Alenka Pavko-Čuden, Anže Kupljenik
University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Textiles

Knitted Fabrics from Bamboo Viscose

Preliminary Communication

Received *January 2012* • Accepted *February 2012*

Abstract

In the last decade, the use of fibres from bamboo has been on the increase: natural bamboo fibres and regenerated cellulose fibres, bamboo viscose in particular. The advantage of the bamboo plant lies in its fast and dense growth and the possibility of organic production. Bamboo viscose is often used in the production of knitwear, home textiles and accessories. Textile products made of bamboo are characterised by high moisture absorption, pleasant hand, porosity and air permeability, as well as by the antibacterial effect, antifungal resistance and UV protection properties. In the preliminary research, knitted fabrics made from bamboo viscose and blends with other fibres (organic cotton, elastane, polyester) in various structures were analysed. Their structural parameters, air permeability and absorption properties were studied and compared.

Keywords: bamboo, bamboo viscose, knitting, air permeability, moisture absorption

1 Introduction

1.1 Bamboo: sustainable raw material

Industrial raw materials such as metal, plastics, glass, artificial leather and fabrics are applied continuously in all classes of products, breaking the possibility that a certain material could dominate the market and design fashion. Though the application of such a variety of materials enriches our life, it causes problems to our natural environment [1]. In China, bamboo has been a rich natural resource, used in agriculture, paper and furniture industry, architecture and handicraft for thousands of years. It has also been known as the "green gold ore". Moreover, bamboo is a traditional Chinese cultural element and a symbol of Chinese design. The advantages of bamboo products are easy processing, characteristic texture, dense structure, uniform natural colour, possibility of bleaching and dyeing, low cost, durability, environmental friendliness and good performance properties. Only in the last decade, bamboo has also been used for the production of textile fibres [1, 2].

Bamboo is a fast growing plant. It needs 3–5 years for growth, it does not occupy large areas of cultivated land and it does not require irrigation. Furthermore, it reduces the formation of greenhouse gases, absorbs five times more CO_2 than an equivalent stand of trees and produces by 35% more oxygen. It can grow in very hard conditions without any need of pesticides and herbicides [3, 4]. Bamboo roots stabilise the soil and inhibit erosion.

1.2 Bamboo: textile raw material

In China, bamboo is planted on 5 million hectares of land and the bamboo plantation is still growing. The annual bamboo fibre production already amount to nearly 40,000 tons and is still increasing [3].

There are two main types of textile fibres from bamboo. Natural bamboo fibres are produced from the bamboo plant with physical and chemical treatments. They have a round cross-section and a small round lumen. With respect to their structure, they

Corresponding author:
dr. Alenka Pavko Čuden
phone: +386 1 200 32 16
e-mail: alenka.cuden@ntf.uni-lj.si

are similar to ramie fibres; however, they are finer and shorter. Individual natural bamboo fibres are very short, i.e. 2–3 mm, with the average of 2.8 mm. 10–20 individual fibres are packed into bundles. They have a rough surface. The crystalline structure of natural bamboo fibres is different from the flax, cotton and ramie fibre structure. The degree of crystallinity of natural bamboo fibres is lower than that of cotton and flax, and is similar to jute. The natural bamboo fibre is composed of 73% cellulose, 10% lignin and approximately 12% hemicellulose. Among the significant components of natural bamboo fibres, there is also 2,6-dimethoxy-p-benzoquinone, which is responsible for the antibacterial properties of fibres, and the protein dendrocin, which contributes to a high resistance against fungi [2, 3].

The regenerated bamboo fibre, i.e. bamboo viscose, is produced from bamboo pulp with a chemical process similar to the manufacture of viscose fibres by wet spinning. With the hydrolysis alkalisation and the multi-phase bleaching of the inner part of bamboo trunk and leaves, the cellulose pulp is made. After the ageing and xanthogenation, a viscous mass for forming regenerated cellulose fibres, i.e. viscose fibres, is produced from it. Viscose formed from bamboo cellulose is used for the products which are characterised by a number of good features, e.g. comfort, soft and silky hand, nice drape, high absorbency and breathability. The products are also supposed to be durable and resistant to abrasion. Due to the numerous promoted comfort and performance properties, and low price, the diversity of the use of bamboo viscose fibres is in full swing – they are found in sportswear, summer clothing, garments for children and expectant mothers, socks, underwear, bed, kitchen and bathroom linen etc [2, 5, 6]. Viscose fibres from bamboo cellulose are commercially successful due to the supply under the name of "bamboo" or "bamboo fibres" and the organic impression they give. Their comfort and performance properties have been recorded in the literature, yet not all have been proven, e.g. antimicrobial properties.

1.3 Properties of bamboo viscose products

The manufacturers of bamboo textiles promote their products with good properties which include:

- natural antimicrobial properties,
- natural ability to protect against UV radiation,
- pleasant hand,
- smooth surface that does not irritate the skin,
- natural lustre similar to silk (without mercerisation),
- natural ability to prevent odour,
- high water absorption and quick drying due to the porous surface of fibres,
- good thermoregulatory capacity (better than cotton and hemp),
- high durability,
- low shrinking,
- wrinkle resistance (better than cotton),
- biodegradability [3].

Because of the promotion of their good properties, bamboo products have established themselves in the fashion industry, sports, paramedics use etc. Due to inadequate labelling, the products made from natural bamboo fibres are often confused with the products made from regenerated bamboo fibres, i.e. bamboo viscose, which is man-made. The products made from bamboo viscose dominate the market due to their significantly lower price and processing conditions.

The hand of natural bamboo fibres is similar to the hand of ramie, hemp and flax, while bamboo viscose has a very soft hand. Bamboo viscose shrinks considerably during laundering, whereas natural bamboo fibres do not. Research has shown that the breaking strength and elongation of bamboo viscose is lower than for conventional viscose, while the degree of crystallinity is comparable. Natural bamboo fibres are stronger than bamboo viscose [6, 7]. The moisture absorption and moisture transport of natural bamboo fibres is greater than that of bamboo viscose due to their different morphological structure. Natural bamboo fibres have many grooves, cracks and gaps on the surface that affect the capillary effect [7–9]. The antibacterial properties of natural bamboo fibres are similar to the antibacterial properties of flax and ramie. Bamboo viscose is not known for its antibacterial properties [6, 10]. Antibacterial and UV protection properties, and natural ability to prevent odours are much better in the case of natural bamboo fibres than for bamboo viscose, as the good natural characteristics of bamboo diminish during the chemical processing to bamboo viscose [3, 7]. The UPF of natural bamboo fibres is 22 and is greater than the UPF of ramie, which is 12 [11].

1.4 Labelling of bamboo textiles

The experts from the Technical University of Łodz, Faculty of Material Technologies and Textile Design investigated which fibres, natural bamboo or bamboo viscose, are incorporated into textile products labelled with tags quoting "bamboo fibres", "bamboo", "100% bamboo", "organic bamboo fibres", "bio bamboo fibres" etc. By means of different methods of identification, it was established that most products were made from bamboo viscose [6].

When textile products contain natural bamboo fibres, these fibres should be called by the generic (genus) name "bamboo fibres" or "natural bamboo fibres" in line with the name under the serial number 44 in Annex I of the Regulation on fibre composition and textile names [6].

When textile products contain viscose in which the input raw material is bamboo pulp the fibres should be named by the generic (genus) name "viscose", which can be followed (in parentheses) by the source material like "viscose (from bamboo cellulose)" or "viscose (from bamboo)" or "viscose (bamboo)" according to the name under the serial number 44 in Annex I of the Regulation on fibre composition and textile names [6].

1.5 Knitted fabrics from natural bamboo fibres and bamboo viscose

Weft knitted fabrics are stretchable and elastic flat textile structures which are characterised by porosity and good absorbance and transfer properties; therefore, they are comfortable and pleasant to wear. They are used in the production of underwear, sleepwear, sportswear and casual wear, bedding interior textiles and accessories. Their performance properties depend on the material composition, yarn structure, knitted structure type and knitted structure parameters.

In the last decade, the use of bamboo fibres for the production of knitted fabrics has increased. Pure bamboo fibres or blends are suitable for the manufacture of knitted fabrics for underwear, outerwear, home textiles etc. Natural bamboo fibres are mainly used in blends for the manufacture of knitted products; their share is less than 50% due to their rather rough hand. As a consequence of their good properties, they are suitable for socks [12]. More often than natural bamboo fibres, bamboo viscose is used for textiles and clothing. The promotion of good properties of knitted fabrics and knitwear from bamboo is often misleading due to the inconsistent labelling of products from natural bamboo fibres and man-made bamboo fibres, respectively.

2 State of research

The increased use of bamboo for textile processing has boosted basic and applied research of bamboo textiles.

Erdomlu N. and Ozipek B. have investigated the properties of viscose fibres and ring-spun yarns made from bamboo viscose. They found that viscose fibres and yarns from bamboo viscose exhibit similar properties than conventional viscose fibres and yarns, however, they are more expensive. Bamboo viscose yarns with linear density less than 16.4 tex do not meet acceptable quality; hence, the use of blends with other fibres is recommended [5].

Yao W. and Zhang W. studied the processing and application of natural bamboo fibres. They found that the moisture content is similar to that of viscose fibres. The degree of polymerisation and crystallinity of fibres are low, as is the wet strength of fibres. The deodorisation performance of a bamboo fabric is much better than that of a cotton fabric. They critically evaluated the problems involved in the industrial production and processing of natural bamboo fibres. This paper provides an extensive list of references. The study was supported by the Natural Science Foundation of Zheijang Province [13]. The treatments of natural bamboo fibres for textile processing and use were also studied by Liu et al [14].

Cimilli S., Nergis B.U. and Candan C. studied comfort properties of socks made from different fibres (modal, micromodal, bamboo, soybean, chitosan) compared with cotton and viscose. The absorption, drying speed, air permeability, water vapour permeability and thermal resistance were measured. The socks from bamboo and soybean fibres exhibited maximum thermal resistance, while the cotton socks exhibited the lowest. The micromodal and modal socks showed the highest air permeability while the cotton socks showed the lowest. The thickness of knitted fabric had a significant influence on the air permeability. The socks from bamboo fibres exhibited good water vapour permeability. The most absorbent were the cotton socks, whereas the bamboo socks were the least absorbent. The cotton socks dried the fastest [15].

Table 1: Knitted fabrics made from bamboo viscose: material composition, knitted structure type and nominal mass per unit area – M

Sample	Material composition	Knitted structure	M [gm^{-2}]
1	100% bamboo viscose	single jersey	170
2	70% bamboo viscose 30% organic cotton	single jersey	170
3	70% bamboo viscose 25% organic cotton 5% elastane	half tuck relief structure	170
4	70% bamboo viscose 30% organic cotton	1 × 1 rib	240
5	70% bamboo viscose 25% organic cotton 5% elastane	2 × 2 rib	240
6	70% bamboo viscose 28% organic cotton 2% polyester	loop plush	240
7	70% bamboo viscose 28% organic cotton 2% polyester	cut plush	260
8	70% bamboo viscose 25% organic cotton 5% elastane	fleece	260

Majumdar A., Muhkopadhyay S. and Yadav R. investigated the thermal properties of knitted fabrics from cotton, cotton blends, bamboo viscose (50/50) and 100% bamboo viscose. It was found that the thermal conductivity decreases with the increase of the bamboo viscose content. In contrast, air permeability and water vapour permeability increase with the bamboo viscose increase. The maximum heat resistance was exhibited by interlock structures, while single structures showed the highest air permeability and water vapour permeability [16].
Sarkar A.K. and Appidi S. investigated the antimicrobial and UV protection properties of a bamboo viscose knitted fabric. They found that the untreated bamboo viscose knitted fabric shows weak antibacterial and UV protection properties. They also found that those properties can be significantly improved by dyeing and finishing [17].
Bivainyte A. and Mikučioniene D. explored the air permeability and water vapour permeability of double-layered knitted fabrics. They found that the structural characteristics of knitted fabrics, i.e. loop length, structure compactness and structure type, have an important influence on the air permeability of a knitted fabric. The material composition of knitted fabrics has the most important impact on the water vapour permeability [18].
Demiroz Gun A., Ünal C. and Ünal B.T. studied the dimensional and physical properties of knitted fabrics made from blends of modal, bamboo viscose and conventional viscose fibres with cotton. They found that the mass per unit area, thickness and air permeability of knitted fabrics do not depend on the type of incorporated fibres. The dimensional properties of all knitted fabrics were similar. The knitted fabrics made from a blend of bamboo viscose with cotton were less prone to pilling [19].

3 Preliminary research of comfort properties of knitted fabrics from bamboo viscose

3.1 Research objective

The purpose of the preliminary study was to analyse the comfort properties of knitted fabrics made from bamboo viscose and blends with other fibres (organic cotton, elastane, polyester) in various knitted structures. The dimensional properties of a knitted fabric were analysed. Moreover, their permeability and water absorption properties of knitted fabric were tested.

3.2 Preparation of samples

Weft knitted fabrics made from bamboo viscose and blends with other fibres (organic cotton, elastane, polyester) with different mass per unit area and in various knitted structures were examined. Commonly used knitted structures for underwear, sleepwear, outerwear and sportswear were selected, namely single jersey, half tuck structure with absorbent and relief surface, 1 × 1 and 2 × 2 rib, loop plush, cut plush and fleece. All knitted samples made from blends contained the same proportion of bamboo viscose, i.e. 70%. While the elastane content was 5%, the polyester content was 2%. The nominal mass per unit area of knitted fabrics was 170 gm^{-2}, 240 gm^{-2} and 260 gm^{-2}. The samples were dynamically wet relaxed: machine washed at 40 °C at the programme for sportswear and machine dried at the programme for cotton wear.

The sample labelling, material composition and nominal mass per unit area – M are given in Table 1.

3.3 Knitted structure parameters

Prior to the examination of comfort properties, knitted structure parameters were analysed, namely knitted fabric thickness – T, horizontal (wale) density – Dh and vertical (course) density – Dv. Mass per unit area – D and density coefficient – C were calculated. The change in the fabric thickness – ΔT after relaxation was calculated as well. From the change of the vertical and horizontal density of the knitted fabric during relaxation, the width relaxation shrinkage – ΔW and the length relaxation shrinkage – ΔL were calculated. The knitted structure parameters and knitted fabric dimensional change after the relaxation are shown in Table 2.

Absorption was evaluated with the sinking test method. A sample of 3 × 3 cm was cut from the fabric and placed onto the surface layer of water in a 500 ml beaker. The wetting time was estimated with a stop watch as the time interval between the moment of immersion and the moment when the sample sunk under the water level. Each experiment was performed at least five times. The sinking time of about 5 sec is generally considered satisfactory for cellulosic materials [20].

Air permeability was measured according to the ISO 9237:1999 (E) standard on the FX 3300 apparatus (Textest Switzerland) at 100 Pa. The measurement results of air permeability and absorption are shown in Table 3.

Table 2: Knitted structure parameters and knitted fabric dimensional changes after relaxation

Sample	ΔW [%]	ΔL [%]	T [mm]	ΔT [%]	D [cm^{-2}]	C
1	−7,7	0,0	0,57	+20,5	208	0,81
2	−9,1	0,0	0,71	+12,8	165	0,73
3	−4,8	−16,7	1,12	+44,0	504	0,88
4	−5,3	0,0	1,01	+2,7	323	1,12
5	+12,0	−18,2	1,08	+22,1	550	1,14
6	0,0	0,0	1,40	+21,4	143	0,85
7	+10,0	−10,5	1,75	+30,8	190	0,53
8	−6,3	−12,5	1,05	+31,1	384	0,67

Table 3: Air permeability – AP on the face and rear side of knitted structure, and wetting time

Sample	AP-face [$lm^{-2}s^{-1}$]	AP-rear [$lm^{-2}s^{-1}$]	WT [s]
1	1286	1266	1,31
2	420	420	0,98
3	691	687	1,27
4	364	359	2,94
5	325	312	1,15
6	887	882	0,85
7	414	407	2,73
8	138	132	1,33

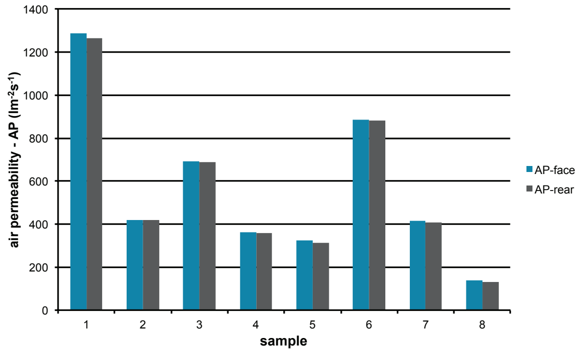

Figure 1: Air permeability of knitted samples

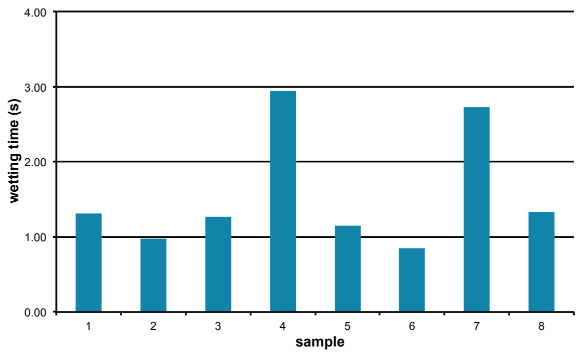

Figure 2: Wetting time of knitted samples

4 Discussion and conclusions

The measurement results showed that in most cases, the tested knitted fabrics were dimensionally unstable. The maximum width and length changes after the relaxation were noticeable with 2 × 2 rib (Sample 5) and cut plush (Sample 7) – the width of the knitted fabrics increased while their length decreased. The most dimensionally stable knitted structure was the loop plush (Sample 6). Single jersey from 100% bamboo viscose (Sample 1) and the same structure made from a bamboo viscose and organic cotton blend (Sample 2) exhibited similar relaxation shrinkage.

The thickness of all knitted fabrics increased with wet relaxation. The increase was the smallest with 1 × 1 rib (Sample 4) and the largest with half tuck relief structure (Sample 3) which exhibited high length shrinkage. The thickness of a single structure made from 100% bamboo viscose (Sample 1) increased more than the thickness of a single structure made from a bamboo viscose and organic cotton blend (Sample 2).

The density coefficient of all structures except for ribbed was C < 1, while C > 1 for 1 × 1 and 2 × 2 rib. The density coefficient does not actually describe the porosity of the knitted structure but defines the loop shape, i.e. the ratio between the loop height and width.

The highest air permeability was exhibited by the single structure made from 100% bamboo viscose (Sample 1) which was also the thinnest. The loop plush (Sample 6) and half tuck relief structure (Sample 3) showed high air permeability as well. The air permeability of the knitted structure made from 100% bamboo viscose (Sample 1) was significantly higher than the air permeability of the knitted structure made from a bamboo viscose and organic cotton blend (Sample 2). The lowest air permeability was exhibited by the fleece structure (Sample 8). For all the samples, the air permeability on the front of the knitted fabric exceeded the air permeability on the rear side. The differences were minimal. The coefficient of variation of air permeability was 2–10%.

The fastest wetting was exhibited by the loop plush (Sample 6) which contained 2% polyester in addition to an equal share of bamboo viscose as did all the samples made from fibre blends. The single structure from the bamboo viscose and organic cotton blend (Sample 2) also wetted very quickly. The 1 × 1 rib structure exhibited the slowest wetting. All investigated knitted structures demonstrated good wettability as the wetting time for all samples was less than 5 seconds. The coefficient of variation of wicking time was 5–10%.

5 References

1. YUANWU, S., QUINLIN, S. Green research on the application of bamboo material on home appliances. Dostopno na svetovnem spletu. http://skdr.dyndns.org/proceedings/fpt2010/pdf/0216-112d.pdf (2. 9. 2011).
2. YUEPING, W. Structures of Bamboo Fiber for Textiles. *Textile Research Journal*, 2010, vol. 80, (4), p. 334–343.
3. LIPP-SYMONOWICZ, B., SZTAJNOWSKI, S., WOJCIECHOWSKA, D. New commercial fibres called "bamboo fibres" – their structure and properties. *Fibres & Textiles in Eastern Europe*, 2011, vol. 19, no. 1 (84), p. 18–23.
4. Good for the environment. Dostopno na sve-

tovnem spletu http://www.bambooclothes.com/ABOU.html (2. 9. 2011).

5. ERDUMLU, D., OZIPEK, B. Investigation of regenerated bamboo fibre and yarn characteristics. *Fibres & Textiles in Eastern Europe*, 2008, vol. 16, no. 4 (69), p. 43–47.
6. Preverite pravilnost navedbe surovinske sestave - Naravna bambusova vlakna ali viskoza (iz bambusa) … Dostopno na svetovnem spletu http://www.oznake-tekstila.si/index.php?option=com_content&view=article&id=245&Itemid=50&lang=sl (2. 9. 2011).
7. Difference between original bamboo fiber & bamboo viscose fiber. Dostopno na svetovnem spletu http://www.konfi.com/new1.htm (4. 9. 2011).
8. Original bamboo fiber structure and morphology. Dostopno na svetovnem spletu http://www.konfi.com/new2.htm (4. 9. 2011).
9. Natural original bamboo fiber properties and parameter. Dostopno na svetovnem spletu http://www.konfi.com/new3.htm (4. 9. 2011).
10. Natural original bamboo fiber anti-bacterial and deodorant function. Dostopno na svetovnem spletu http://www.konfi.com/new4.htm (4. 9. 2011).
11. Natural original bamboo fiber anti-ultraviolet function. Dostopno na svetovnem spletu http://www.konfi.com/new5.htm (4. 9. 2011).
12. WU, J. The best raw material for socks – original bamboo fiber. Dostopno na svetovnem spletu http://www.fibre2fashion.com (4. 9. 2011).
13. YAO, W., ZHANG, W. Research on manufacturing technology and application of natural bamboo fibre. Fourth international conference on intelligent computation technology and automation, Shenzhen Guangdong 2011. Dostopno na svetovnem spletu DOI: 10.1109/ICICTA.2011.327 (4. 9. 2011).
14. LIU, L., WANG, Q., CHENG, L., QIAN, J., YU, J. Modification of natural bamboo fibers for textile application. *Fibres and polymers*, 2011, vol. 12, (1), p. 95–103.
15. CIMILLI, S., NERGIS, B.U.,CANDAN, C. A comparative study of some comfort-related properties of socks of different fiber types. *Textile Research Journal*, 2010, vol. 80, (10), p. 948–957.
16. MAJUMDAR, A., MUHKOPADHYAY, S., YADAV, R. Thermal properties of knitted fabrics made from cotton and regenerated bamboo cellulosic fibres. *International Journal of Thermal Sciences*, 2010, vol. 49, p. 2042–2048.
17. SARKAR, A. K., APPIDI, S. Single bath process for imparting antimicrobial activity and ultraviolet protective property to bamboo viscose fabric. *Cellulose*, 2009, vol.16, p. 923–928.
18. BIVAINYTE, A., MIKUČIONIENE, D. Investigation on the air and water vapour permeability of double-layered weft knitted fabrics. *Fibres & Textiles in Eastern Europe*, 2011, let. 19, no. 3 (86), p. 69–73.
19. DEMIROZ GUN, A., UNAL, C., UNAL, B. T. Dimensional and physical properties of plain knitted fabrics made from 50/50 bamboo/cotton blended yarns. *Fibres and polymers*, 2008, vol. 19, (5), p. 588–592.
20. FOJKAR, A., PAVKO, A. Wetting of immobilizing plaster bandages by immersion before application. *Acta Chimica Slovenica*, 2004, vol. 51, (2), p. 325–332.