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## Bamboo fibres and their unique properties

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**Abstract.** This paper collates the different properties of bamboo fibres as claimed by bamboo fibre and product manufacturers. The available information suggests that bamboo fibres have unique properties such as excellent appearance and feel, natural antibacterial, UV-shielding and moisture-controlling characteristics. Hence bamboo fibres provide a very promising alternative to other natural fibres by virtue of their novel properties. However, those properties may largely depend on the manufacturing process, which is not widely disclosed. Moreover, common manufacturing process may require the use of a large amount of chemicals and hence further process development may be required in order to make the product truly eco-friendly. It is identified that the data of those unique properties rarely appear in scientific journals and the validity of those claims can be speculative. Therefore, there is a strong need for non-biased scientific research and evaluation on the unique properties of bamboo fibres.

**Keywords:** bamboo fibres, UV protection, antibacterial, air conditioning, clothing

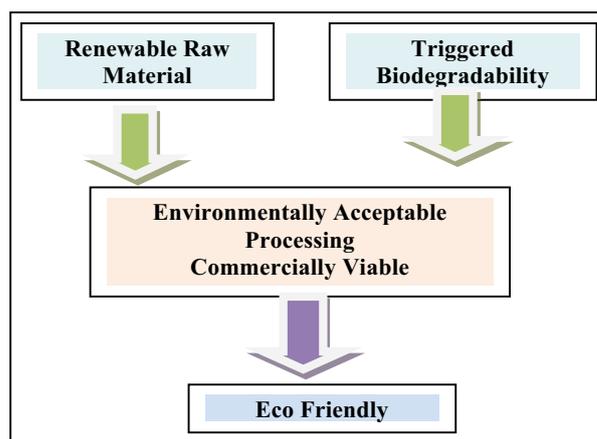
### 1. Introduction

Bamboo is one of the fastest growing plants in the world. It grows to its maximum height in about 3 months and reaches maturity in 3-4 years. It can grow up to 1 metre over night. As such, it spreads rapidly across large areas and can be used to improve soil quality in degraded and eroded areas of land. The yield from an acre of bamboo is 10 times greater than that from cotton. Bamboo needs no pesticides, chemical weeding, insecticides, and fungicide to grow, whilst cotton requires a large amount of harmful pesticides to grow. Unlike cotton, bamboo needs no irrigation and bamboo clothing has three times service life span than cotton (Bambrotex, 2008).

*business sense at every retail level. And as organics become more commercially appealing, so new opportunities are opening up around the world for products which fit this brief" (Just style, 2005).*

The fibres made from renewable raw materials using an environmentally friendly and commercially viable process can be termed as "Green" process (Poole, et al., 2009). Those fibres would also be biodegradable in composting situations after disposal and have significant recycling capability, hence can be considered as "Eco-friendly" (Figure 1).

According to this concept, bamboo fibre is a satisfactory example of eco-friendly products as it comes from nature and completely returns to nature in the end, retaining carbon-neutral characteristics through the product life cycle (Yu, et al. 2003). Normally a forest tree requires at least 60 years to recover once it is cut, but natural bamboo recovers with a growth period of 2-3 years. Therefore, bamboo can be highly praised as one of the natural, green and eco-friendly new-type textile materials due to its distinctive properties (Bamboo fabric store, 2008; Bamboo-t-shirt, 2009).



**FIGURE 1:** Concept of eco-friendly fibres (Poole, et al., 2008)

### 2. Morphology of bamboo fibres

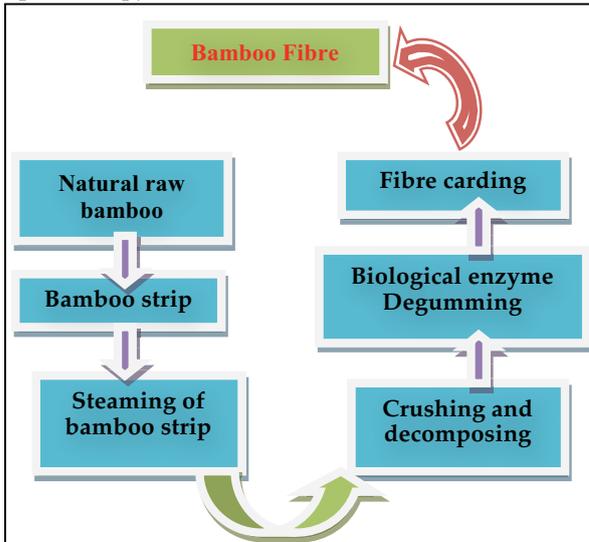
According to Okubo, et al. (2004), the chemical constituents of bamboo are primarily cellulose, hemicellulose and lignin, with cellulose making up approximately 60% and lignin around 32%.

As a natural nanocomposite, bamboo possesses multi-nodes and functional gradient structures, macroscopically as well as microscopically. The fibres are distributed densely in the outer surface region and sparsely in the inner surface region (Rao and Rao, 2005). Its structure is designed to have uniform strength at all positions in both the radial direction on the transverse section and the lengthwise direction (Nogata and Takahashi, 1995).

There is an immense demand of sustainable clothing or "Green" or "Eco-friendly" technology. A clothing industry information group, Just-Style, reported that: *"Buying goods with an organic label is already deemed good*

Parameswaran and Liese indicated that the thick-walled bamboo fibres exhibit a polylamellate structure with alternating broad and narrow lamellae. The concentration of lignin is higher in the narrow lamellae than in the broad ones. Xylan seems to occur in a higher concentration in the narrow lamellae (Parameswaran and Liese, 1976).

Ikeda, et al. (2007) succeeded in extracting pure fibres from bamboo culms and developed the method to distinguish bamboo fibres from other plant fibres using microscopy and infrared spectroscopy.



**FIGURE 2:** The production flow of natural original bamboo fibres (China KongFi Textile Co. Ltd., 2008)

### 3. Manufacturing of bamboo fibres

Very few companies disclosed the detailed procedure for the production of bamboo fibres. In this paper, the production procedures of four companies are reviewed.

For the production of bamboo yarns, *Phyllostachys pubescens* or Moso bamboo of Yunnan province are generally used that can reach a mature height of 75 feet in just 45 to 60 days (Bamboo fabric store, 2008). A company, Organic Clothing, (2008) describes the common manufacturing procedure for bamboo fibres and yarns as follows:

**Extraction and Crushing:** Bamboo leaves and the soft, inner pith from the hard bamboo trunk are extracted and crushed.

**Alkali cellulose formation:** The crushed bamboo cellulose is soaked in a solution of 15% to 20% sodium hydroxide at a temperature between 20 to 25°C for one to three hours to form alkali cellulose.

**Removal of excess sodium hydroxide:** The bamboo alkali cellulose is then pressed to remove any excess sodium hydroxide solution. The alkali cellulose is crushed by a grinder and left to dry for 24 hours.

**Jelly Formation:** Roughly a third as much carbon disulfide is added to the bamboo alkali cellulose to sulphurise the compound causing it to become jelly.

**Evaporation:** Any remaining carbon disulfide is removed by evaporation and cellulose sodium xanthogenate formation.

**Preparation of viscose solution:** A diluted solution of sodium hydroxide is added to the cellulose sodium xanthogenate dissolving it to create a viscose solution consisting of about 5% sodium hydroxide and 7% to 15% bamboo fibre cellulose.

**Bamboo Yarn preparation:** The viscose bamboo cellulose is forced through spinneret nozzles into a large container of a diluted sulphuric acid solution which hardens the viscose bamboo cellulose sodium xanthogenate and reconverts it to cellulose bamboo fibres which are spun into yarns to be woven into reconstructed and regenerated bamboo fabric.

China KongFi Textile Co. Ltd. (2008) uses the production flow as shown in Figure 2. They claim that the average fibre length can be controlled between 30 mm and 90 mm to suit various applications. At present, their bamboo fibres' fineness is average 6 dtex. Their bamboo fibres are similar to cotton in its unspun form giving an appearance of a light, airy puffball of fibres (Figure 3).

Formosa Taffeta Co. Ltd. extracts cellulose from the bamboo plant and produces bamboo fibres by means of various physical treatments such as steaming and boiling. It has a soft handle like any other viscose, and can be spun either 100% or in blends with other raw materials such as cotton, hemp, artificial silk, natural silk, modal, silk ribbon and Dacron (FTC, 2008).



**FIGURE 3:** Appearance of bamboo fibres (Bambrotex, 2008)

Bambrotex (2008) states that they process bamboo fibres in the following manner: (i) Cutting raw material, (ii) washing, (iii) brazing, (iv) bleaching, (v) smashing, (vi) etiolating, (vii) filtrating, (viii) filaturing, (ix) binding (x) cutting and drying.

Bambrotex has identified that vapour pre-treatment is required to improve the humidity during roving and drawing of bamboo fibres to prevent breakages. High-activation, high-stability and selective enzymes are used for desizing bamboo. All dye stuffs that are suitable for cotton can be used to dye bamboo fibres. Infrared drying is suggested to ensure even evaporation of moisture, good softness and handle, and to avoid reduction in fibre tenacity (Bambrotex, 2008).

Again, Das (2008) has indicated that 100% bamboo yarns demonstrate remarkable elasticity that is nearly 20%. This property is evident even in 100% bamboo woven fabrics that eliminate the necessity of blending with Elastane. He also indicated that dyestuff pick up of bamboo fibres is better than cotton, modal or viscose. Hence, it requires less quantity of dye stuff and gives bright colour shades. Bambrotex (2008) has confirmed in their technical manual that bamboo yarn production stages are very similar to traditional viscose production but with some minor adjustments. However, it is not clear which components (lignin etc.) of the bamboo are removed and which are remaining in their commercial products. Although the actual yarns may well be 100% bamboo, the amount of the different additives or constituents mixed with the bamboo through different stages of processing can provide end products with different characteristics (Hand weavers and spinners guild of NSW inc., 2008). Moreover, these manufacturing processes indicate the use of a large amount of chemicals and, as such, the process may not be called as truly eco-friendly. More benign and harmful chemical free treatments are required to process bamboo fibres.

#### 4. Properties of bamboo fibres

##### 4.1 Physical properties

Extremely soft, comfortable and cool bamboo fibres possess a bright colour. Jain, et al. (1992) found that the tensile, flexural and impact strengths of bamboo along the fibres are  $200.5 \text{ MN m}^{-2}$ ,  $230.09 \text{ MN m}^{-2}$  and  $63.54 \text{ kJ m}^{-2}$ , respectively. It has high elastic resilience, moisture absorption, good drapability, wearability and excellent spinnability. He, et al. (2007) pointed out that bamboo and ramie fibres have similar crystallinity which is greater than that of flax and cotton. Table 1 compares the properties of bamboo and cotton fibres.

##### 4.2 UV protection nature of bamboo fibres

The Cancer Council Australia (2009) states that Australia has the highest incidence rate of skin cancer, melanoma. More than 1200 people die

from melanoma each year and 10,000 cases are diagnosed yearly. Sun-protective clothes can offer a great protection from UV light as a barrier between skin and sun but those clothing must have the following properties:

**TABLE 1:** Comparative study between physical parameters of bamboo and cotton fibres (Bambrotex, 2008)

Parameters	Bamboo Fibre	Cotton Fibre
Linear density (dtex)	1.67	1.5~1.7
Single dry tensile strength (cN/dtex)	2.2~2.5	2.5~3.1
Single wet tensile strength (cN/dtex)	1.3~1.7	1.5~2.1
Dry tensile elongation percentage (%)	14~18	8~10
Moisture regain (%)	13	8.5
Absorbency rates %	90~120	45~60
Specific density ( $\text{g/cm}^3$ )	1.32	1.5~1.6
Mass specification resistance $/\Omega.\text{g.cm}^{-2}$	$1.09 \times 10^8$	$10^8$

- Sun protection 30+ SPF
- Good durability
- Quick drying
- Shape and colour retention ability

Bamboo fibres can be a candidate material to make such protective clothes as they deliver all the required properties.

Ikeda, et al. (2007) confirmed the UV shielding effect of bamboo fibres. Many manufacturing companies also witnessed the UV shielding effect not just from their in-house analysis but also from reputed testing authorities. In April 2005, a bamboo fibre and clothing manufacturing company, Bamboosa, sent out purely natural 100% bamboo jersey to the Sun Care Research Laboratories in Winston Salem, N.C. for UV protection testing. The UPF label rating was 15 and the fabric scored 18.3 on the UPF scale with 94.15% UVA block and 93.17% UVB block (Bamboosa, 2009).

Another bamboo manufacturer, Bambrotex (2008) has tested the UV-screening ability of bamboo and cotton fabrics. Fabric samples for both bamboo and cotton were taken of the same colour, same count and similar appearance in all aspects. They found that bamboo has significantly higher UVB blocking efficiency than cotton and obtained a high rate of user satisfaction for their bamboo products. Again, Hoffmann, et al. (2001) identified that one third of present commercial summer clothing items provide a sun protection factor of less than 15. Therefore, it indicates the promising potential for replacing cotton clothing with bamboo

fabrics to protect human skin from the harmful UV rays.

### 4.3 Biomedical and health-care use of bamboo fibres

Bamboo's ability as a medicine has been recognised for a long time. For example, bamboo plays a significant role in Ayurveda and Chinese acupuncture. To treat asthma, coughs and as an aphrodisiac, the powder made of the hardened secretion of bamboo is used. Ingredients from the root of the black bamboo are used to treat kidney disease. Roots and leaves are used to make medicine for venereal disease, cancer and to improve oral hygiene. It is believed that sap helps to reduce fever and ash is a cure of prickly heat (Lu, et al. 2005; Song, et al. 2006; Shan, et al. 2008).

According to Kweon, et al. (2001), butanol-soluble extract of the bamboo leaves has a significant antioxidant activity, as measured by scavenging the stable 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical and the superoxide anion radical ( $O_2^-$ ) in the xanthine/xanthine oxidase assay system.

Bamboo possesses a unique antibacterial property derived from a bio-agent named bamboo "Kun" or "Kunh" (also called "bamboo chinone"). Bamboo Kun combines tightly with cellulose molecules all along during the production of bamboo fibres (Organic Clothing, 2008). Death rate of bacteria is 70% after they

are incubated on bamboo fibre fabric (Bamboo-t-shirt, 2009).

Nishina, et al. (1991) stated that both bamboo and bamboo grass possess strong antibacterial activity. Among them extract from bamboo has higher activity. They have identified that the antibacterial compound of bamboo is 2, 6-dimethoxy-p-benzoquinone. Quitain, et al. (2004) described both antimicrobial and antioxidant properties of bamboo and remarked that the antimicrobial characteristics are due to polyphenols and lipids.

An antibacterial test was conducted by China Textile Industry Testing Centre according to the China Textile Industry Standard FZ/T 01021-92. The results showed that bamboo has a strong antibacterial effect while cotton has no such effect (Table 2). Bamboo clothing manufacturers have also conducted several antibacterial tests according to Japanese industrial standard JIS L1902 (Halo test) and found that bamboo fibres have inhibited the proliferation of the bacteria *Staphylococcus aureus* (Ftcamerica, 2008).

It was also found that natural antibacterial function of bamboo fibres differs greatly from that of chemical antimicrobials in that bamboo does not cause skin allergy (Quitain, et al. 2004; Bamboo-t-shirt, 2009). It is validated by Japan Textile Inspection Association that, even after fifty times of washing, bamboo fibre fabrics still possess excellent antibacterial and bacteriostatic functions (Bambrotex, 2008).

**TABLE 2:** Antibacterial test report of bamboo fibres (Bamboo-t-shirt, 2009)

Testing fabric	0 hour: bacteria number	Inoculated	24 hour later: bacteria number	Anti-bacteria rate
Bamboo fabric	$8.60 \times 10^4$		$0.6 \times 10^2$	>99.8%
Cotton fabric	$2.0 \times 10^5$		$1.1 \times 10^8$	

Bamboo fibre also has particular and natural functions of deodorization. The deodorization rate of bamboo is 80% for the  $NH_3$  test (Ftcamerica, 2008). Under these circumstances, bamboo fibres promise their place in sanitary towels, gauze mask, absorbent pads, food packing, surgical clothes, operating coat and nurse dresses (Kim, et al. 2005).

### 4.4 Air conditioning bamboo clothing

Bamboo is characterised by having excellent hygroscopic properties along with good ventilation, coolness, permeability and splendid colour effects of pigmentation. It has an outstanding wicking property as it wicks away moisture or perspiration in a second without clinging against body. It has 12 times stronger anti-static effect than cotton products (Copperwiki, 2009).

Figure 4 shows the images of bamboo fibres taken under optical and scanning electron microscopes. The fibres have numerous micro-fibre surface grooves, horizontal irregular oval and round waist, with the cavity filled with circumferential and small gaps. Due to those micro gaps or holes, cracks and grooves, like capillary, bamboo clothing wearers experience instant moisture absorption and evaporation. This is why it is sometimes described as "Will breathe fibre" (China KonFi Textile co ltd., 2008).

The temperature of the apparels made from bamboo fibres is 1-2 degrees lower than normal apparels in hot summer. The fibres have round smooth surfaces so that they do not cause irritating stimulation against human skin. They are also described as "air conditioning" garments as they are cooler during summer and feel comfortably fluffy and warmer during cold weather (Bamboo fabric store, 2009).

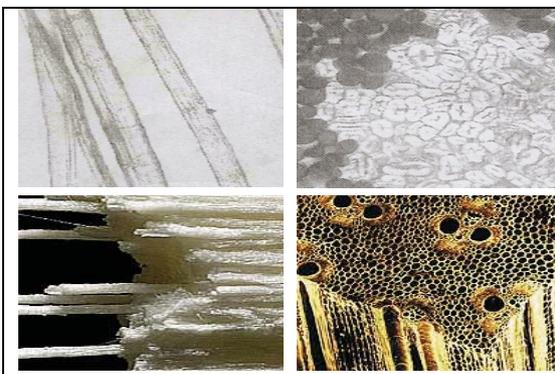
## 5. Fashion trend and bamboo clothing

Bamboo has attracted increasing attention from the designers around the world due to the growing environmental awareness among consumers. Designer Kate O'Connor has started to use bamboo fabrics as an eco-friendly and cheap replacement for silk. She indicated that it gives a similar drape to silk and makes perfect summer fabrics.

Other savvy eco-fashion designers such as Linda Loudermilk, Katherine Hamnett, Miho Aoki and Thuy Pham frequently incorporate bamboo into their eco-fashions due to its light, soft and luxurious appeal. Designer Amanda Shi of Avita also has some of the most exciting and originally beautiful eco-fashion in bamboo (Organic clothing, 2008).

Bamboo clothing is naturally more wrinkle-resistant than cotton. Bamboo clothing can be machine washed in cool water with mild soap on the gentle cycle, though softeners or bleaches are good to be avoided for bamboo clothing. It is best if garments made of bamboo are hung to dry. Surprisingly, it dries faster than most other fabrics (Earth Easy, 2009).

Bamboo socks, bed sheets, jackets are very common items among the web based retailers. Fashion retailer, Target and Sussan are already selling bamboo textile products in Australian market. Bamboo clothing may create a new dimension in the fashion trend of sunny region of the world like Australia for its multi functionality.



**FIGURE 4:** Lengthways appearance (left); Cross section appearance (right) of bamboo fibres (KongFi and Eratheasy, 2008)

## 6. Conclusions

A Chinese poet once wrote, "Man can live without meat, but he will die without bamboo" (Ding, 2008). This reflects the significant potential of bamboo fibres. The available information suggests that bamboo fibres have unique properties such as excellent appearance and feel, natural antibacterial, UV-shielding and moisture-controlling characteristics. However, those unique properties may largely depend on

the manufacturing processes, the details of which are usually close guarded by the manufacturing companies.

Although many companies made claims for the unique properties of bamboo fibres, little evidence was able to be collected from scientific literatures. For instance, the claimed "cool in summer" and "warm in winter" characteristics of bamboo fibres would need to be verified in well controlled experimentation. There is a strong need for unbiased laboratory experiments being conducted in a rigorous manner to elucidate the origin of those unique properties of bamboo fibres and to develop the methods to effectively utilise the properties in the final products.

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