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Investigation on the Unevenness, Tenacity and Elongation Properties of Bamboo/Cotton Blended Yarns

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Abstract
This study investigated the effect of bamboo fiber, which has recently begun to be commonly used in textiles, on the performance properties of yarn. The present study used 100% bamboo yarn of 19.68 tex, which was ring-spun under industrial conditions, bamboo/cotton with varying blend ratios and 100% cotton yarns. The unevenness, tenacity and elongation at break of the yarns were measured. The effect of yarn type on these properties was analysed by analysis of variance and the Tukey test, which were used to determine statistically significant differences between yarn types. The results indicated that the ratio of bamboo fibre in the blend had an effect on the properties of yarn.

Key words: *bamboo yarn, performance properties, blended yarn, bamboo ratio.*

Introduction

The most important factor that determines the properties of yarn is the type and ratio of fibre used in the blend. The properties of yarn vary according to those of the fibres used in production.

Thanks to micro gaps in its structure, bamboo fibre has high air permeability and water absorption properties. Bamboo-based fabrics are antibacterial and very soft, with a low amount of pilling and creasing [1 - 6].

Fabrics made of bamboo fibre have very good physical properties. When compared to cotton fabrics, bamboo fabrics require a lower amount of dye for the dying level required. Moreover the coloring agent is absorbed better and faster than in cotton fabrics, and bamboo exhibits fabric colours better than cotton fabrics [5].

Bamboo clothing is an excellent organic choice that has many benefits and advantages over cotton: Bamboo fabric is softer than cotton, with a texture similar to silk; it is a natural antibacterial product grown without the use of chemicals or pesticides; it is also quick to absorb moisture, thereby keeping you dry and odour free. Moreover pure bamboo clothes can dry twice as fast as cotton ones [7, 8].

Bamboo fibres have a wide variety of applications. In addition to traditional uses in apparel and home furnishings, bamboo fibres are also important for geotextiles, industrial belts and filters, tire cord, ornamentation inside vehicles, motorways, building construction, medical implants and aviation. They also form the basis for today's high-tech composite materials, offering light weight, high-performance alternatives to metals. Bamboo fibre is used in many products that protect the environment, ranging from geotextiles for land stabilisation and erosion prevention, such as liquid filtration, to filtration materials that clean air and water. It is also used in special absorbents designed to remove spilled oil from waterways and wetlands [6, 9].

The disadvantages of bamboo are that it has low fibre strength and high cost. Although previous studies have indicated that the fibre strength of bamboo is sufficient, the Chinese firm Bambro Textile recommends yarn spinning in the range 73.81 – 9.84 tex; however, it does not recommend yarn spinning in narrower ranges [2].

Dündar [10] reported that the friction strength of fabrics knitted with 100% bamboo yarn was higher than that of fabric knitted with 100% cotton yarn. Okubo et al. [11] analysed the mechanical properties of bamboo fibre and reported that the strength of bamboo fibre was equivalent to that of glass fibre.

Lipp-Symonowicz et al.[12] compared bamboo fibres and viscose fibres and they stated that so-called bamboo fibres are in reality man-made viscose fibres made from bamboo cellulose and bamboo fibres comparable to viscose fibres in their morphogical structure and properties.

Erdumlu and Özipek [13] analysed the general properties of bamboo fibre and its applications in the textile industry. They produced 100% bamboo yarns of 6 different counts, using ring yarn spinning technology. The test results were evaluated using the parameters of 100% viscose rayon calculated by way of Uster statistics. The researchers reported that yarns finer than 16.4 tex would not be able to meet acceptable levels of quality, and therefore it is suggested that blends with other fibres be used, taking into consideration the stress-strain characteristics.

Chen et al. [14] compared the antibacterial properties of bamboo-viscose (jersey knit) and common wood-viscose (jersey knit) and found that the antibacterial properties of bamboo fabrics were significantly higher than those of common wood-viscose fabric. They reported that the reason for the high antibacterial property of bamboo fabric was that it rapidly absorbs and evaporates water due to its structure, and that bacteria cannot survive in such a dry environment.

Kawahito [15] manufactured rib weave fabric from 100% bamboo and 100% cotton yarn. The results indicated that cotton fabrics had a higher tenacity, greater

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thickness under a heavier load, faster water absorption and better drying properties than bamboo fabrics.

Grineviciute et al. [16] analysed the fabric hand properties of bamboo, cotton and cotton/bamboo fabrics. Raw and finished fabrics gave the same results. Bamboo fibre provided better hand properties than cotton fabrics. The researchers concluded that by changing bamboo mixture ratios, fabrics with differing characteristics could be manufactured.

Sarkar and Appidi [17] analysed the ultraviolet protection and antimicrobial effects of bamboo fabric and concluded that untreated raw fabric had low as well as insufficient protection and antimicrobial effects.

Gun et al. [18] analysed the dimensional and physical properties of plain knitted fabric manufactured from 50/50 bamboo/cotton yarn and compared them with those of 50/50 viscose/cotton and 50/50 modal/cotton blended fabrics. They reported that fabrics made from these three yarns had a similar appearance. The study analysed the weight per unit area, thickness, bursting strength, air permeability and pilling of the fabrics, and it was found that the weight, thickness and air permeability was independent of the fibre type, for example bamboo/cotton knitted fabric had lower pilling and modal/cotton yarn had higher bursting strength.

Bamboo fibre can be used alone or in combination with other fibres (such as terylene, nitrile, ramie, wool, Tencel, rayon, cotton, silk, modal etc) according to the product required [19].

To our knowledge there is not enough information to indicate the effects of the bamboo blend ratio in blended yarns on the unevenness, tenacity and elongation properties of yarns. The objective of the present study was to manufacture yarns with varying ratios of blended bamboo fibre, and to analyse the unevenness, tenacity and elongation at break of the yarns.

Table 1. *Properties of the fibres.*

Fibre properties	Bamboo	Cotton
Fibre fineness, dtex	1.56	1.77
Fibre length, mm	38	30
Tenacity, cN/tex	21.33	36.37
Elongation at break, %	23.8	7.4

Table 2. *Physical properties of the yarns manufactured.*

Property	100% Bamboo	50/50% Bamboo/Cotton	60/40% Bamboo/ Cotton	100% Cotton
Linear density of yarn, tex	19.87	20.04	20.04	19.85
Twist, t.p.m.	78.17	75.02	81.21	74.58
Yarn unevenness, U%	9.95	10.27	9.75	9.90
Yarn unevenness, CVm%	12.61	13.10	12.37	12.54
Thin places, – 50%/1000 m	1.4	1.8	1.5	0.9
Thick places, +50%/1000 m	26.2	55.7	37.5	41.4
Neps, + 280%/1000 m	20.2	27.4	29.3	31.8

Material and method

Bamboo fibres used in this research are man-made fibres - regenerated cellulose fibres manufactured from bamboo pulp. Bamboo fibre was purchased from a firm in China, which produces the bamboo fibre from raw materials of bamboo pulp. Bamboo pulp is refined from bamboo through a process of hydrolysis-alkalisation and multi-phase bleaching and then bamboo pulp is processed into bamboo fibre. It is similar to viscose technology [2]. Bamboo fibre, which is purchased outside, is blended with cotton fibre in the blow- room in the factory. The yarns are produced by ring spinning.

The study used ring-spun 19.68 tex 100% bamboo yarn, 100% cotton yarn and bamboo/cotton yard, blended in two different ratios. The properties of the fibres are given in ***Table 1***.

Unevenness, thin, thick and nep values were measured using a Statex Evenness Tester 600. The yarn tenacity and elongation at break were measured in accordance with the TS 245 standard using a YG(B)021DX yarn strength test device. The yarn twist was measured in accordance with Standard TS 244 using a Y(B)331C Digital Yarn Twister device.

The test results were analysed for significant differences using one way analysis of variance (ANOVA) and the Tukey post hoc test at a 95% level of confidence in SPSS 11.0.

The hypotheses to be tested in the study were determined as follows [20]:

Ho: There is no significant difference between average yarn unevenness properties of different types of yarn

The alternative hypothesis was as follows:

H1: There is a significant difference between average yarn unevenness properties of the types of yarn

The same hypotheses were determined for the yarn tenacity and elongation at break.

Results and evaluation

Physical and mechanical properties of the yarns manufactured are given in ***Table 2***. Similar physical properties are obtained for 19.68 tex 100% bamboo yarn by industrial firms [21].

Table 2 indicate that the unevenness and thin section numbers of the yarns are similar; 50/50 bamboo/cotton yarn had the highest number for the thick section, and 100% cotton yarn had the highest number of neps. The data presented in ***Table 1*** was analysed for statistically significant differences. ***Table 3*** indicates that differences between the unevenness values of the yarns were statistically significant at a 5% significance level. Since the variation in thin sections of the yarns was not statistically significant, this property was not included in the subsequent Tukey test.

Results of unevenness values from the Tukey tests are shown in ***Table 4***.

Table 4 can be interpreted as follows:

- There was a statistically significant difference between 50/50% bamboo/cotton and 60/40% bamboo/cotton in terms of U% and CV% yarn unevenness. As the ratio of bamboo in the blend increases, unevenness decreases.
- There was a statistically significant difference between 100% bamboo

Table 3. *Analysis of variance of unevenness values of the yarns; *α = 0.05 significance level.*

Parameter, unit	F	*p-value
U, %	2.904	0.048
CV, %	3.362	0.029
Thin places	0.298	0.827
Thick places	6.233	0.002
Neps	3.214	0.034

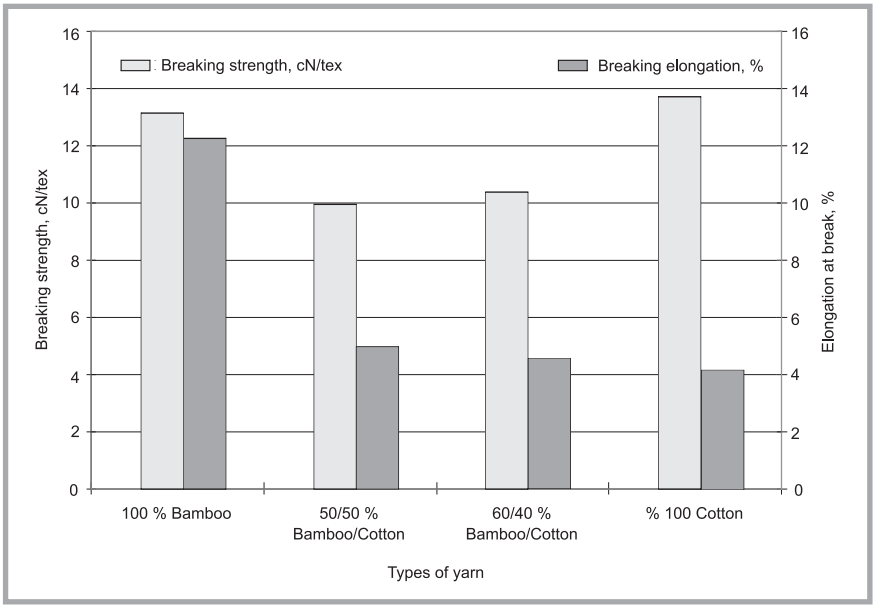

Figure 1. *Tenacity and elongation at break results.*

Table 4. *Tukey test results for unevenness values of different types of yarn, *α = 0.05 significance level.*

I	II	U, %	CV, %	Thick Places, +50/km	Neps, +280/km
100% Cotton	100% Bamboo	0.991	0.990	0.142	*0.027
	50/50% B/C	0.196	0.111	0.181	0.681
	60/40% B/C	0.837	0.900	0.942	0.920
100% Bamboo	100% Cotton	0.991	0.990	0.142	*0.027
	50/50% B/C	0.319	0.200	*0.001	0.276
	60/40% B/C	0.675	0.752	0.371	0.114
50/50% B/C	100% Cotton	0.196	0.111	0.181	0.681
	100% Bamboo	0.319	0.200	*0.001	0.276
	60/40% B/C	*0.033	*0.023	0.057	0.962
60/40% B/C	100% Cotton	0.837	0.900	0.942	0.920
	100% Bamboo	0.675	0.752	0.371	0.114
	50/50% B/C	*0.033	*0.023	0.057	0.962

Table 5. *Analysis of variance (ANOVA) for the tenacity and elongation at break of yarns; *∝=0.05 significance level.*

Source	Breaking strength		Elongation at break	
	F	p- value	F	p- value
Types of yarn	42.210	*0.000	216.216	*0.000

Table 6. *Tukey test results for the tenacity and elongation at break of yarns; *∝ = 0.05 significance level.*

I	II	Breaking strength	Elongation at break
100% Cotton	100% Bamboo	0.547	*0.000
	50/50% B/C	*0.000	0.133
	60/40% B/C	*0.000	0.594
100% Bamboo	100% Cotton	0.547	*0.000
	50/50% B/C	*0.000	*0.000
	60/40% B/C	*0.000	*0.000
50/50% B/C	100% Cotton	*0.000	0.133
	100% Bamboo	*0.000	*0.000
	60/40% B/C	0.692	0.776
60/40% B/C	100% Cotton	*0.000	0.594
	100% Bamboo	*0.000	*0.000
	50/50% B/C	0.692	0.776

yarn and 50/50% bamboo/cotton blended yarn in terms of the thick section.

- There was a statistically significant difference between 100% bamboo yarn and 100% cotton yarn only in terms of the number of neps.

Figure 1 shows tenacity and elongation results.

Figure 1 indicates that 100% bamboo yarn and 100% cotton yarn has a higher tenacity than blended yarns, and that 100% bamboo yarn has the highest elongation at break value. Moreover 100% cotton yarn has a higher tenacity than 100% bamboo yarn. Furthermore some scientists have indicated that cotton fabrics have a higher tenacity than bamboo fabrics [15].

Table 5 indicates that differences between the tenacity and elongation means of the yarns were statistically significant at a 5% significance level. To make a pairwise comparison of the tenacity and elongation means, a Tukey test was performed. Results of the Tukey tests with respect to tenacity and elongation are shown in ***Table 6***.

Table 6 can be interpreted as follows:

- There is a statistically significant difference between 100% cotton yarn and 60/40% bamboo/cotton, 100% cotton yarn and 50%50% bamboo/cotton yarn, 100% bamboo yarn and 60/40% bamboo/cotton, and between 100% bamboo yarn and 50%50% bamboo/cotton yarn.
- There is no significant difference between 100% cotton and 100% bamboo yarn in terms of tenacity.
- There is a statistically significant difference between 100% bamboo yarn and 100% cotton yarn, and between 60/40% bamboo/cotton and 50/50% bamboo/cotton blended yarns in terms of elongation at break.

General evaluation and results

Bamboo fibre has recently begun to be commonly used in textile. The objective of this study was to analyse the effect of differing proportions of bamboo fibre on the properties of bamboo/cotton blended yarns.

- There was a statistically significant difference between 50/50% bamboo/cotton and 60/40% bamboo/cotton in

terms of U% and CV% yarn unevenness. As the ratio of bamboo in the blend increases, unevenness decreases.

- There was a statistically significant difference between 100% bamboo yarn and 50/50% bamboo/cotton blended yarn in terms of the places.
- There was a statistically significant difference between 100% bamboo yarn and 100% cotton yarn only in terms of the number of neps.
- There is a statistically significant difference between 100% cotton yarn and 60/40% bamboo/cotton, 100% cotton yarn and 50%50% bamboo/cotton yarn, 100% bamboo yarn and 60/40% bamboo/cotton, and between 100% bamboo yarn and 50/50% bamboo/cotton yarn in terms of tenacity.
- There is a statistically significant difference between 100% bamboo yarn and 100% cotton yarn, and between 60/40% bamboo/cotton, and 50/50% bamboo/cotton blended yarns in terms of elongation at break.

It was concluded that the ratio of bamboo Fibre in the blend effects yarn unevenness properties. As the ratio of bamboo increases, yarn unevenness decreases. However, there was no apparent significant effect of the ratio of bamboo on the yarn tenacity and elongation. Moreover the investigation shows that there is no significant difference between the tenacitys of 100% bamboo yarn and 100% cotton yarn.

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