

Antimicrobial Studies of Knitted Fabrics from Bamboo, Soybean and Flax Fibers at Various Blends

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Abstract

In the current study, the single jersey knitted fabric from natural fibers bamboo (*Dendrocalamus strictus*), soybean (*Glycine max*) and flax (*Linum usitatissimum*) at various blend ratios are prepared for comparison of physical strength and antimicrobial properties. For the general characteristic evaluations it is deduced that the fiber strength of pure flax is comparatively stronger than bamboo and soybean, whereas the antimicrobial properties of the bamboo fibers are the highest. Therefore, the blended fabric with multiple compositions for these three fibers is prepared and compared with the fabric made from individual pure fibers. In sum, the blended fabrics showed enhanced results for both antibacterial activity and strength, where the strength of flax/bamboo blended fabric with equal ratios (50/50) at higher twists and antibacterial activity of soybean/bamboo blended fabric with blend ratio 10/90 was found the best as compared to other combinations.

Keywords: Flax; Bamboo; Soybean; Fiber blend ratios; Antimicrobial activity; Fabric strength

Introduction

In recent years, the demands of textiles have changed with the development in technology and the raised living standards. Along with style and durability, the clothing-comfort that includes thermo-physiological comfort. It is evident that fiber type, yarn properties, fabric structure, finishing treatments and clothing conditions are the main factors affecting the clothing comfort [1]. Over the last few years, there has been growing interest in knitted fabrics due to comfortable stretch, freedom of movement and good air-, and water vapor-permeability characteristics. Therefore, knitted fabrics are also preferred for sportswear, casual wear and all types of intimate apparel like hosiery, bathing suits, fit-in t-shirts and socks applications [2].

The development of bioactive textile materials and clothing loaded with antimicrobial properties has become the pioneer demand of the smart textiles. Wool, silk, and cellulosic material such as cotton, jute, and flax in contact with body provide ideal environment for growth and sustainability of pathogenic microbes [3]. The persistence of such microorganism in textile materials results in alteration of final structure of the fabric causing decoloration, fetid odor generation, skin infections, product deterioration and allergic responses. To avoid such counter effects, the textile goods loaded with antimicrobial agents, being the special type of medical textiles have got attention of consumers and manufacturers in all over the world [4]. Specifically, a broader market for anti-microbial fibers has been developed in outdoor textiles, air filters, automotive textiles and domestic home furnishings.

Antimicrobial properties can be achieved by the application of diversified chemicals and finishes but negative effects of such chemicals on skin and on overall health of the wearer cannot completely be ignored [5]. Hence, the use of natural fibers in fabric manufacturing as value addition is preferred in order to make the product more environmentally friendly.

Until lately, the bamboo is being consumed as a raw material for textiles mainly due to its renewability, biodegradability and carbon sequestering abilities [6]. Similarly, flax, due to similar properties as that of cotton and comparatively inexpensive in price has become the good substitute for garments with subsidized costs. The use of flax in blends helps in reducing the shrinkage, absorbing of dye, good wicking

properties and shortening of drying times for the fabric [7]. In the same context, soybean fibers due to luster, similar to silk have excellent drape properties, are soft to touch, carry light weight and have good moisture transmission values. Additionally, the fiber contains the properties of anti-creasing, ease at washing and quick drying [8]. Keeping in mind the above highlighted specialties of bamboo, flax and soybean fibers, the present research study was conducted to compare the fiber strength and antimicrobial properties of knitted fabric composed of three fibers individually and at a blend ratio of 10-50% with respect to each other.

Materials and Methods

The proposed research was initiated with evaluation of fiber characteristics of bamboo (*Dendrocalamus strictus*), soybean (*Glycine max*) and flax (*Linum usitatissimum*), fibers to assess their potential according to International standards of ASTM D-5867 [9]. The physical characteristics of bamboo like staple length, fiber bundle strength, denier and elongation to break are comparable to soybean. However, the soybean protein fiber due to small fineness of single fiber has low specific gravity and tensile elongation. The moisture absorption and discharge activity, permeability properties, heat-retaining ability and spinning performance of soybean is also intermediate [10]. The physical strength of flax fiber is higher and the moisture absorbent properties for flax are lesser in this comparison. Therefore, the pre-treatment process is essentially conducted for flax in order to remove the hydrophobic impurities and to increase the water absorption of the fibers [11].

Spinning process

For the present research the blending of Bamboo, Soybean and

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Received March 11, 2015; **Accepted** March 19, 2015; **Published** April 30, 2015

Citation: Tusief MQ, Amin N, Mahmood N, Ahmad I, Abbas M (2015) Antimicrobial Studies of Knitted Fabrics from Bamboo, Soybean and Flax Fibers at Various Blends. J Textile Sci Eng 5: 195. doi:10.4172/2165-8064.1000195

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Flax fibers and the manufacturing of blended yarn as per the decided variables were made in a small spinning laboratory that contains unique miniature textile machinery. This facility provides a quick approach for evaluation of the fibers and their blends. The flax, bamboo and soybean fibers were blended and processed at mini spinning system for making 30S yarn samples. Control specimens were composed of 100 percent material. Following variables were trialed in the research work, keeping hundred percent flax, soybean and bamboo as under control treatment (F4, F5 and F6) and spun into yarn of 30S at different levels as given in Tables 1 and 2.

Knitting process

Knitting of the fabric from the yarns was made according to the selected variables was accomplished in a local textile mill. The knitting was processed in the machine of 33/4 inch gauge, 2 feeders, 33/4 inch cylinder diameter and dial height of 4 inch was engaged for the preparation of knitted fabric samples from all the yarn samples of different blends.

Knitted fabric evaluation

The knitted fabric samples were placed on the flat surface for 24 hours at $65 \pm 2\%$ relative humidity and $20 \pm 2\%$ temperature for conditioning purpose to maintain the characteristics of the samples at standard test methods.

Fabric strength

Bursting strength is the force in kilopascals (kPa) was determined according to the ASTM standard method **D-3786** [12]. Mullen Burst Strength Tester was used for measuring bursting strength.

Antimicrobial activity (%)

Antimicrobial activity of the fabric samples was estimated using AATCC standard method **AATCC 147-2011** [13]. According to this disc diffusion method with some minor modification was used for screening the fabric samples for antimicrobial activity. The dispensed, sterilized and autoclaved nutrient agar was poured into flat bottomed Petri dish. Then, nutrient agar was allowed to gel firmly before inoculating. The nutrient agar plates were inoculated with 0.1 ml of an appropriate dilution of tested culture. The fabric samples of 1 cm diameter were placed on the surface of inoculated plates. The plates were incubated at appropriate temperature for 24 hours. Then the diameter of inhibition zone (mm) including the disc diameter was measured for each treatment and the antibacterial activity against gram positive bacteria *Staphylococcus aureus* was calculated and microorganism inhibition is reported as relative percentage.

Statistical evaluation

The results were statistically analyzed by factorial design using Statistical Package for Social Sciences (SPSS) as suggested by Montgomery [14]. The factorial design was preferably selected because the interaction effects can only be studied in factorial experiments. Moreover, all factors involved in this study are studied at the same of level of precision. The small letters a-e used in Tables 3 and 4, reflect the significance or non-significance difference among the means at $\alpha = 0.05$. The same letters mean non-significant difference among the mean values at 0.05 level of probability.

Results and Discussion

The comparative analysis of three fibers concludes that bamboo fiber has excellent antimicrobial properties that make it ideal for

processing into textile. The bactericide characteristics is mainly due to presence of a bio-agent “bamboo kun” in the fiber. In contrast, the staple length, fiber bundle strength and denier for flax fiber are higher as compared to bamboo and soybean [15]. The effects of different blend ratios of Bamboo, Soybean and Flax fibers at various twist levels on the strength and antimicrobial activity of the knitted fabric were calculated in order to investigate the performance of the fabric with special reference to its strength and Antibacterial activity [16].

Fabric bursting strength

The statistical comparison of individual means for Fabric bursting strength measured in kPa is presented in Table 3, The statistical distribution clearly indicates that the maximum strength was attained for F2 (Flax/Bamboo fabric) at B5 (50/50) blend ratio having high twist level T3 (4.2) with the mean values 409.82, 438.92 and 440.78 kPa. The results revealed that the use of Flax fiber in the blend improved the strength of the fabric, whereas the share of bamboo fiber if increased in the blend results for the decrease in fabric strength. The studies confirmed that the bursting strength of the fabric reduces with increasing bamboo content in the blend. The elongation at break of the bamboo fiber is lower which may result in decreasing elongation of yarn samples with increasing bamboo content in the blend and this could be the reason for lower bursting strength of bamboo rich fabrics. It may also be attributed to the lower strength of bamboo fibers [17]. These findings also get support from the results of hundred percent pure bamboo, soybean and flax knitted fabric as given in Table 4 where the strength of the fabrics made from pure bamboo and soybean fibers were lower than that of the fabric made from pure flax fiber.

The fabric bursting of variously blended fabrics is presented in Figure 1. The results clearly present the fabric strength at different blend ratio and twist count. The regular pattern was observed for the fabric strength as the twist count and / or the ratio of flax fiber was increased

Fiber Types	Staple Length (mm)	Fiber Bundle Strength (g/tex)	Fiber Fineness (dtex)	Elongation (%)	Moisture Regain (%)
Bamboo	38	31.41	1.5	23.80	13.03
Soybean	38	26.04	1.80	18.40	8.60
Flax	40.83	43.4	2.5	5.6	7

Table 1: Physical characteristics of Bamboo, Soybean and Flax fibers.

Fiber Type (F)	Blend Ratios (B)	Twist Multiplier (T)
F ₁ = Flax/Soybean	B ₁ = 10:90	T ₁ = 3.8
F ₂ = Flax/Bamboo	B ₂ = 20:80	T ₂ = 4.0
F ₃ = Soybean/Bamboo	B ₃ = 30:70	T ₃ = 4.2
F ₄ = 100% Bamboo	B ₄ = 40:60	
F ₅ = 100% Soybean	B ₅ = 50:50	
F ₆ = 100% Flax		

Table 2: Variables selected for the study.

Fiber Type	Blend Ratio	Twist Multiplier
F ₁ = 399.48a	B ₁ = 416.72e	T ₁ = 414.10c
F ₂ = 409.82c	B ₂ = 421.34d	T ₂ = 427.88b
F ₃ = 378.04b	B ₃ = 428.23c	T ₃ = 440.78a
	B ₄ = 432.78b	
	B ₅ = 438.92a	

Table 3: Comparison of individual treatments means for Fabric Strength (kPa).

in the fabric. Therefore, minimum fabric bursting strength was observed for soybean/bamboo with the ratio of 10/90 at 3.8 yarn twist multiplier, whereas maximum strength was attained for Flax/Bamboo fabric at 50/50 blend ratio having high twist level of 4.2. The results revealed that the use of Flax fiber in the blend improved the strength of the fabric and the share of bamboo fiber, if increased in the blend, decreases the strength of the fabric. The results were in accordance with the reported data in literature [18]. The elongation at break of the bamboo fiber is lower which may result in decreasing elongation of yarn samples with increasing bamboo content in the blend and hence can be the reason for lower bursting strength for bamboo rich fabrics. Finally, the fabric bursting strength tests for pure bamboo, soybean and flax knitted fabric with yarn twist fixed at 4 were evaluated. The strength of fabrics from 100% bamboo and soybean fibers were lower than that of the fabric made from pure flax fiber. Twist multiplier factor plays a significant role on the strength of the fabric. The increase in twist results in increase of fabric strength (Figure 1).

Fabric antimicrobial activity

The antibacterial activity for blended fabrics is presented in Figure 2, which indicates that the maximum antimicrobial activity was achieved from soybean/Bamboo blended fabric at the blend ratio of 10/90. It is clear from these results that both soybean and bamboo fibers put a decisive impact on the antimicrobial activity of the fabric. More influentially, the bamboos share in the blend, the more it plays a significant role to improve the antibacterial properties of the fabric. These findings were verified by the exploration of previous studies which revealed that the soybean protein fabric had good capacity to retain warmth, had good biocompatibility and were also beneficial to human health [19]. Furthermore, it was evaluated that twist yarn count does not contribute significantly for the variations in results against microorganism growth.

From the results in Table 4, the antimicrobial activity made from pure bamboo, soybean and flax fibers, it was evident from the results that bamboo fibers improve the antibacterial activity of the fabric.

Fiber Type	Fabric bursting strength (kPa)	Fabric Antimicrobial activity (%)
F ₄	403.6	78
F ₅	383.7	59
F ₆	446.62	29

Table 4: Fabric bursting strength and antimicrobial activity of 100 % pure yarn fabric.

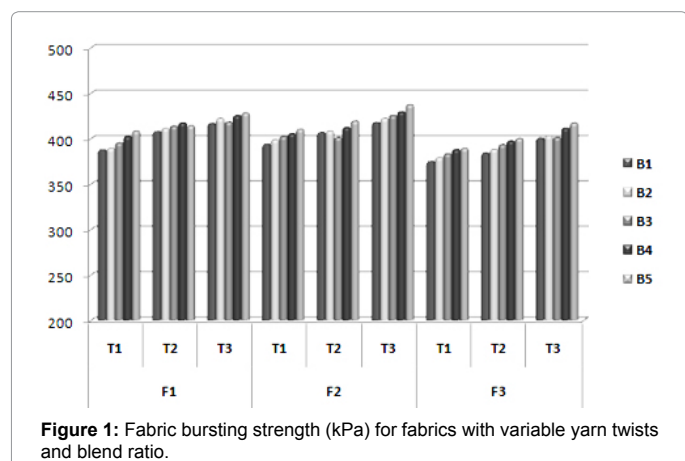


Figure 1: Fabric bursting strength (kPa) for fabrics with variable yarn twists and blend ratio.

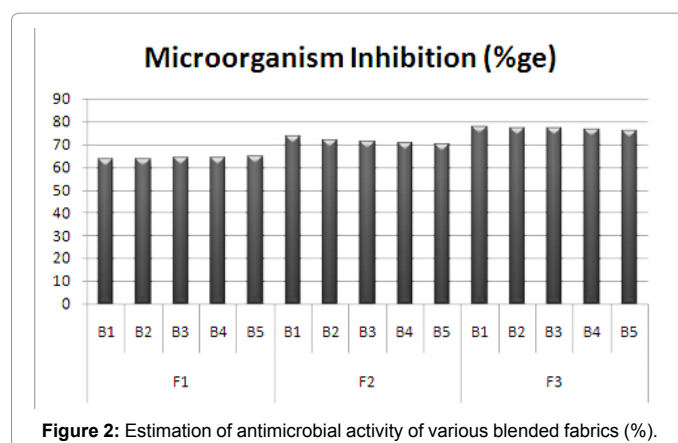


Figure 2: Estimation of antimicrobial activity of various blended fabrics (%).

Conclusions

In the light of above observations, it can be deduced that

- The use of Bamboo fibers in the blend increases the antimicrobial activity of the knitted fabric significantly.
- In addition to improve the antibacterial properties of the fabric the use of bamboo/ soybean and flax fiber in blends had good impact on the strength of the knitted fabric.
- The natural fibers can be the better choice in order to create antibacterial properties in the fabric along-with improved strength and can be good substitute for the chemical or biofinishes.

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