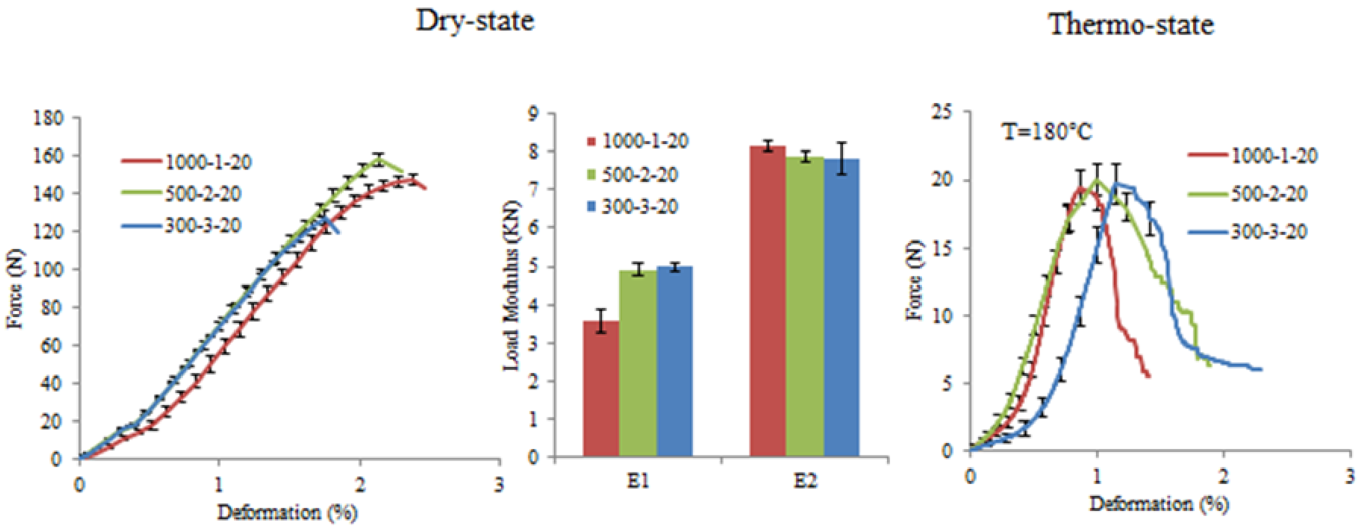

Fig.2 Tensile test results for 20° PP braiding angle based MBYs in dry- and thermo-state

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support from China Scholarship Council (CSC) with project no. 201908070059.

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COMPUTATION OF ASYMMETRIC TENSILE LOADING OF WOVEN FABRIC USING SIGMOIDAL APPROXIMATION OF NONLINEAR TENSILE RESPONSE

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ABSTRACT
In a computational analysis of deformational behaviour of textile materials their specific tensile nonlinearity needs to be adequately described. Comparison of fitting accuracy for a selection of possible approximate models indicates that the sigmoidal curve offers an excellent fit for a wide spectrum of woven fabrics. In the asymmetric tensile loading, the tensile force is applied to a rectangular fabric specimen via the rigid cross-bar, and the linear distribution of strain results in nonlinear stress distribution, including zero stress in the zone of compressive strain at large load eccentricities. The adopted sigmoidal model of tensile response is incorporated into the static conditions of equilibrium between tensile force and stresses in the fabric. The computed results allow a precise estimate of stress concentration and apparent reduction in strength and stiffness resulting from the eccentricity of load application.

MATERIALS AND METHODS
This work is a continuation of the authors' previous research [1] that considered the analysis of woven fabrics under asymmetric tensile loading, Figure 1a, based on a parabolic approximation. In this work instead, the asymmetric tensile loading of the fabrics will be analyzed by a sigmoidal curve. A sigmoidal curve, Figure 1b, can be divided into three sections, out of which the first one is an initial exponential part of the function, the second is an approximately linear part of the function with the inflection point where the growth rate is maximal and an asymptotic third part, in which the curve approaches a constant asymptote.

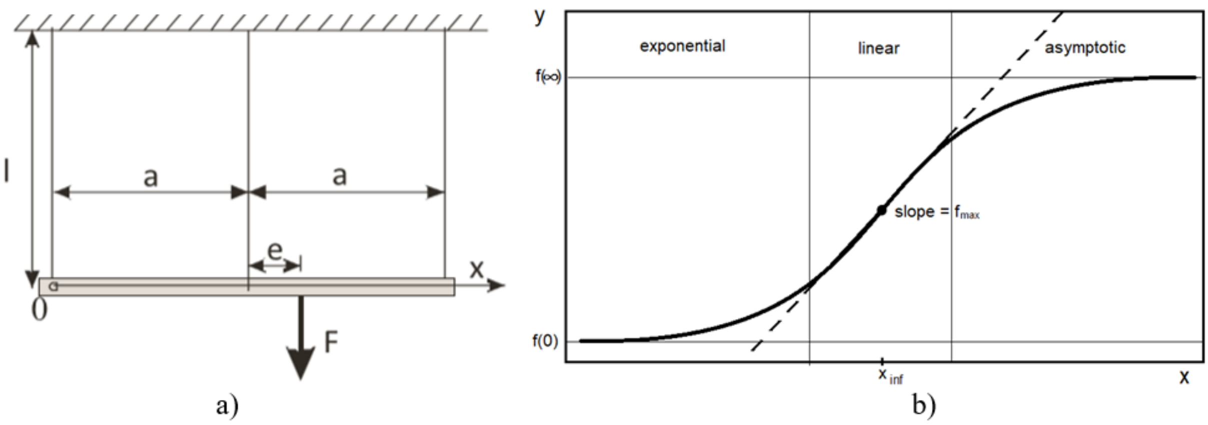

Figure 1. Out-of-the centre specimen tensile loading (a), the sigmoidal curve (b) [1, 2]

The analysis [2] showed that the tensile mechanical behavior of the woven fabric is best described by a curve in the category of Sigmoid growth curves, a dose-response function showing the ratio between strain, where the strain function (logx0-x) lies on x axis and the associated force / strain on the y axes. The form of the curve function is $y = A_1 + \frac{A_2 - A_1}{1+10^{(\log x_0 - x)p}}$ where A1, A2, x0 and p are constants. This function approximates the data to a „S" shaped curve with very high accuracy, as evidenced by the adjusted R2 coefficient which is a modified version of R2 (coefficient of determination), that is, an adjusted measure of model fit. The adjusted R2 takes into account the loss of degrees of freedom in multi-variable models, giving a more realistic picture of the quality of the model. The S curve offered an excellent fit, as an approximate model, for a wide spectrum of woven fabrics, thus was incorporated into the static conditions of equilibrium between tensile force and stresses in the fabric.

RESULTS AND DISCUSSSION

Figure 2 gives the comparison of the sigmoidal fitting of a force-deformation curve with other characteristic fitting models for a plain weave fabric with warp-weft densities 20 threads/cm. The highest fitting level R-squared value (value very close to 1) was determined to be 0.99982 for the sigmoidal curve, while lowest fitting level of 0.81640 was indicated by the polynomial curve [1].

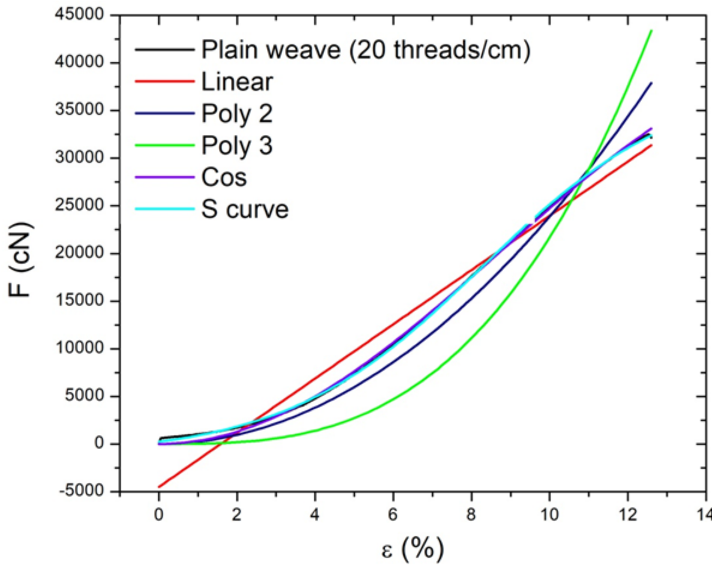

Figure 2. Comparison of sigmoidal fitting with other characteristic curves for a plain weave fabric [1]

CONCLUSION

The sigmoidal model was used in the static conditions of equilibrium between tensile force and stresses in the fabric. The results obtained can provide precision in the estimation of stress concentration and apparent reduction in strength and stiffness based on out-of-centre loading.

ACKNOWLEDGMENT

This work has been fully supported by Croatian Science Foundation under the project number IP-2018-01-3170.

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DEVELOPMENT OF MULTI-FUNCTIONAL WOVEN FABRICS FOR THERMAL PROTECTIVE CLOTHING BY OPTIMIZING STRUCTURAL AND CONSTRUCTIONAL PARAMETERS

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ABSTRACT
Previously conducted research as well as determination of development segment in the form of improvement of woven fabrics currently available on the global market of technical textiles, represents the basis for future extensive research of design and manufacture of multifunctional non-flammable woven fabric, which will be conducted within the project "Development of multifunctional non-flammable woven fabrics for dual purpose". The goal is to design the fabric (maintaining the existing protective and tensile properties, but also to improve it by optimizing the structural and constructional parameters) which will optimally meet the requirements of the global market and combine the characteristics of non-flammability (protection against heat), comfort, breathability, resistance and durability.

INTRODUCTION
Detailed analysis of the current state of the global technical textiles market in the segment of protective non-flammable woven fabrics for military and civilian use, determinate the absence of woven fabric that fully integrates all crucial properties (protection, comfort and durability). Protective clothing must maintain body temperature stable and allow the flow of air and water vapour through the material, i.e. allow heat regulation, while not being heavy, with rough surface that causes irritation, or hindering body movement. Commercially available non-flammable woven fabrics composed of a mixture of different natural and synthetic fibres (in different proportions) have satisfactory FR (flame retardant) properties, while some other properties, such as usability resistance (FR resistance and colour fastness to washing, abrasion and light), are not technically satisfactory.

DEVELOPMENT
A team of scientists from the University of Zagreb, Faculty of Textile Technology, conducted a series of research in the segment of constructional and structural parameters of woven fabrics and the entire designing and manufacturing process for the above-mentioned specific purpose. The conducted analyses of the mentioned researches give a wide overview of micro, meso and macro level of woven fabrics. An overview of the fibres properties used to meet a high degree of woven fabrics thermal protection, such as aramid fibres, especially m-aramid fibres, viscous fibres of reduced flammability (CVFR), modacrylic fibres (MAC), carbon fibre (CF), etc., and fibres of other characteristics (cotton, PA) which are extremely important for improving the properties of dual - use fabrics, was also obtained. The research clearly defines the influence of structural and constructional parameters of woven fabrics on the effectiveness of protection properties, but also on the comfort properties in the form of water vapour permeability, porosity and the like (Kiš, 2019, Kovačević, 2020, Kiš, 2020, Schwarz, 2020).

Therefore, the task and goal were set to design a woven fabric that maintain the existing protective and tensile properties, but with improvements in the segment of water vapour permeability through the material, as well as the bending properties. These improvements are planned to be achieved by optimizing the structural and constructional parameters of woven fabrics, all within the Project "Development of multifunctional non-flammable fabric for dual use" (KK.01.2.1.02.0064). This Project started 17.08.2020. and is a collaborative project of the Croatian textile factory Čateks tt and the University of Zagreb, Faculty of Textile Technology financed by the European Regional Development Fund, whose implementation will last 3 years.
The aim of the project is to develop a new multi-functional fabric for dual use, which due to its comprehensive and advanced properties will be a novelty in the global market of a wide range of protective textiles, in the development of which extremely large financial resources and knowledge are invested. Great attention is focused on the production of woven fabrics using new raw materials and constructions, but also surface treatments. Therefore, in this Project, extensive research will be undertaken in both segments of new product development, the technological process of designing and manufacturing woven fabric, and finishing processes. The Project main goal is to solve the currently problem, which is the inability to meet market demands for a woven fabric that combines the key features of a protective woven fabric in the final application conditions.
Fabric properties that are planned to be achieved by incorporating all influential parameters at the micro and meso-level (improvement of tensile properties, wear resistance, thermo-physiological properties, etc.) in all research segments are properties of non-flammability, higher durability, better colour fastness and comfort. It will represent a significant technological breakthrough, and provide the product with innovation, uniqueness and competitiveness.

ACKNOWLEDGMENTS

This work has been supported by the European Union from the European Regional Development Fund under the project KK.01.2.1.02.0064 Development of multifunctional non-flammable fabric for dual use.

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ANTIMICROBIALLY-ACTIVE VISCOSEYARNS RING-SPUN WITH INTEGRATED AMINO-FUNCTIONALIZED NANOCELLULOSE

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ABSTRACT

Most commercially available antimicrobially active textile materials lack biodegradability or recyclability, thus have limited applications where recyclability and renewability are of interest. Besides, although conventional man-made or natural fibers satisfy the bio-degradability requirements, they cannot compete with synthetic fibers in terms of performance. The aim of this research was, thus, to develop a ring-spun process for production of viscose yarns with integrated antimicrobially active cellulose nanofibrils / CNF. In this frame, the CNF were first surface aminated (CNF-amino) and characterized related to the antimicrobial properties and technical performance (i.e. dispersability and sprayability using different sizes of nozzle opening). The challenges related to the integration of high-enough and evenly-distributed functional CNF within the fibres, their drying without gluing, and spinning-ability without flowing and tearing problems have been examined. The effect of functional CNF concentration on the yarn's tensile strength, finesses, wetting and antimicrobial properties were studied.

MATERIALS AND METHODS

The chain-like CNF, with diameters in the 10-70 nm range and length of the micrometer scale, were supplied from the University of Maine, USA. The 100% viscose fibres of 1.3 dtex and 39 mm long produced by Lenzing AG, were prepared as a compact sliver of 1.2 ktex (21.5 Nm), by Litia spinnery Ltd according to the conventional industrial process (including mixing, carding and rowing steps) and used through all the study. All other chemicals used were purchased from Sigma Aldrich Co. Ltd. and used without further purification.

RESULTS AND DISCUSSSION

Evenly distributed application of functional CNF on a viscose-fibers sliver, without excessive physical adhesion of the fibers during the drying, was essential for successful spinning enable continuous flow of the fiber thread during twisting without its tearing. For that purpose, the spraying process and highly-drying medium were used to apply suitably suspended functional CNF. The spraying process was thus first optimized in terms of functional CNF dispersibility using different concentration, suspension mediums and size of nozzle openings. The effect of CNF dispersibility in fast-volatile mediums was analysed by zeta-potential and size-distribution values as well as by SEM imaging of samples sprayed on Alu. foil (Figure 1).

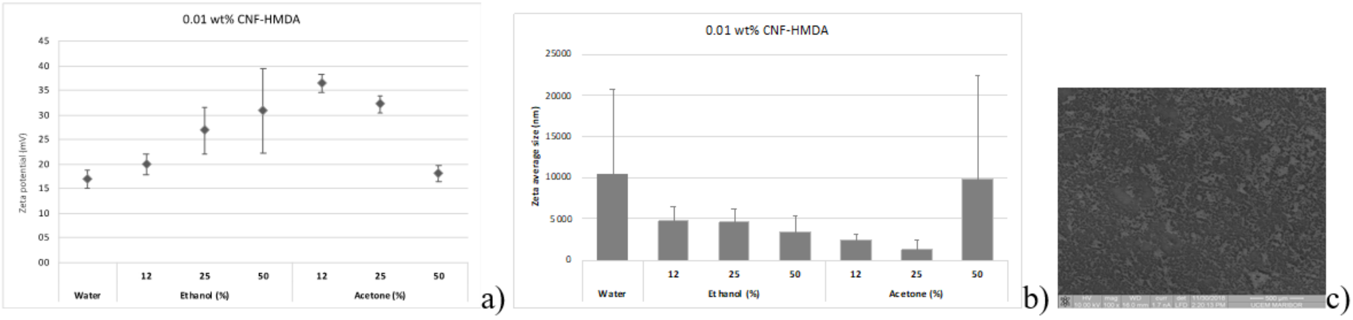

Figure 1 a) Zeta potential and **b)** Average size distribution of 0.01 wt% CNF-amino in different aqueous media, supported by **c)** SEM images of 5 wt% CNF-amino (in 35% ethanol) suspension, sprayed to Al-foil at ~3 bars and a distance of ~15 cm using 0.4 mm sized nozzle openings.

The surface charge, fineness, wettability/hydrophobicity and tensile strength properties of the successfully spinned yarns were assessed to get information about the yarns functionality and influence on growth reduction of selected microorganisms (Figure 2).

Amount of CNF-amino /yarn	Time of complete wetting (s)	Weight increase at complete wetting (%)	Contact angle (°)	Functional gr. Total / Amino (mmol/kg)	Fineness (Nm)	Tensile strength (cN/tex)
REF	122±13.0	64.8±1.4	88.8±0.60	0	24.6	19.42±0.60
33.3 mg/g	133±5.7	63.1±4.7	87.5±0.81	40.8 / 7.98	21.0	17.43±1.14
66.7 mg/g	140±0	56.0±3.7	87.6±0.12	55.6 / 2.56	20.0	15.84±1.07
100 mg/g	140±2.0	53.9±1.5	86.7±0.35	51.8 / 4.00	20.5	17.43±1.13
133 mg/g	150±8.6	52.9±1.5	87.6±0.28	59.6 / 10.29	22.2	14.11±1.01
160 mg/g	155±6.4	52.7±1.0	73.3±1.34	65.8 / 13.80	21.9	15.61±0.96

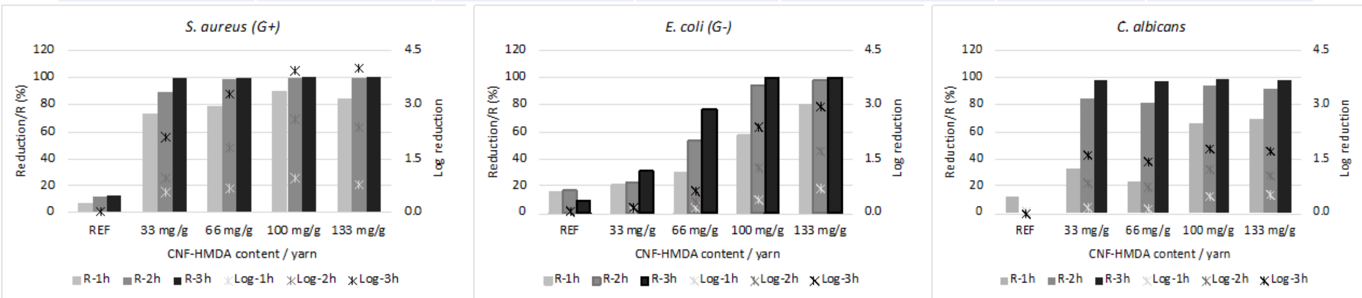

Figure 2. Yarn properties prepared with different content of CNF-amino

Good dispersibility of CNF-mino in a highly-dryable bipolar medium enable its spraying with relative high homogeneity up to 5 wt% conc. and using nozzles with up to 0.4 mm size openings. Such a deposition of CNF-amino to the viscose fibers sliver resulted to a more hydrophilic yarns with faster, but capacity lower, wetting ability, and durable antimicrobial properties, without affecting on its finesses and tenacity. This work brought new knowledge into the designing of bio-based, non-toxic and biodegradable antimicrobially active textiles using renewable nanomaterials and conventional technological processes, thus offering also the potential for creating many other multifunctional or specific protection properties.

FUNDING

The work was carried out within the project Cel.Cycle: »Potential of biomass for development of advanced materials and bio-based products« (Contract no. OP20.00365), co-financed by the Republic of Slovenia, Ministry of Education, Science and Sport and European Union under the European Regional Development Fund.

INNOVATIVE NEEDLED NONWOVENS WITH NATURAL ADDITIVES

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ABSTRACT

The technology of producing nonwovens by the needle punching method is known and widely used in industry, but so far no composite nonwoven with the use of silicate, kevlar and cotton fiber wastes or cardboard waste in the form of dust has been developed. The innovative composite non-woven fabric is produced by the needling technique, in which the basic component is biodegradable material in the form of sheep wool in the amount of about 70%, and 30% are various additives that are post-production waste. Composite needle-punched nonwovens, depending on the type of additive introduced, are characterized by different functional and strength properties, and thus, a various application:

• agrotextiles for soil fertilization, protection of plants, vegetables and fruit

• geotextiles to protect embankment and water reservoirs, in the production of roads, as drainage and insulation nonwovens

INTRODUCTION

A special type of post-production waste, which are a huge problem, are waste from the textile industry, such as cotton or wool dust, generated at all stages of production. These types of post-production waste are of natural origin, and their fibrous form is favorable for the use in the manufacture of biodegradable composite nonwovens.

There are also post-production waste from which it can be obtained silicate and aramid (kevlar) fibers and use them for the production of non-biodegradable composite nonwovens for other purposes.

As part of the own research, included in the scope of the doctoral dissertation, hard-to-manage waste materials were used to produce composite needle-punched nonwovens based on sheep wool.

The following waste materials were selected for the research:

• Fibers from scraps of denim from garment manufacture
• Cotton fibers from the production of bedding
• Waste of silicate fibers
• Cardboard in the form of dust
• Waste paper in the form of dust
• Aramid fibers from kevlar nonwoven fabric generated during the production of the vests

Manufacture of composite needled nonwoven

Wool fibers of 50 mm long and bi-component fibers of 52 mm long, in proportion 90/10, were mixed in an extractor-mixer and introduced into a carding machine. Additives from waste materials were applied to a single fleece fed from a carding machine.

The resulting fleece, after stacking several layers, is needle punched at a speed of 30 Hz, and then consolidated on a calender at the melting point of the bicomponent fibers that act as a bonding structure of the resulting nonwoven fabric.

Demonstrative photos of nonwovens taken with a camera:

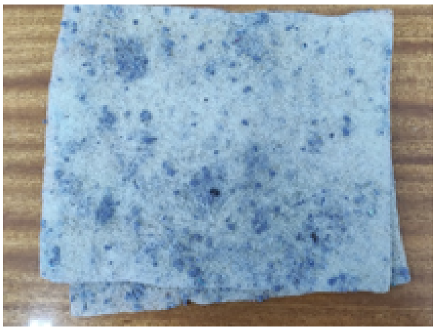

Fig.1 Nonwoven fabric with the addition of blue cotton fibers, "jeans" type

Fig.3 Nonwoven fabric with the addition of silicate fibers

Fig.2 Nonwoven fabric with the addition of cotton fibers from the production of bedding

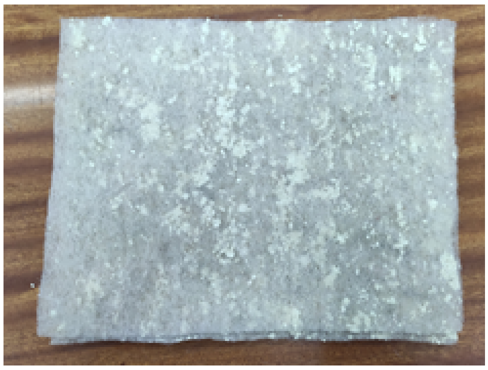

Fig.4 Nonwoven fabric with the addition of kevlar fibers

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EFFECT OF ELASTANE FIBERS ON THE COMFORT PROPERTIES OF COTTON KNITTED FABRICS

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ABSTRACT
This study investigates the effect of elastane fibers, namely Lcyra® and Lycra® T400, in the jersey knitted structure in terms of comfort. To examine comfort properties of the fabrics, water absorbency, air permeability, water vapor permeability, vertical-horizontal wicking, drying rate tests were performed and evaluated.

INTRODUCTION
The wearing comfort can be achieved by using elastic materials in the fiber composition. The invention of Lcyra® in 1958 was a milestone for elastic textile production (Voyce, Dafniotis, & Towlson, 2005). Due to losing stretching properties of elastane fibers during processing (damaging at high-temperature dyeing), it is desired to discover a new material covering disadvantages. Lcyra® T400 is a bi-component (polytrimethylene terephthalate (PTT)/polyester (PET)) filament yarn, which is polyester-based and has the advantages of polyester. It is chlorine proof and withstands the bleaching process. In addition to these features, users feel less compressed in Lcyra® T400 products when compared to Lcyra® ones. Using this new fiber with the combination of Lcyra® has been trending for last decades and there were numerous studies were achieved considering the fiber content ratios, elongation, and recovery properties (Broega, Rocha, Souto, Ferreira, & Oliveira, 2016; Liu, Jiao, & Wang, 2013). Zhao et. al have studied with the PTT/PET bi-component filament, which was used for developing seamless garments, and its performance was compared with thoe of commercially available products. The results show that the fabric made of the PTT/PET bi-component filament has much better dimensional stability, much better elastic recovery property, and much better wrinkle resistance comparing commercially available fabrics (Zhao, hu, Shen, & Rong, 2013). Another study proves that components included in the PTT/PET bicomponent fiber not only affects the mechanical properties but also influence the chemical properties of the products. Souissi et. al offered a procedure to dye bicomponent PTT/PET fibers without sacrificing elastic recovery performances (Souissi et al., 2020). During enhancing the elastic properties of products, it is essential to keep comfort properties at the required levels. In this study, there are three types of jersey knitted fabrics were produced using different amounts of Pima cotton, Lcyra®, and Lcyra® T400 fibers. To compare their comfort properties; water absorbency, air permeability, water vapor permeability, vertical-horizontal wicking, drying rate tests were performed according to appropriate standards.

RESULTS AND CONCLUSIONS
Average wetting time, drying rate, water vapor permeability, and air permeability results are given in Table 1. Due to most of the fabric composition is cotton, the fabrics are water absorbent and their water absorbency results are very close to each other. Although the basis weight of the first fabric is lower than those of others and it is expected to dry faster, drying rate results showed that the second fabric dries faster compared to others. The lower basis weight of the first fabric causes a more porous structure which leads to better wa-

ter vapor and air permeability results. Analyzing the second and third fabric indicates the effects of Lcyra® amount on the comfort properties. Increasing Lcyra® component in the structure affects air permeability adversely as a result of the tight structure.

Table 1 Comfort test results

Fabric Compositions	Average Wetting Time (s)	Average Drying Rates ($g/m^2/h$)	Average Water Vapor Permeability ($g/m^2/day$)	Average Air Permeability (mm/s)
82.5 % Pima Cotton 17.5 % Lycra®	10.33 ± 1.53	35.19 ± 1.97	881.05 ± 96.30	246.06 ± 20.63
79.6 % Pima Cotton 9.9 % Lycra® T400 10.5 % Lycra®	6.00 ± 1.00	46.52 ± 1.50	773.69 ± 82.20	231.48 ± 18.36
74.1 % Pima Cotton 9.9 % Lycra® T400 16 % Lycra®	8.33 ± 1.53	40.36 ± 0.35	868.11 ± 87.67	88.41 ± 4.53

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by SANKO Textile Facilities Research & Development Center “Development of Environmental-Friendly Biodegradable Washable Menstruation Panties and Pads”, under grants of “AP19” project.

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INVESTIGATION ON THE EFFECT OF KNITTING CONSTRUCTION ON THE COMFORT PROPERTIES OF 100% COTTON FABRICS

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ABSTRACT
In this study, three different knitted fabric construction (jersey, rib, and interlock) were produced with 100% cotton, Ne 40/1. Without any extra chemical processes, only the effect of fabric construction on the comfort properties was investigated. It is found that there is a relation between fabric construction and the comfort of a knitted fabric.

INTRODUCTION
Clothing plays a vital role in human life and comfort is an essential feature expected from a textile product. Numerous studies were conducted related to the effect of fabric parameters on comfort such as structure, thickness, yarn count, process type, fiber type, and blend ratios, etc. Cimilli et. al. (Cimilli, Nergis, Candan, & Özdemir, 2010) have considered many types of fibers in terms of comfort properties and found that chitosan, modal, and viscose fabrics were performed relatively better results comparing bamboo, soybean, and cotton. Another study was focused on different blend ratios of cotton and angora fibers (Oglakcioglu, Celik, Ute, Marmarali, & Kadoglu, 2009). Research about yarn parameters showed that finer yarn count and lower twist amount increased thermal resistance while decreasing moisture vapor permeability (Özdil, Marmarali, & Kretzschmar, 2007). Afzal et. al. (Afzal et al., 2017) had research on the comfort properties of double-layer knitted fabrics, and investigated fabric parameters; fiber content, yarn count, and fabric thickness. It was found that thermal resistance of the fabrics depends on the fiber type and blend ratios, also yarn count and fabric thickness directly affect thermal isolation. In addition to fabric parameters, Cimilli and Şahin (Cimilli Duru & Şahin, 2020) have studied on chemical process history of the jersey knitted fabrics made of different yarns and applied different softener types at different concentrations. Water-related comfort properties were found to be affected by the softener treatment negatively and silicone softeners performed better among the three softener types. In this study, three different knitting structures (jersey, rib, interlock) were produced with 100% cotton yarn (Ne 40/1), and their comfort-related properties were investigated. Water absorbency, air permeability, water vapor permeability, vertical-horizontal wicking, drying rate tests were conducted to evaluate the effect of knitting structure on comfort.

RESULTS AND CONCLUSIONS
Jersey, rib, and interlock samples, used in this study, were demonstrated in Fig. 1. Test results showed that there is a relation between fabric construction and the comfort properties of fabrics.

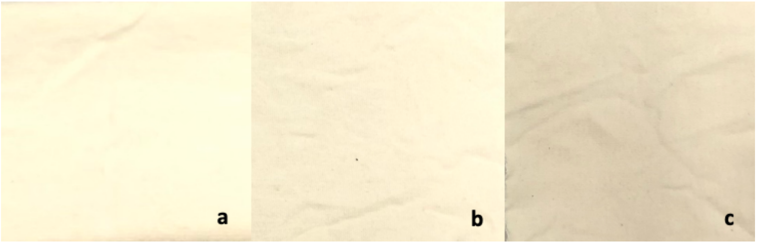
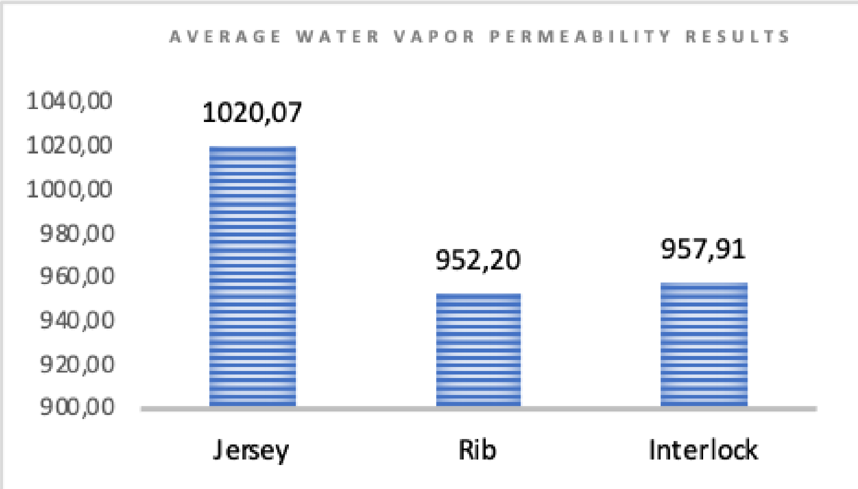


Fig.1 Jersey (a), rib (b), interlock (c) knitted fabrics

In Fig. 2, average water vapor permeability results are given and it is seen that jersey fabrics have higher water vapor permeability values (1020.07 g/m2/day), meaning they are more able to remove water vapor from one side of the fabric to another side. In other words, they are more comfortable in case of perspiration.



ACKNOWLEDGMENTS

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COMPREHENSIVE SURFACE CHARACTERIZATION AND WATER SORPTION ISOTHERM OF CELLULOSE-BASED MATERIALS USING SORPTION TECHNIQUES

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ABSTRACT

This study provides an overview on the applicability and capability of sorption techniques for comprehensive surface characterization of fibres including natural fibres, ligno-cellulosic fibres, cellulose nano-fibrils (CNFs), cellulose nano-crystals (CNCs). The determination of the dispersive surface free energy, acid-base properties, and specific surface area will be presented. Furthermore, the water sorption properties of recycled and non-recycled cellulose-based bathroom tissues are presented.

INTRODUCTION

Inverse gas chromatography (IGC) is a rapid technique to determine thermodynamic parameters of gas–solid interactions and to characterize physicochemical properties of solid substrates. Natural fibers have a complex surface chemistry and unique microstructure that challenge the current capabilities to perform surface characterization. Natural fibers also suffer from considerable batch-to-batch heterogeneity and particularly dimensional variability, which directly affect the tensile properties. Most of researchers working with fibers or composites use Contact Angle (CA) to measure the surface properties, because CA measuring devices have been commercially available for longer, but recent research data and publications show IGC provides more accurate and precise measurement of the surface properties of fibers. Over the past few years, we have noticed that researchers in this area and composite developer companies [1-5] rely on IGC for key characterization methodology of fibers such as natural fibres, ligno-cellulosic fibres, CNFs, and CNCs. The determination of the dispersive surface free energy, acid-base interactions, specific surface area using iGC will be presented. Furthermore, presented is the water sorption and surface properties of cellulose-based bathroom tissues. Bathroom tissues have characteristics that optimise their application to absorb water. Their surface topography enhances their elasticity and maximise their absorbance. These properties modify the surface heterogeneity. With the increasing awareness of the importance to protect the environment, manufacturing companies are developing more environmentally responsible blends of components to create their product. This study compares the surface chemistry of commercially available bathroom tissues and their water sorption uptakes.

RESULTS AND CONCLUSIONS

For the IGC experiments a small piece of paper sample was packed in a column with 30 cm length and a 3 mm ID. All IGC analyses were carried out using iGC Surface Energy Analyzer (SMS, Alperton, UK) and the data were analysed using advanced SEA Analysis Software. Dynamic Vapor Sorption (DVS) experiments were carried out using DVS Endeavor system (SMS, Allentown, USA).

The recycled super soft sample has the highest specific surface area, indicating higher surface roughness. It was expected based on the procedures applied during the recycling process and the production of these types of products. During recycling process, the paper is going through extra treatments compared with the non-recycled products, usually bleaching, in order to whiten it and to get aesthetically acceptable colour for its application and during production of recycled paper, the paper passes through certain stages where it is heated to high temperatures and so it is practically sterilised [6]. These treatments chemically modify the surface and creates polar functional groups on it. Due to this treatment the recycled paper has higher specific surface energy and more heterogenous specific surface energy profile, it is shown on Figure 1.

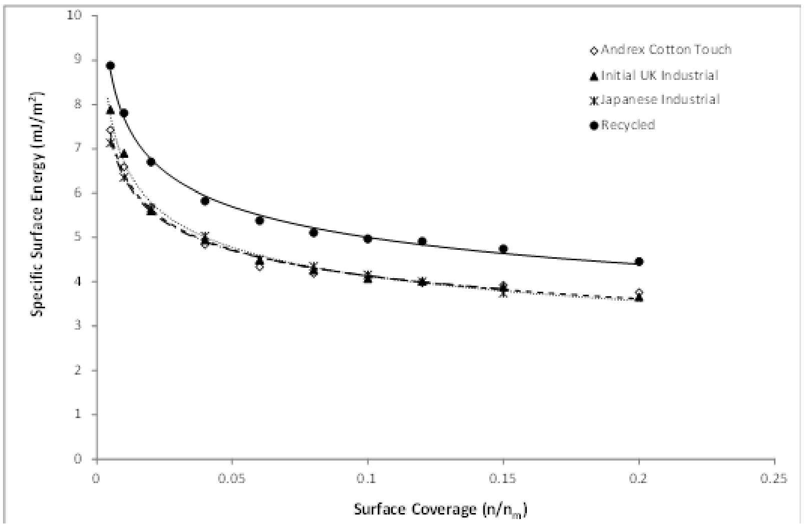

Figure 1 Specific Surface Energy Profile of the samples at 303.15K

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BIO-POLYMER WITH NATURAL FILLERS AS BIO-COMPOSITES FOR HANDHELD 3D PRINTING

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ABSTRACT

This study explores the potential of organic waste as a filler for bio-composites. Alginate as a biopolymer was considered for application through a 3D extruder.

A qualitative methodology was used. In order to quickly study results, a novel extruder was developed from a previous open-source 3D extruder model. Several different experiments with bio-composites using sodium alginate and organic waste as fillers were completed with success and utilizing a novel handheld 3D printer, revealing feasibility.

Results equally show the importance of Fab Lab communities (i.e., open-source hardware, material recipes) in providing for support, fast data or solutions and lesser time operations.

INTRODUCTION

Various studies confirm the existence of microplastics contaminating the food chain, hence the urgency in discovering new safe materials and solutions in packaging design (Sauerwein, 2020). Biobased materials present significant opportunities in dealing with disposable plastic issues, contributing to packaging bio-degradation and compostability, helping to reduce contamination and toxicity for all ecosystems.

This project was developed under the 2020 Fabricademy assignment 'Open-source hardware: from fibres to textile', Textile Lab Amsterdam, aiming to create new open-source hardware and biobased materials to be extruded resourcing to a handheld 3D printer (Jongenburger, 2013)

The search for recipes started from provided references (Kochhar, 2018)(Ferlatte, 2019) (Bolumburu, 2018). These were adjusted for an appropriate usage of a syringe with an electric handheld extruder. Egg-shells, shell-sand and coffee grains were experimented as fillers as shown in Fig. 1.

RESULTS AND CONCLUSIONS

Results show materials behave as expected; an appropriate thickness was needed to that specific nozzle (Fig. 1). A handler was attached to the device for better control of the extrusion (Fig. 2).

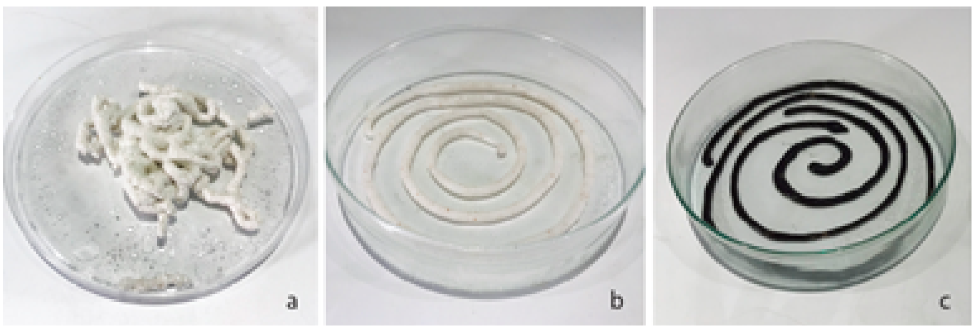

Fig.1 Bio-Composite samples – best results with different fillers:
a) eggshells; b) shells sand; c) coffee grains; images from authors

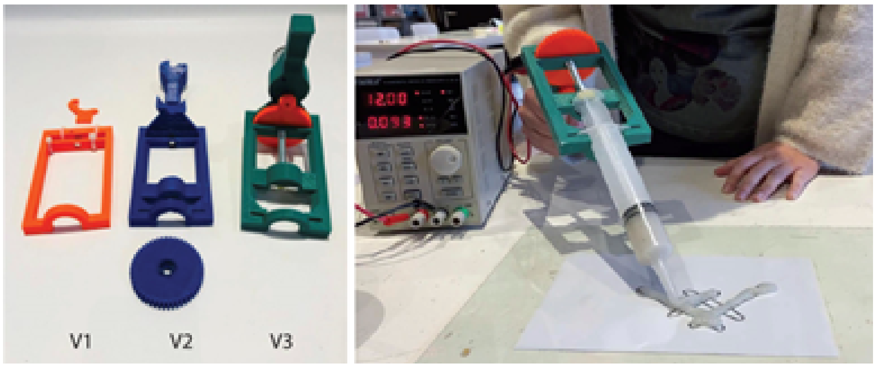

Fig.2 Evolution of 3D Extruder, adapted from (Jongenburger, 2013), image from authors

These reveal that designing small actionable projects using biowaste to obtain renewable and biodegradable raw material contributes to cost-effective processes and highlight the potential of an open-source approach for the development of design for the Circular Economy, with direct positive impacts. Based on open-shared feats and reduced apprentice time, the open-source hardware, protocols and recipes represent a global and interdisciplinary collaboration of opportunities and build-ups towards solutions (Fig. 2). Studies are to be considered for further data collection (e.g., properties, moulds, applications).

ACKNOWLEDGMENTS

The authors gratefully acknowledge TextileLab Amsterdam - Fabricademy collaboration and FCT - Foundation for Science and Technology, Portugal.

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SUSTAINABLE PRODUCTION FROM A DIRECT AID FUND FOR SMALL SILK PRODUCERS IN THE FRAMEWORK OF SILK PROJECT EUROPE AID LA/2016/378-553

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ABSTRACT

Silk is an important natural fiber and a resource for biomaterial. The SILK PROJECT focused on small-scale silk production in Latin America and Caribbean. It`s funded by the European Union through ADELANTE, a triangular cooperation programme. Along the project activities, a Development Support Fund was established to help local value in silk production chain, with sustainable practices and a gender perspective and biomaterials production. Also, three guide booklets were published oriented to sustainable sericulture within a circular economy focus. Actually, there are 30 experiencies in-work, which some of them are producing biomaterials, and three booklets online available.

INTRODUCTION

The SILK PROJECT began in 2017 and its funded by the European Union with the aim to promote sericulture in Latin America and the Caribbean with a sustainable approach, contributing to the United Nations Sustainable Development Goals. Silk is an important natural fiber. It`s produced by Bombyx mori (L). Sericulture is an activity that generates genuine employment, it`s environmental friendly and it´s an important local development activity for small farmers and small and medium textile entrepreneurs (SMEs) or artisans. In addition, silk is a biomaterial that could be used in differents applications: cosmetics, food and medicine. Currently a large number of researches (included in SILK PROJECT) carry out trials on fibroin and sericine and its derivatives for innovative applications, beyond textiles / clothing (Gaviria et al, 2017).
Aware that textile and fashion industry is the second activity with major global environmental impact, one of Project major actions one of the most important action of SILK PROJECT was a Development Support Fund (DSF) for sericulture farmers and silk artisans, to include actions viculed with circular economy promote sustainable and circular economy practices and to provide raw material suitable for biomateriales development.
Another action activity was the development of booklets oriented to farmers and SMEs, linked to the circular economy. It major goal was to provide teorethical support for farmers and textile SMEs, to include concepts of circular economy in their production strategies.

RESULTS AND CONCLUSIONS

The start of the actions were delayed for Covid-19 outbreak. There were 80 requests from Latinamercian countries, from which 31 projects were selected. Actually the funds are in execution time, with some good results related with mulberry crops and sustainable management.

Regarding circular economy booklets (Figure 1), there was divided in three independent parts: "Aspects that govern a production based on the circular economy", "Steps for implementation in a production system" and "Practical examples from the world of fashion and in particular of sericulture production". This materials are available online, and actually they have been distributed printed copies to farmers and SMEs (Salvatierra et al, 2019)

Figure 1. Booklets of Sericulture, Textile and Circular Economy

ACKNOWLEDGMENTS

The authors are grateful for the contribution of the professionals of the institutions associated with the SILK PROJECT, the sericulturists and silk artisans of the LAC region, as well as the European Union through ADELANTE a programme on triangular cooperation and his technical assistance team.

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GEOMETRICAL AND THERMAL PROPERTIES OF ELASTIC SINGLE JERSEY KNITTED FABRIC

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ABSTRACT

In this work, the geometrical and thermal properties of full plaited single jersey knitted fabric were investigated. Nine elastic plain fabric samples were produced at the three levels of loop length (2.7, 2.9, 3.1 mm) and three levels of Lycra rate (6.5, 6, 5.5 %) with yarn count 30/1 Ne. the geometrical properties (thickness, bulk density, stitch density and spirality), thermal properties (resistance, absorptivity and water vapour resistance) and air permeability were measured and compared to the pure cotton produced from the same yarn count and loop length levels. The result showed that stretched fabric thickness and density, stitch density, thermal resistance and thermal absorptivity increased compared to pure cotton. On the other hand, spirality and air permeability of stretched fabric decreased due to the additional Lycra.

INTRODUCTION

Knitted fabrics are characterized by comfort compared to woven fabrics due to their high extensibility and air permeability. The recovery power is considered the main disadvantage of plain knitted fabrics; therefore, Lycra is increasingly used to impart a greater level of stretch and improve the dimensional stability [1][2]. Spandex is used as a core in the core spun yarns with natural and synthetic fibers or additional yarn (full and half plaited) in circular knitting machines. A few researchers concerned with the thermal comfort properties of elastic knitted fabrics [3][2][4][5]. So, the aim of this research is to investigate the effect of Lycra rate on the geometrical and thermal properties of stretched single jersey knitted fabrics and compared with pure cotton fabric samples.

MATERIAL AND METHODS

Table 1 shows the samples specification. All fabric samples were finished according to stretched knitted fabric finishing recipe. After finishing, all samples were washed three consecutive washing cycles at 40˚C in laboratory washing machine.

Table 1. samples specification.

		100% cotton	full plaited		
Lycra percent %		0	5.5	6	6.5
loop length (mm)	2.7	√	√	√	√
	2.9	√	√	√	√
	3.1	√	√	√	√

Fabric thickness was measured according to ASTM D1777. The angle of spirality was measured as the angle between the wale line and the line parallel to the machine running direction[1][6]. Thermal resistance and absorptivity were measured by using Alambeta tester according to the standard ISO EN 31092 – 1994.

Water vapour resistance was tested by Permetest according to ISO 11092. Air permeability was measured according to EN ISO 9,237. The statistical Multivariate Analysis of Variance (MANOVA) was performed for the experimental results by using SPSS program to determine the significance effects of the spandex loop length on all tested properties.

RESULTS AND CONCLUSIONS

The increasing of spirality angle has a bad effect on sewing line which is markedly distorted after repeated washing and is unaccepted by consumers. The additional Lycra decreased the spirality angle of stretched knitted fabric compared to pure cotton samples by 83% at loop length 2.7 mm as shown in figure (1) so the distortion of sewing line reduces. The water vapour resistance of full plated samples is higher than pure cotton by 69% as shown in figure (2). This may be due to the increasing of stitch density of full plated samples compared to pure cotton therefore, the pure cotton fabric contains a large size of pores that can permit the water vapour transfer by convection.

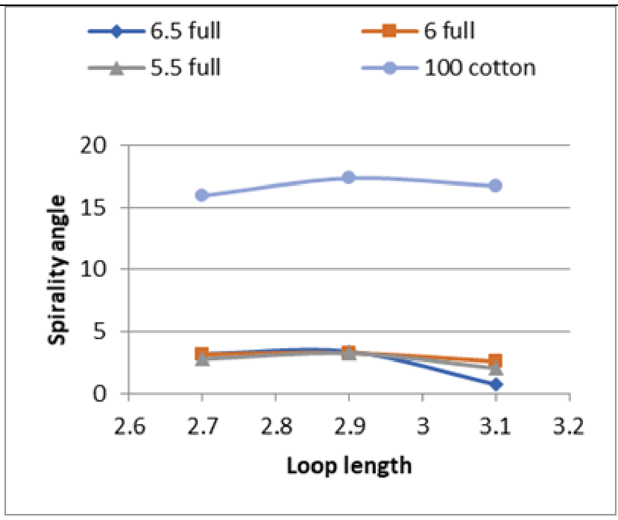

Figure 1. Effect of loop length on spirality angle at three level of Lycra rate.

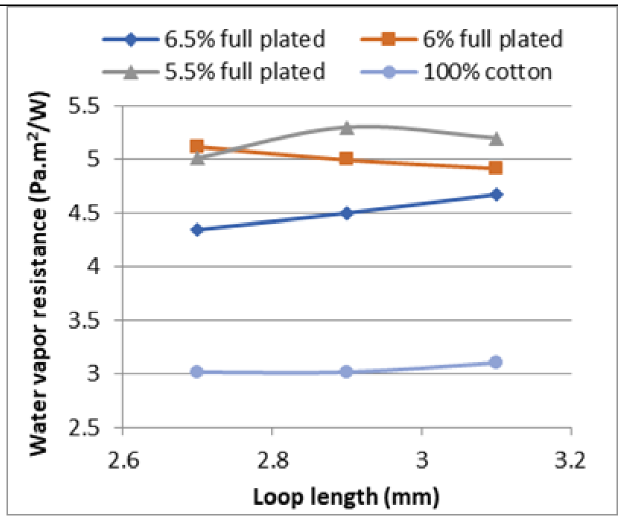

Figure 2. Effect of loop length on water vapour resistance at three level of Lycra rate.

Fig.1 Tensile test results

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YARN POSITIONING EFFECT ON MOISTURE MANAGEMENT PROPERTIES OF PLATED KNITTED FABRICS

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ABSTRACT
Four knitted fabric samples were developed with the combination of hydrophilic cotton and modal hydrophobic polyester and micro-polyester. It was concluded that moisture management property was highly dependent on the material used in the development of fabric. The combination of synthetic and regenerated fibers proved to be a good choice for moisture management properties. These plated fabrics have a scope for being used in sportswear and leisurewear due to their good moisture management and breathability.

INTRODUCTION
Moisture management of fabric defines its comfort properties (Oglakcioglu et al. 2011). Plated fabrics have long been used for their surface interest, patterns, and certain physical properties. The wicking process in plated fabrics is advantageous because of the two-layered structure whose chemical and physical demography contribute collectively the moisture management (Xian 2009). The plated fabrics with such combinations for better wicking can be used in leisurewear and sportswear (ÖZDİL and ANAND 2014). SJ plated fabrics are the ones that are formed by simultaneous knitting of two or more yarns in the same needle hook.

RESULTS AND CONCLUSIONS
The materials used in this study are Modal (40Ne), Cotton (40Ne), micro-polyester (75D/144f), and Polyester (75D/48f). These materials were used to develop four types of fabric samples. Knitted samples were developed on a single jersey circular knitting machine of diameter 34", gauge 24 and loop length for face yarn was kept 0.31cm, and for plating, yarn was kept 0.29cm. The moisture management test was conducted according to AATCC 195-2009 after the conditioning of samples according to ASTM D 1776. Moisture management test results are given in Table 1.

Table 1 Moisture management test results

Fabric Composition	Wetting time		Absorption Rate		Wetted Radius		Spreading Speed		Accumulative one-way transport	OMMC
	Top (s)	Bottom (s)	Top (%/sec)	Bottom (%/sec)	Top(mm)	Bottom (mm)	Top (mm/s)	Bottom (mm/s)	Index (%)	
Cotton/Polyester	4.48	4.64	32.41	46.91	15.0	15.00	2.19	2.17	130.68	0.40
Cotton/micro polyester	4.11	4.18	35.37	49.92	15.0	18.75	2.52	2.62	131.81	0.44
Modal/Polyester	4.60	4.44	23.85	60.49	15.0	20.00	2.25	2.54	416.35	0.76
Modal /micro Polyester	7.19	3.94	10.27	42.81	15.0	20.00	1.57	2.89	449.83	0.77

The test results of knitted plated fabric showed fabric's behavior towards moisture management. Knitted plated fabric developed with modal & micro-polyester showed the highest Accumulative one-way transport Index (%) and OMMC. The reason could be narrow channels in the micro-polyester structure that reduces the wicking time and quickly transfers the water from the skin to the outer surface(Varshney, Kothari et. al. 2010) where Modal quickly absorbs the water and spreads it to evaporate (Schuster, Suchomel et al. 2006). The purpose of using hydrophobic fibers on the technical back was to achieve the wicking of moisture by capillary action and not to absorb but to adsorb the moisture on the surface of the fibers.

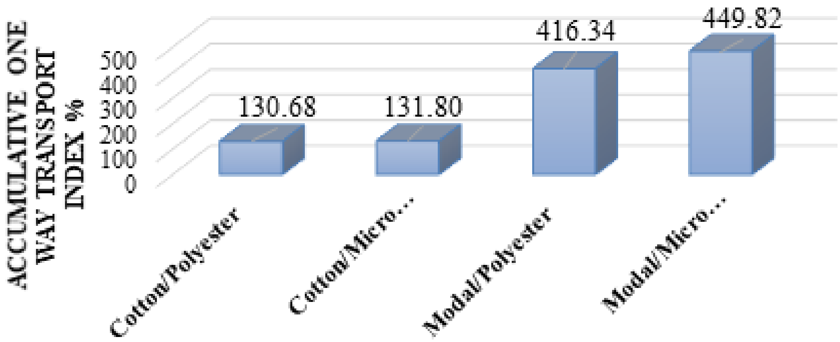

Figure 1 Accumulative one-way transport Index %

It was concluded that the moisture management property of the plated knitted fabrics depends upon the properties of the materials from which they are developed. The second factor is the positioning of the right material on either side. The hydrophobic and hydrophilic nature of the materials in plated fabric aids each other to achieve better wicking and transportation of moisture. Modal and micro-polyester knitted plated fabric showed effective moisture management 240% more than others.

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DESIGN AND DEVELOPMENT OF BIO-BASED FILAMENT FROM CELLULOSE NANOFIBRES AND BIOPOLYMERS FOR 3D PRINTING APPLICATIONS.

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ABSTRACT
This study deals with the development of cellulose nanofibre (CNF) reinforced PLA bio-nanocomposites for production of bio-based filaments for 3D printing applications. Cellulose nanofibres (CNFs) were extracted from sawdust by chemical and mechanical techniques. The extracted CNFs were characterized by analytical techniques such as thermogravimetry analysis (TGA) and Fourier transform infra-red spectroscopy (FTIR). Thermal analysis results revealed that extracted CNFs were thermally stable within the intended processing temperature ranges. Bionanocomposite pellets were prepared from master-batches of PLA, CNFs and triacetin plasticiser followed by melt compounding in a twin screw extruder. The pellets were further extruded to form bio-based filaments which were 3D printed in fused deposition modelling (FDM) desktop 3D printer (WANHAO Duplicator i3) to form dumbbell specimens and other prototypes. Both filaments and 3D printed dumbbell specimens were subjected to mechanical and thermal characterization.

INTRODUCTION
The sourcing and utilization of nanocelluloses such as cellulose nanofibers (CNFs) from waste lignocellulosic biomass continues to gain much attention. This is mainly because of the low density and high aspect ratio of CNFs making it a promising reinforcing phase in the production of bionanocomposites [1]. For instance, poly(lactic acid) (PLA) bionanocomposites containing CNFs has attracted a lot of interest amongst the fused deposition modelling (FDM) 3D printing community [2]. This interest has been fuelled by the promising improvements in the physicochemical properties of CNF reinforced PLA biocomposites [3].
Poly(lactic acid) (PLA) remains the most used thermoplastic in FDM 3D printing. However, the applicability of unmodified PLA is mainly limited due to issues like slow crystallization, poor melt strength, low heat distortion temperature and brittleness [4]. Although modifications of PLA via plasticization and co-blending with other thermoplastic polymers are common,the addition of CNFs is known to further improve the crystallization behaviour, biodegradability, and other physicomechanical properties of PLA [4]. Thus, these eco-friendly and waste derived bionanocomposites provides the much needed diversity to the range of materials currently available for 3D printing prototypes, semi-functional and fully functional materials.

RESULTS AND CONCLUSIONS
Thermogravimetric analysis (TGA) profile of the CNFs in Figure 1a shows characteristic loss of moisture and volatiles around 60 – 150°C range. The onset around 222°C is a characteristic decomposition profile of amorphous cellulose chains. The peak degradation temperature is observed at around 325°C. The analysis of the chemical composition of the CNFs is as shown in the FTIR spectrum in Figure 1b. The characteristic adsorption of cellulosic based functional groups was visible. No significant adsorption due to ring vibration of lignin and hemicellulose components is seen at 1230 cm-1 and 1500 cm-1. This infers a successful removal of the lignin and hemicellulose components. Table 1 shows the results from the uniaxial

tensile analysis of the 3D printed dumbbell samples. The biocomposite filaments showed good printability.

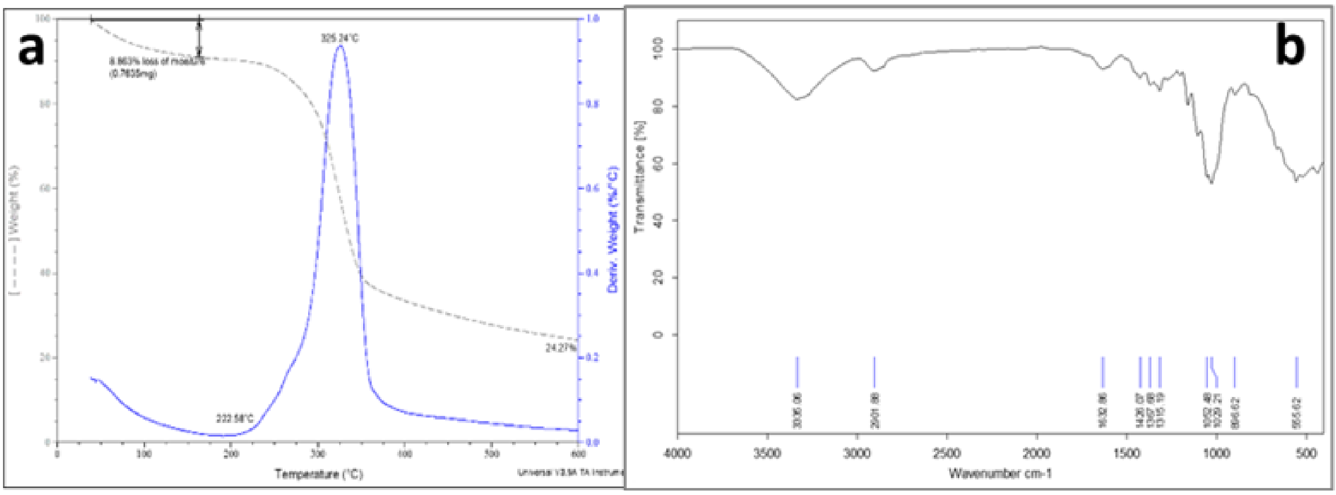

Figure 1: (a) Thermal decomposition profile of CNFs (overlay of TGA and DTG curves). (b) FTIR spectrum showing the functional groups i CNFs

Table 1: Results from the tensile analysis of 3D printed tensile dumbbell specimens

Sample description	UTS (MPa)	Elongation at Break (%)	Maximum breaking force (N)
PLA	22.7 (±0.0071)	0.1073 (±0.0002)	556,5 (±0,71)
PLA$_{plasticized}$	27.8 (± 0.1202)	0.1425 (±0.0004)	671 (±021)
Bionanocomposite 1	25.43 (±0.2828)	105,17 (±32.8805)	623 (±4,24)
Bionanocomposite 2	22.41 (±2.5242)	78.71 (±32.8805)	549 (±65,48)

Ductile fracture was observed for the PLA/CNF/TA samples, indicating an improvement in brittleness. This current work has demonstrated the potential to develop value-added bio-based products from waste resources. Further research is underway to improve the overall characteristics of the 3D printable bionanocomposites.

ACKNOWLEDGMENTS

The authors acknowledge the funding provided by the Department of Science and Innovation (DSI), in collaboration with the Biorefinery Industry Development Facility (BIDF) CSIR and Nelson Mandela University (South Africa).

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ANALYSIS OF PARAMETERS CHARACTERIZING THE GEOMETRIC STRUCTURE OF THE SURFACE OF PLAIN WEAVE COTTON FABRICS

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ABSTRACT

Currently, the geometric structure of the object surface is of great functional, operational and aesthetic importance. In recent years, the dynamic development of a variety of surface metrology technologies makes it possible to predict the functional and operational properties of surfaces. The paper presents selected results of tests on the surface quality of plain weave fabrics made of cotton.

INTRODUCTION

The geometrical structure of material surfaces consists of three main elements: shape, waviness and roughness. Roughness is one of the characteristics of the surface quality most often assessed by quantitative indicators called surface roughness parameters. The surface topography is commonly understood as a set of detailed three-dimensional features of a certain limited area of surface. The aim of the presented research was to analyze the parameters characterizing the surface topography of the plain weave fabrics made of cotton. Surface topography measurements have been performed using the MicroSpy® Profile profilometer. The parameters characterizing the surface topography of the fabrics have been determined using the Mark III software. Based on the results obtained from the profilometer, a number of parameters characterizing the surface topography of the tested fabrics were determined. Additionally, the influence of the fabrics' structure of their surface roughness parameters have been analyzed. Three variants of finished cotton fabrics were tested in the range of their surface topography. These fabrics were made on the basis of a single warp of OE yarn of 50 tex linear density. The weft was made of the 100 tex OE yarn. The fabric variants differ between teach other in the range of the weft density: 110, 90 and 70 per dm.

RESULTS AND CONCLUSIONS

Based on the results from the profilometer, a number of indicators characterizing the geometric structure of the fabric surface were determined, among others:

Ra - it is the arithmetic mean value of the residual surface deviation within the sampling area,

Rq - is the root mean square value of the surface roughness deviation within the sampling area,

Rz - it is the sum of the height of the highest profile elevation Rp and the depth of the lowest profile recess Rv inside the sampling segment

Rt - total profile height.

The exemplary values of the calculated surface parameters are presented in table 1. The system makes it possible to determine the autocorrelation function of the surface height, surface height (z-value) distribution, angle distribution and many other analyses.

Table 1 Results from the profilometer [mm]

Variant	Ra	Rq	Rz	Rt
1 - weft density 110/dm	0.021	0.026	0.208	0.404
2 - weft density 90/dm	0.023	0.029	0.224	0.411
3 - weft density 70/dm	0.026	0.031	0.213	0.390

Figure 1 shows the exemplary histograms for fabric variants No. 1 and No. 3. The histograms show the frequency of occurrence of points of a certain height. For variant No. 1 the highest frequency (33.4 %) was observed at a height of 0.87 mm. For variants No. 2 and No. 3 the highest frequency was appropriately: 20.0 % and 28.3 % both at the height 0.84 mm.

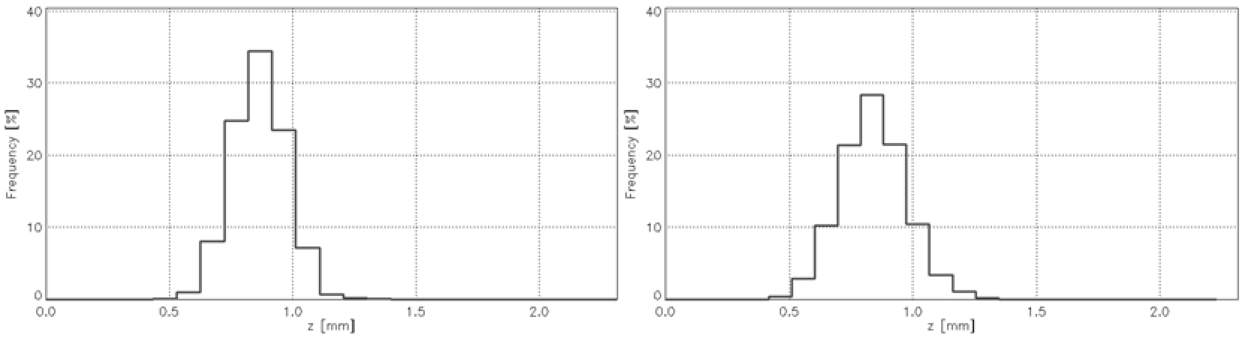

Fig.1 Exemplary histogram of z-value for variants No.1 and 3

The conducted research confirmed that it is possible to comprehensively analyze the surface topography of fabrics based on the results obtained with the MicroSpy® Profile profilometer by FRT. The Mark III software cooperating with the profilometer enables the calculation of a number of indicators characterizing the surface roughness of fabrics. The obtained results showed that the tested cotton fabrics with a plain weave were characterized by different roughness parameters dependably on the weft density.

ACKNOWLEDGMENTS

This work is partially financed by National Science Centre, Poland in the frame of the project titled „Geometrical mechanical and biophysical parameterization of the three-dimensional woven structures", project No. 2016/23/B/ST8/02041

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EFFECTS OF DRY ETCHING PLASMA TREATMENTS ON NATURAL AND SYNTHETIC FIBERS: A COMPARATIVE STUDY

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ABSTRACT

This work presents the results of dry etching plasma treatments on the tensile strength and surface morphology of Guadua Angustifolia, Fique and Nylon fibers.
Natural and synthetic fibers were exposed to a physical bombardment with argon ions during different treatment times. Scanning electron microscopy (SEM) analysis showed that all treated fibers exhibited rough surfaces, were the surfaces roughness increased by increasing the bombardment time. The tensile resistance displayed a significant increase in Guadua an Fique fibers but did not change significantly in Nylon fibers as a function of bommardment time. However, other studies should be carried out in order to determine the main causes, which increase the tensile strength in natural fibers.

INTRODUCTION

Ionized gases or plasmas can interact, unlike neutral gases, with electric and magnetic fields. This coupling between the dynamics of the charged plasma particles and the electromagnetic fields phenomena has opened a whole horizon of new physical and chemical phenomena of great interest. These interesting properties have led to the practical use of plasmas in a multitude of technological applications during the last 60 years. Among all these applications, the processing of new materials with plasmas is currently one of the most active branches of applied research. On the other side, the use of natural fibers as reinforcement of polymeric matrices has multiple benefits, such as a less abrasion during production, possibility of being recycled, high mechanical properties per unit of weight and low production cost per unit volume. Modifying the surface and mechanical properties of the fiber using Dry Etching Plasma is an innovative and environmentally friendly technique as it does not generate any type of residue; the objective of this treatment is to increase mechanical adhesion at the fiber-matrix interface, by modifying the surface properties of the fibers, without making major alterations in the composition or macroscopic properties of these.
Previous studies have focused on modifying mechanical properties such as resistance to traction and morphology of natural fibers using physical plasma treatment. For this, different treatment times at a given energy have been used and it has been found that natural fibers they can effectively be treated with plasma without affecting the resistance of the treated fibers. In this work Natural and synthetic fibers were exposed to a physical bombardment with argon ions during different treatment times (900, 950, 1000, 1200, and 1400 sec). The Young's Modulus and surface morphology of the fibers was measured from tensile tests and SEM analysis respectively.

RESULTS AND CONCLUSIONS

The results of the Young's Modulus are shown in Fig. 1. From the stress-strain curves, Young's modulus was calculated as the slope between 30% and 60% of the maximum stress for Guadua, Fique and Nylon fibers. We opted to show te Young's módulus instead te tensile strength because of it doesn't depend of the area's fibers and the effect of bombardement Is easier to see.

As displayed in Fig.1, the Young’s modulus increases as a function of bombardment time for Guadua and Fique fibers. However, the Nylon fibers didn’t show significant changes.

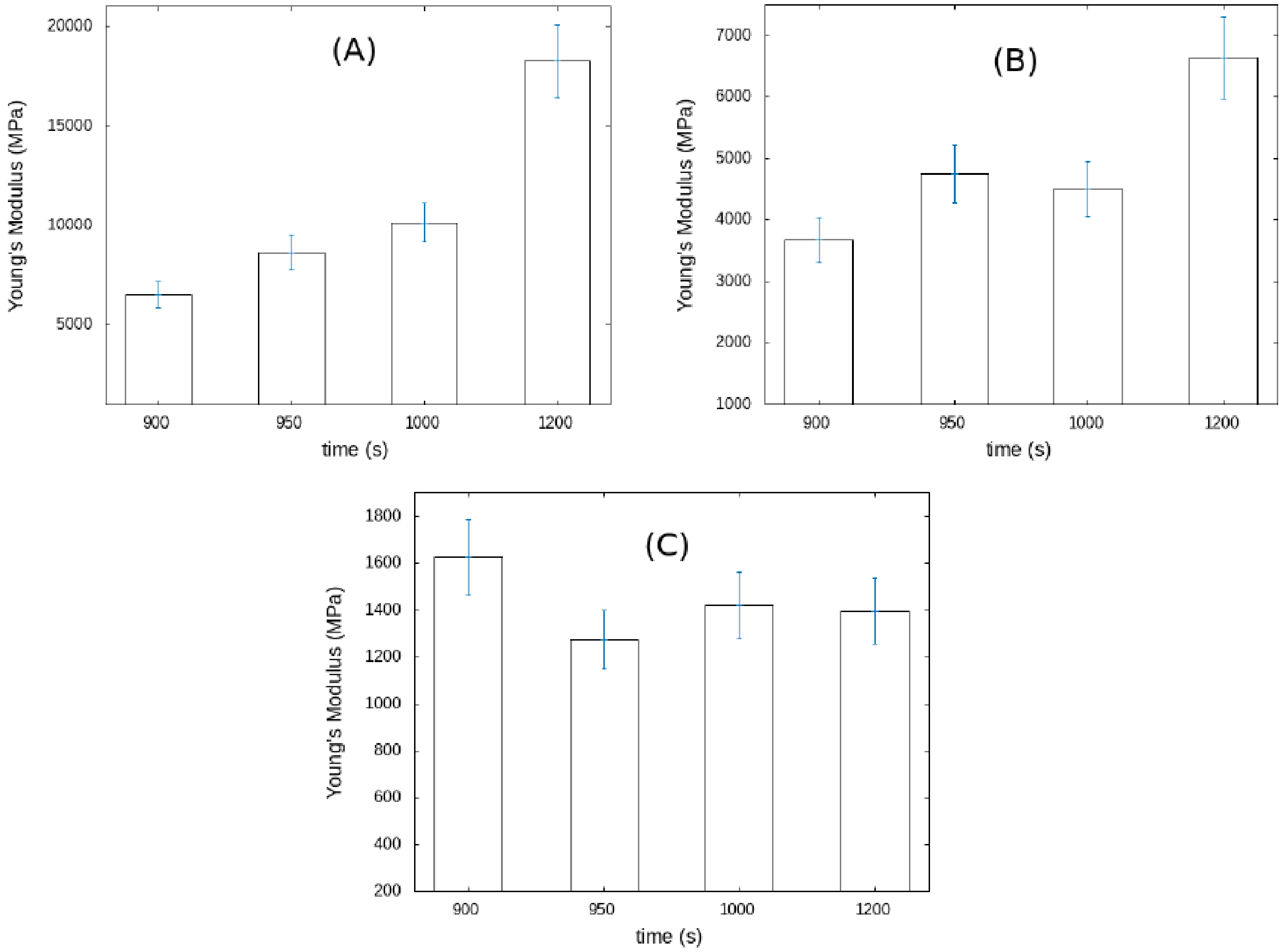

Fig.1 Young’s Modulus for Guadua Angustifolia (A), Fique (B) and Nylon (C) Fibers vs Bombardment time.

ACKNOWLEDGMENTS

We want to thank to the Universidad Nacional de Colombia, for financial support.

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CORE-SHELL BIODEGRADABLE ELECTROSPUN NANOFIBERS FOR ENHANCED CANCER PHOTODYNAMIC THERAPY (PDT)

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ABSTRACT

Core-shell nanofibers based on biodegradable polymers (gelatin (Gel)-chitosan (CS)/polyethylene oxide (PEO)/cellulose nanocrystals (CNC)) were developed by co-axial electrospinning to act as drug delivery system (DDS) for cancer photodynamic therapy (PDT). The optimization of solutions and electrospinning conditions was performed. After this process, defect-free core-shell nanofibers with uniform morphology and diameters (275 nm) were obtained using 29 kV, 0.5 mL/h and 170 mm. The photosensitizers (PSs) were incorporated into the best system and the samples were characterized by different techniques.

INTRODUCTION

Cancer is one of the biggest health problems and the second leading cause of death worldwide. Over the last years, PDT has acquiring increasing attention for the treatment of cancer due its minimal invasiveness and intrinsic selectivity. This therapeutic strategy is based on the combination of the PS, light and molecular oxygen present in tissues. After the administration of the PS, the irradiation of the lesion area with specific wavelength is required to excite the PS, which in the presence of oxygen, will generate highly reactive oxygen species that will lead to cell death and tissue destruction (Ferreira, 2016 and Friães, 2019).

The use of DDS to carry the therapeutic agent within the body is essential to prevent the drug degradation and to control the rate, time and site of release, thereby improving its efficacy and safety (Lin, 2018). Recently, electrospun nanofibers have demonstrated a great potential to be used as DDS, due to their very interesting properties, including large surface area, which is favorable for drug loading, ability to incorporate different molecules, controlled drug release profile, good mechanical properties, biocompatibility and biodegradability. This last feature can be achieved using biodegradable polymers, and it's crucial to ensure total drug release and to avoid surgical removal (Goonoo, 2014). Core-shell nanofibers produced by co-axial electrospinning are very promising structures to obtain higher prolonged action time and controlled drug release, since the therapeutic agent can be encapsulated into the core, which in turn will be protected by the shell (Fu, 2018). Nevertheless, despite their potential, these structures are poorly explored in cancer PDT applications.

The aim of this work was the development of core-shell nanofibers using biodegradable polymers. Firstly, the optimization of polymeric formulations and electrospinning parameters was performed, and the best system was selected for the incorporation of synthetized PS (porphyrins, heptacyanines and squaraines) at different concentrations. All developed nanofibers were characterized by optical microscopy, TEM, FESEM, ATR-FTIR, WCA, GSDR, DMA and TGA analysis. The dispersion of the PS, the drug release profile and biocompatibility will be also evaluated.

RESULTS AND CONCLUSIONS

Firstly, different parameters regarding the polymeric formulations and electrospinning conditions were optimized, such as the type and concentrations of the polymers under use, applied voltage, feed rate and distance needle-collector. After the optimization process, the best nanofibers' morphology was obtained with 29 kV, 0.5 mL/h and 170 mm, in which the core was composed by 25% Gel and the shell by 1%CS/1%PEO/1%CNC. Fig. 1 shows the FESEM images and the respective diameter distribution histogram of the optimized core-shell nanofibers. Defect-free core-shell nanofibers were successfully produced with uniform morphology and mean diameters around 275 nm.

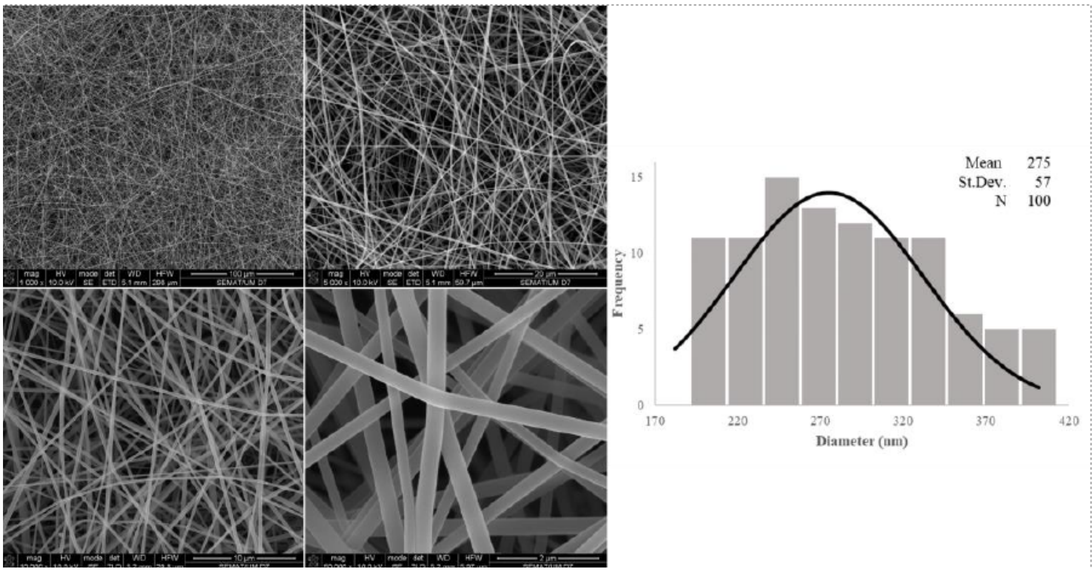

Fig.1 FESEM images and diameter distribution histogram of Gel-CS/PEO/CNC core-shell nanofibers obtained with 29 kV, 0.5 mL/h and 170 mm, at 100, 20, 10 and 2 μm.

The optimization of the PS incorporation into nanofibers will be performed in terms of PS concentration and electrospinning parameters. Moreover, the effect of PS in the morphology, diameters, hydrophilic character, mechanical and thermal properties of nanofibers will be assessed. The drug release profile and biocompatibility of the final systems will be evaluated.

ACKNOWLEDGMENTS

The authors are thankful to project UID/CTM/00264/2021 of 2C2T – Centro de Ciência e Tecnologia Têxtil, funded by National Founds through FCT/MCTES- Fundação para a Ciência e a Tecnologia. Sofia M. Costa is thankful to FCT PhD Scholarship (SFRH/BD/147517/2019). Diana Ferreira is thankful to CEECIND/02803/2017.

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FIBER EXTRACTION OF PHILIPPINE BAMBOO SPECIES 'KAWAYAN TINIK' *(BAMBUSA BLUMEANA)* AND ITS TEXTILE POTENTIAL

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ABSTRACT
Mechanical-chemical fiber extraction methods: mechanical softening/crushing-combing (MSC), mechanical softening/decortication (MSD), and chemical-mechanical softening and washing (CMSW) to extract textile fiber from Bambusa Blumeana. The physical tests such as breaking strength, fiber fineness, gum content, total and alpha celluloses, water and alcohol-benzene extractives, moisture content, and lignin content of the 'kawayang tinik' fiber. Spinnability tests were also conducted to determine the suitability of the extracted 'kawayang tinik' fiber for spinning into yarns.

INTRODUCTION
In this study, three mechanical-chemical fiber extraction methods were performed. First, the mechanical softening/crushing-combing (MSC) extraction method wherein nodes of Bambusa blumeana were first removed, and the remaining parts were cleaved in a longitudinal direction with 2-3 mm in thickness before feeding into the mechanical softening machine to flatten and partially open. The partially opened bamboo slats were manually combed by steel brush to extract the fiber. Second, the mechanical softening/crushing-decortication (MSD) method wherein Bambusa blumeana were first manually cleaved to longitudinal thin slats with 80 cm in length and 2-3 mm thickness using bolo before feeding to the mechanical softening machine to flatten and partially open and the partially opened bamboo slats were decorticated to extract the fiber. Third, the chemical-mechanical softening-washing (CMSW) method wherein the Bambusa blumeana were first manually cleaved to longitudinal thin slats with 50 cm in length and 2-3 mm thickness using bolo and were then immersed in NaOH solution (concentrations of NaOH were 1%, 2%, 3%, 4%, and 5%) at room temperature (26 – 34 ºC) for 14 h or less. The chemically-treated slats were flattened/crushed through a mechanical softening machine before washing, acid neutralization, washing, and drying.
The physical properties of the extracted bamboo textile fibers such as strength and fineness were determined following the ASTM D3822: Single Fiber and ASTM D1577-07 test methods respectively. Chemical components like residual gum and moisture content or moisture regain were analyzed using the modified Jute Technology Research Laboratory (JTRL) and PTRI Standard Method of Test for Moisture and Moisture Regain of Textile Material (PNS/PTRI 37 - 1992) respectively. The celluloses and extractives were analyzed following the Technical Association of Pulp and Paper Industry (TAPPI) test methods while lignin content was determined using the modified FORPREDICOM method. Spinnability testing of the extracted bamboo fibers was done using the mini-spinning machine with pure bamboo or with a blend of cotton or polyester fibers.

RESULTS AND CONCLUSIONS
Based on the fiber recovery results of Bambusa blumeana using the three mechanical-chemical fiber extraction methods, the mechanical softening/decortication (MSD) extraction method has the highest fiber

recovery percent yield of 45%. However, the proximity analysis and physical property tests showed that the most cost-efficient method in extracting Bambusa blumeana fiber is through chemical-mechanical softening-washing (CMSW) and has the highest potential of up-scaling by using a big degumming vessel for washing or fiber pretreatment right after chemical-mechanical softening.

The spinning of pure bamboo fiber was done using the mini-spinning machine with a blend of cotton and another with polyester fibers. The blend ratio was 75/25 cotton/bamboo and 75/25 polyester/bamboo. Based on the spinnability test results of the fiber extracted Bambusa blumeana, the yarn realization of cotton/Bambusa blumeana blend is 58.33% while polyester/Bambusa blumeana blend is 59.83%. Moreover, a higher yarn count (10Ne) was achieved with polyester/bamboo blended yarn compared to cotton blended bamboo with 5Ne count. These results entail that finer and stronger yarn is produced from the polyester/ bamboo blend and thus more applicable for textile and apparel end-use.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding of the Department of Science and Technology- Philippine Textile Research Institute (DOST-PTRI) through Republic Act (RA) No. 11260, the General Appropriations Act (GAA) of the funding of the research.

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WASHING PERFORMANCE OF DENIM FABRICS COMPOSED OF CO/HEMP BLEND FIBERS

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ABSTRACT
This work shows the washing performance of denim fabrics composed of CO(cotton)/Hemp (cottonized hemp) blend fiber with and without dual core-spun yarn. Fabric's weight change, stiffness, color fastness to crocking, tearing strength, tensile strength and shrinkage are measured before and after washing. It is found that after 3 home wash CO/Hemp blended fabrics performance is statistically significant with 100%Cotton samples.

INTRODUCTION
From the beginning to now, denim is well accepted due to its fashionable look and appearance. Denim is mostly made from cotton which has sustainable issues due to the using lots of chemicals, pesticides and water in its cultivation [1]. Having the environmental issue with cotton now it is focused on organic cotton or cotton blended with other sustainable fibers for denim production [1]. To make the denim production more sustainable and reduce the demand on cotton fiber, CO/Hemp blended fabric is a good alternate as hemp is a more sustainable fiber that has good aesthetics properties and CO/Hemp blended fabric has special performance such as moisture absorption, anti-mildew, anti-bacterial, anti-ultraviolet ray, antistatic, drip dry property, etc. which is ideal for sports and summer fabric and also has the good potentiality for household upholstery[2,3]. Hemp fiber spinning and fabric formation have some difficulties which are overcome by cotton and hemp blending where the fabric has both hemp properties as well as soft, comfortableness of cotton fiber. But CO/Hemp blended fabric has impurities on its surface as well as roughness. Here, different types of washing method is applied to remove impurities and make the surface smooth which is also helpful to make the denim fabric fashionable and wear comfortable garments as denim is very strong, stiff and hard to wear [4]. Though CO/Hemp blended denim fabric's washing effect is not investigated at all, here in this study washing performance has been done and Table 1 shows the composition of 3/1 Z twill denim fabric samples.

Table 1 Composition of fabrics

Samples	Warp yarn	Weft yarn
CO/Hemp stretch fabric	69%CO/31%Hemp	76%CO/20%Hemp/3%T400®/1%Elastane
CO/Hemp	69%CO/31%Hemp	69%CO/31%Hemp
100% Cotton	Cotton	Cotton

RESULTS AND CONCLUSIONS
For CO/Hemp weft stretch fabric there is an increase of gsm after wash due to having elastane but others are decreased. CO/Hemp blended fabrics have slightly high stiffness than cotton after washing which is also in a comfortable range. Moreover, CO/Hemp blended fabrics have less significance on color fastness to crocking after wash. CO/Hemp stretch denim fabric shows better tearing strength than CO/Hemp fabric after washing but less than 100% cotton fabric. After washing, both CO/Hemp blended fabric's tensile

strength are decreased significantly and lower than 100% cotton fabric. For having elastane, CO/Hemp stretch fabric shows high shrinkage in the weft direction after washing where CO/Hemp shows the minimum result. Statistically, a significant difference is found among the samples washing performance by one-way ANOVA test (P<0.05).

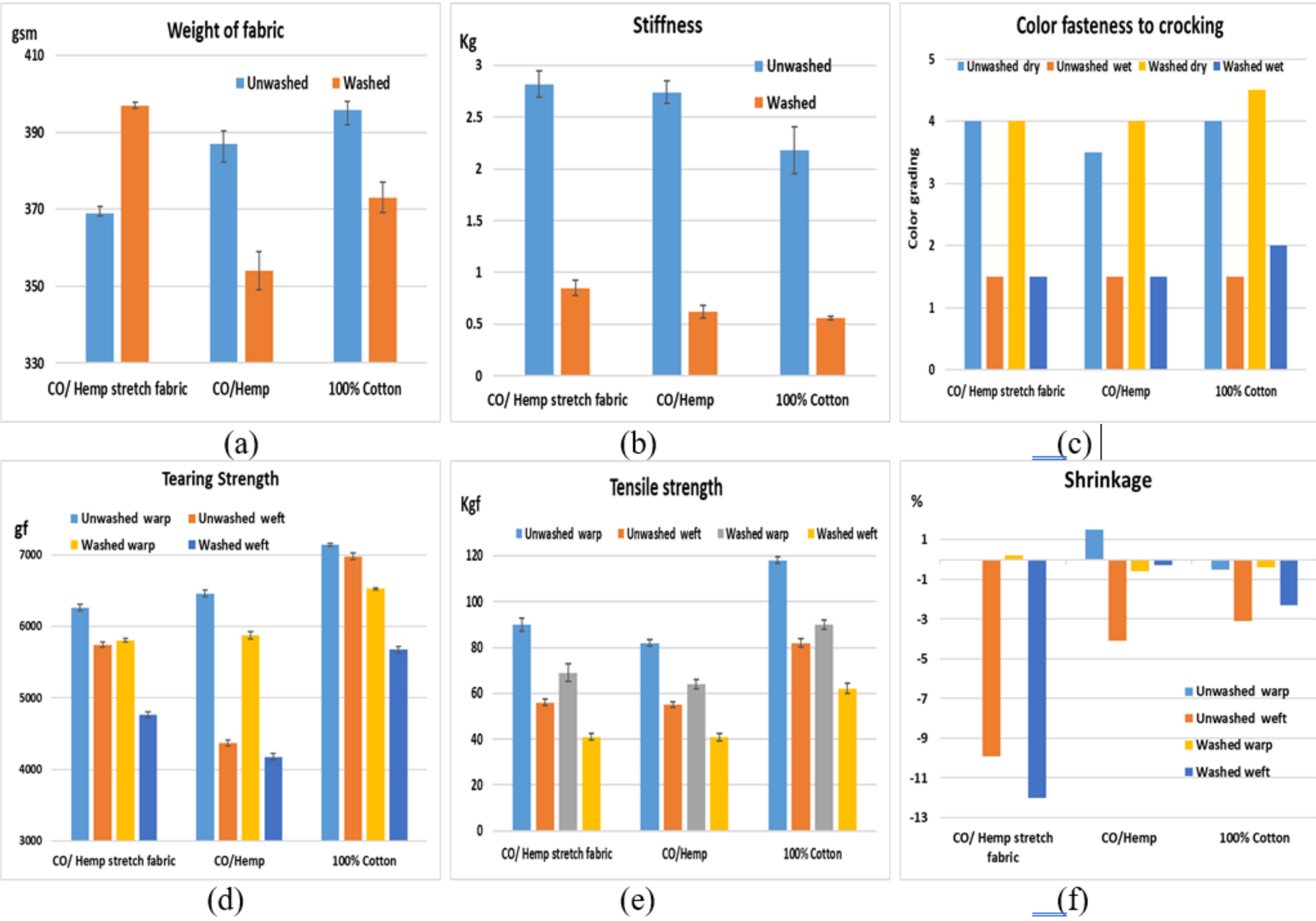

Figure: Denim fabric samples (a) weight of fabric (b) stiffness, (c) color fastness to crocking (d)tearing strength (e) tensile strength and (f) shrinkage

ACKNOWLEDGMENTS

The authors gratefully thanks to the Çalık Denim Tekstil AŞ for their support and cooperation.

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TRAJE À VIANESA – A STUDY ON NATURAL VS. SYNTHETIC MATERIALS

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ABSTRACT

This paper investigates the Traje à Vianesa costume and questions its contemporary design through the study of its original techniques and local natural resources. Different samples of the Traje à Vianesa were analysed and compared to understand if contemporary folk garment designs followed the guidelines from the accreditation book, in terms of accuracy, for its originality, particularly on the characteristics of raw materials (as it was until 20th Century).
A qualitative methodology - relevant literature review, observation, in situ, and interviews to experts -, was used. Results confirm that local natural materials (e.g., wool, natural dyes) have been regularly replaced by synthetics. The implications are challenging for the design of the costume itself and can also extend to other contexts, such as product design education and industry, where researchers/designers occasionally resource to strategies that look into traditional textiles inspiration, costume, techniques, know how or others, to produce goods.

INTRODUCTION

The Traje à Vianesa is a traditional costume from the North Portuguese Region of Minho. The costume certification process aims to establish the conceptual and form standards thus protecting its genuine features which prevents its mischaracterization and misrepresentation. Nevertheless, various deviations are sometimes noted, not so much on its aesthetics (which apparently evolved acceptedly over time) but rather in its construction, particularly its raw materials. This aspect is obviously a challenge for cultural heritage protection and identity continuity purposes (which is confirmed by the interviewed experts) but the implication of this can extend to other contexts, such as product design education and industry.
Designers occasionally resource to strategies (e.g., Ted's10 Card nr. 6) or inspiration that look into textile practices from history or habits from a specific culture in a traditional folk costume to gain fresh perspective on processes and methods (Earley & Goldsworthy 2017). This is equally the case if designers are interested in learning specific techniques to apply in projects or to support community, social engagement or cultural identity continuity. Whatever reason, in terms of research, misleading designs may compromise scientific accuracy, creating serious obstacles.
According to the accreditation book Traje à Vianesa – Caderno de Especificações para a Certificação (Ramos & Pires, 2017), it is of relevance to maintain the typology of the garment but several details are still to be explored; authors and experts agree the book needs improvement in terms of data on its original raw materials and eventual motifs that were changed or lost throughout the times.
Deviations to the characteristics of the original traditional costume started since the industrial revolution, following the invention of synthetic materials which might have had influence the materialisation of the design. The study compares diverse samples of materials that are found in the Traje à Vianesa, trying to establish a fair assessment on the evidence that recent folk garments might differ from the original ones (developed with local and natural raw materials until the beginning of the 20th century). Gathered cross-examined data supported by observation and experts confirm the existence of inconsistencies.

RESULTS AND CONCLUSIONS

Original costumes, dated from the 19th century, were compared with recent ones. Results are presented in Table 1.

Table 1 Comparison between materials from original (prior the 20th century) and recent samples.

Material Samples	Original Sample Composition	Synthetic Sample Composition
1. Manually Weaved Fabric (apron)	Warp 100% CO | Weft 100% WO	Warp 100% CO | Weft with Acrylic (PC)
2. Wool Cloth (vest)	100% WO	80% WO 20% PL
3. Sequins	Metal	PL
4. Metallic thread (*palheto*)	Metal	PL, PA
5. Dyes	Natural	Synthetic

Recent designs reveal the application of various polymers and synthetic dyes, which might represent challenges, compromising accuracy and related aspects, such as the educational side of it, including the cultural identity continuity. The difficulty behind material application (e.g., sequins and metallic thread) is related to prices and market access. Regarding dyes it appears to be both due to the loss of technical knowledge on resources and methods as well as price and time-consuming factors. Results also expose the level of awareness on varied elements, of craftmanship, by the artisans (and concerning increasing loss of know how) who regularly employ synthetics as a way of keeping the production cost low.
Additional research is needed to further explore accuracy in production and quality. It is crucial a system that may prevent knowledge from declining, technically and aesthetically.

ACKNOWLEDGMENTS

The authors gratefully acknowledge support from REDes, FCT and CIAUD, Lisbon School of Architecture, Universidade de Lisboa.

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NANOCELLULOSE FROM WATER HYACINTH: CURRENT DEVELOPMENTS AND POTENTIAL

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ABSTRACT

Water hyacinth (WH) (Eichhornia crassipes) is a prolifically and undesirably spreading perennial aquatic weeds, commonly clogs the water surface forming a closely packed layer. This results in inhibition of light supply, phytoplankton production and reduction of oxygen in water leading to an invasive impact on the ecosystem. However, due to its high cellulose content (around 43-60%), abundance and biodegradable nature, WH can be an alternative potential resource for nanocellulose extraction. Nanocellulose from WH has already been used in composite reinforcement, filtration, bio-medical, health and hygiene products, papers and textiles. Earlier reviews on WH have been conducted focusing on the ecology and socio-economic impact, biological control, bio-sorption and bio-conversion (to ethanol), though the potential of WH as a resource for extraction of nanocellulose has not been addressed. Therefore, this review aims to emphasize on identifying the true potential of WH as a sustainable nanocellulose resource starting from its structure and properties, followed by critical analysis on the isolation processes, influencing factors, and the basis of future use.

INTRODUCTION

Rising demand for sustainable and non-petroleum-based materials makes nanocellulose a potential candidate for preparing highly valued product with exceptional mechanical and physical characteristics. Materials in nanoscale exhibit special characteristics as compared to the bulk material. In addition, some imperative properties such as crystallinity, surface area, functionality, mechanical properties of the cellulose-based product can be enhanced by using nanoscale materials. The current global nanocellulose market is $146.7 million, and expected to reach $418 million by 2026 (Global market insights, 2020).Recently, non-woody plants and crops have become alternative sources of wood for nanocellulose extraction due to the high demand for wood in paper manufacturing, furniture and industrial applications. Moreover, selection of appropriate cellulose plant fibre is very essential for efficient nanocellulose extraction to reduce the requirement of energy, time and chemicals to remove the lignin and hemicellulose from lignocellulose and then break strong inter-fibrillar bonds in cellulose. Therefore, rapidly growing, inexpensive and renewable bio-sources with a lower lignin and hemicellulose content are desired. Water hyacinth (WH), a rapid growing herb, originated from South America, now commonly found in tropical and sub-tropical regions floating in the water surface. Due to its cover on water surface, it causes smothering of aquatic life, blocks the supply intakes for hydroelectric plant and degrades water quality. Surprisingly, this noxious weed has lower lignin (>10% wt) and higher cellulose (about 60% cellulose) than other cultivated plants, such as banana stem, bamboo, corncob, sugarcane bagasse (Tanpichai, 2019).Therefore, cellulose-rich WH with limited lignin content has become a promising alternative source for nanocellulose preparation. This has motivated numerous research endeavors that initiated in the last decade. Up to now, several mechanical methods (high-pressure homogenization, ultra-sonication, cryo crush), chemical processes (alkali treatment, acid hydrolysis), biological techniques (enzymatic treatment), or combination of them have been used to extract nanocellulose from WH, and several forms of nanocellulose, such as cellulose nanofibrils and nanocrystals have been successfully extracted. Moreover, the worldwide environmental concern has also given the acceleration on the momentum of using sustainable product like WH in nanocellulose extraction.

RESULTS AND CONCLUSIONS

This review paper highlights the feasibility of nanocellulose extraction from rapidly reproducible, and cheap WH. It was found that while the alkaline treatment is the most efficient method (Tanpichai, 2019), acid hydrolysis is also effective to reduce the lignin and hemicellulose contents from WH. A very high crystallinity index of 84.87% achieved by acid hydrolysis, where lignin and hemicellulose contents further decreased following the sonication (Asrofi, 2018). Highly purified nanocellulose (up to 70% cellulose) can be obtained from WH after a series of treatment. Three-stage chemical treatments (alkalization, acid hydrolysis, and bleaching) used in combination with ultrasonic homogenizing isolation process, resulted in nanoparticles with high crystallinity index (73%) (Asrofi, 2017).The cost of cellulose nanofibres extraction from lignin poor WH is likely to be lower than similar extraction from wood or other lignocellulosic sources that requires extra time and more use of chemicals (Tanpichai, 2019). In case of bio-composite filled with WH nanofibre, the achieved maximum tensile strength (11.4 MPa) and modulus of elasticity (443 MPa) suggested potential application as environmentally friendly plastics in food packaging (Asrofi, 2018). Overall, current findings explore the potential use of nanocellulose from WH in a wide range of applications in near future, e.g., composites, electronics, paper products, automotive, flexible electronic, packaging, and membranes.

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CONCENTRATION OF SELECTED METALS IN SHEEP WOOL

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ABSTRACT

This work compares the concentration of selected macroelements and microelements in sheep wool from three origins. Chemical analysis by atomic absorption spectroscopy (AAS) allows evaluating the content of particular elements. It states that even though the fleece was tested in grease form (without scouring), its quality from heavy metal concentration is satisfactory.

INTRODUCTION

The primary element composition of wool has been known for a long time. Due to the chemical structure and morphology, keratin wool fibres have a high adsorption capacity to bind elements from the environment. Heavy metals are naturally occurring compounds; however, the development of different industry branches and the same anthropogenic activities introduce them in large quantities in many environmental compartments. The risk of affecting animals pastured in open areas is growing together with the increasing emission of heavy metals. One of the routes of the uptake of heavy metals in the case of sheep is via gastric and respiratory systems and via absorption on the skin and wool (Rogowska, 2009). Despite the route of uptake, finally, if the environment is polluted, traces of heavy metals can also be found in the wool of sheep pastured in polluted areas. Because of strong toxic properties of heavy metals, the content of particular elements in materials should be limited, and in the case of textile materials the limits are given by Oeko-Tex standard (Oeko-Tex Standard 100). Except for toxic metals, copper or zinc is indispensable for living organisms functioning, as they are a constituent of enzymes.

This study determined the content of selected metals in grease wool obtained from sheep pastured in different locations. It is a preliminary study to determine the suitability and safety for processing wool obtained from sheep of the Polish mountain breed and two sheep from Norway.

Samples of wool from 3 regions and different breeds were tested for the presence of metals such as Cr, Cd, Co, Cu, Pb, Zn, Ni, and Ca, Mg, K, and Mn. Sheep wool that was tested was obtained from pastures in Norway (coastal and inland) and Poland. Samples were prepared from fleeces, a selection of which was used to minimise contamination from the soil, grass, and other exogenous material. To evaluate the metal content of wool, samples were dried to constant mass. The 0.2 (±0,01) g of dry wool was placed into the microwave vessel. The mineralisation was done in H_2SO_4 (98%) with the addition of H_2O_2 (30%). All chemicals were analytical grade. The concentration of metals was determined by atomic absorption spectroscopy (AAS).

RESULTS AND CONCLUSIONS

The results from the analysis of metals concentration in 3 types of wool are shown in Table 1.

Table 1 Concentration of metals in wool.

	Concentration of metals in wool (mg·kg^{-1})		
The type of metal	**Norwegian Inland Sheep**	**Norwegian coastal sheep**	**Polish Mountain Sheep**
Cr	4.91 ↑	0	0
Cd	14.73	7.36	0
Co	93.34↑	14.74↑	3.52
Cu	0	0	0
Pb	137.56↑	0	24.67
Zn	49.12	18.43	7.04
Ni	0	0	21.15
Ca	0	0	0
Mg	653.45	770.54	285.58
K	0	0	14.10
Mn	510.96	342.87	1900.00

The concentration of metals in sheep wool collected in the three areas is different and varied within a wide range. The permitted concentration of chromium (Cr) and lead (Pb) was exceeded the standard total allowed concentration in the case of Norwegian Inland Sheep wool, while cobalt (Co) concentration was exceeded in the case of both inland and coastal wool. However, it should be taken into account that wool was tested in grease form, and the concentration of most metals are on the level accepted by OekoTex 100 standard. It can be expected that in the case of scoured wool, the content of all metals could be below the limits, as concentrations of metals can be reduced by washing significantly (Hristev 2008; Hawkins, 2009). Moreover, those results indicate improved environmental conditions, resulting in lower concentrations of metals in Polish Mountain Sheep wool compared to previous results (Patkowska-Sokoła, 2009).

ACKNOWLEDGMENTS

The research leading to these results has received funding from the Norway Grants 2014–2021 via the National Centre for Research and Development.

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COARSE SHEEP WOOL AS A PRECIOUS RAW MATERIAL FOR PRODUCTION OF RUG YARNS

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ABSTRACT

During investigations the wool from the Polish Mountain Sheep was tested and its suitability for the production of yarns intended for interior decoration elements was analysed. In the preliminary tests the fibres morphology was analysed and the thickness and length of the fibres were determined. Subsequently, a batch of core yarn was produced. As a result of the trials, the suitability of wool for the production of valuable products was confirmed.

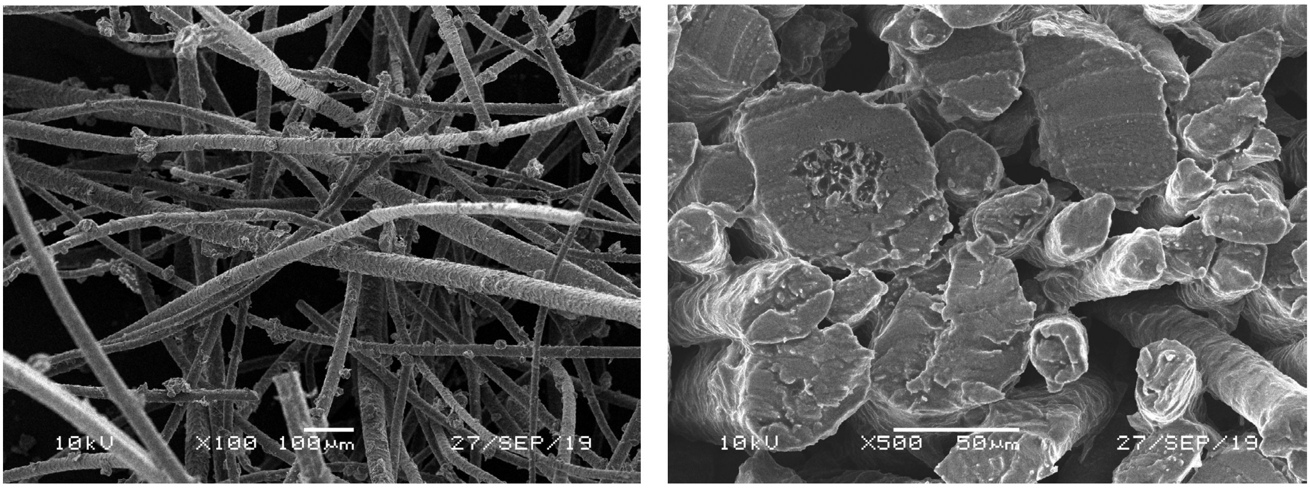
INTRODUCTION

Sheep husbandry in Polish Carpathian Mountains has went through a crisis over the last several decades. The absence of sheep in mountain meadows caused mountain glades to turn into forests, certain species of fauna and flora to disappear, the picturesque mountain landscape to deteriorate and several elements of cultural heritage to disappear (Sobala, 2018). For these reasons, some national and international projects have been conducted to stop environmental degradation and protect the cultural heritage. As a result, sheep grazing in the mountains was partially restored. Well-adapted to steep slopes, harsh climactic and forage conditions, the Polish Mountain Sheep (PMS) is bred there. Sheep's milk is used to produce traditional and well-liked Polish cheese, while meat is predominantly exported to the Western European countries. At the same time, wool has become a problematic by-product of sheep husbandry. Wool from mountain sheep possess low economic value as it is unsuitable for the production of apparel textiles. The costs of sheep-shearing outweigh wool price and a significant portion of the wool is stored without being scoured or deposed in local, sometimes illegal, landfills.

To find a reasonable and economically justified way to utilise wool obtained from mountain sheep the Polish-Norwegian project was initiated. During preliminary tests, the wool sheared from mountain sheep was characterised. The morphology of fibres was analysed and basic parameters of wool were determined. Subsequently, the wool was used for the production of rug yarns with false spin technique.

RESULTS AND CONCLUSIONS

Fig.1 presents SEM microphotographs of wool sheared from mountain sheep. Two fibre populations are visible on the pictures. Thinner fibres with a diameter of approximately 30μm represent fibres forming undercoat; the second fraction represent coarser covering hairs with a diameter of 70μm. Several thick fibres with wide medulla are visible in the cross section of fibres.



a) b)

Fig.1 SEM image of wool in fleece of Polish Mountain Sheep; a/ longitudinal view; b/ cross section.

Table 1. Basic parameters of wool of Polish Mountain Sheep

Wool kind		Diameter [µm]	S_td	Length [mm]	S_td	Content of inner coat [%]
White	**Inner**	33	8	52	20	50
	Outer	69	14	119	23	50
Pigmented	**Inner**	31	8	51	17	45
	Outer	68	10	108	19	55

The wool was used to produce core spun composite yarn. The fibres taken directly from the card web were twisted by false spin around the core made of additional three play wool yarn with linear density exceeding 500tex obtained as a by-product. As a result, thick yarn with a diameter of about 8 mm was produced (Fig.2).

Fig.2 Core spun yarns made from Polish Mountain Sheep wool

The study shows that coarse wool from Polish Mountain Sheep can be used in core spun spinning technique to produce yarn which is suitable for producing rug-like structures by various textile techniques.

ACKNOWLEDGMENTS

This research was funded by the Norwegian Funds 2014-2021 through the National Centre for Research and Development.

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BIODEGRADABLE ELECTROSPUN MEMBRANES FOR EFFECTIVE AIR FILTRATION AND ACTIVE DEGRADATION OF MICROORGANISMS

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ABSTRACT

The aim of this study was to develop electrospun membranes based on biodegradable polymers and nanoparticles (NPs) with high filtration capacity and the ability to degrade microorganisms. These membranes will work as the active layer of facemasks based on natural fibers and electrospun micro/nanofibers incorporated with different NPs. The biodegradable polycaprolactone (PCL) polymer was used to produce micro/nanofibers by electrospinning, and titanium oxide (TiO2) and magnesium oxide (MgO) NPs were added into the polymeric formulation at different concentrations (0.1, 1, and 3 % (w/v)). The developed electrospun membranes were characterized by optical microscopy, ATR-FTIR, FESEM, TGA, WCA and water vapor and air permeability. Moreover, the filtration capacity and antimicrobial activity were also evaluated.

INTRODUCTION

The ongoing COVID-19 pandemic caused by SARS-CoV-2 virus has been responsible for the deaths of thousands of people worldwide. Due to the easy and fast transmission of this virus, the use of facemasks is strongly recommended (Ullah, 2020). This type of personal protective equipment works as a barrier system, filtering out the particles and microorganisms (Tebyetekerwa, 2020). However, the excessive number of facemasks composed by non-biodegradable polymers has been generating serious environmental problems due to their inappropriate disposal. Thus, there is an increasing need not only to develop sustainable facemasks using biodegradable materials, but also to improve their performance, by the ability to filtrate small airborne particles and degrade microorganisms (Fadare, 2020).

Membranes produced by electrospinning are great candidates to act as filtering layer, due to their high surface area-to-volume ratio, highly porous structure with good internal connectivity, reduced fiber diameters, lightweight and good air/water permeability. Moreover, the possibility to functionalize the electrospun membranes with NPs can provide new functionalities, including antimicrobial activity (Woon Fong Leung, 2020). Therefore, the aim of this work was to develop electrospun membranes using a biodegradable polymer (PCL) functionalized with different NPs to work as the intermediate layer of the facemask, giving better filtration efficiency, breathability, and antimicrobial properties (Thomas, 2015). In this way, the electrospun membranes were developed using 15 % (w/v) PCL incorporated with different types of NPs: TiO2 and MgO (0.1, 1 and 3 % (w/v)). All the membranes were characterized by optical microscopy, FESEM, ATR-FTIR, TGA, WCA and water vapor and air permeability. Filtration capacity and antimicrobial activity was also assessed.

RESULTS AND CONCLUSIONS

All the membranes were produced by electrospinning using a static collector and a needle with diameter of 0.61 mm. The final electrospinning parameters were 260 mm of distance needle-collector, 25 kV of applied voltage and 1 mL/h of feed rate. Figure 1 shows the FESEM images of the PCL electrospun membranes with several concentrations of TiO2 and MgO NPs (0.1, 1, and 3 % (w/v)). FESEM images revealed the development of PCL defect-free nano/microfibers with diameters ranging from 670.2 nm to 2.44 µm. In PCL/TiO2 NPs and PCL/MgO NPs membranes it's possible to observe the formation of fibers with uniforms diameters as well as the presence of NPs in fibers.

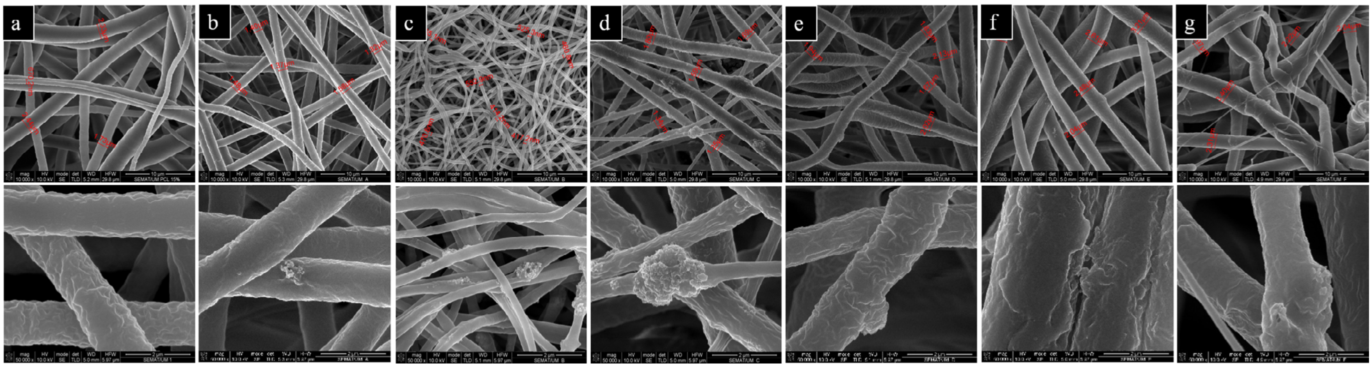

Fig. 1: FESEM images of PCL electrospun membranes (a) combined with different concentrations of NPs: 0.1 (b), 1 (c) and 3 (d) % TiO2; 0.1 (e), 1 (f) and 3 (g) % MgO, at 10 and 2 µm (from the top to the bottom).

All the samples were characterized by ATR-FTIR, TGA, WCA, water vapor and air permeability techniques. As an example, the ATR-FTIR analysis confirmed the presence of NPs in PCL/TiO2 NPs and PCL/MgO NPs membranes, by the appearance of the bands peaking at 453 and 408 cm-1. The TGA revealed that PCL decomposition in the PCL/NPs membranes occurred around 235-550 °C. It was also possible to observe that with the increase of NPs concentration there was an increase of residues present at the samples possibly related with the presence of the NPs. More tests will be performed, including filtration and antimicrobial activity, in order to evaluate the effect of the type and concentration of NPs into the performance of the PCL electrospun membranes. These membranes will finally be deposited onto natural fibers substrates in order to test their performance as face masks for personal protection.

ACKNOWLEDGMENTS

The authors are thankful to project UID/CTM/00264/2021 of 2C2T – Centro de Ciência e Tecnologia Têxtil, funded by National Founds through FCT/MCTES- Fundação para a Ciência e a Tecnologia. Sofia M. Costa is thankful to FCT PhD Scholarship (SFRH/BD/147517/2019). Diana Ferreira is thankful to CEECIND/02803/2017.

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NATURAL FIBER REINFORCED COMPOSITES AND APPLICATIONS OF IN HIGH END SECTORS

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ABSTRACT

In recent years, there has been considerable interest in the use of natural fibers to replace synthetic fibers such as glass, aramid and carbon as reinforcement material in polymer matrix composites. By evaluating the performance of natural fiber reinforced polymer composites, it is possible to produce composite materials that can meet ecological needs. Natural fibers are an alternative to synthetic fibers due to their abundance in nature, low density, biodegradable properties, higher specific strength, stiffness, and inexpensive. In addition, natural fiber composites used in various applications often have some disadvantages such as moisture absorption, low impact resistance for structural applications and service life. This study aims to reveal the types and properties of fibers used in natural fiber reinforced composites and the relationships between fiber and matrix element with considering that parameters such as matrix, fillers, fiber contents, fiber processing and production procedures are effective on the mechanical properties of materials. Including improvement procedures to overcome the disadvantages of plant-based fibers, issues that need to be investigated in order to expand the potential application areas of natural fibers are highlighted. This study is concluded with the properties of natural fiber reinforced composites are discussed from the specified directions, potential application areas are shown and their potential uses in smart materials are revealed.

INTRODUCTION

With the increasing demand for materials, besides the production of composite materials with advanced properties, the interest in the production of environmentally friendly materials is increasing. At this point, studies on the production of environmentally friendly composite materials with good mechanical properties using natural fibers have increased in recent years (Peças et al., 2018).

Natural fibers have advantages such as biodegradability, light weight, low price, life-cycle superiority, and satisfactory mechanical properties as well as disadvantages such as water absorption, low thermal stability, incompatibility with hydrophobic matrices, and propensity to agglomeration (Li et al., 2020).

In order to eliminate these disadvantages of materials hybridization with chemically modified fibers is recommended. Because by adding another form of hydrophobic fiber to hydrophilic fiber composites, a good interface formation can be achieved with the hydrophobic matrix. In addition, with this method, the resistance to moisture is increased and the deterioration of the properties of NFPC can be reduced (Ahmed et al., 2021).

This study aims to reveal the fiber type, ratio, fiber / matrix interfaces used in material production, considering the mechanical properties of natural fiber reinforced composites that affect their end use areas. In addition to these, improvements to be made to ensure that these materials are used more widely in structural applications are emphasized and information is given about their potential advanced applications.

RESULTS AND CONCLUSIONS

In the study, it has been observed that diameter, length of fiber, fiber content of the fibers used in the production of natural fiber reinforced composites have a significant effect on the material. When the recent studies on this subject are examined, it has been seen that the studies on reducing the disadvantages of natural fiber reinforced composites have increased. In this study, the proposed methods for eliminating the disadvantages of natural fiber reinforced composites are included, and it has been tried to guide future studies to increase the use of these composites in advanced applications and smart materials.

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COMPARATIVE STUDY OF GREASE EXTRACTION USING GREEN SOLVENT FROM ITALIAN SHEEP

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ABSTRACT
In this study wool wax/lanolin recovery by green solvent was carried out using cyclopentyl methyl ether in comparison with conventional solvents like diethyl ether and hexan. The extraction study shows that cyclopentyl methyl ether shows higher amount of grease extraction in comparison with conventional solvents. Very big difference was found between the amount of wool grease from coarse wool both used for milk and meat production and fine wool from sheep breed for production of wool and meat. As shown by FTIR spectroscopy, the most principal and characteristic bands found in commercial lanolin spectra are also found in the extracted wax. Those bands belong to the organic acids, esters of organic acids and tertiary alcohols.

INTRODUCTION
Low quality coarse wool from Italian sheep is a large biomass unavoidably joined to sheep farming and it is to be disposed or adequately managed. Management of shorn wool (from 14 000 to 16000 tons/year in Italy) mainly implies scouring processes and related costs. Waste wool scouring provides wool wax, further refined into lanolin, in 5-20% yield and washed low-quality wools. Waste wool scouring would become profitable if scouring process optimization and further valorisation of lanolin could be associated to the scarcely remunerative non-textile uses of washed low-quality wools. The recovery of wool grease from wastewater can be carried out either to obtain crude lanolin exploitable in cosmetic and pharmaceutical fields, either to reduce the COD and the BOD of effluents. In recent years new technology to scour wool using solvent in order to replace the conventional water scouring has been studied and a prototype plant has been realized during the project Wool Dry Scouring (WDS) – Eco-Efficient Dry Wool Scouring with total by-products recovery LIFE11 ENV/ES/000588 by LEITAT Technological Center (Spain) and partners.
In the present study the lanolin solvent extraction was carried out in the laboratory using solvents which are not classified as ‘banned’ or ‘undesirable’ in the most recent solvent selection guides rating solvents greenness. Three different types of greasy wool were obtained from local wool supplier in piedmont region, Italy: 1) very long and coarse wool 38 μm diameter (breed for milk production- like Sarda breed) 2) very coarse but shorter wool 36 μm diameter (breed for meat production - like Biellese breed) 3) fine wool 22 μm diameter (breed for wool and meat – like Sopravissana breed), supposed to be consisting of a high amount of grease content in comparison with the other kind of wool. The green solvent used in this study for extraction is cyclopentyl methyl ether along with classical solvents for grease extraction consisting of n-hexan and diethyl ether. **Wool grease extraction from raw wool:** greasy wool of type 1, 2 and 3 have been extracted for 4 h using a Soxhlet apparatus and cyclopentyl methyl ether, n-hexane and diethyl ether as solvents. **Wool grease characterization:** wool grease was characterized by Fourier Transform Infrared Spectroscopy.

RESULTS AND CONCLUSIONS
Table 1 shows very big difference between the amount of wool grease from coarse wool both used for

milk and meat production and fine wool from sheep bred for production of wool and meat. This is due to the fact that, the finer is the diameter of wool fibres the higher is the amount of grease present in the wool fibres in comparison with the coarse and long fibres. The amount of grease extracted using green solvent cyclopentyl methyl ether is observed to be more in comparison with grease amount extracted using diethyl ether and hexan. The ranking for maximum grease extraction using solvents was found to be cyclopentyl methyl ether > diethyl ether > hexan as can be seen in table 2. This effect might be due to the slightly more polar nature of cyclopentyl methyl ether compared with diethyl ether and hexane (non polar). As a consequence more compounds can be extracted from the matrix. A higher dissolving ability of cyclopentyl methyl ether for polar extracted compounds might also be pointed out by the higher temperature used to boil this solvent. FT-IR spectra were obtained from the grease extracted from the three different types of wool by solvent extraction using Soxhlet apparatus with cyclopentyl methyl ether, hexane and diethyl ether and compared with the spectrum for a sample of a commercial pure wool wax (lanolin). As a result, the most principal and characteristic bands found in pure wool wax spectrum are also found in the extracted wax. Those bands belong to the organic acids, esters of organic acids and tertiary alcohols, mainly products expected to be found in this kind of wax.

Table 1. Mean of grease extraction from three different types of wool.

Sample	Mean
1	4.01
2	4.13
3	22.29

Table 2. Mean of grease extraction from three different types of solvents

Solvent	Mean
Hexan	8.19
Diethyl ether	10.28
Cyclopentyl methyl ether	11.95

In conclusion, the extraction of wool grease using green solvent cyclopenthyl methyl ether resulted in more grease extraction in comparison with conventional solvents hexan and diethyl ether and, as shown by FTIR spectroscopy, the most principal and characteristic bands found in commercial lanolin spectra are also found in the extracted wax.

ACKNOWLEDGMENTS

The authors would like to express their appreciation to the Cariplo Foundation for the financial support - project Falstaff 2018-2781- Lanolin and valuable hydroxyl fatty acids from raw wool processing: integrating

GREEN TECHNOLOGY FOR DESIGNING INDUSTRIAL GARMENT WITH UBIQUITOUS COMPUTING

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ABSTRACT
Though the attire is assumed as semiotics of civilization but ubiquitous computing is a field of computer engineering that concerns the access and use of computing resources- ideally-in any place and at any time and its realized as intelligent environment and in distant future with implants. Industrial garment design is mostly based on product, process and ambience. In this foreign technology though, ambient intelligence is emphasized to achieve intelligent environment but 6Ts' are considered collectively viz. nanotechnology, space technology, biology technology, culture technology, information technology and environment technology. Presently, E-Textile software services are used to address these needs as it is event-driven service based software.

INTRODUCTION
Semiotic Engineering is the meta heuristic methodology for analysis of knowledge with a reverence to emphasize on cognitive psychology for system engineering to give a scientific approach in the hybrid domain of social engineering, cosmogony (interoceptivity and exteroceptivity), humanities and sociology i.e. psychology, politics, growth of society and science of nature leading to modality by conglomeration of intuition, common sense, knowledge, expertise and experience resulting in X- ability of product, process and ambience. The goal of ergonomics or human factor engineering or engineering psychology is to improve human's work activity with flexibility so it should be treated as the sub function of X- ability for process design however aesthetic attributes for product design respectively to avoid over functional chaos or exponential complexity.

Fig. 2 Meta Heuristics of Wearability

RESULTS AND CONCLUSION
Major finding for design with overall luxury handle index leads to multitasking of several modalities can be termed as 'Multimodality' or 'Conjoint Analysis Technique' based on the multi-functionality with a reverence to emphasize on co-creation; Therefore, semiotics is applied by architecting the expert system with heuristics to achieve multitude of good design i.e. X ability; it is based on scenario which consists of both engineering control system and physiological control system. Influencing factors can be quality based or quantity based; however the focus is on engineering control system or digitalization as it includes both; with

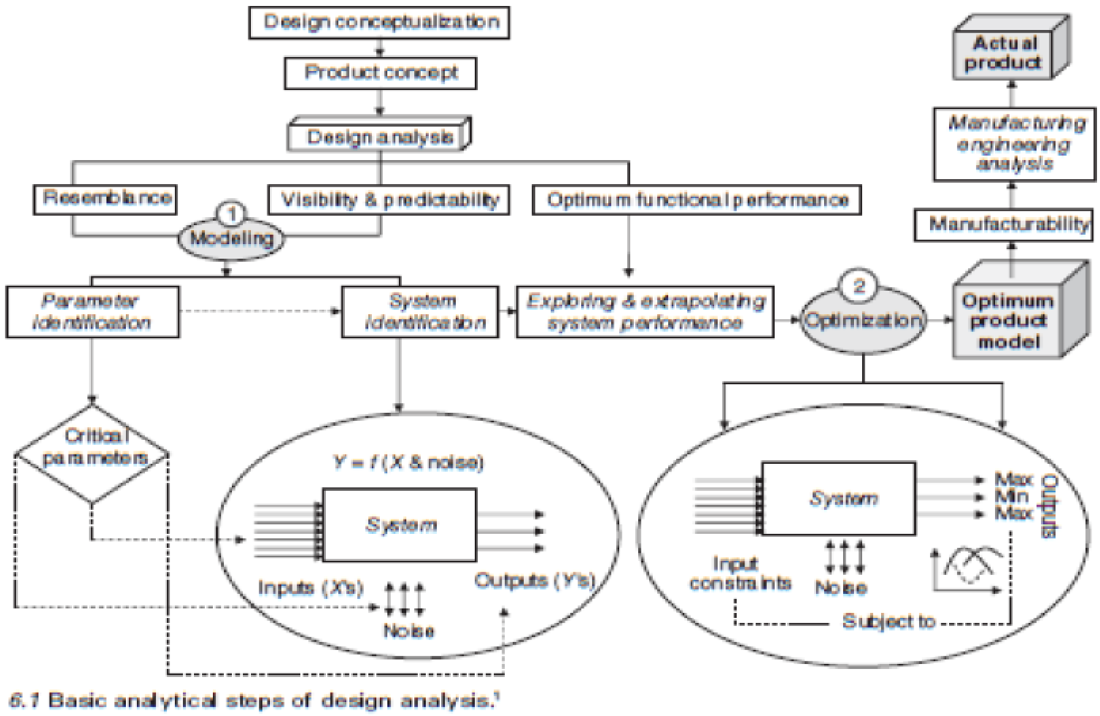

Fig.1 Well Worn

Concluding with 'Green Technology' as it works in totality for designing industrial garments as major factors of mechanistic, animate, social and ecological are validated for valorization. Green technology is an interesting and realistic conclusion because it is comprehensive, manageable and meaningful but it is important to validate and valourize it as being adequate for the reality to fill the gap in a structural and systematic manner between competing theories and approaches known to date including circular and linear economy. As per product design equipment; Fabric Assuring Simple Testing, Kawabata Evaluation System are co-evoluted to (FAMOUS) Fabric Automated Measurement and Optimizing Universal System and for its co-existence through cognitive engineering. Fabric Ultimate Requirement Identification and Optimizing Universal System (FURIOUS) may be developed from Newton for optimized co-creation of utility function and technical rationality through comprehensive functionality for industrial garment design. As electronic waste management is a sustainable factor to be considered for designing industrial garments with ubiquitous computing therefore 'Green Technology' is a well worn approach.

ACKNOWLEDGMENTS

Author gratefully acknowledges the Department of Textile Technology, National Institute of Technology, Jalandhar, Department of Textile Technology, Indian Institute of Technology, Delhi, India & University of Minho, Portugal.

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MULTICOMPONENT WOUND DRESSING

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ABSTRACT

This works describes the antimicrobial (antibacterial and antiviral) performance of a multicomponent fabric for wound dressing. The fabric comprises a scaffold of plasma activated polyester (PES), enveloped in a matrix of chitosan (CH) containing silver nanoparticles (AgNPs) and the zeolite mordenite (MOR). The antimicrobial efficacy of the cumulative addition of each of these components was evaluated.

INTRODUCTION

The development of antimicrobial medical fabrics has never been subjected to such a high and urgent demand. Silver nanoparticles (AgNPs) have been transversely used in a multitude of applications that required an antimicrobial effect. Nevertheless, the indiscriminate application of AgNPs has been subjected to controversy, particularly due to their unsettled cytotoxicity, their ability to cross the blood brain barrier, and finally their negative environmental impact (Liao, 2019; Park, 2009). A simple strategy to minimize all these impacts is to avoid the release of AgNPs form their matrix, to reduce the cytotoxicity, prevent their systemic release and facilitate waste management.

This work envisages the evaluation of antimicrobial activity of the application of natural products, in particular a matrix and a zeolite, as strategies to prevent the release of AgNPs from a composite fabric. For the antimicrobial assessment, two different model bacteria and a model bacteriophage were used. Staphylococcus aureus represents a Gram-positive coccus, widely renowned as a nosocomial pathogen. Escherichia coli, is considered as model Gram-negative bacterium, with some strains known to cause grievous food infections. MS2 bacteriophage comprises a capsid architecture similar to SARS-CoV-2 and its genome is also composed of RNA.

RESULTS AND CONCLUSIONS

The results from the antimicrobial activity are described in Table 1.

Table 1 Antimicrobial activity evaluated through shake flask (incubation 5 h). Units are expressed in Log reduction of colony forming units per mL (CFU mL-1) for bacteria and Log reduction of plate forming units (PFU mL-1)

Microorganism	*S. aureus*	*E. coli*	MS2
PES	0.77	0.15	0.20
PES+CH+AgNPs	0.72	1.68	1.27
PES+CH+AgNPs +MOR	0.85	1.07	1.22

This study displays the potential of the multicomponent fabrics against MS2 bacteriophage and the Gram-negative bacterium. However, both formulations did not display any antibacterial activity against S. aureus. Therefore, further improvements are mandatory to considerably enhance both bactericidal efficacy, and its antiviral activity.

ACKNOWLEDGMENTS

The authors would like to acknowledge the project PLASMAMED - PTDC/CTM-TEX/28295/2017 financed by FCT, FEDER and POCI in the frame of the Portugal 2020 program, the project UID/CTM/00264/2019 of 2C2T under the COMPETE and FCT/MCTES (PIDDAC) co-financed by FEDER through the PT2020 program.

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PERFORMANCE AND LIFE CYCLE ANALYSIS OF DENIM FABRICS PRODUCED USING SOYBEAN PROTEIN FIBER AND COTTON FIBER

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ABSTRACT
In this study, the usability and life cycle analysis of soybean protein fiber, a biodegradable and regenerated vegetable protein fiber, in denim fabric as a different and innovative raw material was investigated. Color fastness tests, fabric performance tests were applied to denim fabrics and life cycle analysis was performed. After different dyeing and washing, in denim fabric performance tests containing soybean protein fiber, acceptable results were obtained in color fastness and it was revealed that it was a more natural production than 100% cotton denim fabric with life cycle evaluation.

INTRODUCTION
Denim fabrics predominantly contain cotton yarn, are highly comfortable, environmentally friendly and the most attractive product of the world fashion, and are very open to innovative studies. Fabrics from the soybean fiber have the following features: magnificent and noble appearance, cashmere feel, dry and comfortable, good colour fastness, healthy and functional property. The crimp value of soybean fiber is relatively low compared to other chemical fibers, where the value is between 10-15%. The elastic recovery rate for soybean fiber is also lower than the common values of other chemical fibers (70-80%). Spinning soybean fiber and cotton fiber are similar and close. A comparison of soybean fiber and cotton fiber values are given in the table 1.

Table 1. A comparison of soybean fiber and cotton fiber values

PROPERTY	UNIT	VALUES FOR SOYBEAN	VALUES FOR COTTON
Breaking strength	cN/tex	3.8 - 4.0 for dry (2.5-3.0 for wet)	1.9-3.1 for dry (2.2-3.1for wet)
Fineness	dtex	0.9-3	1.9-3.1
Length	mm	38-76	25-45
Dry breaking extension	%	18-21	7-10
Density	g/m³	1.29	1.5
Moisture regain	%	8.6	8.5

Life cycle assessments (LCA) of denim fabrics, which have an important place in textile and ready-to-wear production, have been of great importance in recent years and many studies have been conducted. In 1992, a guideline on Environmental Life Cycle Assessment (LCA) methodology was published (Guinee 2002). Researchers have stated that LCA can be used to assess environmental impacts in textiles, from raw material to fiber processing, textile production, distribution and use, disposal or recycling (Peters and

et al. 2015, Roos and et al. 2015, Roos and Peters (2015). Some studies have shown that high toxicity to the ecological environment occurs in the warp dyeing and bleaching phase in denim production (Qian and et al. 2018, Yi and et al. (2020). Donmez and Sabır (2018) In their studies, they performed LCA analysis by reducing the use of caustic in the mercerization of denim fabric, and it was shown that the carbon footprint measurements in nature provided improvement in every parameter.
In this study, soybean protein fiber was mixed with 30% cotton fiber and produced by ring spinning technology as weft yarn. In the study, 100% cotton blend weft yarn was also produced. Thus, the fabrics produced are two pieces, the first fabric (A, cotton denim), its warp and weft are 100% cotton yarn, the second fabric (B, Soybean fiber denim) has 100% cotton yarn and weft 70% cotton/30% recycle soybean protein. The structures of the fabrics were chosen as 3/1 twill and the ground color of all the samples are pure indigo. Four washing (rins, enzyme, stone, stone + hypo), Burning (fabric front side) + Finishing + Sanforization processes were carried out in a single machine and the machine speed is 35 m / min and the drum temperature is 110°C. The fabrics went through the last finishing boat and sanforization process. Color fastness tests (against rubbing, washing and sweat), tensile and tearing strength tests were applied to the fabrics. And also, Life cycle analysis was done by LCA study.

RESULTS AND DISCUSSION

100% Cotton yarn and 30% Soybean-70% Cotton yarns used in denim fabric; Tensile strength and Elongation, Unevenness, Thin Place, Thick Place, Neps, Hairiness test values were found to be close to each other. A comparison of 100% Cotton weft yarn and 30% Soybean-70% Cotton weft yarn is given in the table 2.

Table 2. Yarn quality test results of yarns

YARN	Breaking Strength (cN)	CV%	Rkm	U%	CV%	Thin Places % /Km	Thick Places % /Km	Neps % /Km	Hairiness %
WEFT-1	1230	2,56	19,54	14,75	18,53	0,54	109,01	10,78	9,21
WEFT-2	1302	4,59	15,81	7,70	9,75	0	60	32	10,21

No difference was observed in the appearance of black sulfur dyeing and indigo dyeing and after washing of the finished denim fabrics and acceptable results were obtained in color fastness values. Tensile and tear strength results of both denim fabrics for weft and warp directions were compared in Figure 1. According to the A (cotton) fabric of the B (soybean) fabric; For the weft tensile strength and weft tear strength values were found to be at acceptable levels, although slightly lower. It is also seen that the warp direction of soybean fiber does not affect the fabric strength values negatively. With the Life Cycle Assessment (LCA), it has been shown that fabric B produced with 30% Soybean-70% Cotton is less harmful to the nature compared to A fabric produced with 100% cotton yarn.
In the comparison of LCA, when denim was produced with 30% soybean fiber content, 15% improvement in "Toxic Effect on Terrestrial Life", 14% improvement in "Toxic Effect on Freshwater Life", 13% improvement in "Total Water Use" and 9% improvement in "Resource Consumption" were observed. As a result, this study revealed that the use of soybean protein fiber as weft yarn in denim fabric does not affect the denim fabric performance negatively and it is a more environmentally friendly production in the life cycle analysis study.

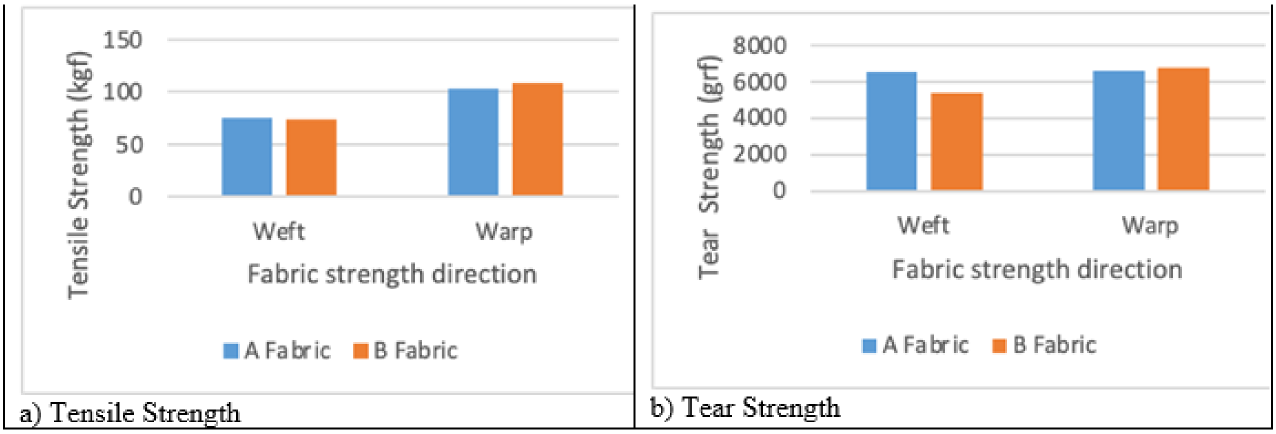

Figure 1. Weft Strength and Warp Strength test results of A and B fabric a) Tensile Strength b) Tear Strength

As soybean fiber is more expensive than cotton fiber, when the costs of fabrics made are compared, fabric B is 30% more expensive than fabric A.

ACKNOWLEDGMENTS

This study is carried out between BOSSA T.A.S / Adana enterprise and Cukurova University as a University-Industry Cooperation Project. (Project ID Number: 12668)

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THE INFLUENCE OF THE ALKALINE TREATMENT OF RICE HUSK INCORPORATED IN CEMENTITIOUS COMPOSITES

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ABSTRACT
The present study addresses the incorporation of rice husk, with and without alkaline pre-treatment, namely sodium hydroxide (NaOH), in cementitious composites. The main purpose of this treatment is to eliminate part of the existing organic material harmful to the cementitious composites to be produced, thus improving their characteristics. This work compares the treatment's intensity and duration influence on the chemical analysis of leachate and on cementitious pastes and mortars made with rice husk, through chemical, physical, mechanical, durability and microstructural characterization.

INTRODUCTION
One of the main concerns nowadays is the reduction of environmental impacts from the most diverse sectors of current society, due to the recognition of the risks caused by climate change and the intensive use of natural resources. The construction industry has strict demands in terms of economic and eco-friendly solutions with good performance. In this context, there is a need to implement sustainable measures to minimize the negative impacts that this sector has on the environment, for example through the recovery of waste and the disposal of products from other industries. There are still few commercial construction solutions with incorporation of agricultural waste or by-products. The incorporation of rice husk (RH) solutions in different building materials has emerged as an important sustainability strategy since their use in place of the commonly used fibres (e.g. glass, asbestos, polymeric fibres) allowing the reduction of economic costs and environmental impacts related to their production (Si & Co-promoção, 2015).
The present study presents three experimental campaigns to approach different modes, intensities, and duration of rice husk treatments. The reference composites, not subjected to any treatment, were produced in the first experimental campaign (0% NaOH; 2h). In the second experimental campaign, an initial concentration of 6% of NaOH was considered since the results obtained by previous studies (Guduri et al., 2009) (Bisht & Gope, 2018) suggested that this was the concentration that would lead to the most balanced results (6% NaOH; 1h, 2h, 4h). The duration of the third experimental campaign was defined according to the results obtained in the second campaign and the concentrations considered the minimum and maximum limits for treating fibres with these characteristics (Akil & Mazuki, 2011) (Bisht & Gope, 2018) (3% and 9% NaOH; 2h).

RESULTS AND CONCLUSIONS
This study shows that the alkaline treatment, namely with the use of sodium hydroxide (NaOH), improved the characteristics of the rice husk and it is more influential at the husk-paste interface: i) the morphology of the RH changes, increasing the bulk density and reducing the voids; ii) the ideal immersion time is 2 hours; iii) the concentration and the immersion period allow an increase of the compressive and flexural strength

of mortars; iv) after drying/wetting cycles, mortars with treated RH had higher resistance, and consequently more durability. Thus, the intensity of the treatment is positive for the rice husk and cementitious composites made with it, namely because of the high improvement of adhesion and interconnection between the rice husk and the cementitious matrix shown in Fig. 1.

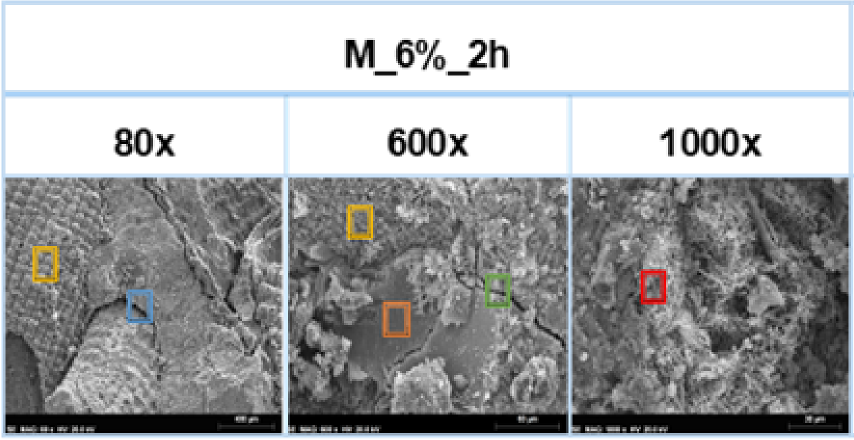

Fig. 1 Images captured in the SEM test, for the mortar sample observed.

The incorporation of rice husk is not intended for structural purposes of the composite elements but as a lightweight aggregate. It is concluded that the ideal mix considering the cost/benefit ratio is the mortar with 6% of NaOH concentration and 2 h of treatment duration (M_6%_2h). Therefore, the use of this waste, like other fibres, contributes to the reduction of the negative impacts caused by the construction sector, with the potential development of new sustainable materials for thermal and acoustical applications.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by FEDER, under the research project POCI-01-0247-FEDER-039577 and LISBOA-01-0247-FEDER-039577, Farcimar for the availability of rice husk, FCT, CERIS and IST.

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MECHANICAL CHARACTERIZATION OF NATURAL FIBER REINFORECED POLYMER BLEND

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ABSTRACT

This work evaluates the mechanical properties of a newly developed natural fiber reinforced polymer blend. Polypropylene (PP) and high-density polyethylene (PE) are blended together (50%PP/50%PE) and is used as matrix for the developed bio-composite. Natural fibers are extracted from date palm pedicels (DPP) agro-residues and powdered to be used as filler in the blend (20%DPP/40%PP/40%PE). Characterization of the mechanical properties are determined via physical experimental setup. Results appears promising although no modification of ingredients has been implemented.

INTRODUCTION

Natural fiber composites have captured a considerable attention for various applications due to their inherent properties like strength and lightweight over conventional polymers. Natural fillers are generated from natural sources and are classified mainly in two categories: fibers and particles. It is well established that natural fillers, in the form of flour, fibers, particulate pulp, are suitable as reinforcement for thermoplastics (Alzebdeh et al., 2019; Väisänen et al., 2017). The composition of natural fibers is mainly cellulose, hemicellulose, lignin, pectin, waxes, and other impurities. Conventionally, natural fiber composites are fabricated using a single type of polymer due to physio-mechanical differences between synthetic polymers. Polymer blends are physical mixtures of two or more polymers with or without any chemical treatment between the constituents (Bátori et al., 2017). The purpose of polymer blending is to achieve commercially viable products through either unique properties or lower cost than homopolymers. The subject is vast and has been the focus of immense research, both theoretical and experimental (Maou et al., 2019). In many cases, properties of polymer blends are superior to those of component homopolymers. In general, owing to the incompatibility between the blending components, the factors affecting the rheological properties of polymer blend melts during extension are more complex than those of a single polymer melt (Liang, 2019). In specific, interaction among phases and morphology of flow have a considerable impact on the rheological properties. The presence of natural fillers/fibers can alter the rheological properties of the blend. The rheological behavior determined by flow rate measurements, have been widely investigated, focusing on the interfacial tension. However, the properties under continuous flow have been scarcely analyzed for polymer blends containing natural fillers (Sangroniz et al., 2018). In this study, we develop a natural bio-composite from virgin polymers and extracted filler from date palm agro-residue. Mechanical properties are measured through an experimental setup. Analysis of other material properties such as physical, chemical, and thermal will be performed.

RESULTS AND CONCLUSIONS

Fig. 1. shows the tensile and flexural strengths of the developed natural fiber bio-composite blend in comparison with the neat polymers and base polymer blend. Although the tensile strength is degraded in comparison to the neat homopolymers, it is slightly enhanced due to the inclusion of the natural filler. How-

ever, the flexural strength showed degermation in the case of natural fibre-based blend compared PP/PE blend. It is also found that the modulus of elasticity is improved for the blend and the natural filled blend while flexural modulus is decreased. The elongation at break is getting decreased due to the discontinuity of the filler and the rigidity nature which reduce the bio-composite molecular chain mobility. Further study is needed to assess the fabrication process and the critical parameters affecting mechanical properties such as interfacial bonding between fibre and surrounding blend and natural fibre distribution. Analysis of treatment methods of fibre and functionalization of polymers is underway.

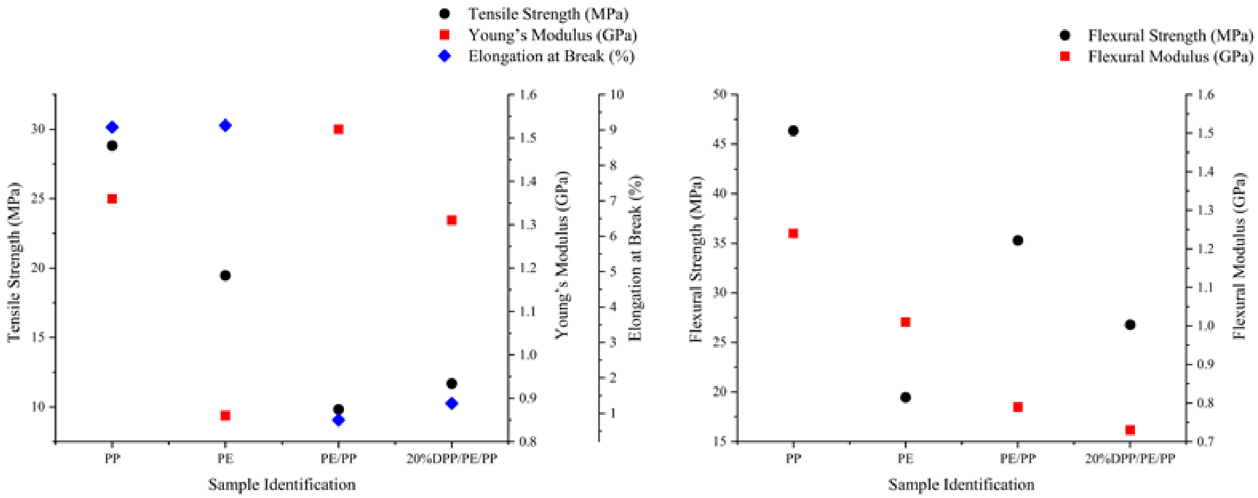

Fig.1 Tensile and flexural test results

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SYNTHESIS AND CHARACTERIZATION OF SILVER-CHITOSAN NANOPARTICLES ON TEXTILE

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ABSTRACT
Metal nanoparticles these times have gathered huge popularity in the fields of health industry. This study focuses on synthesis of silver and chitosan nanoparticles and study their antibacterial effects and cytotoxicity when they are coated on a fabric. The prepared fabric was subjected to characterization techniques such as XPS, XRD, EDX and SEM. These tests confirmed the presence of silver nanoparticles on the surface of the fabric. Antibacterial and cytotoxicity tests were conducted, and the results exhibited that silver nanoparticles have showed good antibacterial effect on both gram positive and gram-negative bacteria and showed no cytotoxicity. The antibacterial effect was effective after 10 cycles of washing.

INTRODUCTION
Silver nanoparticles (AgNPs) are known to exhibit inhibitory and bactericidal effects. Physical and chemical methods are employed for the preparation of metal nanoparticles. However, chemical methods such as reduction are most often used. AgNPs were previously applied onto polyester fabric by exhaustion method (Chattopadhyay, 2010). However, very few researchers (Chattopadhyay, 2010), (Thomas, 2011) have studied and demonstrated the effects of silver-chitosan nanoparticles on polyester fabric. In literature, XRD, EDS and SEM analysis have been mostly used for characterizing and proving the presence of silver nanoparticles on the fabric. This coating has shown positive results when tested the fabric sample against Gram-negative bacteria Escherichia coli and Gram-positive Staphylococcus aureus (Ali, 2011), (Ilić, 2009). This work studied the application of silver-chitosan nanoparticles on polyester fabrics for application in biomedical industry.

RESULTS AND CONCLUSIONS
Synthesis of silver-chitosan nanoparticles in acidic media was performed successfully by using exhaustion method. From XRD analysis, the value of 2θ was found to be 38.1° and the size of the crystallite was determined as 12 nm using Shearer Debye relation confirming the presence of silver in metal state. From UV-Vis analysis, the adsorption rate of silver nanoparticles at concentration of 0.02 % was reported as 423 nm. The XPS elemental analysis was used to confirm the presence of silver nanoparticles and its distribution was confirmed in the EDX mapping analysis (Figure 1). The SEM analysis (Figure 2) of the silver-chitosan sample confirm that silver nanoparticles are uniformly distributed on the fibre surface. The antimicrobial effect of the AgNPs was determined by testing them against Gram-negative bacteria Escherichia coli and Gram-positive Staphylococcus aureus. From the results (Table 2) it can be concluded that all the configurations show positive effect against both bacteria. After 10 washing cycles the samples with only silver or chitosan showed a slight decrease in antimicrobial efficacy while the sample with the chitosan-silver nanoparticles did not show any loss in the antimicrobial efficiency. The samples show no cytotoxicity (Table 2).

Table 1 Synthesis Conditions of Silver Nanoparticles with Different Weight Percentages

Sample	Silver Nitrate w/v %	Chitosan w/v %	Citric Acid w/v %	Sodium Hypophosphite w/v %
1 – Ag + Chit	0.002	0.1	0.5	0.3
2 – Chit	-	0.1	0.5	-
3 – Ag	0.002	-	0.5	0.3

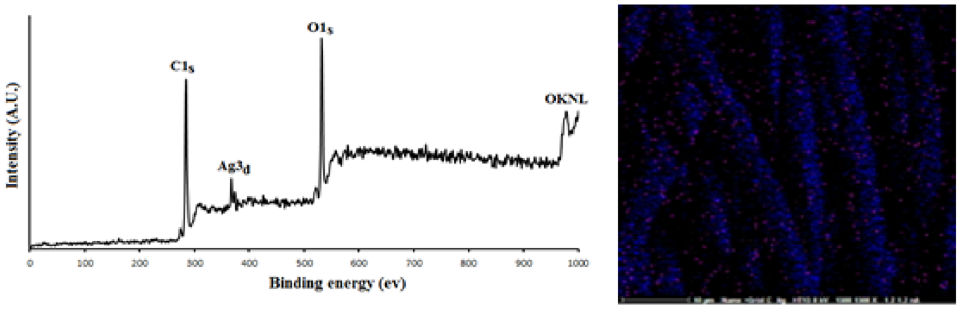

Fig.1 XPS and EDX Mapping Analysis

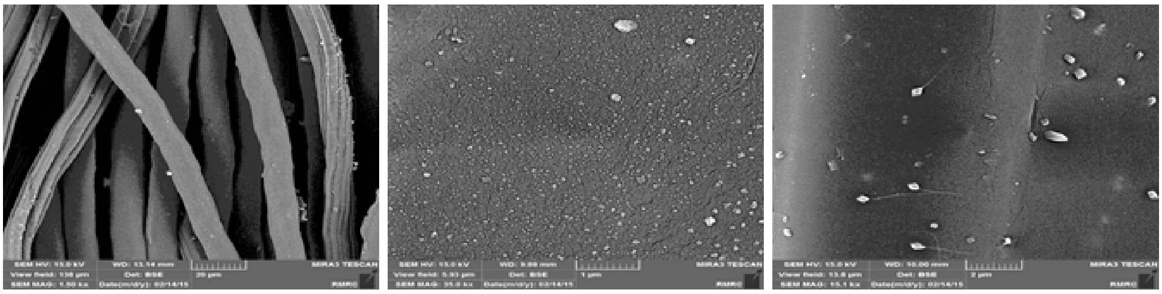

Fig.2 SEM Images of Polyester and Silver Chitosan Sample with Two Magnifications

Table 2 Antimicrobial Activity Before and After Washing and Cytotoxicity Results

Sample	*S. Aureus*	*E. Coli*	*S. Aureus after wash*	*E. Coli after wash*	cytotoxicity
1 – Ag + Chit	99.9	99.9	99.9	99.9	0
2 – Chit	99.9	98.1	99.9	67.3	0
3 – Ag	99.9	99.9	99.9	98.3	0

ACKNOWLEDGMENTS

The authors would like to acknowledge the project PLASMAMED - PTDC/CTM-TEX/28295/2017 financed by FCT, FEDER and POCI in the frame of the Portugal 2020 program, the project UID/CTM/00264/2019 of 2C2T under the COMPETE and FCT/MCTES (PIDDAC) co-financed by FEDER through the PT2020 program.

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INFLUENCE OF FIBRES NATURE ON STRUCTURAL AND PHYSICAL PROPERTIES OF KNITS

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ABSTRACT

During this study structural parameters and physical properties, such as actual loop length, course and wale spacing, loop shape factor, area density of knits, were investigated and tightness factor was calculated. It was determined that structural parameters and physical properties of knitted fabrics are strongly related to the number of yarns in one loop and the fibre composition of the used yarn. Considering this, it is very important to take into account nature of raw material of yarns on the step of theoretical prediction of properties of newly designed knits because of particular behaviour of the different yarns during knitting process.

MATERIALS AND METHODS

The experiments were carried out with cotton, viscose and man-made bamboo yarns with 19.5 tex linear density and 227 m-1 twist factor. Twelve variants of knits, varying in raw material of the yarn and number of yarns in a loop, were knitted from these yarns in single jersey knitting pattern on the same one needle-bed circular weft-knitting machine. Tensile properties of the yarns were determined using universal testing machine ZWICK/Z005. The stress-strain characteristics of studied yarns were obtained following the standard ISO 2062. The coefficient of friction was determined investigating the friction of yarns to 2 mm diameter needle at speed 0.10 m/s. The air permeability test was provided according to the standard EN ISO 9237:1997, using the head area of 10 cm2 and pressure difference of 100 Pa.

RESULTS AND CONCLUSIONS

Study has shown that the yarn count number and yarn fibre composition influenced structural parameters of knitted fabric. It was determined that by increasing of yarns count in one loop the loop length increases also. The increase in yarn number in one loop increases the wale spacing, but decreases the course spacing. The influence of the number of yarns in one loop on structural parameters of the knitted fabrics gradually decreases until the structure of the knit is fully interspaced. Fibrous composition in the yarn had more impact on loop geometry, when total yarn linear density was higher. Man-made bamboo and cotton knits had shorter loops than viscose ones. Fabrics knitted from cotton yarns had highest wale spacing and man-made bamboo – lowest. Although, the course spacing in viscose samples is higher than in cotton and man-made bamboo. The results also show that the number of yarns in the loop and raw material of the yarn had influence on the course and wale spacing as well as the dependence of the loop shape factor. Dependences of loop length, wale and course spacing and loop shape factor on the number of yarns in one loop and raw material of yarn are presented in Figure 1, respectively a, b, c and d. It is also found that air permeability significantly decreases when yarn count number increases. This was also influenced by the fibre composition of yarns. These results are presented in Figure 2. The results show that viscose knits have the highest permeability to air and the cotton knits – the lowest.

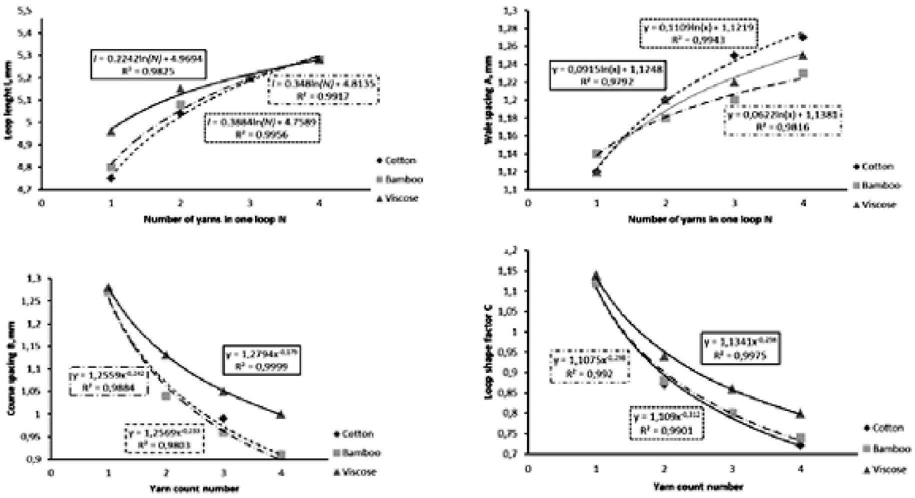

Fig.1 Dependence of: a) loop length, b) wale spacing, c) course spacing and d) loop shape factor on the number of yarns in one loop and raw material of yarn.

It was concluded that structural parameters of man-made bamboo knits are closer to those of cotton. The loop length has higher dependence on raw material of the yarn in looser structures. Although, the influence of the raw material on wale spacing and the loop shape factor is observable for knits with a tighter structure. The air permeability of man-made bamboo knits has values closer to viscose knits than to cotton ones, despite that the structural parameters of bamboo knits are closer to those of cotton knits. Despite the fact that all yarns of the knitted samples are of cellulose nature, the behavior of yarns during knitting differs. Therefore, it is impossible to predict the properties of bamboo knits in accordance with cotton or viscose knits without appropriate investigations.

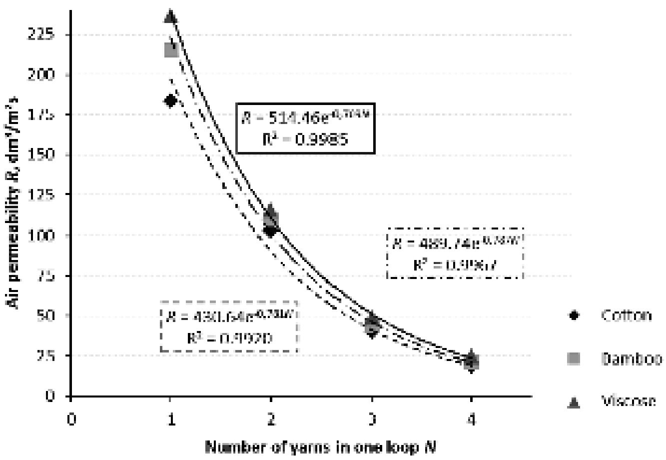

Fig.1 Dependence of air permeability on the number of yarns in one loop and raw material of yarn.

RESULTS AND CONCLUSIONS

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CONTEMPORARY JEWELLERY: COMPOSITE MATERIAL REINFORCED WITH CHICKEN FEATHER FIBERS

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ABSTRACT

This study aims to develop a composite material reinforced with chicken feather fibers (CFF) for application in contemporary jewellery. Design Thinking is used as a methodology. Samples with different volumes of CFF and epoxy resin were developed using hand lay-up technique (100% resin, 5% feather/95% resin, 10% feather/90% resin, 20% feather/80% resin, 30% feathers/70% resin) and evaluated for the following aspects: aesthetic (field research), technical (FESEM, FTIR, DSC, TGA and liquid absorption test) and sustainability.

INTRODUCTION

The need for change has been imposed by the increase in pollution and the shortage of natural resources, what explains the industry's initiative in the search for sustainable materials (Takamitsu e Menezes, 2014). In this context, concepts such as the circular economy and contemporary jewellery emerge. Circular economy projects consider waste and pollution in order to keep products and materials in use (Ellen MacArtur Foundation, 2017). Contemporary jewellery proposes a greater appreciation to the concept and symbolic values whit the use of non-traditional materials (non-precious) (Guilgen e Kistmann, 2013). The combination of CFF with epoxy resin to form a composite material reaches the concepts presented considering that these fibers are classified as residues of the food industry that are transformed into raw materials (Alonso, 2017). Five samples were made and evaluated. A field survey was carried out with 100 interviewees using a questionnaire on the Google Docs that sought to evaluate the qualitative aspects related to the development of the product and its acceptance by consumers. Samples were analysed using FESEM, ATR-FTIR and DSC. The tensile tests were performed using an adaptation of the ASTM D5035 standard: 2KN load cell, at a speed of 2mm/min. and a distance between the jaws of 30mm. Finally, the immersion liquid absorption test was carried out based on an adaptation of the ASTM D570-98 standard, with distilled water being replaced by saline.

RESULTS AND CONCLUSIONS

The fiber morphology identifies the existence of a structure with branches, hooks, rough texture and also the presence of internal divisions that form air pockets inside the fiber. The FTIR analysis shows an interaction between the composite phases, but shows the loss of epoxy groups in the samples with 5% feathers/95% resin and 10% feathers/90% resin. The tensile test shows that the higher the percentage of CFF, the lower the values of maximum tensile strength and modulus of elasticity (table 1), demonstrating a difficulty in impregnating the fibers and reducing the interaction between the composite phases.

Table 1. Comparative table of the average of the maximum tension and the modulus of elasticity.

% Penas	□ Max (MPa)		E (GPa)	
	Média	Desvio padrão	Média	Desvio padrão
0%	52,06	8,40	1,87	0,16
5%	27,2	1,92	1,44	0,14
10%	21,93	1,85	1,30	0,15
20%	18,04	1,14	1,10	0,15
30%	9,23	2,52	0,75	0,10

DSC indicates that the decomposition temperature of the CFF starts at 220oC and ends at 240oC improving the thermal behaviour in the composites. TGA test presents a greateramount of residue at the end of the test for the composite with a higher percentage of fibersand reveals that the presence of CFF increases the thermal instability. With the results of the field survey, it is possible to conclude that the interviewees demonstrate to value and consider aspects in the purchase process such as: new materials, design and sustainability. Respondents gave greater importance to the aesthetic aspect when compared to the technical aspects and showed preference for samples with lesser portion of fibers and less natural appearance. The research presented a new perspective that is based on the circular economy and proposes the use of CFF in the jewellery sector as seen in the prototypes shown in figure 1. The decrease in the thermoplastic matrix, due to the introduction of a percentage of feathers, worldwide, considering only the segment of this product, is a considerable factor.

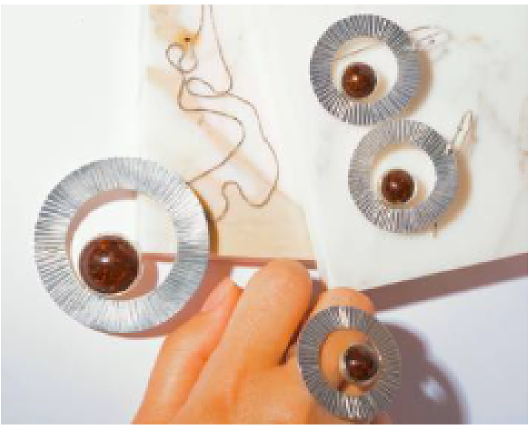

Fig.1 Prototype made with 950 silver and composite material reinforced with cff.

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APPLICATION OF FLAX HYBRID COMPOSITE ON THE HIGH PERFORMANCE ELECTRIC PERSONAL WATERCRAFT

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ABSTRACT

This article deals with the study of the applicability of flax fabrics in the production of composite parts usable in personal watercraft. The use of natural materials, in addition to the environmental aspects, brings other benefits, such as damping vibrations and noise caused by the engine. The current solution for the production of the float is made purely of carbon composites, due to their low weight and high strength. In order to achieve high strength even when using flax composites, the application of a hybrid composite Carbon - Flax was started. For the purposes of design and implementation, several types of measurements of individual samples of materials were performed.

INTRODUCTION

For a purposeful design of the composite in real use, it was necessary to perform laboratory samples and measurements of mechanical properties. The aim was not to obtain the theoretical properties of the fiber, these are given in (Yan, 2014) and others, but to bring closer the tests of the real use of the composite part. For this reason, samples were produced for tensile testing according to EN ISO 527, three-point bending test EN ISO 14125, for both initial materials and materials exposed to humid environments, immersed in salt water for 60 days (Fiore, 2016). All samples were made by Resin Transfer Moulding (RTM) with epoxy resin. In order to determine the vibration damping, the Frequency Response Function (FRF) and Root Mean Square (RMS) plates and their oscillation shape were measured. Plates and samples for tests were made of various combinations of fabrics, to determine optimal results, these fabrics are from Carbon, E-Glass, Flax, and hybrid Carbon- Flax fibers, twill and biaxial type fabrics. For practical purposes and measurements an engine cover of Jetsurf electric personal watercraft was manufactured. This was made from a Carbon-Flax hybrid fabric.

RESULTS AND CONCLUSIONS

The test results proved the suitability of using a hybrid carbon-flax composite, which showed a very good strength σtu and tensile modulus E. Result correspond to Mahboob (2016) and Shamsuyeva (2019), dealing with flax and hybrid composites, differences are mainly caused by using different fabrics (twill). The results of laboratory measurements of test plates and samples, especially the course of RMS size and the course of FRF, show a effect of the flax insert within the hybrid Carbon composite. For the initial tests, a composite with a partial liner made of flax is designed, which resists the effects of moisture and its attenuation is significant for both the user and the environment. Sound level measured for different materials can be observe in Fig.1.

Table 1 Tension test results

Materials	V_f [%]	E [GPa]	σ^{tu} [MPa]	ε^{tu} [%]
Carbon - Twill	42,74	14,98	511,26	3,47
Glass - Twill	38,51	4,36	216,22	5,03
Glass - Biax	46,13	6,43	339,43	5,77
Flax - Twill	31,12	1,73	93,87	4,06
Flax - Biax	39,64	2,42	99,9	4,25

Fig.1 Laboratory measurement setup and real measurement of float.

Fig.1 Laboratory measurement setup and real measurement of float.

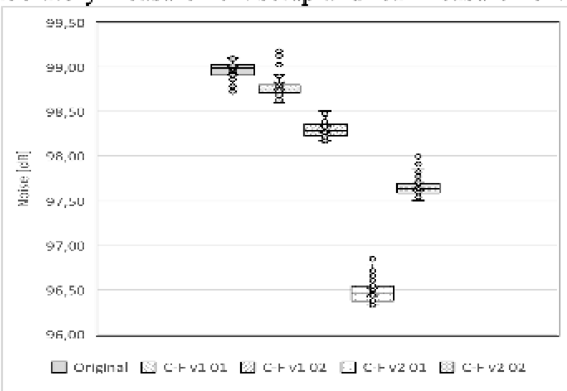

Fig.1 A comparison of the noise levels recorded during the operation of electric engine with carbon flax covers.

ACKNOWLEDGMENTS

This research work was supported by the Brno University of Technology, FME, Specific research 2019, with the grant " Research of perspective production technologies ", FSI-S-19-6014 and Advancement and support of R&D for “Centre for diagnostics and quality testing of materials“, in the domains of the RIS3 SK specialization, ITMS2014+:313011W442, based on the Operational Programme Integrated Infrastructure and funded from the European Regional Development Fund.

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ENVIRONMENTAL IMPACT OF POLYESTER-COTTON BLEND COMPARED TO COTTON FIBER PRODUCTION IN BRAZIL

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ABSTRACT

The main use of PET in the textile industry is mixed with cotton fibers in order to produce PET/CO blend fabrics, which are widely used in clothing and home textiles. The degradation of PET is slow (up to 400 years) causing environmental problems. The aim of this research was to compare the environmental impacts of pure cotton production and the mixture of PET-CO, through an overview of the Brazilian textile and clothing industry, highlighting the manufacturing and recycling processes. It is understood the need to adopt the circular economy deeply so that textile waste returns to the beginning of the production cycle, as well as the need to improve the production process so that there is a correct separation and disposal of waste.

INTRODUCTION

Brazil is an important producer of textile articles in the world: 4th largest producer with nearly 9 billion pieces of manufactured articles in 2019; 4th largest producer and consumer of denim; 4th major producers of knitted fabrics (ABIT, 2020). Brazil has the largest textile chain in the Western countries, from fiber production, such as cotton plantation, to fashion shows, through spinning, weaving, processing, clothing and retail (ABIT, 2020). However, this production generates large quantities of pre and post consumption wastes. It is estimated that annually 175 thousand tons of textile scraps only from the cuts in the clothing industry in Brazil. More than 90% of these are destined to landfills or environmentally incorrect disposal (Sinditêxtil-SP, 2012).

In some cases, mixed fabrics wastes are incinerated to generate energy. However, they are usually incorrectly disposed in landfills (Amaral, 2018). The degradation of PET is slow (up to 400 years) causing environmental problems. In addition, a valuable non-renewable petroleum-based resource is lost.

To compare the environmental impacts of pure cotton production and the mixture of PET-CO, a bibliographic study was carried out and an overview of the Brazilian textile and clothing industry was presented, highlighting the manufacturing and recycling processes.

RESULTS AND CONCLUSIONS

Brazil is prominent in the cotton production scenario due to the quality of its cotton. It has 85% of all production certified by the Responsible Brazilian Cotton (ABR) program, which in 2017 reached 170 million tons, an increase of 12% in comparison to the last few years (FCEM, 2020), with 667 tons consumed in 2016/2017 according to ABRAPA (2017).

The production process of Brazilian cotton textiles involves seven fundamental stages: farming, spinning, weaving, dyeing, finishing, clothing industry, and retail distribution. Cotton farming and spinning are those that have the greatest impact due to the amount of pesticides and dust generated in the spinning process

(Barbosa et al., 2016).
On the other hand, PET has become a fiber commonly used in the manufacture of clothing in Brazil, being a strong competitor to cotton, especially when used in mixed fibers. According to ABRAFAS (2019), the apparent consumption of synthetic fibers in 2019 was 709,848 tons, of which around 79% is polyester.
Regarding its production, the impacts of PET start with the extraction of oil, a finite natural resource, in addition to representing greater energy consumption in its production, highlighting the burning of fuel oil and firewood in boiler houses (Barbosa et al., 2016) Recycling and reuse processes contribute to the management and conservation of raw materials that would otherwise be discarded, decreasing the need for new exploration of natural resources for the production of new goods and products (Abramovay et al., 2013) .
As an attempt to reduce environmental impacts, the recycling of textile yarns is being highly demanded, although in Brazil mechanical recycling of textiles has been the main form of reprocessing discarded garment scrap. Many of the technologies for recycling chemistry are still in the experimental stage or are not disseminated (Ciclo Vivo, 2020).
According to Sinditêxtil-SP (2020), the difficulty in separating textile waste in the recycling industries is due to the fact that the garments make a particular model of clothes bother using different types and colors of fabrics, in order to minimize the time of production and, consequently, costs. The recycling process is done by washing the waste, centrifuging, and then passing through a shredder, made up of six rotating cylinders, which cuts, tears and shreds the waste. In the case of fabrics composed of PES-CO, it is only possible to use 3 cylinders, since there is heating that can melt and damage synthetic waste. Then, a hydraulic press transforms the shreds into bales, which are subjected to two sequential openers, guided by a conveyor belt and finally, are subjected to a blanket making machine (Ciclo Vivo, 2020).
In 8 years, Brazil imported more than 220 thousand tons of waste, a cost of US $ 257.9 million, while at the same time, lost to recycle US $ 12 billion in its own waste due to the lack of correct separation. By 2016, only 21 cooperatives and companies, present in only 7% of Brazilian municipalities, recycle textiles in order to generate raw materials for the automobile industry (Amaral, 2018). By reusing existing materials, companies can avoid the costs problems of acquisition of raw materials, as well as their environmental impact. It is understood the need to adopt the circular economy deeply so that textile waste returns to the beginning of the production cycle, as well as the need to improve the production process so that there is a correct separation and disposal of waste.

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DEVELOPMENT OF NATURALLY FUNCTIONALIZED PLA FILAMENTS

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ABSTRACT
Mosquito-borne diseases have a major influence on the quality of life and socioeconomic development of a large part of the human population. Malaria is one of those diseases. Responsible for reaching almost half of the world population, its occurrence has a tremendous impact on human health - in 2018, approximately 228 million cases occurred causing the death of more than 405 thousand people - and significant economic losses (WHO, 2019).
Furthermore, recent increases in resistance to medicines (medicines and repellents) and climate change have led to major environmental changes and, consequently, their spread to new geographical areas, especially across Europe. Aware of this situation, the authors of this research developed and applied a new high-value, biodegradable and antimalarial technological solution to clothing, which may, in the future, contribute to minimize the impact of malaria in human health.

INTRODUCTION
In the history of humanity, the great changes and transformations that we have witnessed have their origin in the development of technology, whether through the introduction of new products, new processes, new technologies or new systems. Observing today's society, it is soon clear that the evolution in the field of textile functionalization and development brings a constant improvement in the market, not only providing new goods and services that meet the demands and expectations of consumers, but also making possible the tireless search for the new, where new technological solutions incorporate new properties and increased functionality.
In this sense and with regard to functionalization, the design and development of innovative textile materials and processes is today, a factor of differentiation and competitiveness. However, these new products sometimes end up not completely satisfying the required requirements, as the overwhelming majority do not meet environmental requirements. Aware of this reality, this scientific research work seeks to contribute to the development and clothing application with sustainable and functional textile materials, capable of efficiently protecting not only humans but also the environment, based on a biodegradable and antimalarial textile structure, consisting of a biopolymer - PLA - and silica nanocapsules containing a natural essential oil - Schinus molle - applied during the extrusion phase. The results obtained proved that the proposed innovative solution meets all the necessary requirements and is therefore a valid alternative for the development of biodegradable antimalarial clothing.

1. DEVELOPMENT
1.1. Physiopathology of Malaria: Public Health Perspective
Growing drug and insecticide resistance, environmental change, and human migration have led to an increase in tropical epidemics, particularly malaria. Caused by the reproduction of Plasmodium parasites in human blood, malaria is transmitted through the bloodstream through the bite of the female Anopheles mosquito in rural and semi-rural subtropical climate zones (Goldman & Schafer, 2014). This pathology is nicknamed malarial or malaria is of Italian origin, and etymologically means "bad air," bad 'aria" (Carter &

Mendis, 2002), "badly coming from the air", originating from the fumes and miasma of certain marshy regions, among other designations is one of the most serious and potentially fatal infectious diseases in the world (Cunha & Cunha, 2008).
According to the Centers for Disease Control and Prevention (CDC) (2016), it is one of the most significant diseases for humanity due to its devastating impact on social and economic damage because the losses from malaria are deep, in addition to an enormous detriment to the social well-being of the population and very serious damage to health also bring aggregate, a high economic burden for the host country - its occurrence has a direct impact on human resources, not only results in lost lives and productivity, but also hampers children's normal schooling and social development due to absenteeism and permanent family harm (WHO & RBM, 2006).

1.2. Repellent action: anti-malarial active ingredients

For centuries, mankind has been looking for solutions to prevent insect bites, using different methods, in an attempt to avoid their painful bites and increased diseases. Insect repellents are an economic alternative for both human protection and vector control, playing an important role in combating insect bites and reducing human-vector contact.
In recent years, due to the increase in resistance seen in vectors and the climate change under way, insect repellents have gained a growing and particular interest in public health in protecting against vectors. (Dickens & Bohbot, 2013).
Currently, the development of new repellent action products has grown exponentially, aiming at an adequate protection against different transmitting vectors, bringing to the final consumer different application/use possibilities applied on the skin or incorporated in textiles, thus reducing the chances of disease transmission (Katz, Miller, & Hebert, 2008; Leo, Del Regno, Gregory, & Clark, 2001). However, it is important to note that most of these formulations are not environmentally friendly and are associated with allergies, skin irritations and sometimes severe asthma reactions.
Lately, interest in botanical products has been shown, due to the use of synthetic products, to raise several concerns both in biological control and in the development of resistance, undesirable effects on non-target organisms, and both human and animal health and environmental concerns (Kim et al., 2003). There is now a growing interest in organic products, free of pesticides, with substances that have good efficacy and environmentally friendly (Nerio et al., 2010).
We currently have in nature a large number of plants that are known for their numerous release of chemical substances, which have served as a basis for various applications in folk medicine (Dias et al., 2012). An accurate example is the essential oils that have been evaluated/tested due to their repellent properties as a valuable natural resource (Corrêa & Salgado, 2011). They are considered the first drugs used by primitive man (Figueiredo, Pedro, & Barroso, 2007) and pesticides of minimal risk of high added value.

1.3. Schinus molle

Schinus molle L. commonly called California pepper, Peruvian pepper, false pepper, mastic tree, among others, is a wild tree usually used in landscaping or afforestation of the streets and grows around 15 meters (Martins, Arantes, Candeias, Tinoco, & Cruz-Morais, 2014). There are several studies on this plant that report different biological activities of its essential oils, such as antiviral, topical antiseptic, antifungal, antioxidant, anti-inflammatory, tumor and antispasmodic, antibacterial, analgesic, healing (Bigliani et al.., 2012; Mehani & Segni, 2012), and especially with repellent and anti-malarial activity (Eryigit, Yildirim, Ekici, & Çirka, 2017; Taylor et al., 2016). In addition to all the properties previously seen, around 60% of the essential oils of Schinus molle L. have antifungal activity and 35% have antibacterial properties (Marongiu, Porcedda, Casu, & Pierucci, 2004; Silva et al., 2010), which makes this an excellent candidate, an alternative to synthetic chemicals in pest control (Bendaoud, Romdhane, Souchard, Cazaux, & Bouajila, 2010).

The chemical composition of essential oil mainly consists of monoterpene hydrocarbons (e.g. α-pinene, Sabinene, terpinen-4-ol) and some sesquiterpenes such as (+)-spathulenol and germacrene-D) which represent a total of 94.0% of essential oil (Rocha et al., 2012).

Figure 1. Schinus molle.

1.4 Development of mosquito repellent textiles

In recent years, several studies have been carried out on the incorporation of mosquito repellents in textiles and clothing intended for outdoor activities; however, these repellent textiles are based on synthetic repellents, such as permethrin, which is extremely polluting and highly harmful to human health.

Mosquito repellent textiles are usually obtained by finishing with repellent agents, however they can also be produced by incorporating repellent agents into the yarn or fiber before production. This method has some advantages over the impregnation of textiles with mosquito repellents in a final phase.

Treatments with the incorporation of repellent agents within the fiber are less polluting and their production cost is reduced as the incorporation of the repellent and the production of fibers are commonly performed in a single process (Langenhove & Paul, 2014).

Processes of impregnation finishing generally do not guarantee such an efficient durability of the repellent on the textile surface. In addition to this fact, the chemicals used in this method may bring some environmental concerns.

It is worth mentioning processes that include the functionalization and the slow release system in textile materials that incorporate mosquito repellent compounds in fibers:

— Extrusion;
— Or electro-wiring.

Other possibilities include:

Incorporation of microcapsules or three-dimensional molecules, such as cyclodextrins, which are integrated into the fibre or a coating that is applied to a fabric (Anuar & Yusof, 2016).

2.MATERIALS

2.1 Selection of repellent agents

From the various options available on the market it was chosen to select an encapsulant that would provide the necessary thermal protection to the natural essential oil during the extrusion process and would have good chemical stability, not interacting with the natural essence or with permethrin. In this way, silica nano-capsules were chosen, since they have a porous honeycomb structure with hundreds of empty channels (mesoporous) that are able to absorb and/or encapsulate relatively large amounts of bioactive molecules. Additionally, their morphology and specific area are also the most appropriate for our objectives (Chen et al., 2013; Giraldo et al., 2007).

2.2 Encapsulants-Porous Silica

From the various options available on the market it was chosen to select an encapsulant that would provide the necessary thermal protection to the natural essential oil during the extrusion process and would have good chemical stability, not interacting with the natural essence or with permethrin. In this way, silica nano-capsules were chosen, since they have a porous honeycomb structure with hundreds of empty channels (mesoporous) that are able to absorb and/or encapsulate relatively large amounts of bioactive molecules. Additionally, their morphology and specific area are also the most appropriate for our objectives (Chen et al., 2013; Giraldo et al., 2007).

2.3 Biopolymer-PLA

Taking into account the need to have a totally biodegradable fiber and that would be able to withstand the thermal and rheological conditions of a fusion extrusion process, Natureworks Ingeo 6201D PLA15 biopolymer was selected, marketed under the brand Ingeo™ biopolymer is a polymer that offers environmental benefits because it is made from renewable resources.
The main characteristics of the above mentioned polymer are represented in table 1.

PHYSICAL PROPERTIES	METRIC	COMMENTS
Specific Gravity	1,24 g/cm³	ASTM D792
Melt Density	1,08 G/cm³ at 230°c	ASTM D1238
Viscosity Measurement	3,1	Relative Viscosity; CD internal Viscotek method
Melt flow	15-30 g/10 min at load 2,16 Kg and temperature 210°C	ASTM D1238
Thermal Properties	**Metric**	**Comments**
Melting Point	160°C-170°C	ASTM D3418
Glass Transition Temp.	55°C-60°C	ASTM D3417
Shrinkage	5%-15%	ASTM D32102 Boiling Water

Table 1- Typical properties of PLA Ingeo 6201D

3. EXPERIMENTAL METHODS

3.1 Adsorption nanoencapsulation

The encapsulation of both chemical agents occurred individually and was performed using the adsorption method. The adsorption process consists of mixing the components, followed by stirring and collecting the prepared mixture. Quality control tests such as DSL, TGA, FTIR, DLS, SEM, were conducted to characterize the nanocapsules obtained.

3.2. Extrusion of Functionalized PLA Multifilaments

The functionalized PLA multifilaments were obtained through a fusion extrusion operation and were performed in a melt spinning unit of Hills Inc.
The temperatures used in the different sections of the extruder were defined based on the lower limit of temperatures at which the used PLA can be processed, aiming at maximizing the conservation of the additive used throughout the extrusion process, since this way its volatilization and thermal degradation is reduced to a minimum.
Thus, PLA multi-filaments extruded with incorporated nanocapsules (with an added agent) in a 21 mm double screw extruder from Randall Technology were used.

Figure 2. Extrusion of Functionalized PLA Multifilaments

Regarding multifilaments, three polypropylene dyes were added: ISPLEN® PP086Y1E, in blue (PLA+silica nano capsules + essential oil schinus molle), pink (PLA+silica nanocapsules with Permethrin) and yellow (PLA) in order to distinguish between them. All tests have been carried out under the same conditions to ensure that any differences between the fibres produced are the result not of the process conditions but of the additives used.
Based on the multifilaments and with a Flat V electronic bed Shima Seiki machine model SES 122FF a textile structure suitable for the manufacture of biodegradable antimalarial clothing - mesh structure - Jersey with high production capacity and economic cost was produced.

4. PRODUCT AND APPLICATION

4.1 Clothing Repellent Apparel Market and Development

Insect repellent clothing, although new on the market and at an early stage, there are huge growth opportunities around the world. In recent years, a growing trend of insect-borne diseases has been observed in gradual globalization, where insect-borne diseases in tropical and subtropical regions of the world are spreading in temperate regions, such as North America and Western Europe. Some causes of this phenomenon can be attributed to the increase in commercial activities and climate change.
Mosquito repellent clothes are a great source of protection against unpleasant insects, such as mosquitoes, mites, ticks, flies and many others. Recently, the dangers have been highlighted by the emergence of new diseases such as the Zika virus and Lyme disease, bringing serious effects if they are not treated quickly. At the moment, the best insect repellent clothes on the market are long-sleeved shirts, t-shirts, pants, bandanas, bracelets / ankles, etc. however, most of these clothes have permethrin, a synthetic chemical agent extremely effective, but which causes negative and undesirable effects on humans and the environment. In addition, mosquitoes are developing resistance to conventional repellents, making them ineffective.
The authors of this research, in addition to the development of anti-malaria technology, are also developing and designing possible applications of this technological solution in multifunctional clothing and accessories, adaptable and accessible to all.

5.TRIALS AND TESTS

In order to verify the efficacy of the proposed technological solution, an Anopheles Spp mosquito repellency test was carried out in the laboratories of the company BTS (Biotech Testing Services) on knitted samples functionalized with each of the antimalarial agents tested. The WHO Excito Repellency Test method according to WHO/CTD/WHO PES/IC/96.1 was used with male and female Anopheles Spp mosquitoes during 10 minutes of exposure through the metal box method. The assay was composed of two distinct tests, in the first test the samples were rubbed 10 times with circular movements through a device that applies a force and a constant rotation speed, similar to the abrasimeter to cause mechanical surface wear equivalent to the use. In the second test, they were submitted to 5 wash cycles (150 minutes) at 40º and with a standard detergent, after which they were rinsed and dried in a conditioned environment. In both trials, the mosquitoes were released into the test chamber containing the mesh sample treated with the antimalarial agent and the control sample, untreated, in order to observe the behaviour of the mosquitoes in terms of number of dead mosquitoes, number of mobile mosquitoes, as well as their behaviour.
Other tests were also important to assess the surface and mechanical properties of the knitted structure produced - washing strength test, abrasion resistance test, butterfly resistance test and tensile strength test.

6. RESULTS AND CONCLUSIONS

This research study found the existence of antimalarial activity for both knitted samples with incorporated nanocapsules.
As expected, it was found that the technological solution developed based on silica nanocapsules incorpo-

rating natural essential oil Schinus molle is more eco-sustainable and provides better antimalarial efficacy results when compared to silica nanocapsules integrating Permethrin.

In relation to the tests carried out subsequently, the sample obtained a satisfactory behavior in all the properties evaluated. In a combined global analysis of all the properties evaluated, this research leads to the conclusion that the 100% PLA knitted structure with encapsulated natural essential oil is the one that combines the best characteristics for the design of biodegradable antimalarial clothing.

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BRAZILIAN AGRO-INDUSTRIAL WASTES AS POTENTIAL TEXTILE RAW MATERIALS: A SUSTAINABLE APPROACH

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ABSTRACT

The textile and agricultural are important Brazilian sectors. The intense demand and productive capacity, in the current economic structure, exploits natural resources and generates waste, causing significant social and environmental risks. Considering the agro-industrial residues and sustainability guidelines, this study investigates the potential to promote new textile materials and products development. The results show that the agricultural biomass of some of the country's main crops has characteristics capable of potential textile application such as natural fibers, composites and polymers. The research results have not yet considered materials applied into industry; however, the set of variables is the assumption of new sustainable materials for the future.

INTRODUCTION

In Brazil, agribusiness plays an important role in food production, processing and transformation. According to the Brazilian Institute of Geography and Statistics (IBGE, 2021), the agricultural production harvest foresees a record of 2.5% in 2021, and to meet food needs in 2050 requires an increase of 60% in planted area, and water consumption in the midst of hydric crises (ABRAS, 2017). The abundance is the result of increased activity in the modern agricultural sector, which produces 291.1 million/ton. of waste in its largest crops (IPEA, 2012).

Although, this system presents unexplored economic opportunities, it pressures resources conservancy, pollutes and degrades the natural ecosystems, causing environmental risks and contamination for society (Macarthur, 2017; ABRAS, 2017). The use, processing and characterization of pulp-based agro-industrial waste shows itself to be a great opportunity for value generation and development of textile products (Berté, 2009; Islam et al., 2013). For Dungani et al. (2016) agricultural waste is the most abundant form of natural fiber.

The aim of this study was to present the Brazilian panorama of the main residual inputs as important source of natural fibers, considering their potential characteristics for textile application. The method displays a systematic review of the literature and the creation of a bibliometric analysis network, based on the concepts of industrial ecology (Giannetti; Almeida, 2006). The network was built by grouping bibliographic sources on the Scopus platform and transcribed by the VOSviewer Software (Universiteit Leiden). The results were compared with data from the Ministries of Agriculture and Environment of Brazil and related associations, examining research on the use of agro-waste for the development of textile materials through sustainability.

RESULTS AND CONCLUSIONS

The organic matter includes 45.3% of the total solid waste generated in 2020 in Brazil (ABRELPE, 2020). The average yield per crop year and product shows main crops being: sugar cane, corn, rice, soybean and coffee (IBGE, 2020). The latest IPEA Organic Waste Report reveals that only sugarcane produces 201,418,487 million/ton of waste, followed by soybean (41,862,129), corn (29,432,678), orange (8,825,276), wheat (3,033,315) and rice (2,530,355) (IPEA, 2012). It is possible to observe a high incidence of these terms in network analysis (Fig 1).

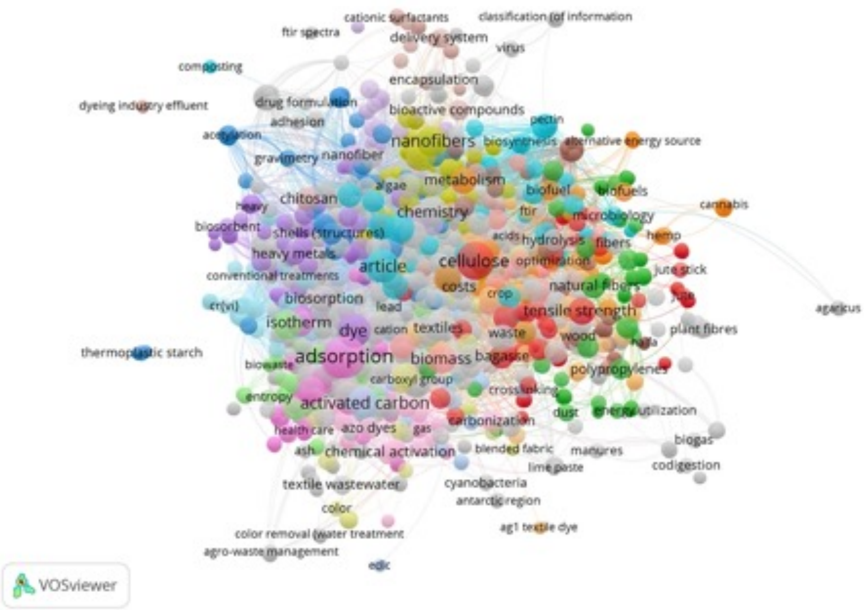

Fig.1 Network built with VOSviewer software (Universiteit Leiden) through the analysis of 305 articles and co-occurrence of 2,496 specific expressions. The agro-industrial materials with the highest co-occurrence are: "sugarcane", "fruits", "soybean straw", "cassava" and "rice". The main formats involve "bagasse," biomass," fibers," nanocrystals" and "polymers," while the applicability is in "absorption," enzymes," textile fibers, "effluents" and "ethanol. There is a great interest in the discovery of physical-chemical characteristics of materials by analyzing the frequency of the term's "crystallinity", "pH", "mechanical properties", "chemical composition" and "degradation".

Based on parameters of chemical composition, growth rate and disposition, in Brazil, soybean straw, followed by sugarcane leaf, bark and corn and sugarcane bagasse straw stand out as the most promising materials (Martelli-Tosi et al., 2017; Araújo et al., 2018). Analysis of these materials has been widely studied for textile applications, such as: the high mechanical strength of sugarcane straw fibers, and its characteristics compatible with lyocell (Costa et al., 2015; Outa, et al., 2016); rice and pineapple husk fiber with a characteristic crystalline structure similar to cotton fiber (Padro; Spinacé, 2011); corn bagasse for strengthening textile modeling bio composites (Satyanarayana, 2009); and biopolymers from açai waste fibers (Euterpe oleracea) (Wataya et al., 2015), among other materials.

It is observed, that some of the main crops in Brazil are the most adequate fibers residually, however, the implementation of material reallocation systems still demonstrates incipient advances. The research results have not yet considered materials applied into industry; however, the set of variables is the assumption of new sustainable materials for the future.

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SUSTAINABLE BIOMATERIALS FROM RENEWABLE SOURCES IN PORTUGUESE FLORA AND LOW ENVIRONMENTAL IMPACT

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ABSTRACT

In 2020, humanity went into debt to planet Earth on August 22, the day the natural resources foreseen for the whole year were used, above their natural capacity for regeneration. This fact is due to our uncontrolled consumption and industrial exploitation. In the same year, the whole world was isolated at home due to the covid-19 pandemic and through this event it was possible to see clearly how the human race has been harmful to nature. The pollution rate in countries like China decreased and it was possible to see the change from space, rivers and seas started to run again with crystal clear waters and the marine population returned as in Venice in Italy. Changes in the world system of production and consumption are of extreme urgency, the planet cries out for help. Everything we have is taken from nature, we repay with toxic products, pollution, garbage and in this way the cycle does not close; and the planet becomes a garbage dump. The solution is not utopian, just look at nature and the life cycle. All natural waste is degraded and is transformed back into compounds. The solution for a sustainable life is in biomaterials, it is necessary to replace the usual materials and thus make the economy circular and all biodegradable waste.

INTRODUCTION

According to calculations by the Global Footprint Network, a non-governmental organization in partnership with the British independent research institute New Economics Foundation. Our demand for renewable ecological resources, currently equals almost 2 Earth planets and since 2001, Overshoot Day has been anticipating more each year. Since industrialization and the beginning of environmental concern in the 1970s, our ecological debt has been increasing; and we pay high interest rates, such as food shortages, soil erosion and the accumulation of CO2 in our atmosphere, which causes changes and, with them, devastating environmental and economic costs. The nature and perpetuation of the human race are at risk and we have been inhabiting the planet for only 200,000 years. We have an urgent need for a low carbon economy, a reduction in the excessive use of natural resources and the accumulation of waste and pollution. All to avoid a major mass extinction, caused by ourselves. In 2019, the overload date was July 29th. In 2020, it was delayed by three weeks due to the pandemic, and passed to August 22. While the world population was isolated, the planet was able to recover and thus it was possible to see how our existence negatively affects life on earth.

The industries are taking slow steps in the search for solutions and in the use of alternative materials with less environmental impact. Research and production of sustainable raw materials is the solution, currently, what exists is not suitable for large-scale production. Due to the quality of the fiber, high cost, low production and the final cost of the product. The market can reduce the cost by increasing the demand for the textile and fashion industry, when the supply grows and the values tend to fall. The pandemic has accelerated all changes and the need for research in search of new materials is a priority. There are unexplored Portuguese botanical plants for the purpose of manufacturing raw materials for biomaterials with biodegradable properties. Portugal has the potential to be a producer and manufacturer of future materials and inputs for the production of fibers for the textile industry.

RESULTS AND CONCLUSIONS

The expected result is the feasibility in the industrial processing of plants native to the region of Portugal for the production of inputs that correctly handled can originate biomaterials for the various areas. Through massive research, experimental tests and analyzes, the aim is to develop by-products through easy-to-grow, fast-growing plants with low environmental impact. Mediated by a multidisciplinary team of professors, research institutions and external partnerships to be established. The objective is the industrialization of the pre-input developed in the tests, when there is a positive answer to the hypothesis, the data will be forwarded to industry experts for laboratory scale tests.

The short-term relevance of the research will be the identification of new inputs for the development of fibers for the industrial production of sustainable textiles. In the medium term, it will stimulate the local economy with the cultivation of raw materials for the production of by-products with biodegradable properties. In the long term, in addition to the environmental factor, it will be to make Portugal ecologically self-sufficient, a producer of renewable raw materials and of low impact for the planet. It is estimated to obtain future innovative materials produced in Portugal. The objective of this investigation is to prioritize innovation in sustainable materials and make the country an example of a green, circular and self-sustainable economy. Fostering a worldwide movement for the conservation of the planet, reducing the impact of the use of natural resources by applying the same method in other countries, giving priority to underdeveloped regions such as Brazil and Africa.

ACKNOWLEDGMENTS

The author thanks the professors of the University of Minho for awakening and encouraging academic research in favor of sustainable development.

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USE OF MULTI-HOLLOW POLYESTER PARTICLES AS OPTICAL BRIGHTENERS TO MEDIUM DENSITY FIBREBOARD

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ABSTRACT

This work presents the results of the project Valchromat-Rainbow, promoted by Valbopan and having as partners IPV (Polytechnic Institute of Viseu) and ARCP (Association Competence Network in Polymers). The main goal is designing a new MDF coloured in the bulk with an extended colour palette including pastel colours to be used in construction, furniture, interior claddings, interior design, shopfitting or artistic carpentry. One of the key points of the project is to increase the fibre brightness using an innovative opacifying filler based on multi-hollow polyester particles.

INTRODUCTION

Valbopan is the only producer of colored dry process fiberboards (MDF) as structural component for indoor use in humid conditions. Dry-process fiberboard (MDF) is a wood-based panel manufactured from lignocellulosic fibres (Pinus pinaster Ait.) by the “dry process”, i.e. having a fibre moisture content less than 20% at the forming stage and being essentially produced under heat and pressure with the addition of an adhesive. The production of MDF (Valchromat) with a white and pastel colors is an enormous challenge due to the characteristics of the fiber itself. Currently the production of white MDF requires the use of a high amounts of white pigments, namely the titanium dioxide (TiO2). The effectiveness of titanium dioxide particles in conferring opacity results from its excellent light scattering properties, however the high cost and the price fluctuation combined with its availability have motivated the industry to research alternatives, in order to reduce the amount of TiO2. Multi-hollow polyester particles have industrial use as opacifying agents in waterborne paints). The large refractive index difference between polymer shell and entrapped air results in scattering of incident light, increasing the opacity of a coating loaded with these particles (Monteiro, 2016).

In this work we investigate the potential of using multi-hollow particles based on styrene-crosslinked unsaturated polyester produced by a one-step double emulsion process, to replace the TiO2 in the production of white Valchromat.

RESULTS AND CONCLUSIONS

Multi-hollow polyester particles were synthesised using a single-step double emulsification procedure described in previous works (Dias, 2013) (Silva, 2020). Figure 1 shows SEM images of the MHP used as substitute of TiO2 to bleach the fibers used in the manufacture of MDF. MHP are spherical particles with holes on the surface, associated with collapse of the walls of the outer voids.

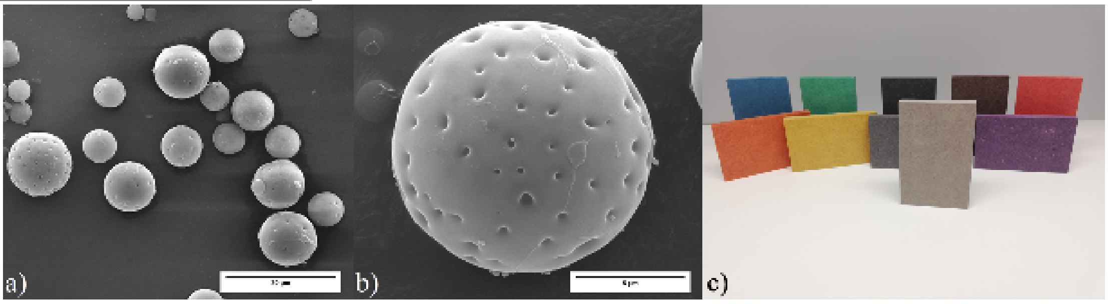

Fig 1 SEM images of MHP (magnification: (a) 4000×; (b) 16 000×) and c) coloured MDF

In order to evaluate the performance of MHP as opacifiers of MDF different mass fractions of these materials were added to wood fibres in the gluing stage. The results from colorimetry of MDF panels produced with MHP are shown in Fig. 2. It is possible to observed that the panels produced with multi-hollow polyester particles had L* values lower than the reference. The values obtained to a*and b* are very similar.

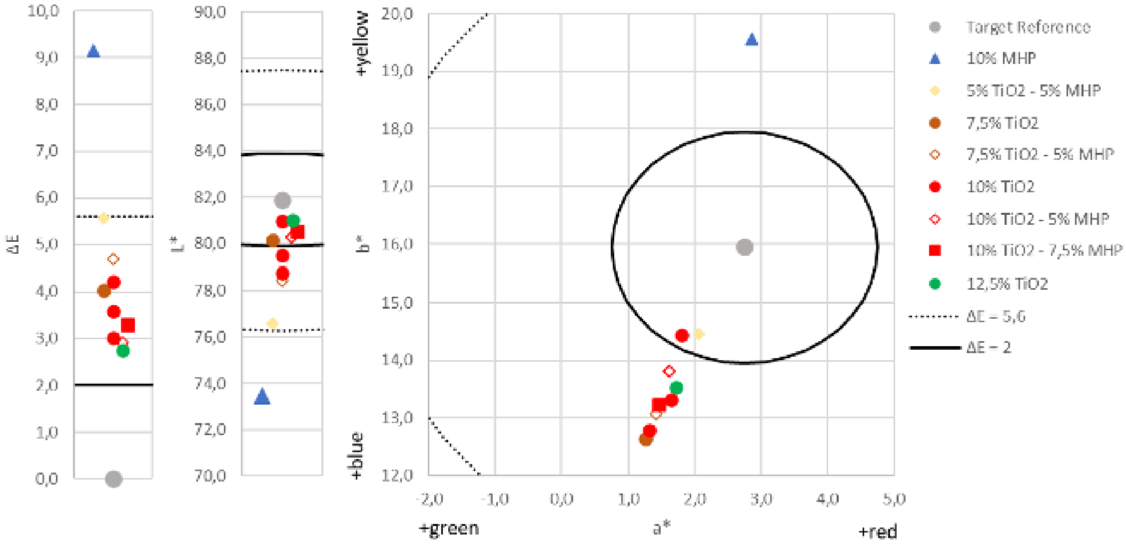

Fig 2 Colorimetry results of MDF panels produced with different amounts of MHP

ACKNOWLEDGMENTS

This work was financially supported by: Base Funding - UIDB/00511/2020 of the Laboratory for Process Engineering, Environment, Biotechnology and Energy – LEPABE - funded by national funds through the FCT/MCTES (PIDDAC). Project VALCHROMAT RAINBOW (SI I&DT - Projects in co-promotion, POCI-01-0247-FEDER-033759) in the scope of Portugal 2020, co-funded by FEDER (Fundo Europeu de Desenvolvimento Regional) under the framework of POCI (Programa Operacional Competitividade e Internacionalização

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BANANA FIBER (MUSA SP.): EXTRACTION PROCESS, PROCESSING AND ITS APPLICABILITY IN TEXTILE PRODUCTS

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ABSTRACT

Brazil is the 5th largest producer of the banana in the world, and the state of São Paulo, in the Vale do Ribeira region, the largest national producer. An alternative would be pseudostem use to obtain textile fibers. This study aimed to report the process of extraction and processing of tree banana fiber by the riverside community of "Quilombo de Ivaporunduva" and determination of the physicochemical characteristics of the banana tree fiber (cultivar AAB Prata). The main values found for the characterization of banana tree fibers were: Cellulose - External Fiber (EF): 61.30% and Internal Fiber (IF): 72.81%; Lignin - EF: 26.70% and IF: 9.13%; and Crystallinity index – EF 66.71%; IF: 61.01%. In the comparisons with fibers of recognized textile employability, similarity of properties was found, notably tensile, with other leaf fibers, such as pineapple and sisal.

INTRODUCTION

The banana is present in 129 countries around the world (Japan Echo Inc., 2005). Brazil is the 5th largest producer in the world (FAO, 2018) and the state of São Paulo, in the Vale do Ribeira region, the largest national producer (EMBRAPA, 2019). The cut pseudostem, if it has no destination, is discarded in the soil, constituting a polluting agent (Soffner, 2001). An alternative would be the use of this to obtain textile fibers. In Miracatu and Eldorado (Vale do Ribeira cities), several groups of artisans collect, process and use the banana tree fibers for the handmade manufacture of textiles on handlooms and employing various braiding techniques (Garavello, 2005). This study aimed to report the process of extraction and processing of tree banana fiber by the riverside community of "Quilombo de Ivaporunduva" (Vale do Ribeira - SP). Bleaching and dyeing tests and determination of the physicochemical characteristics of the banana tree fiber (cultivar AAB Prata) (tensile tests, SEM, DSC, TGA, FTIR, color and whiteness analysis, and XRD) were also carried out. These results were compared with those of fibers of recognized textile employability and suggestions for using were done with focus on technical applications and design.

RESULTS AND CONCLUSIONS

The main values found for the characterization of banana tree fibers were expressed in Table 1. In the comparisons with fibers of recognized textile employability, similarity of properties was found, notably tensile, with other leaf fibers, such as pineapple and sisal. The cellulase and pectinase bath was effective in degrading part of the pectin and cellulose present in the fiber, as it was able to decrease the levels of these constituents (the focus of the action of enzymes), but also affected the levels of hemicellulose. It was observed in the group of artisans of the Ivaporunduva community, that the handicraft practices with banana tree straw (before the extraction of fibers) (Fig. 1), passed on to the women artisans in the communities, remained alive and even today it is observed that in addition to being an income generating activity, it contributes to sustainability of these communities.

Characterization of banana tree fiber *(Musa sp.)*	
Crystallinity Index - External Fiber (%)	66.71
Crystallinity Index - Internal Fiber (%)	61.01
Cellulose - External Fiber (%)	61.30
Lignin– External Fiber (%)	26.70
Cellulose - Internal Fiber (%)	72.81
Lignin– Internal Fiber (%)	9.13
Tenacity - Coarse External Fiber (cN / tex)	21.88
Tenacity - Fine external fiber (cN / tex)	22.16
Elongation - Coarse external fiber (%)	3.64
Elongation - Fine external fiber (%)	4.64
Tenacity - Internal Fiber (cN / tex)	34.00
Elongation - Internal Fiber (%)	9.69
Regain – External fiber *in natura*	6.89
Regain – Internal fiber *in natura*	6.67

Table 1 Characterization of banana tree fiber (cultivar AAB Prata) (Musa sp.)

(a) (b)

Fig 1 Quilombo Ivaporunduva – Banana straw in manual loom: (a) cushion; (b) bag.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by CAPES (Coordenacao de Aperfeicoamento de Pessoal de Nivel Superior).

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EVALUATION OF THE CHEMICAL PROTECTION BEHAVIOUR OF GNP'S FUNCTIONALIZED WOOL FABRICS

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ABSTRACT

Chemical resistant materials have high demand in the growing market of Personal Protective Equipment (PPE). The combination of wool-based fabrics as a fibrous substrate with Graphene Nanoplatelets (GNP) proprieties is expected to enable massive breakthroughs regarding Chemical-Protective Clothing (CPC). GNP is known for its conductivity, resilient structure, transmittance, among others. The association of technological advances with high-performance textiles, such as wool, due to its appealing characteristics, becomes possible to achieve the functionalization potential of the material. The present work focuses on providing chemical protection while assuring comfort and well-being for the user through impregnation with GNP in polymeric-based dispersions – polyurethane (PU), a well-known versatile polymer, and chitosan (CS), which provides a more sustainable approach. Considering the outcomes, the PU 2% GNP sample provided the most promising results in parallel with CS 1% GNP regarding chemical protection.

INTRODUCTION

Given the present scientific and technological advances that extend throughout all industrial sectors, it's a rising demand for personal protective equipment (PPE) to minimize safety risks while ensuring a healthy and secure environment [1]. Therefore, Chemical-Protective Clothing (CPC) is applied when chemical risk can't be avoided or eliminated, minimizing the level of risk of exposure. Thus it's fundamental to grant a balance between chemical impermeability, user comfort and durability, resulting in SMART materials [2]. Due to the commercialization scarcity of these products, there is a propensity to secure and facilitate market access, aiming to replace bulky and heavy outdated equipment by adding integrated intelligent systems into ergonomic materials to increase ease of use and risk reduction. Although fluorocarbons reveal strong adhesion to a substrate, chemical resistance, high-temperature resistance and water resistance [3], they also portray high environmental toxicity levels [4]. So, to reach protective guidelines and standards goals, new alternatives, such as graphene, have shown promising results regarding its application as a PPE or CPC, with no reported hazardous effects [5]. The application of wool fabric as a PPE, due to its appealing proprieties [6], after functionalization with active substances, should provide a reliable solution as a CPC, as an abundant and sustainable solution that impulses a new line of protective clothing with a new material application.

The current study promotes the application and incorporation of GNP within the wool fibres while granting comfort and mobility through textile functionalization procedures (impregnation and coating).

RESULTS AND CONCLUSIONS

To advance towards the development of chemical protective textiles with a more environmentally sustainable approach, using a wool twill weave fabric (575 g/m2), produced and provided by A Penteadora S.A., as the substrate for further functionalization with GNPs provided by Graphnest, Portugal.

To guarantee an even dispersion, and decrease porosity and increase hydrophobicity, the GNPs (1% and 2%) were emulsified in two different polymeric solutions a chitosan suspension (1% to 5% w/v), conjugated with bonding agents such as acetic acid and glycerol, to study the potential of a natural polymer on the protection field of application. Those results were compared with a polyurethane (PU) solution from Tanatex Chemicals (1% to 5% w/v).

These were tested based on their performance under moisture management and chemical protection characteristics and compared to the non-functionalized wool to perceive the effectiveness of the new functionalized wool textiles through Dip-Pad-Dry impregnation properties. Towards observing the sample absorption behaviour, a water drop test was performed using a Contact Angle System OCA. Supportive guidelines and standards were consulted to develop laboratory protocols that correctly verify the critical factors for moisture management, absorption, permeability, capillarity, and moisture release. Concerning chemical protection, the evaluation approach resulted from an EN ISO 6530, a standard for material resistance to liquid penetration.

The results outcome from the electrical nature of the polymeric bases where the CS, positively charged, and therefore polar grants a more sensitive interaction with GNP and more affinity with water-based or polar solutions. As the PU is electrically neutral, having fewer affinity to polar and water-based solutions. The PU formulations exhibited a more hydrophobic behaviour than the others, showing more significant potential for liquid repellency. CS 0% behaves very closely to NF wool in most tests, although with slightly lower permeability. That may be due to the intrinsic properties of CS not being ideal to act as a barrier, or even because test conditions exceed chitosan saturation level, causing the properties of the wool to overlap polymer characteristics. These differences between the polymeric base impulse various ranged applications that begin with either prioritizing chemical protection or thermophysiological comfort.

ACKNOWLEDGMENTS

The authors would like to express appreciation for the support of Portugal2020 for funding the project nº 038328," MultiscaleProtech", granted by Fundo Europeu do Desenvolvimento Regional (FEDER). Are also thankful to CEECIND/02803/2017 and UID/CTM/00264/2019 funded by National Founds through FCT/MCTES

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UPCYCLING BASED ON TRADITIONAL WEAVING

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ABSTRACT
The garment designed in this research is inspired by traditional weaving, the bearer of a rich cultural heritage from which imagination and artistic expression speaks up. Preservation of history and cultural heritage through the creation of environmentally friendly fashion can be achieved based on the upcycling concept. With the upcycling creativity, a combination of traditional, contemporary and environmentally conscious values can be achieved.

INTRODUCTION
It is known that the textile industry is one of the world's largest polluters, as well as a major consumer of natural resources. Additionally, this issue emphasize today's fast fashion, which encourages the race for change, novelty and diversity. The fast fashion industries are forced to use inexpensive materials to enable the fast and cost-effective change of trends collection. Such cheap short-life products are more likely to result in high levels of textile waste. In order to extend the life of “used” and waste textile materials, the upcycling concept is applied, which implies the conversion and reuse of materials in a different way, without disassembly into simple elements, as opposed to recycling. This design method uses existing materials forming them in a way that is contrary to the conventional method of designing process. With the upcycling concept, discarded materials are transformed into unique garments or fashion accessories with aesthetic and ecological value. The use of hand weaving technique as a processing tool is a relevant method that is used today not only as a visual choice, but also as a solution to a current problem.

DEVELOPMENT
The research starting point, for the used style and weaving techniques is a hand-woven blanket from the 1930s from the area of Macedonia. The characteristics of this woven fabric are manifested by the use of natural fibers: cotton warp threads and silk weft threads, which emphasize the characteristic eye motif (Fig. 1a). This motif is used for personal interpretation and creation of three new motifs (weaves), while maintaining structural integrity, which requires great skill and knowledge as well as represents a harmony of different weaving techniques (Fig. 1b). To apply the upcycling concept based on inspiration of traditional fabric, a skirt, designed as part of the collection presented at expo Zagreb Design Week 2018, was used. The skirt was made of tulle, a woven fabric made from natural raw material - cotton and silk, thus creating an additional link with the traditional woven fabric. Parts of the skirt were used as warp and weft "threads", for making three woven fabrics, according to previously defined weaves, which will unified form a whole new garment (Fig. 1c). This type of creation recognizes a combination of nostalgia and sentimentality and takes the opportunity to make striking pieces of clothing, such as the corset in this case (Fig. 2). This process is the highest form of upcycling.

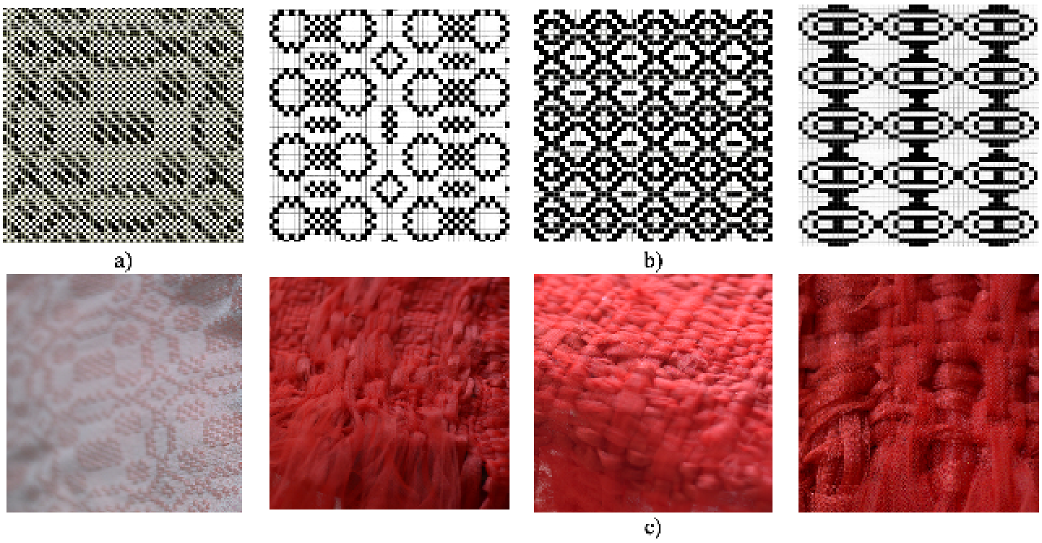

Fig.1 a) Traditional woven fabric and motif weave; b) Weaves of interpreted motifs;
c) Fabrics woven according to interpreted motifs

Fig.2 Upcycled textile product

CONCLUSION

The garment created on the basis of traditional woven fabric according to the concept of upcycling, represents an exceptional wealth not only in aesthetic, but also in historical, cultural and ecological terms. This way, the true goal of sentimentality is defined, finding a contemporary use of fabric that distracts it from the original past and adapts it to future problems. Ecology and sustainability have become the biggest trend in fashion today, so upcycling would be one of the ways to solve the crucial problem of waste disposal in the textile industry. Through this approach, the past is viewed in a new light, which is why upcycling is used as a means of expression rather than as an exclusive goal.

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INFLUENCE OF FIBRE DIAMETER ON THE WOOL-BASED FELTS PROPERTIES

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ABSTRACT

The current work aims to study the influence of the fibre diameter in the wool-based felts performance, mainly in terms of air permeability (AP) and mechanical properties, considering a range of felts prepared with blends of wool fibres with distinct diameters – namely 14, 16 and 18 μm. The felted structures were tested for physical characteristics (thickness, aerial mass), air permeability, and tearing and tensile strength, in a comparative analysis in order to assess the effect of fibre diameter. The results show that the fibre diameter has implications in the structure of the three-dimensional structure, leading to different behaviours in terms of the properties studied within this work.

INTRODUCTION

Felts have been following human evolution for centuries and due to their unique properties, are showing an increased interest in the scientific and academic communities. Felts can be found in a wide variety of applications, ranging from musical instruments, industrial sound insulation until fashion, resultant from their three-dimensional structure that can not be achieved by knitting and weaving [1]. Felt structure comprises the entanglement of fibres, in such a way that the fibres establish stable interactions among them forming a three-dimensional structure with fibres and pores formed by the surrounding air [2].

MATERIALS AND METHODS

a) Fibre Properties and Felt preparation

Three types of wool fibres were used in the production of felted structures (14, 16 and 18 μm), producing an outcome of 6 samples: 14μm (100% wool 14 μm), 16μm (100% wool 16 μm), 18μm (100% wool 18 μm), 14/16μm (50% wool 14 μm/50% wool 16 μm), 14/18μm (50% wool 14 μm/50% wool 18 μm) and 16/18μm (50% wool 16 μm/50% wool 18 μm).

The fibres used in the samples preparation were supplied by FEPSA, Felt Hat Bodies, and stored in the same conditions and felts were produced using the same machine's parameters following the conventional felting method. The final products obtained are cone-shaped felted structures (29 cm of height, 22 cm of base diameter) of 110 grams of initial raw-material, produced on the same conditions.

b) Testing Methods

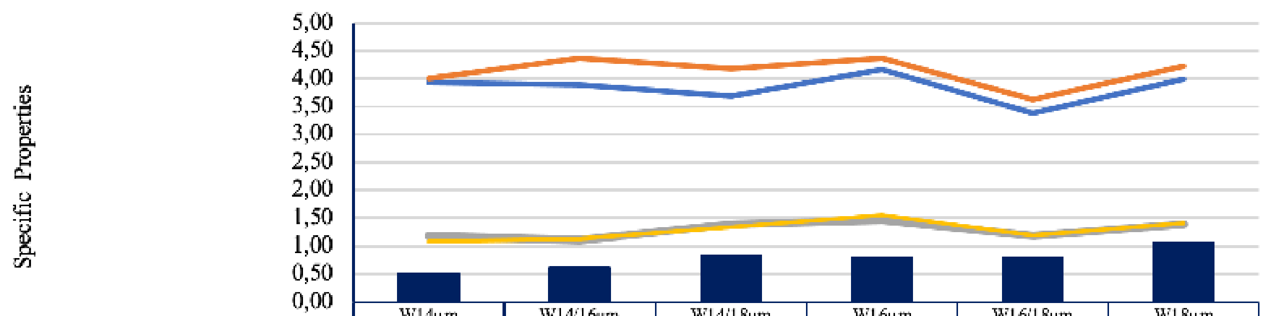
The following tests were carried out: mass per unit area (ISO 9073-1:1989); thickness (ISO 9073-2:1995); dimensional stability (ISO 5077:2007); air permeability (ISO 92137:1995); tensile strength (EDANA 20.2-89); tearing strength (ASTM D5733-99).

RESULTS AND CONCLUSIONS

Once the studied felts present some oscillations in absolute values of thickness and mass per unit area, a factor denominated compaction factor (cf) was introduced to allow a more comprehensive result analysis. cf represents [mass per unit area (g/m2)]/[thickness(mm)].

In terms of AP, the samples present regular behaviour, as can be observed in Figure 1. The results in specific terms present an increase of the AP values while fibre diameter increases. The felts obtained from different mixtures of fibres demonstrate a similar behaviour in general, with the increase of the fibre diameter to result in higher properties of AP. From the results presented in Figure 1, it's possible to observe that the values obtained in W14/18μm, W16μm and W16/18μm are very similar. Although, it's fairly visible the influence of the fibre diameter in the AP in the remaining samples.

The mechanical parameters for tensile and tearing strength represented in Figure 1, shows that it is not possible to establish a linear correlation with the fibre diameter. Although, every result is comprised in a similar range, less than 0.78 N/(cf) in case of tensile strength and less than 0.46 N/(cf) between samples. In this way, it is possible to conclude that the fibre diameter is not strongly affecting the mechanical performance of the felts.



	W14μm	W14/16μm	W14/18μm	W16μm	W16/18μm	W18μm
Air Permeability [(l/m^2/s)/cf]	0,51	0,62	0.82	0.79	0.79	1,06
Tensile Strength Longitudinal [(N)/cf]	3,94	3,89	3.69	4.17	3.39	3,99
Tensile Strength Transversal [(N)/cf]	4,01	4,36	4,18	4,37	3,62	4,22
Tear Strength Longitudinal [(N)/cf]	1,18	1,11	1,39	1,46	1,17	1,38
Tear Strength Transversal [(N)/cf]	1,08	1,13	1.33	1.54	1.19	1,40

Figure 1: Results of specific air permeability, tensile and tear strength test.

The results obtained within the various tests undertaken shows that the physical characteristics, like aerial mass and thickness, are strongly influenced by the fibre diameter. In the same way, a linear relationship between the fibre diameter and AP can be established as increasing the fibre diameter leads to higher values of AP and consequently, more breathability. Contrarily, relationships between the fibre diameter and the mechanical performance, tensile and tear, were not found.

ACKNOWLEDGEMENT

The authors would like to express appreciation for the funding provided by Portugal 2020 through the project nº POCI-01-0247-FEDER-038435, NanoFelt – "Nova geração de estruturas de feltro com base em fibras inovadoras recorrendo à nanotecnologia".

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INFLUENCE OF ORGANIC AND INORGANIC REINFORCEMENTS ON THE MECHANICAL PROPERTIES OF HOMECOMPOSTABLE BIOPOLYMERS.

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ABSTRACT

This work compares the tensile properties of different masterbatches produced in an extrusion process with a home compostable biopolymer reinforced with organic and inorganic materials, of cellulosic and mineral origin, respectively, in ratios of 2.5, 10 e 20 % w/w. The tensile tests performed allowed to verify a trend to improve the Young's Modulus of the masterbatches made with cellulosic fibres, especially wood. In this case, it was obtained an increase of 43% of this property for an incorporation of 20 % w/w of wood.

INTRODUCTION

Synthetic polymers (produced from petroleum) like PET, PVC, PE, PP, PS and PA, have been applied in the manufacture of packaging for a long time given the very attractive characteristics inherent to them. However, the excessive use of these types of materials, in single use plastics, has led to serious environmental problems, since most of them are neither recyclable nor biodegradable, seriously compromising the stability of the environment [1].

In this sense, the European Commission has been creating regulations regarding the way plastic products are designed, used, produced and recycled, in order to make them more sustainable in the EU [2]. The objective is to replace these plastics by a biodegradable, compostable and recyclable polymers. Biodegradable polymers are characterized by the ability to convert to water and carbon dioxide through the action of microorganisms, while a compostable plastic is a material that in the specific conditions, such as temperature, can be turned into compost. Usually, these conditions are only found in an industrial composting facility. However, the polymer used in this work is homecompostable, meaning it can be compostable in a home environment. Currently the mechanical properties of biodegradable polymers, especially homecompostable, aren't great, that's why the objective of this work was to increase the properties through the combination with vegetable and mineral reinforcements. The polymer used in this work incorporates raw material from plant origin, thus the carbon present in the polymer backbone came from atmospheric CO2.

The masterbatches used in this work were produced by mixing the homecompostable polymer and several organic and inorganic reinforcements, in a twin-screw corotating extruder. The objective of these masterbatches is to use them in an injection processes to produce sustainable single use packaging. A total of 12 masterbatches were produced, in a twin-screw extruder with a temperature profile between 165-130oC (die), using the homecompostable polymer and four different reinforcements, namely: two organic (wood and coconut fiber) and two inorganic (slate and slag residues). The amount of incorporation of the reinforcements in the polymer were, 2.5, 10 and 20 % w/w. Tensile tests specimens of each sample were then produced using an injection machine, and tested in a tensile test according to the standard ISO 527.

RESULTS AND CONCLUSIONS

The results from the tensile tests are shown in Table. 1. In this table is presented the Young's Modulus of each masterbatch, and these results are then compared with the Young's Modulus of the neat polymer (Reference). It can be observed from Table. 1 that the samples who incorporated wood fibres are the ones who presents the greatest increase in this mechanical property. The sample that contains 20 % w/w of wood shows an improvement of the Modulus of around 43%, with to the reference sample. The samples made with cellulosic fibres (wood and coconut) demonstrates a trend to in present better values of Young's Modulus than the samples made with mineral reinforcements. This aspect probably happens due to the cellulosic fibres are anchoring better with the polymer through chemical bonds, than the mineral residues who are chemical inert and thus doesn't form chemical bonds with the polymer, but only physical bonds who are much weaker than the other type of bond.

Sample	Reinforcement (wt%)	Young's Modulus (GPa)	Variation of the Modulus (%)
Polymer (Reference)	-	0,77	-
Polymer + Wood	2,5	0,89	15,58
	10	0,9	16,88
	20	1,1	42,86
Polymer + Coconut	2,5	0,71	-7,79
	10	0,78	1,30
	20	0,88	14,29
Polymer + Slate	2,5	0,79	2,60
	10	0,87	12,99
	20	0,84	9,09
Polymer + Slag	2,5	0,69	-10,39
	10	0,85	10,39
	20	0,78	1,30

Table 1. Tensile test results.

This study shows the potential to use the organic and inorganic reinforcements to improve the mechanical properties of homecompostable polymers to use for several applications, such as packaging. In particular, there are significant improvements on the mechanical properties of the samples who incorporate cellulosic fibers, especially wood. On the other hand, the mineral reinforcements didn't improve so much the mechanical properties as expected, probably because of the inert nature of these materials.

An acknowledgment to B4logic, which sells these materials with low environmental impact.

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NEW GENERATION OF HIGH-TECH NONWOVENS THROUGH NANOTECHNOLOGY

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ABSTRACT

In this scientific research, the main objective was to achieve a simplified and low environmental impact process to nano functionalization of wool-based felts (sheep and rabbit fibers), produced from the conventional felting process. The objective of this functionalization at the nanoscale was to create a new generation of high-tech nonwovens, using Zinc (Zn) and Silver (Ag) nanoparticles (NPs), to obtain self-cleaning, anti-static and anti-microbial properties. From the results obtained, Zn NPs presented themselves as the most effective in self-cleaning and anti-microbial properties, whereas Ag nanoparticles in the anti-static behaviour.

INTRODUCTION

One of the major roles for the wool-based felt industry is to obtain fabrics with high durability, lightness, that don't unravel, easy to handle, mouldable, versatile, in conjunction with the fundamental parameters of density, resilience, strength and porosity [1]. These products are characterized by their unique three-dimensional structure – which comprises the entanglement of fibres, in such a way that the fibres establish stable interactions among them – that cannot be achieved by knitting and weaving [2], [3]. Functionalization at the nanoscale – in addition to its natural structural properties – stands out in creating a new generation of high-tech felts. In this sense, the main goal of this scientific research is to study the functionalization of wool-based felts using nanotechnology – Ag and Zn nanoparticles – to obtain self-cleaning, anti-static and anti-microbial properties, by a low impact exhaustion method. In the case of this type of fibres, with a high percentage of proteins, specifically keratin, the ionizable groups associated with this type of biomolecules reveal themselves as potential binding points for metallic particles [4]–[6].

RESULTS AND CONCLUSIONS

Two types of felted materials were used for further functionalization – including sheep wool fibre and rabbit wool fibre – using NPs exhaustion technology of Ag and Zn obtained commercially from IoLiTec-Ionic Liquids Technologies GmbH in a low impact and simplified chemical and mechanical process. The functionalization was tested in concentrations of 2,5%, 5,0% and 10% w/w. Electron microscopy images and X-ray spectroscopy were used to analyse the presence and the dispersion (Not presented). The antibacterial effect under study – presented in Figure 1 – allows verifying the intended effect of antibacterial reduction, where the best performance is achieved for the Zn's NPs in relation to those of Ag. Moreover, the percentage of 2.5% of Zn reveals itself to be of great importance, as it will be the one that has the best benefit quantity/effect desired, verifying that after 2 hours there is a bacterial reduction in the order of 70%, being quite close to 100% after

6 hours of testing. The best results are seen in the samples of 5% and 10%, there are no noticeable differences between them for S. aureus bacteria, only visible for E.coli. The percentage of 2,5% can be seen with high potential for S. aureus, presenting a bacterial reduction of 80% after 6 hours of testing.

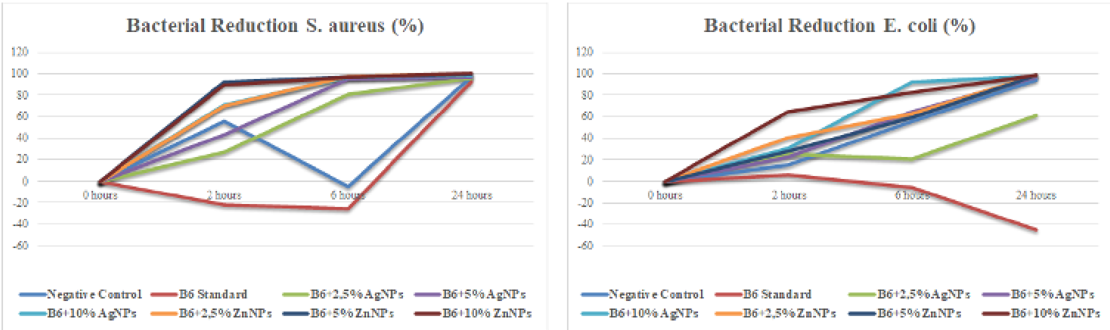

Figure 1: Results of antimicrobial activity in sheep wool felts (B6).

Through observation of ΔE difference obtained in CIELAB referential, it was possible to conclude that for sheep wool samples, the addition of Zn NPs allows achieving the self-cleaning effect, not presented before the functionalization, with the best results at a concentration of 5% w/w. In the other turn, the addition of silver NPs did not motivate an increase in this aspect of the study (Results Not presented). In terms of the antistatic effect, it was measured the time (in seconds) that it took to decay to a half load of the generated potential (150 V). In both materials – sheep and rabbit felts – the addition of Ag NPs presented the best result in the study, already expected due to the conductive nature that silver presents. The percentage of 10% w/w of Ag NPs was the condition chosen to satisfy the assessed requirement (Results Not presented). Considering the approach made to the intended functionalities, it is possible to conclude that the functionalization process was successfully executed and for the 3 properties requested, 2 are fully satisfied using Zn NPs with relatively low concentrations, with very satisfactory performance levels, namely concerning self-cleaning ability and antimicrobial activity. In turn, Ag NPs proved to be an added advantage about the anti-static effect, being able to potentiate this behaviour quite prominently for samples of felts produced with rabbit wool, despite being only in high concentrations.

ACKNOWLEDGEMENT

The authors would like to express appreciation for the funding provided by Portugal 2020 through project nº POCI-01-0247-FEDER-038435, NanoFelt – “Nova geração de estruturas de feltro com base em fibras inovadoras recorrendo à nanotecnologia”.

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CIRCULAR ECONOMY: MECHANICAL CHARACTERIZATION OF RESIDUES FROM DIFFERENT STAGES OF TERRY TOWEL PRODUCTION

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ABSTRACT

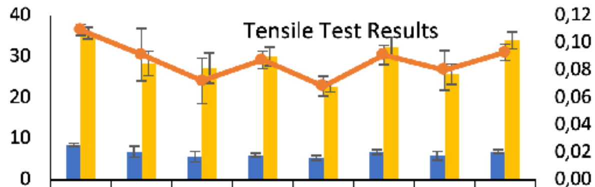
The main objective of this work was to achieve the potential use of the textile waste collected from different processing stages into recycled yarns. In this context, after the waste collection and its conversion into yarns, the mechanical properties of the filiform structures generated were evaluated, in order to allow the influence of the processing phase. An outcome of 6 yarn samples was obtained – C1 (80% weaving raw waste+20% raw CO), C2 (60% weaving raw waste+40% raw CO), D1 (80% weaving dyed waste+20% raw CO), D2 (60% weaving dyed waste+40% raw CO), E1 (80% weaving preparation waste+20% raw CO), E2 (60% weaving preparation waste+40% raw CO) – and compared with the standard yarns – A (100% raw CO) and B (80% dyed CO+20% raw CO). All yarns were produced with Ne 8 and compared in terms of: linear density (ISO 2060); twist (ISO 17202:2002); tensile strength – (ISO 2062:2009). Results show that the yarns produced with residues from the preparation phase present better mechanical performance. In the residues from weaving preparation, an increase of up to 8% in breaking force and up to 13% in elongation at maximum force was verified.

INTRODUCTION

More than 462 billion euros of waste are lost annually, and it is estimated that more than half of fast-fashion clothing will be disposed of in less than a year. Overall, every second, a garbage truck with "textile waste" is landfilled or incinerated. This concept overloads resources and creates devastating impacts on both society and the environment. If the textile industry increases recycling values, it can capture 92 million euros of waste and reduce the negative impacts [1], [2]. In general, awareness of waste management has not yet reached a satisfactory level, as the information available on regulations is deficient and financial limitations. The general principle, agreed by all, to protect the environment is to "reduce, reuse, repair or recycle", and disposal should be the last available resource [2]. Recycling is a key concept in modern waste management [3]. This study intended to analyse the mechanical properties of the individual residues from different stages of terry towel production. For this, yarns were produced from the different stages of terry towel production, approximately the same linear mass and by the same spinning process (open-end), with two percentages of waste – 80% and 60%. This methodology allowed us to effectively compare the raw materials under study, guaranteeing an increase in knowledge of the residues of the textile productive sector. Every sample was tested in terms of tensile strength.

RESULTS AND CONCLUSIONS

For the development of the current work, 8 different staple yarns were used, two of them to serve as a reference – 100% Raw Cotton and 100% Dyed Cotton – and 6 obtained from the spinning of fibrous waste collected at different processing stages: 2 yarns from weaving raw material with 80% and 60% of residues; 2 yarns from weaving dyed material with 80% and 60% of residues; 2 yarns from preparation to weaving with 80% and 60% of residues. The objective of introducing a dyed standard yarn was to evaluate the influence of dyeing on the mechanical properties of the yarns and to ensure a basis of comparison with the dyed residues. The results from the tensile strength tests are shown in Figure 1, which demonstrates that for the same material composition, comparing the yarns produced with 60% and 80% of residues, the lowest percentage of residues corresponds to greater maximum strength, elongation at break and tenacity. On the other hand, comparing the non-dyed yarns, the extremes indicate that the highest losses correspond to the yarns obtained from weaving residues in all analysed results and it is observed that the residues from the preparation stage are 5-13% better in terms of resistance to the maximum force in the different percentages studied. Moreover, it is still interesting to conclude that comparing the standard yarn 100% Dyed Cotton with the yarns obtained from weaving dyed waste, it was possible to achieve similar values in the resistance to the maximum force and tenacity and better results in elongation at break in the yarn produced with 60% of dyed residues.



	A	B	C1	C2	D1	D2	E1	E2
Maximum Force (N)	8,5	6,8	5,6	6,0	5,4	6,7	5,9	6,8
Elongation at Break (mm)	35,7	28,3	27,1	30,0	22,6	32,2	25,6	33,9
Tenacity (N/tex)	0,11	0,09	0,07	0,09	0,07	0,09	0,08	0,09

Figure 1. Tensile test results: A- 100% Raw cotton; B- 80% dyed cotton+20% raw cotton; C- weaving residues (C1 80%, C2 20%); D- weaving dyed residues (D1 80%, D2 20%); E- preparation to weaving residues (E1 80%, E2 20%);

In conclusion terms, the results show that a larger amount of waste naturally impairs the mechanical properties, even if not drastically. Comparing the results, the yarns produced with 60% of waste residues shows, in all cases, higher values – differences between 7,5% and 20%. Analyzing the loss of properties of the production phases, it is possible to understand that between the residues from the pre-stage of weaving and the residues of weaving, a loss among 6%-12% was verified. The residues from the weaving preparation stage and which were consequently subject to less mechanical impact from the weaving operations demonstrate better results in the studied properties.

ACKNOWLEDGMENTS

The authors would like to express appreciation for the funding provided by Portugal 2020 through project nº POCI-01-0247-FEDER-045244, TerryPlanet – “Desenvolvimento de felpos com base em conceitos de economia circular”.

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INFLUENCE OF DEW RETTING DURATION ON THE CHARACTERIS-TICS OF FIBRES EXTRACTED FROM LINSEED FLAX STRAW FOR LOAD BEARING APPLICATION

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ABSTRACT

This work was conducted to investigate the potential of fibers extracted from linseed flax straw for geotextile applications. Four different batches of linseed flax were studied, having different dew retting durations (i.e., from 0 to 14 weeks). Furthermore, a method comprising horizontal breaker rollers, a thresher and then a breaking card was used for extracting continuously the fibers. The different analyses (fibre content inside the starting material, their chemical composition, the length of extracted fibre bundles, the tensile properties of individual fibres, and the fibre purity and yield) show that this resource can be considered for load bearing engineering applications such as geotextiles and composite materials.

INTRODUCTION

Natural fibres get the attention of many researchers, due to versatile properties, renewability, and environmental concerns. For engineering applications specifically, jute, flax, hemp, sisal, kenaf, abaca, and pineapple are nowadays the most used natural fibers (Ghosh et al., 2009). For the next future, linseed flax straw could be an alternate source of bast fibres for technical textiles. In France, 26,000 ha were cultivated for linseed flax in 2017 (Le Ravalec et al. 2020).

In a previous study, Ouagne et al. (2017) extracted successfully fibres from non-retted straw. This mode of extraction was aggressive, and it resulted in the reduction of the mechanical and morphological properties of fibres (350 MPa and 35 GPa for strength and modulus, respectively). In fact, it is not adapted for producing load bearing reinforcement textiles.

Dew retting is a key process when considering fibre extraction. In this study, linseed flax was cultivated in 2018 and 2019 in the South-West of France, and straws were collected after different dew retting durations (up to 14 weeks) after seed harvesting. The influence of dew retting on chemical composition, fibre content inside the straw, fibre length, and tensile properties of individual fibres was studied on fibres extracted using a traditional breaking fluted roller/breaking card route, less aggressive than the fibre opener used by Ouagne et al. (2017).

RESULTS AND CONCLUSIONS

Fibre content inside linseed flax straw (from the Angora cultivar) was found to be globally independent of the dew retting duration, varying from 29% to 32%. The chemical composition of bast fibre samples manually extracted from straws with different dew retting durations is presented in Table 1. As this duration increased, the pectin content was progressively reduced whereas the cellulose content logically increased at the same time. A dew retting duration of at least 12 weeks appears as appropriate to favour fibre extraction.

Depending on the batch, the fibre purity inside the obtained lap was between 67% and 85%, and the fibre yield varied from 23% for batch number 1 to 26% for batch number 4 (Table 2). In addition, the longest dew retting durations (12 and 14 weeks) better preserved the length of fibre bundles. The reduction obtained in the pectin content with longer dew retting durations (batches 3 and 4) contributed also to more resistant individual fibres, for tensile strength and especially for elastic modulus.

Table 1. Chemical composition of the bast fibers inside different dew retted batches of linseed flax straw.

Batch number	1	2	3	4
Dew retting duration (weeks)	0	2	12	14
Pectin content (% of dry matter)	4.4±0.2	4.4±0.1	3.0±0.3	2.7±0.3
Cellulose content (% of dry matter)	62.1±0.4	65.5±0.4	73.9±0.6	75.7±0.4

Table 2. Length of the extracted fibre bundles, mechanical properties of the individual fibres, fibre purity and fibre yield (expressed in proportion to the straw weight) for all the treated batches (n.d., not determined).

Batch number	1	2	3	4
Fibre length (cm)	10.9±5.9	11.1±5.3	13.1±7.1	12.8±7.0
Tensile strength (MPa)	832±578	700±402	922±364	855±348
Elastic modulus (GPa)	41.9±24	40.9±22	56.5±20	52.3±17
Fibre purity (%)	67	85	82	73
Fibre yield (%)	23	n.d.	n.d.	26

To conclude, this work shows that load bearing quality fibres can be produced from linseed flax when a traditional breaking rollers/breaking card route is used. Particularly, the tensile properties are much higher than the ones obtained previously using an “all fibre” opener. The tensile properties and particularly the modulus increase for higher dew retting times. This may be due to an easier extraction from the stems following the decrease of the pectic cements linking the fibres. The tensile properties (≈ 880 MPa and 54 GPa for strength and modulus) are globally situated in the same range of values of hemp extracted using scutching/hackling equipment, and in the lower values of textile flax also extracted by scutching/hackling. These properties combined to a fibre production of about 25% of the stem mass indicate that linseed flax straw processed following the study conditions can lead to the production of fibres fully suitable for engineering load bearing applications such as geotextiles or composite materials.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding attributed to the GEOFIBNET collaborative project by Région Occitanie (France), and the FEDER operational program.

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DEVELOPMENT OF MULTI-FUNCTIONAL WOVEN FABRICS FOR THERMAL PROTECTIVE CLOTHING BY OPTIMIZING STRUCTURAL AND CONSTRUCTIONAL PARAMETERS

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ABSTRACT
Previously conducted research as well as determination of development segment in the form of improvement of woven fabrics currently available on the global market of technical textiles, represents the basis for future extensive research of design and manufacture of multifunctional non-flammable woven fabric, which will be conducted within the project "Development of multifunctional non-flammable woven fabrics for dual purpose". The goal is to design the fabric (maintaining the existing protective and tensile properties, but also to improve it by optimizing the structural and constructional parameters) which will optimally meet the requirements of the global market and combine the characteristics of non-flammability (protection against heat), comfort, breathability, resistance and durability.

INTRODUCTION
Detailed analysis of the current state of the global technical textiles market in the segment of protective non-flammable woven fabrics for military and civilian use, determinate the absence of woven fabric that fully integrates all crucial properties (protection, comfort and durability). Protective clothing must maintain body temperature stable and allow the flow of air and water vapour through the material, i.e. allow heat regulation, while not being heavy, with rough surface that causes irritation, or hindering body movement. Commercially available non-flammable woven fabrics composed of a mixture of different natural and synthetic fibres (in different proportions) have satisfactory FR (flame retardant) properties, while some other properties, such as usability resistance (FR resistance and colour fastness to washing, abrasion and light), are not technically satisfactory.

DEVELOPMENT
A team of scientists from the University of Zagreb, Faculty of Textile Technology, conducted a series of research in the segment of constructional and structural parameters of woven fabrics and the entire designing and manufacturing process for the above-mentioned specific purpose. The conducted analyses of the mentioned researches give a wide overview of micro, meso and macro level of woven fabrics. An overview of the fibres properties used to meet a high degree of woven fabrics thermal protection, such as aramid fibres, especially m-aramid fibres, viscous fibres of reduced flammability (CVFR), modacrylic fibres (MAC), carbon fibre (CF), etc., and fibres of other characteristics (cotton, PA) which are extremely important for improving the properties of dual - use fabrics, was also obtained. The research clearly defines the influence of structural and constructional parameters of woven fabrics on the effectiveness of protection properties, but also on the comfort properties in the form of water vapour permeability, porosity and the like (Kiš, 2019, Kovačević, 2020, Kiš, 2020, Schwarz, 2020).

Therefore, the task and goal were set to design a woven fabric that maintain the existing protective and tensile properties, but with improvements in the segment of water vapour permeability through the material, as well as the bending properties. These improvements are planned to be achieved by optimizing the structural and constructional parameters of woven fabrics, all within the Project "Development of multifunctional non-flammable fabric for dual use" (KK.01.2.1.02.0064). This Project started 17.08.2020. and is a collaborative project of the Croatian textile factory Čateks tt and the University of Zagreb, Faculty of Textile Technology financed by the European Regional Development Fund, whose implementation will last 3 years.

The aim of the project is to develop a new multi-functional fabric for dual use, which due to its comprehensive and advanced properties will be a novelty in the global market of a wide range of protective textiles, in the development of which extremely large financial resources and knowledge are invested. Great attention is focused on the production of woven fabrics using new raw materials and constructions, but also surface treatments. Therefore, in this Project, extensive research will be undertaken in both segments of new product development, the technological process of designing and manufacturing woven fabric, and finishing processes. The Project main goal is to solve the currently problem, which is the inability to meet market demands for a woven fabric that combines the key features of a protective woven fabric in the final application conditions.

Fabric properties that are planned to be achieved by incorporating all influential parameters at the micro and meso-level (improvement of tensile properties, wear resistance, thermo-physiological properties, etc.) in all research segments are properties of non-flammability, higher durability, better colour fastness and comfort. It will represent a significant technological breakthrough, and provide the product with innovation, uniqueness and competitiveness.

ACKNOWLEDGMENTS

This work has been supported by the European Union from the European Regional Development Fund under the project KK.01.2.1.02.0064 Development of multifunctional non-flammable fabric for dual use.

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FIBER EXTRACTION OF PHILIPPINE BAMBOO SPECIES 'KAWAYAN TINIK' (BAMBUSA BLUMEANA) AND ITS TEXTILE POTENTIAL

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ABSTRACT
Mechanical-chemical fiber extraction methods: mechanical softening/crushing-combing (MSC), mechanical softening/decortication (MSD), and chemical-mechanical softening and washing (CMSW) to extract textile fiber from Bambusa Blumeana. The physical tests such as breaking strength, fiber fineness, gum content, total and alpha celluloses, water and alcohol-benzene extractives, moisture content, and lignin content of the 'kawayang tinik' fiber. Spinnability tests were also conducted to determine the suitability of the extracted 'kawayang tinik' fiber for spinning into yarns..

INTRODUCTION
In this study, three mechanical-chemical fiber extraction methods were performed. First, the mechanical softening/crushing-combing (MSC) extraction method wherein nodes of Bambusa blumeana were first removed, and the remaining parts were cleaved in a longitudinal direction with 2-3 mm in thickness before feeding into the mechanical softening machine to flatten and partially open. The partially opened bamboo slats were manually combed by steel brush to extract the fiber. Second, the mechanical softening/crushing-decortication (MSD) method wherein Bambusa blumeana were first manually cleaved to longitudinal thin slats with 80 cm in length and 2-3 mm thickness using bolo before feeding to the mechanical softening machine to flatten and partially open and the partially opened bamboo slats were decorticated to extract the fiber. Third, the chemical-mechanical softening-washing (CMSW) method wherein the Bambusa blumeana were first manually cleaved to longitudinal thin slats with 50 cm in length and 2-3 mm thickness using bolo and were then immersed in NaOH solution (concentrations of NaOH were 1%, 2%, 3%, 4%, and 5%) at room temperature (26 – 34 ºC) for 14 h or less. The chemically-treated slats were flattened/crushed through a mechanical softening machine before washing, acid neutralization, washing, and drying.
The physical properties of the extracted bamboo textile fibers such as strength and fineness were determined following the ASTM D3822: Single Fiber and ASTM D1577-07 test methods respectively. Chemical components like residual gum and moisture content or moisture regain were analyzed using the modified Jute Technology Research Laboratory (JTRL) and PTRI Standard Method of Test for Moisture and Moisture Regain of Textile Material (PNS/PTRI 37 - 1992) respectively. The celluloses and extractives were analyzed following the Technical Association of Pulp and Paper Industry (TAPPI) test methods while lignin content was determined using the modified FORPREDICOM method. Spinnability testing of the extracted bamboo fibers was done using the mini-spinning machine with pure bamboo or with a blend of cotton or polyester fibers.

RESULTS AND CONCLUSIONS
Based on the fiber recovery results of Bambusa blumeana using the three mechanical-chemical fiber extraction methods, the mechanical softening/decortication (MSD) extraction method has the highest fiber recovery percent yield of 45%. However, the proximity analysis and physical property tests showed that the most

cost-efficient method in extracting Bambusa blumeana fiber is through chemical-mechanical softening-washing (CMSW) and has the highest potential of up-scaling by using a big degumming vessel for washing or fiber pretreatment right after chemical-mechanical softening.

The spinning of pure bamboo fiber was done using the mini-spinning machine with a blend of cotton and another with polyester fibers. The blend ratio was 75/25 cotton/bamboo and 75/25 polyester/bamboo. Based on the spinnability test results of the fiber extracted Bambusa blumeana, the yarn realization of cotton/Bambusa blumeana blend is 58.33% while polyester/Bambusa blumeana blend is 59.83%. Moreover, a higher yarn count (10Ne) was achieved with polyester/bamboo blended yarn compared to cotton blended bamboo with 5Ne count. These results entail that finer and stronger yarn is produced from the polyester/bamboo blend and thus more applicable for textile and apparel end-use.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding of the Department of Science and Technology- Philippine Textile Research Institute (DOST-PTRI) through Republic Act (RA) No. 11260, the General Appropriations Act (GAA) of the funding of the research.

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NATURAL FIBER REINFORCED COMPOSITES AND APPLICATIONS OF IN HIGH END SECTORS

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ABSTRACT

In recent years, there has been considerable interest in the use of natural fibers to replace synthetic fibers such as glass, aramid and carbon as reinforcement material in polymer matrix composites. By evaluating the performance of natural fiber reinforced polymer composites, it is possible to produce composite materials that can meet ecological needs. Natural fibers are an alternative to synthetic fibers due to their abundance in nature, low density, biodegradable properties, higher specific strength, stiffness, and inexpensive. In addition, natural fiber composites used in various applications often have some disadvantages such as moisture absorption, low impact resistance for structural applications and service life. This study aims to reveal the types and properties of fibers used in natural fiber reinforced composites and the relationships between fiber and matrix element with considering that parameters such as matrix, fillers, fiber contents, fiber processing and production procedures are effective on the mechanical properties of materials. Including improvement procedures to overcome the disadvantages of plant-based fibers, issues that need to be investigated in order to expand the potential application areas of natural fibers are highlighted. This study is concluded with the properties of natural fiber reinforced composites are discussed from the specified directions, potential application areas are shown and their potential uses in smart materials are revealed.

INTRODUCTION

With the increasing demand for materials, besides the production of composite materials with advanced properties, the interest in the production of environmentally friendly materials is increasing. At this point, studies on the production of environmentally friendly composite materials with good mechanical properties using natural fibers have increased in recent years (Peças et al., 2018).

Natural fibers have advantages such as biodegradability, light weight, low price, life-cycle superiority, and satisfactory mechanical properties as well as disadvantages such as water absorption, low thermal stability, incompatibility with hydrophobic matrices, and propensity to agglomeration (Li et al., 2020).

In order to eliminate these disadvantages of materials hybridization with chemically modified fibers is recommended. Because by adding another form of hydrophobic fiber to hydrophilic fiber composites, a good interface formation can be achieved with the hydrophobic matrix. In addition, with this method, the resistance to moisture is increased and the deterioration of the properties of NFPC can be reduced (Ahmed et al., 2021).

This study aims to reveal the fiber type, ratio, fiber / matrix interfaces used in material production, considering the mechanical properties of natural fiber reinforced composites that affect their end use areas. In addition to these, improvements to be made to ensure that these materials are used more widely in structural applications are emphasized and information is given about their potential advanced applications.

RESULTS AND CONCLUSIONS

In the study, it has been observed that diameter, length of fiber, fiber content of the fibers used in the production of natural fiber reinforced composites have a significant effect on the material. When the recent studies on this subject are examined, it has been seen that the studies on reducing the disadvantages of natural fiber reinforced composites have increased. In this study, the proposed methods for eliminating the disadvantages of natural fiber reinforced composites are included, and it has been tried to guide future studies to increase the use of these composites in advanced applications and smart materials.

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EFFECTS OF FIQUE FIBER TYPE AND ORIENTATION ON THE MECHANICAL PROPERTIES OF EPOXY-FIQUE BIOCOMPOSITES

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ABSTRACT
This work compares the tensile and flexural mechanical properties of biocomposites from an epoxy matrix and three types of Fique arrangements: Fique powder, industrial nonwoven Fique Fiber mat, and a unidirectional fique fiber mat. The mechanical tests performed allowed to identify significant differences in the mechanical properties of the manufactured biocomposites. Furthermore, it was found that fique powder acts as a filler for the epoxy matrix while the fique fiber mats reinforce the polymeric matrix.

INTRODUCTION
A natural fiber extracted from Fique plants (Furcraea Andina), a native plant of the Andean region of South America, has recently shown potential for the manufacture of biocomposites for engineering applications (Muñoz-Velez, 2018). Recent research has shown that this f iber can compete with other known natural fibers to produce reinforced biocomposites (Hidalgo -Salazar, 2018). Therefore, in this work, the mechanical characterization of biocomposites from different types of Fique (Fique powder, industrial nonwoven Fique Fiber mat, and a unidirectional fique fiber mat) with an epoxy matrix was carried out. The effect of the type of fique arrangement used in the tensile and flexural mechanical properties was evaluated. This would allow appreciating the real possibilities of this natural fiber to be used as reinforcement for polymer matrix composites. The tensile and flexural tests were performed at 23 °C with an INSTRON universal testing machine model 3366 according to the ASTM D 638-14 and D 790-17 respectively (Hidalgo-Salazar, 2018). All the results were taken as the average value of five samples. All the biocomposites were manufactured using the resin film infusion technique and the Epoxy-Fique weight fraction was 70/30 (% wt/wt).

RESULTS AND CONCLUSIONS
Figure 1 shows the different biocomposites produced, it is observed that resin film inf usion technique allows manufacturing homogeneous sheets with well-distributed Fique Fibers. The influence of Fique Fibers addition on the Epoxy mechanical properties was evaluated and presented in Table 1. This study shows that there are substantial differences in the mechanical properties of biocomposites. In general terms, the addition of fique fibers improved the mechanical properties of the epoxy matrix. Among the biocomposites, it is observed that the fique powder acts as a filler, while the best results were obtained with the non-woven and unidirectional fique mats.

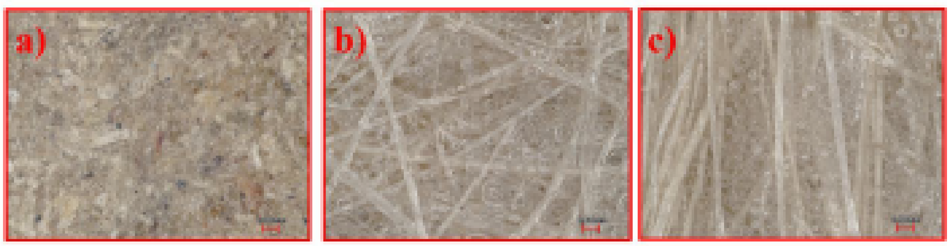

Fig.1 The biocomposites made from epoxy resin and a) fique powder, b) industrial nonwoven Fique Fiber mat and c) unidirectional fique fiber mat

Table 1 Tensile and flexural properties of EP and EP-Fique biocomposites

Sample	Tensile and Flexural Properties*				
	Tensile properties			Flexural properties	
	Modulus (MPa)	Strength (MPa)	Deformation at break (%)	Modulus (MPa)	Strength (MPa)
EP	34 ± 10[a]	9.7 ± 3.3[a]	90 ± 15.3[a]	83 ± 24[a]	2.3 ± 0.6[a]
EP-Fique Powder	925 ± 200[b]	8.8 ± 0.6[a]	2.8 ± 1.1[b]	594 ±85[b]	12.4 ± 1.2[b]
EP-Fique non-woven	1074 ± 198[b]	16.6 ± 1.7[b]	3.8 ± 0.8[b]	390 ± 65[b]	12.9 ± 0.2[b]
EP-Fique unidirectional	2000 ± 414[c]	36.6 ± 4.3[c]	9 ± 0.8[c]	1014 ± 159[c]	21.2 ± 4.6[c]

a–b) Different letters in the same column indicate significative differences ($p < 0.05$).
*Mean of five replications ± standard deviation.

Usually, biocomposites with a higher aspect ratio (L/D) may contribute to higher reinf orcing efficacy because the contact between the reinforcing elements and the matrix occurs over a larger surface. Among the Fique mats, the unidirectional mat exhibits better mechanical properties. Previous studies suggested that at an orientation of 0 °(parallel to the applied load) biocomposites possessed a much longer fiber structure due to minimal fiber breakage that aiding in strengthening the biocomposite structure by a homogeneous distribution of the load (Radzuan, 2020). Finally, this work opens the possibility of considering non-woven Fique fibers as a reinforcement material with a high potential for the manufacture of thermoset biocomposites for automotive and building applications.

ACKNOWLEDGMENTS

We acknowledge to the Universidad Autónoma de Occidente (Cali-Colombia), for the technical and financial support. Also, the authors thank to “Compañia de Empaques de Medellin” (Medellin-Colombia) for providing the nonwoven industrial Fique mat.and “Empaques del Cauca” (Popayan-Colombia) for the untreated Fique fibers.

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BIOMASS DERIVED COMPOSITE MATERIALS AND TECHNOLOGIES FOR A CIRCULAR ECONOMY

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ABSTRACT
This presentation focuses on the recent research activities dealing with bio-based materials at the Council for Scientific and Industrial Research (CSIR), South Africa. The activities at CSIR (Polymers and Composites division) cover a broad range of research and development in the field of biocomposites which include design and fabrication, processing, structural analysis and characterization of composite materials. Research programs encompass a wide range of activities from developing bio-based materials for industrial applications to 3D printing of bionanocomposites. Current presentation will focus on the use of natural fibre based composites for various industrial applications such as in the transport sector. Changing environmental regulations and implementation of circular economy, has seen a movement towards replacement of petroleum based materials with bio-based products and emergence of waste residues as a bio-based feedstock. The development of natural fibre based sandwich panels and laminates for use as secondary structures in automotive and aircrafts will be presented. Studies related to conversion of post-harvest agrowaste residues to value-added bio-based composite products will also be highlighted.

INTRODUCTION
The reduction of non-renewable resources due to growing demand for energy and the accompanying emissions of greenhouse gases are driving communities and governments to shift energy related policies towards cleaner and sustainable energy sources [Shafie, 2012]. Consequently, there is growing interest in developing non-conventional fuels and materials derived from biorenewable sources [Limayem, 2012]. Biomass, a non-fossil and complex organic-inorganic solid material derived from natural and anthropogenic processes, can be converted to biofuels and chemicals [Sudiyani, 2013]. The key advantage of utilizing biomass is that it is renewable on a human timescale unlike fossil fuels.
The current problems of depleting petroleum reserves, global warming and environmental pollution has stirred global efforts to finding a bio-based feedstock (as a replacement for petroleum based reserves) from which bio-based chemicals and materials can be derived. Waste biomass comprises of agricultural (bagasse, corn stover, straws) and industrial residues (saw dust) and are composed of valuable materials that can potentially be utilized as a raw material feedstock to produce high-value products. Currently most of the wastes residues are traditionally land-filled or burned resulting in air pollution and environmental hazards. Lignocellulosic biomass comprises of cellulose, hemicellulose and lignin. Cellulose can be converted to cellulose nanomaterials (cellulose whiskers and cellulose nanofibres) by the process of acid hydrolysis. Cellulose nanomaterials has the potential to be used in fields ranging from material science to biomedical engineering due to its excellent mechanical properties, tailorable surface chemistry, biocompatibility and biodegradable nature. Hemicellulose composed of C5 and C6 sugars have xylan fractions which possess good barrier properties and have applications in the packaging sector. Lignin is a by-product of lignocellulosic biomass utilization processes such as pulping and biomass refinery. It is a highly cross-linked aromatic polymer and possesses flame retardant and antioxidant properties. The presentation will

highlight the conversion of natural fibres and biomass waste residues to value-added bio-based products.

RESULTS AND CONCLUSIONS

Figure 1 presents the xylan-alginate films that were successfully prepared using the solvent casting method. It was found that with an increase in the alginate content there was an increase in the tensile strength and Young's modulus of the films. The water vapour permeability (WVP) values of the samples registered a decrease with increase in alginate content.

Fig.1 Xylan-alginate samples

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by DSI Biocomposites Centre program, DSI Biorefinery program and DSI Waste program.

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NATURAL FIBER COMPOSITES WITH ENCYMATICALLY ENHANCED FIBRE MATRIX ADHESION

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ABSTRACT
Flax fibres are treated with the fungal enzyme laccase for a sustainable modification of the fibres. The aim of this study is to use the laccase induced ring opening reaction of lignin in order to covalently bind reactive species (bifunctional coupling agents) to the fibre which can then improve the fiber matrix interaction.

INTRODUCTION
The interphase between fibre and matrix plays an essential role for the composites' properties. Conventional reinforcing fibers such as glass, aramid or carbon fibres are usually treated with a sizing or coating in order to improve the adhesion to the polymer matrix.
A sustainable method of improving the adhesion between natural fibre and epoxy matrix is presented: Flax fibres are treated with laccase from a Cerrena unicolor polypore fungus in presence of dopamine. Laccase catalyzes a ring opening reaction of lignin, inducing bonds to the coupling agent, which can in turn bond to the epoxy matrix. Surface images of fibres, mechanical studies of laccase treated fibres as well as pull out tests on single fibre microcomposites made of laccase treated fibres are presented.

RESULTS AND CONCLUSIONS
In nature, laccase is part of a fungal enzyme cocktail that degrades wood and cellulosic materials. It is therefore essential to control that the flax fibres are not damaged by the laccase: The tensile strength and Young's modulus of the fibres remain constant during treatment, even at conditions harsher than used in the following bonding study. Laccase and dopamine treatment deposits an additional layer on the fibre surface, as seen in a brownish hue on the fibre, in SEM and AFM micrographs of the fibre surface.
Interfacial Shear Strenghts (IFSS) determined in single fibre pull out tests are shown in Fig. 1. The force displacements curves on single fibre microcomposites are evaluated by two different methods, highlighting different aspects of the fracture behavior. The apparent shear strengths τ_{app} are calculated from the maximum force. They characterize the maximum load the interphase is able to bear, relevant in practice. However, it is nonlocal, averaged over fibre regions of strongly differing local shear stress. The apparent shear strength values increases by 30% due to the laccase dopamine treatment. The local interfacial shear strength, τ_d , is determined by modeling the overall shape of the force displacement curve. It increases by about 30% as well, from (38 ± 8) MPa to (50 ± 10) MPa.

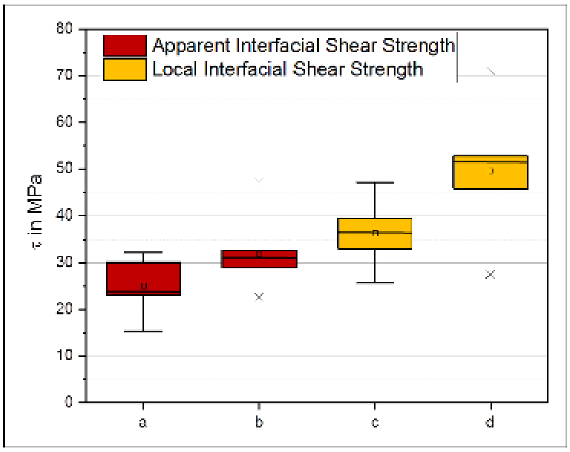

Fig.1 (a,b) apparent IFSS (τapp) and (c,d) local IFSS (τd), 7 evaluable samples each, modification with buffer only (a,c) and buffer + laccase + dopamine (b,d).

Laccase is a fungal enzyme that can infer a ring opening reaction in lignin and thereby bond substrates to natural fibre. If these substrates are bifunctional, they have the potential of also binding to a corresponding matrix.

ACKNOWLEDGMENTS

The laccase treatments were performed in the group of Dr. Annett Werner at the Institute of Bioprocess Engineering of the Technical University of Dresden, Germany.

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APPLICATION OF TAGUCHI METHOD FOR OPTIMIZING PROCESSING PARAMETERS OF COMPRESSION MOULDING AND FABRICATION OF A GREEN COMPOSITE WITH IMPROVED MECHANICAL PERFORMANCE

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ABSTRACT

A shift towards a greener environment has made the researchers focus on producing sustainable materials. It's been observed from the literature that processing parameters are also among the factors that had played a crucial role in achieving the best possible properties. Henceforth a study will be made to optimize the different processing parameters such as temperature, pressure, and time by using the Taguchi technique for a compression moulding machine, to produce a green composite using polylactic acid (PLA) as a polymer and jute woven fabric as a reinforcement. This study focuses on obtaining the best possible combination of processing parameters for producing a composite with good mechanical performance. An analysis will be performed by Minitab software using the Taguchi technique to study the influence of the processing parameters on the performance of the composite.

INTRODUCTION

Tremendous research is going towards the use of natural fibers as reinforcements in polymeric composites. In recent days, biodegradable polymers are gaining huge attention intending to develop the concept of sustainability. PLA is a well-known biopolymer used very often due to its balanced mechanical strength. Considering their advantages like low density, reasonable specific strength, high toughness, and other factors such as biodegradability and renewability, natural fiber reinforced composites (NFRC) are slowly replacing conventional materials in the fields such as automotive and marine. Properties of NFRC will depend on fiber size, fiber treatments, weight % and orientation of reinforcements (S S Yusuf, 2020).

One of the widely used method for producing thermoplastic composites is compression moulding and it can produce thin, strong, stiff, and lightweight composites. There does not exist huge damage to the fibers as they are not subject to any shear loads which is one of the vital elements in this methodology (Rajkumar Govindhraju, 2014). It is understood that the process parameters have a great effect on the quality and properties of the composite (Mohammad Reza Ketabchi, 2019). The important parameters that have a substantial effect on the mechanical properties are temperature, pressure, and heating time (Rajkumar Govindhraju, 2014). It is indeed crucial to optimize the parameters to achieve the good mechanical performance of the composites. Few researchers have tried to do trial and error methods to find the optimal combination of the processing parameters. However, it is very essential to have them studied scientifically. In this study, the Taguchi approach a design of experiments (DOE) method was taken to optimize and study the influence of the processing parameters on the mechanical performance of the composite. The composites will be manufactured using compression moulding where PLA and jute woven fabric are used as polymer and reinforcement respectively. The pre-consolidated sheets are prepared by distributing PLA powder uniformly on the jute woven fabric and subjected to temperature and pressure. Later, pre-consolidated sheets are stacked and compressed to obtain the composite samples. The samples will be tested for the mechanical properties and subsequently, results will be analysed by using the Taguchi approach and Minitab software.

RESULTS AND CONCLUSIONS

The three processing parameters such as temperature, pressure, and time are taken to study. Each parameter is taken at 3 levels and the values are shown in Table 1. To reduce the number of experiments, Minitab software is used to generate the L9 orthogonal array based on the Taguchi method of design, and the orthogonal array is shown in Table 2. After performing the mechanical tests, the optimum combination of parameters for achieving the best mechanical performance will be obtained.

Level	Temperature (°C)	Pressure (bar)	Time (minutes)
1	170	30	5
2	180	35	10
3	190	40	15

Table 2 L9 Orthogonal Array of Processing Parameters of Compression Moulding

Experiment Number	Temperature (°C)	Pressure (bar)	Time (minutes)
1	170	30	5
2	170	35	10
3	170	40	15
4	180	30	10
5	180	35	15
6	180	40	5
7	190	30	15
8	190	35	5
9	190	40	10

Table 1 Processing Parameters of Compression Moulding

Subsequently, Minitab software will be used to analyse the data by using the Taguchi method to study the significant effects of the processing parameters on the quality and performance of PLA/Jute composite. An empirical equation will be developed based on the analysis of the experimental data with the usage of the Taguchi method and Minitab Software.

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ISBN 978-989-54808-5-2

ICNF 2021

5th International Conference on Natural Fibers

Materials of the Future

Book of Abstracts

Edited by R. Fangueiro

ISBN 978-989-54808-5-2

Organized by: Fibrenamics, Universidade do Minho, SCIENCENTRIS From Knowledge to Market