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Organic cotton, lyocell and SPF: a comparative study

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Abstract

Purpose – The purpose of this paper is to present a comparative study on the characteristics of knitted fabrics used in the manufacturing of apparel, which are produced from organic cotton, lyocell and soybean protein fiber (SPF). It is important for both the environment and society that textile industry continues to adopt more ecofriendly materials and furthermore, pushes to increase awareness regarding these material choices available to the consumer and the corresponding impacts of consumers' decisions. The use of sustainable fibers may be a starting point for changing the industrial paradigm of the textile industry.
Design/methodology/approach – The research presented herein analyzes the potential use of three raw materials used in the development of knitted fabrics: organic cotton, lyocell and SPF. The experimental trials, based on norms, determined the weight, pilling, rupture pressure resistance, absorption by capillarity, dimensional alteration and elasticity. The significance of the experimental results was verified through the analysis of variance, with a confidence interval of 95 percent ($p = 0.05$) and the determination of the optimal regulation of the machine was made through an analysis of the response surface.
Findings – The results indicate that each of the studied materials are suitable for textile application; however, the fabrics manufactured from soybean yarn, compared to those manufactured from organic cotton or lyocell, have a higher potential to meet the needs of the costumer.
Social implications – The discussion regarding sustainability is far reaching on the ways it interacts with human life. As such, the latent need for meeting this new demand presents a unique opportunity for the development of new processes and products. In the case of the textile industry, initiatives are gradually being adopted that make the processes used by the supply chain less damaging to the environment. Clothing and fashion are highly visible elements of society, so consequently, the textile industry serves as an excellent candidate for promoting a sustainable and eco-friendly mindset.
Originality/value – The incorporation of sustainable fibers can serve as a starting point for change to the industrial paradigm existing within the textile industry. To this point, this study intended to analyze the potential implementation of three raw materials – organic cotton, lyocell and SPF – in the development of knitted fabrics. The results indicated that these materials are adequate for textile applications.

Keywords Sustainability, Knitting, Lyocell, Organic cotton, SPF
Paper type Research paper

1. Introduction

Sustainable development practices are becoming more and more important for the contemporary world and the future generations. According to Sachs (2008), "the sustainability in the human civilizations time will depend on their capacity to submit to the precepts of ecological prudence and to make a good use of nature."

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For the textile-manufacturing industry, this reality motivates the development of a new supply chain to change the raw material, the creation process, commercialization and post-use of the product. Therefore, certain companies within the industry are using sustainability as a mean to differentiate themselves from their competitors by demanding raw materials produced within systems that are less damaging to the environment and consequently, fashion benefits from these developments.

In this current atmosphere of a greater concern for the environment, it is necessary to adjust a starting point for increased sustainability is consideration and incorporation of alternative materials into the manufacturing of textile products that reduce environmental impact.

Among candidate alternative materials, there are ecological and/or sustainable fibers such as organic cotton, which is grown without use of fertilizers or pesticides and is becoming increasingly popular (Chavan, 2004). Another fiber with low environmental impact is lyocell, a generic name for a regenerated cellulose fiber made from dissolving wood pulp that uses an organic solvent easily recovered and recycled (Chavan, 2004).

The chemical fibers derived from soy proteins are known as “green textile fibers,” as the origin of the raw material derived from soybeans is renewable. The polymer used for the production of soybean protein fiber (SPF) is manufactured from the bioengineering of the residual meal obtained from the extraction of soybean oil (Falcetta, 2003).

Currently, within textile manufacturing is determined by the capacity to comprehend and react to customers’ needs. In this regard, we mat assert that the textile industry must be prepared to respond to the needs of the fashion industry, which requires an enormous versatility of products and processes, but at the same time, should consider the impacts of their choices, whether they are ecological or relate to public welfare, safety and functionality (Filgueiras *et al.*, 2008).

This research aims to address the importance of sustainable material selection by presenting a comparative study on the characteristics of knitted fabrics used in the manufacturing of apparel made from organic cotton, lyocell and SPF.

2. Research scenario

2.1 Sustainable development

In 1987, the United Nations World Commission on Environment and Development defined sustainable development as one “that satisfies the needs of the present without compromising the capacity of future generations to satisfy their own.” This report is part of a series of initiatives that highlight the risks of the excessive use of natural resources. From socioeconomic and ecological problems in the current society, the report interconnects economy, technology, society and politics, observing the new ethical attitude toward the sustainable development (Brundtland, 1987).

According to Sachs (2008), sustainability must be assessed in five dimensions: social, in which a social stability is sought so that the individual differences do not affect the collective performance; environmental, when respecting and highlighting the capacity of self-degradation of the ecosystems; territorial, related to the spatial distribution of the planet’s resources and population; economic, when proposing the development of projects with the mindful use of resources and policies of energy and natural resources preservation; and political, when stimulating any type of action that guarantees human rights.

In studies on consumer behavior, environmental awareness is presented in the form of three dispositions: the consumer intentionally purchases sustainable products, there is an increase in the engagement of purchasing eco products, and facilitated access to information on sustainable production processes (Gam *et al.*, 2014).

Schrettle *et al.* (2014) affirm that the challenge surrounding incorporation of the concept of sustainability into the company ethos has become a major point of focus. From there, emerges the concept of "sustainability technologies," technologies of processes and products, characterized as total systems that include technical-scientific knowledge, procedures, goods, services and equipment, as well as procedures of organization and handling.

2.2 Textile fibers

According to the American Society for Testing and Materials (ASTM D123-03, 2006a, b, c, d, e), textile fiber is a generic term used for all the materials that form a basic textile element characterized by presenting a length a hundred times greater than its diameter. Textile fibers can have several origins, so origin is a criterion frequently used for their classification, as shown in Figure 1 (North Carolina (NC) State University, 2012).

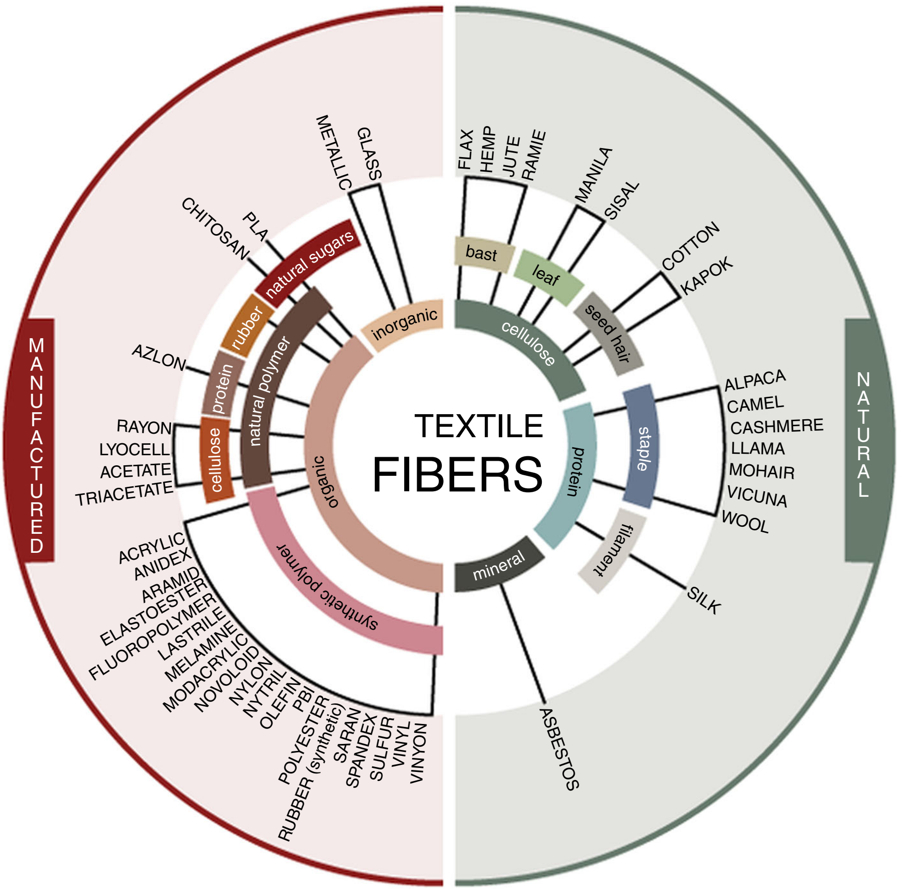


Figure 1. Classification of textile fibers

Notes: *Generic classification based on chemical composition as defined by the Textile Fiber Products Identification Act. (Manufactured Catagory)

Source: North Carolina (NC) State University (2012)

In this manner, fibers can be of natural origin, if produced by nature, in a way that makes them fit for textile processing or of chemical origin, if produced by industrial processes. The non-natural fibers can be obtained from natural polymers transformed by the action of chemical reagents (artificial fibers) or by polymers obtained from chemical synthesis (synthetic fibers) Araújo and Castro (1987).

The history of textile fiber use is closely linked to human history. Laver *et al.* (2002) assert that rarely have civilizations not used natural fibers as way of protection, and even in nomadic civilizations, fibers of animal origin were the basis for fabric production.

The first fibers were made from materials such as grass, rushes and cane and were used for the manufacturing of nets, fishing nets, carpets and ropes. Later, techniques were developed to work on more sophisticated materials, such as linen, animal hair, cotton and silk (Sanches, 2011).

Technological evolution allowed development of artificial fibers, with characteristics similar to those of natural fibers, using knowledge of the polymers' structure. Only in the second half of the nineteenth century was it possible to dissolve cellulose, which led to the development of artificial fiber by extrusion of these solutions through a metallic winnow (Demir, 1997).

Sustainable measures can be taken to reduce the social and environmental impacts in the textile industry. For example, adoption of alternative raw materials, which have low environmental cost and use environmentally friendly production processes. Organic cotton, lyocell and SPF fibers are materials well-suited to meet these demands.

2.2.1 Organic cotton (CO). Agricultural production yields the greatest environmental problems in the textile chain as well as having social, territorial and economic implications (Sachs, 2008). In addition to the use of agrochemicals used during the fiber growth, the finishing stage also relies upon toxic substances used for bleaching and dyeing the textile products.

With the emergence of several movements for environmental protection and the concern regarding currently unsustainable consumption patterns, searching for alternatives that allow a more sustainable development has become a necessity.

Organic agriculture emphasizes sustainable methods that serve a holistic environmental vision, i.e., one focussed on preservation and protection of the delicate balance that exists between fauna, flora and humans. The biodynamic institute (IBD) is one organization that provides organic certification, and according to the IBD, Brazil has the second largest area of organic agriculture in the world. Synthetic agrochemicals, chemical fertilizers and transgenic seeds are forbidden in organic products farming.

Cotton accounts for 38 percent of the world's textile consumption. The area dedicated for growing this fiber corresponds to 2.4 percent of the croplands in the world, and this culture consumes approximately 16 percent of total pesticides (Hassan *et al.*, 2013).

Although cotton itself is a natural fiber, there exists a long chain of non-natural and chemically intense processes used in its production that is hidden to the consumer, and the consequence for air, soil and water quality are often dire. In order to harvest this delicate plant, eight to ten times more pesticides are applied per season, which gradually leaves the fields infertile, in addition to the serious damage that may occur to humans, plants and aquatic life (Chavan, 2004).

The difference between organic and conventional production lies primarily in the cycle of the seasons, and the characteristics of the region. Organic harvesting is carried out during maturation time, that is to say, without induction; there is rotation and consortium of cultures, as well as use of organic fertilizers and material recycling.

Treatment for plagues and diseases prevention is natural, and weeds are handled without herbicides. The products are differentiated from the non-organic products, in terms of their handling, the machinery used, transport and sale; the certifiers supervise their commercialization as well as the environment to which they are exposed. Companies that exploit workers or use child labor will not receive certification (Affonso, 2007; Hedin and Mashouri, 2014).

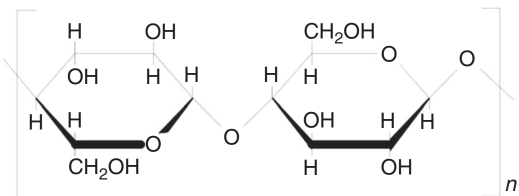
On December 29, 2007, the organic agriculture industry in Brazil began implementation of criteria to regulate the production system, from the rural property where the crops are grown to the point of sale. The law creates the Brazilian System of Organic Conformity Assessment, which will be composed of the Ministry of Agriculture, Livestock and Supply (MAPA), state surveillance authorities and organic conformity assessment bodies.

2.2.2 Lyocell (CLY). The term lyocell, dating back to 1989, has its genesis in the greek words *lyein* (dissolve) and *cel* (cellulose). According to the Bureau International pour la Standardisation des Fibres Artificielles (BISFA) (2009), lyocell is a fiber obtained by "organic solvent spinning," which means formation of a mixture of water and organic chemicals that may be spun without the formation of a derivative, as shown in Figure 2. Because it does not use aggressive chemical agents during the production process, this fiber is acknowledged as eco friendly (Kandhavadivu, 2013).

The starting material for lyocell and rayon manufacturing is the same wood pulp; however, the manufacturing processes are different. No cellulose derivative is formed in the former one, whereas the rayon manufacturing involves the formation of intermediate derivatives and environmentally unfriendly byproducts. Lyocell is manufactured through a direct dissolving process using an organic polar cyclic solvent named *N*-Methylmorpholine *N*-oxide (NMMO, $O(C_4H_6)NOCH_3$), that is non-toxic and is easily recovered and recycled (Eichinger *et al.*, 2001). The process for obtaining this fiber is illustrated in Figure 3 (Borbély, 2008).

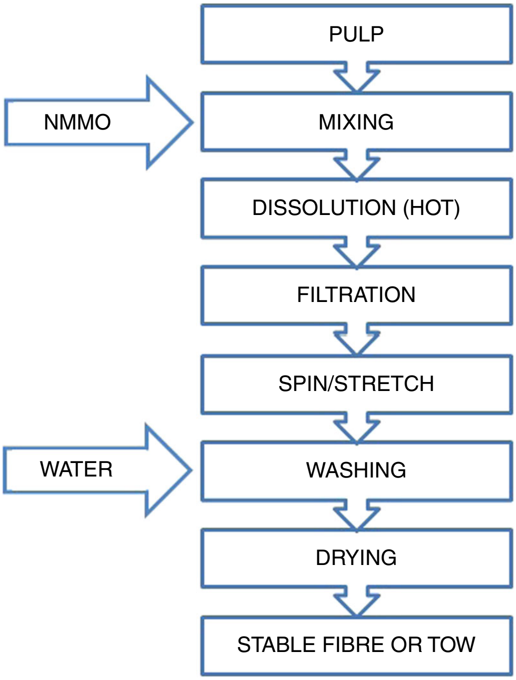
The lyocell fiber has a highly crystalline structure, continuously dispersed along the fiber axis, offering a good resistance to moisture and has an excellent dry mechanical resistance. In addition, this fiber features little shrinkage relative to other cellulosic fibers, such as cotton and rayon (Borbély, 2008). Kandhavadivu (2013) suggests the control and uniform moisture absorption are the main advantages for lyocell fiber use. The uniform moisture absorption is evident in the cross-section of the fiber shown in Figure 4.

2.2.3 SPF. Li Guangi developed the soybean fiber in China, in 1999 (Alves *et al.*, 2008). Because SPF is derived from soybean seeds, it cannot be considered a fiber of natural vegetable origin, but rather an artificial one.



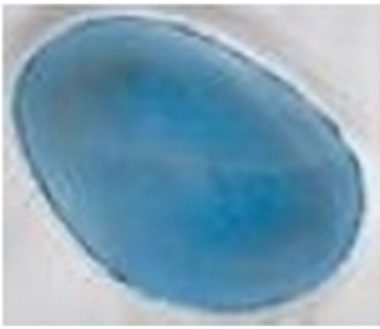
Source: Bureau International pour la Standardisation des Fibres Artificielles, (BISFA) (2009)

Figure 2.
Cellulose chemical formulae



Source: Adapted from Borbély (2008)

Figure 3. Lyocell production system



Source: Kandhavadivu (2013)

Figure 4. Cross-section of lyocell

The protein is extracted from the residual meal obtained from the extraction of soybean oil, through bioengineering technologies. The liquor, high in protein, is submitted to fermentation in the presence of enzymes and auxiliary agents, resulting in the formation of 18 types of amino acids.

Later, the resulting liquid from the fermentation process is heated to modify the protein structure to prepare the solution for extrusion. The process for obtaining the fibers is conducted wet. After that, the fibers are heat set, crimped and cut. The bath must be performed at temperatures below 120°C, to avoid fiber yellowing (Falcetta, 2003).

Figure 5 shows the process for obtaining the soybean fiber (Vynias, 2011).

The articles manufactured from SPF derivatives promote a better comfort to the user, protect and facilitate the moisture evaporation, present a luxurious appearance, provide good mechanical and physical performances and offer health benefits (Yi-You, 2004).

3. Methods

The methodology of this research is divided into three stages: material selection, experimental planning and trials.

3.1 Materials

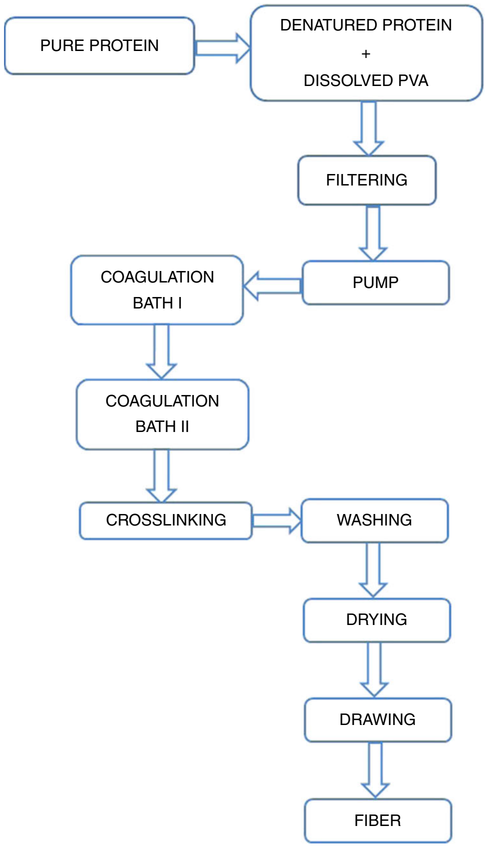
The materials used in the elaboration of this research were divided into three groups:

(1) Organic cotton 18, 0×1 tex spun yarns;

(2) Lyocell 14, 8×1 tex spun yarns; and

(3) SPF 16, 0×1 tex spun yarns.

Each raw material generated a knitted fabric manufactured using L. Degoisey single circular knitting machines, 95.25 mm in diameter ($3\frac{3}{4}$ inches), 236 needles, 20 gauge and



Source: Adapted from Vynias (2011)

Figure 5. Soybean fiber manufacturing

a positive feeding system. The knitted fabrics were finished in a single bath, in a laboratory winch to ensure the same finishing conditions.

3.2 Methods

Completely random 2^2 factorial designs were set, and for each raw material and each machine regulation, a replication was made. The order of execution of the regulations, as well as their replications was determined by lottery.

The significance of the experimental results was verified through analysis of variance (ANOVA), with a confidence interval of 95 percent ($p = 0.05$), and the determination of the optimal regulation of the machine was made through the analysis of the response surface.

3.2.1 Trials. The norm ASTM D 4235-92 recommends the carrying out of the tests of bursting strength (ASTM D 3786-01) and dimensional change (NBR 10320-88) as minimal specification for knitted fabrics. In this work the following physical tests were carried out:

(1) Determination of weight (ASTM D 3776-96): to carry out this test five test samples must be prepared using a qualification of 100 cm^2 area for each. In the sequence the samples must be weighed on an analytical balance. From the weight obtained, one can carry out the calculation to obtain the weight of the paper in grammes per square meter.

(2) Determination of pilling tendency (ASTM D 4970-05): to carry out this test four test samples each 38 mm in diameter, fixed to polyurethane foam and mounted on the Martindale machine. After this first phase of preparation, it is also necessary to mount on the base of the machine, two other strips of knitted fabric with a diameter of 140 mm on the woolen felt cloth of the same diameter. The test ends after 100 cycles of the Martindale machine. The test samples are taken out of the machine and compared with photographic norms.

(3) Determination of bursting strength (ASTM D 3786-01): the norm determines the carrying out of five tests for each paper to be analysed. The equipment used is a Mullen tester which measures the value of the pressure exerted on the test samples through the swelling of its diaphragm. The test end at the instant of the rupture of the test sample. The value of the pressure, designated as the value of the bursting strength in psi, is shown in the visor of the machine.

(4) Determination of elasticity and elongation (JIS L 1018-02): to carry out this test, five test samples cut in the direction of the wales and five in the courses. The extending machine must be regulated with a weight of 300 gf/cm (2,94 N/cm) and the distance between the teeth, marked at the beginning of the test is 7, 5 cm (distance L_0).

    The test consists of the application of weight to the sample for one minute, then the distance between the marks after the elongation is measured (distance L_1). After the predetermined time, one must remove the test sample from the machine and measure again the distance between the initial marks made at the begin nib of the experiment (distance L_2).

    The percentile values of elongation and elasticity are obtained through the following equations:

$$\text{Elasticity}(\%) = \frac{L_0 - L}{L} \times 100$$

$$\text{Elongation}(\%) = \frac{L_0 - L_1}{L_0 - L} \times 100$$

(5) Determination of moisture absorption by capillarity (JIS 1907-02): to carry out this test, one must prepare five test samples and fix them to the apparatus for the test. In sequence, the extremity of each test sample is placed in contact with the water for ten minutes. The determination of the absorption by capillary action is the measure in millimeters of the height reached by the water.

(6) Determination of dimensional change (NBR 10320-88): to carry out this test on a test sample of 38×38 cm, one must mark out three measures of 25 cm, both longitudinally and transversely. First, measurements were made of the initial distances on the knit fabric to be (L_0), carried out on the paper before washing with detergent in an automatic washer. After washing, drying and conditioning of the test sample, are carried out the measures of the distances marked initially (L_1). The percentile values of the dimensional change are calculated by the equation:

$$\text{Dimensional change}(\%) = \frac{L_0 - L_1}{L_0} \times 100$$

4. Results and discussion

The experimental results obtained in the trials conducted with each raw material are summarized in Tables I and II.

The ANOVA seeks to verify if the averages of the experimental values are statistically the same. Thus, we carried out a multiple comparison of averages, with a confidence interval of 95 percent ($p = 0.05$), using the following test of hypothesis:

$$H_0 : \mu_1 = \mu_2 = \mu_3$$

$$H_1 : \mu_1 \neq \mu_2, \quad \text{for any pair } i, j$$

The weights of the finished fabrics varied from 117.26 to 127.70 g/m^2, a difference that can be explained by the linear mass density of the yarns used in the knitted fabrics manufacturing.

Materials	Calculation	Weight (g/m2)	Rupture pressure (kPa)	Transv. elast. (%)	Long. elast. (%)	Pilling Grade
Organic cotton	Average	127.7	412.00	57.83	42.68	1/2
	SD	1.67	29.5	3.22	1.38	*
Lyocell	Average	117.26	354.00	61.59	53.33	3/4
	SD	2.11	32.09	7.96	2.78	*
Soybean	Average	119.36	356.00	68.81	65.59	2/3
	SD	0.8	8.94	3.36	5.94	*

Notes: Average values and standard deviations (SD) of weight, rupture pressure, elasticity on the transversal orientation (transv. elast.), elasticity in the longitudinal orientation (long. elast.) and pilling (authors). *Not applicable

Table I.
Average values and standard deviations (SD)

Materials	Calculation	Trans. water Abs. (cm)	Long. water Abs (cm)	Trans. dim. Stab. (%)	Long. dim. Stab. (%)
Organic cotton	Average	2.14	1.92	−5.16	−5.24
	SD	0.4	0.56	1.1	0.45
Lyocell	Average	8.22	7.66	−7.19	−0.65
	SD	0.33	0.49	1.03	0.56
Soybean	Average	9.8	9.66	−8.60	−10.52
	SD	0.34	0.21	1.6	0.78

Note: Average values and standard deviations (SD) of water absorption on the transversal orientation (trans. water abs.) and longitudinal orientation (long. water abs.) of the knitted fabric, dimensional stability on the transversal orientation (trans. dim. stab.) and longitudinal orientation (long. dim. stab.) (authors)

Table II. Average values and standard deviations

The linear mass density of the raw materials used in the knitted fabrics manufacturing varied from 14.8 × 1 tex to 18.0 × 1 tex. Through the analysis of the response surface, it was possible to determine, for each raw material, the optimal regulation of the circular knitting machine.

To verify that the manufactured fabrics have the same average weight, we set a randomized planning by levels, and the analysis of the results was carried out considering a confidence interval of 95 percent. The results indicated that the fabrics manufactured with organic cotton, lyocell and soybean yarns have average weights that are statistically similar.

The properties of the textile fabrics have a direct influence over the behavior of textiles and their applications. According to Kadolph and Langford (2006), the clothing articles must provide: an aesthetic aspect (feel, fit, appearance), protection (heat, water, cold), ease of maintenance, comfort and durability. In other words, the finished product must meet the consumer's needs and have functionality.

Perceived humidity is a major factor for clothing comfort. As a means to objectively quantify this somewhat subjective phenomenon, we performed experiments on the water absorption characteristics of the fibers due to capillary effects. The results indicate that the moisture transport speed is higher in products manufactured with soybean fibers, followed by lyocell and the organic cotton paper, among the tested materials.

Durability is another crucial characteristic typically desirable in any type of garment. To test this property in the knitted fabrics, we carried out some physical trials of resistance to rupture pressure and elasticity. It was found that the organic cotton fabric is more resistant and has the lowest elasticity in both transversal and longitudinal directions. However, the experimental values of rupture pressure and elasticity percentage are very close, indicating that the three raw materials each have a good durability.

Another key characteristic is ease of maintenance, which we define as the ability of the material to retain its original form. To verify this property, we carried out trials on dimensional stability and tendency for pilling formation. The lyocell fabric presented the lowest tendency for pilling formation whereas the organic cotton presented the highest one. However, organic cotton has the best dimensional stability in the transversal orientation, while the soybean was the worst. Nevertheless, in the longitudinal orientation, lyocell has the best dimensional stability.

The experimental results show that, for each analyzed category, the raw materials selected for this work are adequate for clothing manufacturing. However, the fabrics manufactured with soybean yarn, compared to those manufactured with organic cotton and lyocell, have a higher potential for meeting the consumer's needs.

5. Final considerations

The discussion regarding sustainability is far reaching on the ways it interacts with human life. As such, the latent need for meeting this new demand presents a unique opportunity for the development of new processes and products. In the case of the textile industry, initiatives are gradually being adopted that make the processes used by the supply chain less damaging to the environment. Clothing and fashion are highly visible elements of society, so consequently, the textile industry serves as an excellent candidate for promoting a sustainable and eco-friendly mindset. The incorporation of sustainable fibers can serve as a starting point for change to the industrial paradigm existing within the textile industry. To this point, this study intended to analyze the potential implementation of three raw materials – organic cotton, lyocell and SPF – in the development of knitted fabrics. The results indicated that these materials are adequate for textile applications.

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Japan Industrial Standards (2006a), *Testing Methods for Knitted Fabrics*, JIS L 1018-02, Japan Industrial Standards, Tokyo, p. 55.

Japan Industrial Standards (2006b), *Testing Methods for Water Absorbency of Textiles*, JIS L 1907-02, Japan Industrial Standards, Tokyo, p. 5.

Sanches, R.A. (2006), "Procedure for the development of knitted fabrics from design of experiments (DOE)", unpublished thesis, Universidade Estadual de Campinas, Sao Paulo (in Portuguese).

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