Mechanical Characterization of the Green Coconut Fiber for Application in the Footwear Industry

Célia Regina da Costa
School of Arts, Sciences and Humanities of University of Sao Paulo (EACH-USP)
03828-000 Brazil (55)11 44882043 celiareginadacosta2012@gmail.com

Regina Aparecida Sanches
School of Arts, Sciences and Humanities of University of Sao Paulo (EACH-USP)
03828-000 Brazil (55) 11 3091-8803 regina.sanches@usp.br

Júlia Baruque Ramos
School of Arts, Sciences and Humanities of University of Sao Paulo (EACH-USP)
03828-000 Brazil jbaruque@usp.br (55)11 3091-8116

Jorge Boueri
School of Arts, Sciences and Humanities of University of Sao Paulo (EACH-USP)
03828-000 Brazil jjboueri@usp.br (55)11 3091-1024

Bárbara Maria Gama Guimarães
School of Arts, Sciences and Humanities of University of Sao Paulo (EACH-USP)
03828-000 Brazil barbara.guimaraes@usp.br

*Corresponding author e-mail: celiareginadacosta2012@gmail.com

Abstract
In the tropical countries, the green coconut water consumption generates a great problem with the fruit final destination. To minimize this problem, it is necessary to find applicability to the residues. In this sense, this study had as its objective to investigate the characteristics of the green coconut fiber, from the fruit disposed in the city of Francisco Morato – Sao Paulo, and to compare them to the characteristics from other natural fibers, to check the viability of application of these fibers in the manufacturing of shoe parts. It was made a biological maceration on the fibers and traction and microscopy tests were run. The results showed that the green coconut fibers have potential related to other natural fibers studied in literature, to be used as reinforcement in the manufacturing of shoe parts and other design products.

Keywords: *Cocus nucif*era *L.*, characterization of the green coconut fiber, footwear, traction test, microscopy optical, fiber extraction.

Introduction

The needs required by the modern man led to a rampant consumption of the non- renewable resources which manifests in damage to the environment, such as accumulation of non-biodegradable trash on soil and issue of pollutant gas on the atmosphere (Leite *et al.*, 2010).

The synthetic fibers were initially developed with the objective of improving the characteristics of the natural fibers properties and cooperating when it comes to the vulnerability of the textile industries towards problems in the agricultural production of fibers (Barbosa, 2002). Nowadays, the synthetic fibers derivative from oil had an increasing index in its applications. However, due to the raise of environmental problems emerged from the processing or discard of its products, there was the need to look for biodegradable and renewable raw materials.

In the footwear industry, the components used in the manufacturing are pollutant, essentially when it is about the leather tanning with chromium salts. In this phase there is a great amount of solid and gaseous waste thrown in the effluents (Ganem, 2007); and also when it comes to the manufacturing of other parts of the shoe, such as the sole. The polyurethane (PU), which is a synthetic polymer with a high performance used in the manufacturing of insoles and soles, also generates pollution during its processes, and issue toxic substances in the environment (Fernandes, 2008).

There is a pursuit for new materials that ease these environmental problems, thus there is an interest in research for the development of compounds that use natural fibers as alternatives to replace products that damage the environment (Visconte, 2006). Natural fibers have been used by men for millennia to produce fabric and techniques for textile production, and are present among the world cultures (Duarte *et al.*, 2012).

The use of natural fibers is associated to the factor that they are biodegradable, less abrasive and have a low cost related to the synthetic fibers (Leite, 2010). The green coconut fibers come from renewable sources, originating from the food industry waste in the tropical countries, where the green coconut water is consumed, and its use also collaborates in the reduction of solid waste that is issued in the environment (Visconde, 2006).

The mature coconut fiber is already applied in the industry and agriculture, yet the fiber of the green coconut bark does not have much applicability due to the high moisture of the barks (85%), and the fibers characteristics disfavor certain applications that are often employed with the dry coconut fibers. Its use by the fibers finishing industries is not high because of the lack of knowledge on its properties (Rosa *et al.*, 2001).

The coconut fibers are lignocellulosic materials collected from the coconut mesocarp, the coconut palm fruit (*Cocus nucifera L.*) mainly grown in the tropics. The fibers have hardness and mechanical resistance due to the high lignin, which also serves as a protection for the tissue against the action of microorganisms (Leite *et al.*, 2010).

These characteristics of the green coconut fibers increase its possibilities of use in some shoe parts, for the rigidity provided by the lignin gives a good resistance. Another important element found in these fibers is the preservation against the bacteria attacks, for the lignin has a high natural preservation towards other natural fibers already studied in literature. Table 1 shows percentages of total lignin found on natural fibers:

According to Corrandini *et. al.* (2009), there is still few studies aiming to the use of green coconut fibers despite of their characteristics comparing to other natural fibers.

Embrapa (Brazilian Agricultural Research Corporation), together with a metallurgy industry, developed an equipment to separate the dust and the fiber from the green coconut shell. This equipment made feasible the agricultural use of the fiber, and also provides substrate to the insole manufacturing for the footwear industry (Silveira, 2008).

The main stages for the fiber extraction are (Silveira, 2008):

- **Trituration:** the residue is cut by a roll of fixed knives, which shave the barks, and then goes through fixed hammers that are responsible for the product crushing;

- **Squeezing:** withdrawal of moisture and toxic salts used along the plant cultivation;

- **Fiber selection and dust:** the fibers are separated from the dust with a machine that has a roll of fixed knives and a perforated sheet. The material is whirled along the machine axis, and by a density difference the dust comes out through the sheet holes, and the fiber comes out at the end of the course;

- **Fiber sieving:** the fiber impurities are separated with a thick sieve;

- **Dust thermal treatment:** to eliminate the microorganisms it is undergone a rotative heater at 80°C for 20 minutes;

- **Pressing:** the dust and fiber, which are little dense, are compacted with a hydraulic press to reduce the transportation costs.

The use of green coconut fibers can generate the production of low-cost materials, and also reduce the solid waste resulting from the increasing coconut consumption (Santos, 2002). The knowledge on the chemical, mechanical and other characteristics of the green coconut is substantial to understand its use potential (Corrandini, 2009).

In Brazil, coconut fiber was used in the manufacture of seats car, but was replaced by polyurethane after 1990s. Currently, the sector that has been highlighted is gardening, due the ecological factors in the protection against the extinction of the tree fern (*Dicksonia sellowiana Hook*). The fiber of coconut can be applied in sectors of design objects for home, furniture, composites, geotextiles and others.

The objective of this study was to investigate some mechanical characteristics of the coconut fiber for a possible applicability on the footwear industry, in order to contribute to its potential in the manufacturing of certain parts of the shoe, replacing the ones already made in a very environment-pollutant way (MARTINS *et al*., 2013).

1. Materials and methods

The fruit were collected in disposal areas of the coconut water businesses, in the city of Francisco Morato, greater São Paulo region.

1.1 Chemical characterization

Literatures that relate the lignin with the possibility of green coconut fiber use in the manufacturing of shoe parts that need rigidity were researched.

1.2 Treatment and characterization of the coconut fibers

First, the green coconut fibers were separated from the external part of the bark, then they were subjected to a biological maceration process, in which the coconut barks remained immersed in water for 4 weeks so that the spontaneous anaerobic fermentation of the vegetable matter could happen and help in the woody bundles liberation (Castilhos, 2011). After this stage, the fibers were left in water for 24h more for removal of water-soluble extractives and impurities originary from the maceration process, and air-dried for 24h.

1.3 Samples acclimatization

The fibers were previously acclimatized for a period of 7 days at 20°C and 65% relative humidity. The samples were conditioned in conditioning tool for textiles or conditioner brand Mesdan (Climatest model M250-RH, Italy).

1.4 Optical microscopy

Analyses were analyzed usind an stereo-microscope (Leica, model MS5, Germany)

coupled to video camera to capture digital images (Vista Protos IV, model VPC

122/CH, 1/2" CCD, Britain). The images were captured and processed by the system code 2000 Video Analyser 250 (Mesdan, Italy).

1.5 Mechanical characterization – tension tests

Assays for determining the tensile properties and elongation were performed on a dynamometer ("tester machine") Instron (model 5569, Norwood, USA). The load cell used for testing was a maximum of 10 N (1 kgf or approximately). Were employed rubberized grip jaws with dimensions of 2.5 x 2.5 cm. The distance between the grips was 25 mm and the displacement speed during testing was 50 mm / min. 20 fibers were tested. Were determined averages, standard deviations and coefficients of variation of breaking load (N), tenacity at break (cN / tex), elongation at breaking load (mm), percentage elongation at break (%) and Young's modulus (N / tex).

2. Results and Discussion

2.1 Chemical composition

According to the researched literatures on the total lignin present in the green coconut fibers, approximately 44%, gives the fiber a good resistance and a protection against microorganism attacks, crucial aspects for the use in the footwear industry (Razera, 2006). The high lignin favors the fibers flexibility (Corrandini, 2009; Pannirselvam *et al*., 2005).

2.2 Optical microscopy

The optical microscopy consisted in analyzing the fiber surface, providing an image produced by the interaction between light and fiber, with a wide field of observation. Figure 1 shows the optical microscopy done on the surface of the green coconut fibers, with a magnification of 20 times, and Figure 2 shows the same fiber with a magnification of 32 times. The superficial aspect is shaped like a "twisted shoelace", which gives the fiber a better rigidity.

2.3 Mechanical properties – tension tests

The mean values of linear density, tenacity and tensile strain of the green coconut fibers were determined; the experimental values are on Table 2.

The tenacity values of the green coconut fibers are lower when compared to the ones found in literature on jute and sisal. The tensile strain, on the other hand, is higher than the other natural fibers found in literature (Table 3).

The green coconut fibers can be divided in fine, medium and thick. The experimental results showed that the most resistant fibers are those with higher linear density.

The experimental results indicate that the mechanical properties of the green coconut fibers present a good resistance and demonstrate that these fibers can be applied in shoes. The high lignin provides a good flexibility quality to the fiber.

These results show that the green coconut fiber can be used in parts of shoe manufacturing, for they have good mechanical characteristics, easy production, availability among other advantages.

3. Conclusion

Nowadays we can see a variety of materials used in the shoes manufacturing, such as the polyurethane (PU), used in soles and midsoles due to its resistance to abrasion and good adherence to the ground; the polystyrene, used in heels due to its resistance to impact; the ABS (acrylonitrile butadiene styrene), which has an excellent resistance to break. However, the most used material in the footwear industry is the leather, due to its ideal characteristics like good flexibility and wear. Nevertheless, these materials processes are highly pollutant and come from non- renewable raw materials. There is a trend in using natural materials in the footwear industry because of the scarcity and the environmental problems created during the manufacturing processes. In this sense, the green coconut fiber is being studied for the use in the footwear industry.

From the obtained results, we can conclude that the high lignin in the green coconut fibers provides a good flexibility and a natural protection against microorganism attacks. The tenacity is close to the one found in literature, although it is higher than the values found for other natural fibers, such as: sisal fiber (1,5%) and jute (0,7%). Ergo, the green coconut fibers have potential, compared to other natural fibers researched in literature, to be used as reinforcements in shoe parts manufacturing.

The pursuit for sustainable materials is important to application in sectors that need renewable raw materials and need to reduce their environmental pollution, as the footwear industries and home decoration objects.

References

ASTM (American Society for Testing and Materials) ASTM D 3822. 2001. *Standard Test Method for Tensile Properties of Single Textile Fibers*. Pennsylvania: C ASTM International.

ABNT NBR ISO 139 (Associação Brasileira de Normas Técnicas). 2008. *Têxteis – Atmosferas - padrão para condicionamento e ensaio.*

Barbosa, M. Z. (2002). Perspectivas para a demanda de algodão e de fibras sintéticas (pp. 55-56). *BNDS Relato Setorial*.

Castilhos, L. F. F. (2011). Aproveitamento da fibra de coco. Instituto de Tecnologia do Paraná: TECPAR.

Corrandini, E., Rosa, M. F., Macedo, B.P., Paladin, P. D., & Mattoso, L. H. C. (2009). Composição química, propriedades mecânicas e térmicas da fibra de frutos de cultivares de coco verde (pp. 837-846). Jaboticabal: Revista Brasileira de Fruticultura 3.

Correa, C. A. (2000). Caracterização Mecânica: tração e impacto**.** São Carlos: Associação Brasileira de polímeros - ABPol.

Duarte S. A. Y., Queiroz, , R. S. , Sanches, R. A., Vicentini, C. R. G., & Dedini, F. G. (2012). Ethnobotany of Natural Fibres - Bactris setosa (tucum) in a Traditional Rural Community (pp. 18-20). Poland: Fibres & Textiles in Eastern Europe 2.

Fernandes, I.P.M.F. (2008). Dispersões aquosas de poliuretano e poliuretano-ureia. Concepção do produto e metodologias de caracterização. Dissertação de Mestrado- Escola Superior de Tecnologia e de Gestão de Engenharia Química.

Ganem, R. S., (2007), Curtumes: aspectos ambientais. Biblioteca Digital Câmera dos Deputados. [Online] Avalaible: http://bd.camara.gov.br/bd/bitstream/handle/bdcamara/1281/curtumes_aspectos_senna.pdf?sequence=1(December 7, 2012).

Leite, M. C. A. M., Furtado, C.R. G., Couto, L. O., Oliveira, F. L. B. O., & Marabezi, T. R. C. (2010). Avaliação da biodegradação de compósitos de poli (Ɛ- caprolactona)/fibra de coco verde (pp. 339-344). São Carlos: Polímeros. 20.

MARTINS, A. P., WATANABE, T., SILVA, P. L. R., BORELLI, C., MARCICANO, J. P. P., & SANCHES, R. A. (2013). Aproveitamento de fibra de coco verde para aplicabilidade têxtil. Use of young nut coir fiber for textile applicability. Rio de Janeiro: Redige v.4, n.2.

Pannirselvam, P. V., Lima, F. A. M., Dantas, B. S., Santiago, B. H. S., Ladchumanadasivam, & Fernandes, M. R. P.(2005). Desenvolvimento de projeto para produção de fibra de coco com inovação de tecnologia limpa e geração de energia (pp.56-61). Brasilia: Revista Analytica 15.

Razera, I. A. T. (2006). Fibras lignocelulósicas como agente de reforço de compósitos de matriz fenólica e lignofenólica. Tese de Doutorado, Universidade de São Paulo, São Carlos.

Romero, L. L., Vieira, J. O. W. M, Martins, R. F, & Medeiros, L. A. R.(1995). Fibras artificiais e sintéticas**.** Brasilia: BNDS. Relatório setorial.

Rosa, M. de F., Abreu, F. A. P., Furtado, A. A. L., Brigido, A. K. L., & Norões, E. R. V. (2001). Processo agroindustrial: obtenção de pó de casca de coco verde. Fortaleza: Embrapa Agroindústria Tropical.

Santos, M. S. (2002). Propriedades térmicas e mecânicas de materiais à base de PET pós- consumo e cargas de coco. Dissertação de Mestrado, Universidade Federal do Rio de Janeiro.

Saville, B. P. (2007). Physical testing of textiles. Cambridge: The Textile Institute Woodhead Publishing Limited.

Silveira, M. S. (2008). Aproveitamento das cascas de coco verde para produção de briquete em Salvador-BA. Dissertação Pós–graduação em Gerenciamento e Tecnologias Ambientais no Processo Produtivo – Ênfase em Produção Limpa, Escola Politécnica da Universidade Federal da Bahia.

Visconte, L.L.Y., Ishizaki, M. H., Furtado, C. R. G., Leite, M. C. A. M., & Leblanc, J. L. (2006). Caracterização mecânica e morfológica de compósitos de polipropileno e fibras de coco verde: influência do teor de fibra e das condições de mistura (182-186). Polímeros: Ciência e Tecnologia 16.

Table 1. Lignin in natural fibers

Natural fiber	Total lignin (%)
Mature coconut	48,3±1,9
Green coconut	44±1,0
Banana tree	16,8±1,0
Jute	15,9±0,5
Sisal	12

Font: Razera 2006

Table 2. Mean values of the linear density, tenacity and tensile strain of the *Cocus nucife*ra.

Specimen	Linear density (tex)	Tenacity at Break (cN/tex)	Tensile strain at Break (%)
Mean	20.7	12.91	22.38

Font: Author 2012

Table 3. Tenacity and tensile strain of some fibers

Fiber	Tenacity (cN/tex)	Tensile strain (%)
Jute	26,5	0,7
Sisal	35,3	1,5
Green coconut	12,91	22,38

Font: Razera 2006 and Saville 2007

Figure 1- Green coconut fiber (magnification 20x)

Font: Author 2012

Figure 2 – Green coconut fiber (magnification 32x)

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