The Antibacterial Performance of Natural Bamboo Fiber and Its Influencing Factors

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Abstract

Natural bamboo fiber is a new type of plant fiber using for textile. Its natural antibacterial property has not been investigated fully. In this paper, the nature antibacterial property of natural bamboo fiber was determined with the method of dynamic test referring to GB/T 20944. 3-2008 and compared with other fibers for textile, such as jute fiber, flax fiber, ramie fiber and regenerated bamboo fiber. The bacteria used in the test were *Escherichia coli*． (8099), *Staphylococeus auresu*(ATCC 6538) and *Candida albican*(ATCC 10231).The relationships between the antibacterial property of natural bamboo fiber and its shape, hygroscopicity and extractives were tested to analyze the influencing factors. In the results, compared with natural cotton the bacteriostatic rates of natural bamboo fiber against the bacteria were all zero; that of jute fiber and flax fiber against ATCC10231 were 48% and 8.7%; that of ramie fiber against ATCC 6538 was as high as 90.2%; that of regenerated bamboo fiber against ATCC6538 was higher than 70%. The bacteriostatic rates of the bamboo with different shape were all zero, that of plant fibers was inversely proportional to their moisture regain and the bacteriostatic action against ATCC 10231 of natural bamboo fiber extracted was lower, however, that against 8099, and ATCC 6538 was stronger except extracted with benzene. The results show that natural bamboo fiber has no natural antibacterial property. The shape could not impact the natural antibacterial property of natural bamboo fiber but the hygroscopicity and extractives have influence on that.

***Keywords*:** Natural bamboo fiber, antibacterial property, Influencing factors.

Introduction

As an abundant resource in China and an eco-friendly and multifunctional plant, bamboo has been used in architecture, agriculture, furniture and paper-making for thousands of years. Recently, research on producing textile fiber from bamboo has been conducted. According to different preparation techniques, the bamboo fiber for textile has been divided into two kinds, natural bamboo fiber and regenerated bamboo fiber (Li Qingchun. 2003). The natural bamboo is usually in the form of fiber bundle which is produced by unique chemical and physical technique (Wang Chunhong et al. 2005, Zhang Wei et al. 2007). The regenerated bamboo fiber is made from bamboo pulp, which has a similar processing method to the ordinary viscose fiber (Zhou Hengshu and Zhong Wenyan. 2003).

Clothing manufactured by regenerated bamboo fiber has entered the textile market with a claim for its antimicrobial property, but without scientific evidence (Afrin, T. et al. 2009). With the success of the separation techniques of natural bamboo fiber, people start to pay attention to the antibacterial property of natural bamboo fiber. However, there are different opinions on this issue. High bactericidal rate of natural bamboo fiber against some kinds of bacteria has been reported (Xing Shengyuan and Liu Zheng.2004) and the antibacterial agent in bamboo fiber has been identified as anthraquinone compounds that contain four α-hydroxylation functional groups (Sun Jujuan. 2007). However, results released from other studies have indicated that natural bamboo fiber has no significant antibacterial effect (Zhou Hengshu and Deng Libin. 2005) and even if it does, it is just because of certain natural micro-structure, not the antibacterial constituents (Zhu Liwei et al. 2008).

The aim of this paper was to investigate the natural antibacterial property of natural bamboo fiber and its influencing factors. As cotton, jute, flax and ramie are also plant fiber being used in textiles, they were selected to be compared with natural bamboo fiber. Meanwhile, the antibacterial property of regenerated bamboo fiber was also evaluated and compared with natural bamboo fiber.

Materials and Methods

Materials. Natural bamboo fiber used in this study was produced from the bamboo of Neosinocalamus affinis following the process: bamboo spliting → alkali degumming → acid rinsing → water rinsing → dewatering → shaking → drying → combing. Cotton, jute, flax, ramie and regenerated bamboo fiber used to be compared with natural bamboo fiber were purchased from market. A part of cotton fiber was treated with antibacterial agent SCJ-2000 (produced by Beijing Jlsun High-tech Co. Ltd), while another part of cotton and all of other fibers were untreated. Bamboo bundle used in this study came from the first step of the process and bamboo powder was obtained by grinding the natural bamboo fiber into 40~60 mesh-powder. In this study three repeated sepecimen for each series of test were prepared.

Microorganisms and media. Gram-negative bacteria, *Escherichia coli* (*E. coli*, 8099), gram-positive bacteria, *staphylococcus aureus* (*S. aureus*, ATCC 6538) and fungi *Candida albicans* (C. albicans, ATCC10231) were used as test organism. Nutrient Broth and Nutrition Agar culture medium were prepared for the bacteria growing and Sabouraud's Agar culture medium was used for the fungi culture. Buffer solution used for diluting was phosphate buffer solution (PBS, 0.03mol/L, pH=7.2~7.4).

Evaluation of fiber hygroscopicity. The humidity of the fiber samples was conditioned to balance state on the condition of 20℃ and 65% RH firstly referring to GB 6529-86 Textiles-Standard atmospheres for conditioning and testing. Then the samples were dried to constant weight at 105±2℃ referring to GB/T 9995-1997 Determination of moisture content and moisture regain of textile-Oven-drying method. The moisture regain was evaluated by the following equation:

$$W = \frac{G - G_0}{G_0} \times 100\% \quad (1)$$

Where W is the moisture regain, %, G is the wet weight of the textile fiber, g, and G_0 is the dry weight, g.

Extracting of natural bamboo fiber. Natural bamboo fiber was extracted to remove some kinds of extractives contained in the fiber referring to the determination method of extractives in fibrous raw material stipulated in GB/T2677. The extraction dissolvent used in the test were cold water (room temperature), hot-water (95~100℃), ethanol (density 95%), benzene, benzene/ethanol mixture (2:1, v/v) and 1% NaOH.

Antibacterial test. The antibacterial activity was tested with the shake flask test referring to GB/T 20944. 3-2008 Textiles-Evaluation for antibacterial activity-Part 3: Shake flask method. In the test for investigating the natural antibacterial property of natural bamboo fiber and the effect of bamboo shape on it, the untreated cotton was used as the negative control sample and the antibacterial cotton was used as the positive control sample. The antibacterial properties of test samples were evaluated by calculating the bacteriostatic rate as Equation (2). In the test for investigating the effect of extractive on the antibacterial activity of natural bamboo fiber, the bacterial growth in the flasks containing the natural bamboo fiber extracted and untreated was compared. The effect was evaluated by calculating the efficiency of anti bacteria as Equation (3). Negative number in the result was represented by 0.

$$Y = \frac{W_t - Q_t}{W_t} \times 100 \quad (2)$$

Where Y is the bacteriostatic rate, %, W_t is the average CFU per milliliter for the flask containing the negative control sample after 18h contact, and Q_t is the average CFU per milliliter for the flask containing the test sample after 18h contact.

$$E = \left(1 - \frac{D_t}{D_0}\right) \times 100 \quad (3)$$

Where E is the efficiency of anti bacteria, %, D_t is the average CFU per milliliter for the flask containing the natural bamboo fiber extracted after 18h contact, and D_0 is the average CFU per milliliter for the flask containing the natural bamboo fiber untreated after 18h contact.

Results and Discussion

Antibacterial property. The results of the antibacterial test are shown in Table 1. The untreated cotton as the negative control sample was not effective against bacteria, while the antibacterial cotton was very effective against all test bacteria with a bacteriostatic rate of over 99 % against *E. coli* and 100 % against *S. aureus* and *C. albicans*, indicating dependability of this test. The results showed that natural bamboo fiber was not effective against *E. coli*, *S. aureus* and *C.albicans* since the bacteriostatic rate against all of them was 0. By comparison, the bacteriostatic rate of ramie against *S. aureus* was over 90%, and that of regenerated bamboo fiber was 75.8%. Jute and flax had bacteriostatic activity against *C. albicans* because of bacteriostatic rate of 48% and 8.7%.

Tab.1 Results of the antibacterial test

fiber type	Bacteriostatic rate(%)		
	Escherichia coli	*Staphylococcus aureus*	*Candida albicans*
Untreated cotton	0	0	0
NBF	0（-68.9）	0（-13.2）	0（-41.3）
Jute	0（-15.9）	0（-48.4）	48
Flax	0（-45.0）	0（-88.8）	8.7
Ramie	24.3	90.2	54
RBF	41.4	75.8	0（-12.8）
Antibacterial cotton	>99%	100%	100%

Note: NBF=Natural bamboo fiber, RBF=Regenerated bamboo fiber (the same below)

The bacterial population density on each sample after shaking 18h is shown in Figure 1 in order to compare the inhibiting ability to bacterial growth of each kind of textile fiber. The Histogram shows that compared with natural cotton the population density of *E. coli* and *C. albicans* in natural bamboo fiber increased greatest after 18h. Instead of increasing, *E. coli* density in regenerated bamboo fiber and *S. aureus* density and *C. albicans* density in ramie decreased greatest.The antibacterial performance of regenerated bamboo fiber may largely come from the use of a large amount of chemicals in manufacturing process (Zhang Shiyuan. 2008) and that of ramie has been attributed to the components of pyrimidine, purine or other antibacterial component (Shao Songsheng. 2000).

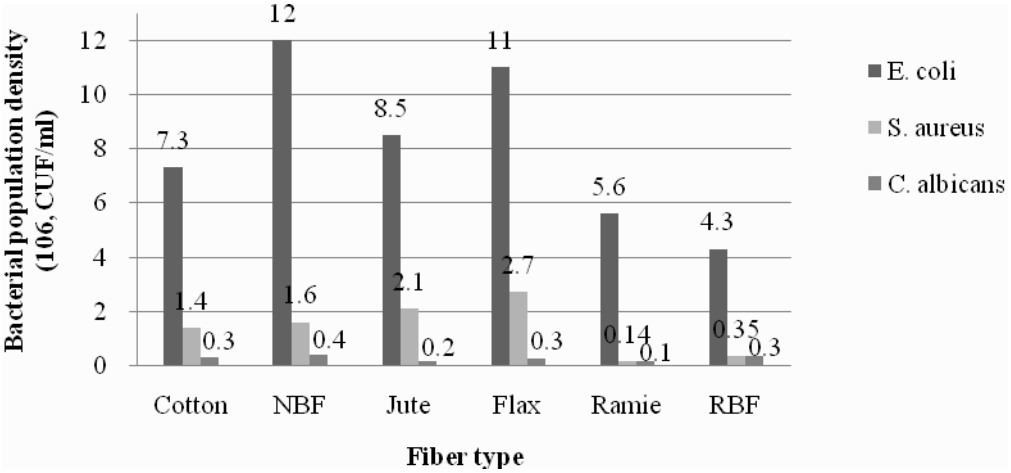

Fig.1 The bacterial population density on each sample after shaking 18h

The effect of bamboo shape. The bacteriostatic rates on the different shapes of bamboo against all the challenge bacteria were all 0 as showed in Table 2 and the bacterial population density of the same bacteria on different shapes of bamboo were nearly equal (Fig.2).

Tab.2 The bacteriostatic rate on different shapes of bamboo

Bamboo shape	Bacteriostatic rate(%)		
	Escherichia coli	*Staphylococcus aureus*	*Candida albicans*
Bundle	0(-69.0)	0(-75.0)	0(-45.5)
Fiber	0(-68.9)	0(-13.2)	0(-41.3)
Powder	0(-54.9)	0(-50.0)	0(-33.4)

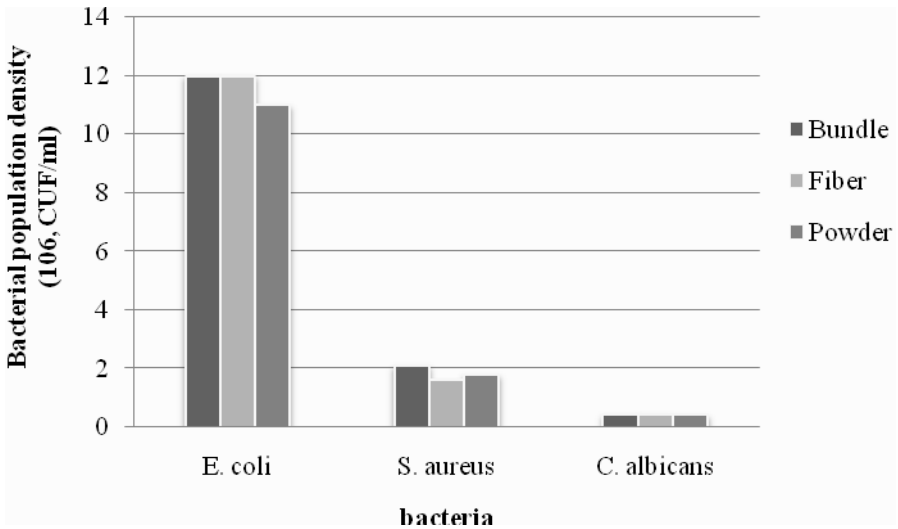

Fig.2 The bacterial population density on different shapes of bamboo

The effect of fiber hygroscopicity. The moisture regains of textile fiber are presented in Table 3, which shows that except the regenerated bamboo fiber the moisture regain of natural bamboo fiber was highest among the plant fibers, while that of ramie was lowest. The moisture regain of fiber is inversely proportional to their degree of crystallization (Wang Yueping et al. 2009). Figure 3 indicates the relationship between the moisture regain of the plant fibers and their bacteriostatic rates. According to the figure presented, it was determined that fiber possessing higher hygroscopicity presented lower bacteriostatic rate. Especially, the fitting correlation coefficient of the bacteriostatic rate against *E. coli* along with the moisture regain was 0.993. However, the regenerated bamboo fiber did not follow this trend (there is no definite relationship between hygroscopicity and its bacteriostatic rate), which may result from its preparation process.

Tab.3 The moisture regain of textile fiber

Fiber name	Moisture regain(%)
NBF	9.80
Cotton	7.75
Flax	9.24
Ramie	6.81
RBF	12.09

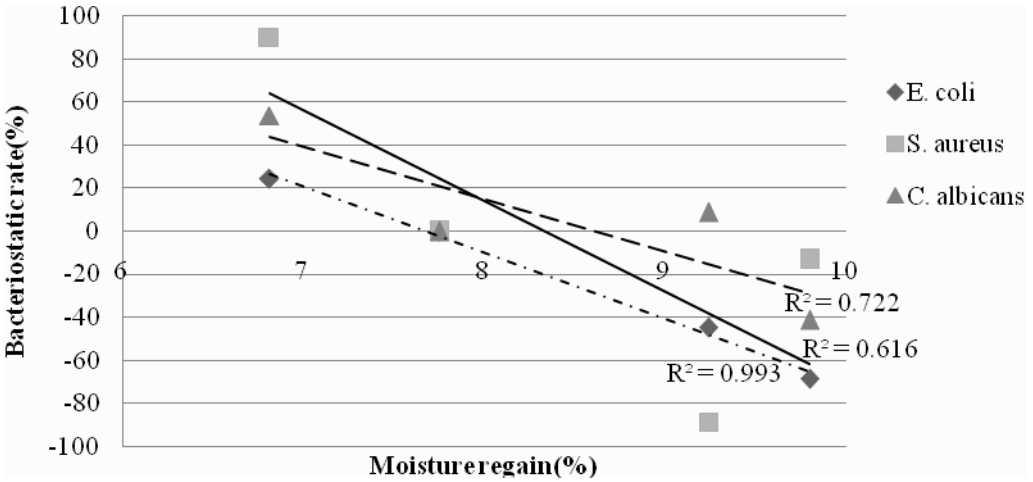

Fig.3 The relationship between moisture regain and bacteriostatic rate

The effect of extractive. It can be seen from Table 4 that extraction was effective in improving the antibacterial performances of natural bamboo fiber against *E. coli* and *S.aureus* except using benzene as the extraction dissolvent. Extraction using hot-water was the most effective method in improving the antibacterial property against *E. coli* with an anti bacteria efficiency of nearly 70% and using 1% NaOH was the best method against *S.aureus* with an anti bacteria efficiency of over 67%. However, there was not

any contribution toward improving the antibacterial activity against *C. albicans* by removing some kinds of extractives from natural bamboo fiber.

Tab.4 Antibacterial Efficiency of different extraction method

Extraction dissolvent name	anti bacteria Efficiency（%）		
	Escherichia coli	*Staphylococcus aureus*	*Candida albicans*
Cold-water	64.35	10.91	0
Hot-water	69.57	30.91	0
Ethanol	18.26	7.88	0
Benzene	0	0	0
Benzene/ethanol	4.35	36.36	0
1% NaOH	58.26	67.88	0

The origins of the extraction influence on the antibacterial property of the natural bamboo fiber may be attributed to three reasons. Firstly the removing of some extractives of natural bamboo fiber such as carbohydrate and inorganic salt (Higuchi, T.1987) which are microbial growth nutrients could improve the antibacterial performance. Secondly the extractives may contain some antibacterial component and the reduction of which may decrease the antibacterial property of the natural bamboo fiber at the same time. And finally, changes in chemical composition changed the pH value of the fiber which could affect the bacteria growth (Sun Fangli et al. 2006). Therefore, we inferred that the combine of the three aspects led to the influence of extraction on the antibacterial property of the natural bamboo fiber.

Conclusion

In this study, the antibacterial property of natural bamboo fiber and its influencing factors were investigated. The antibacterial test results show that natural bamboo fiber has no natural antibacterial property compared with other textile fiber. The fact that the growth of bacteria on different shapes of bamboo was nearly equal may indicate that the shape could not impact the antibacterial activity of natural bamboo fiber. The linear relationship between the moisture regain and the bacteriostatic rate suggests that the hygroscopicity may be a influencing factor in antibacterial performance of fiber. Some extraction method could improve the antibacterial property of natural bamboo fiber against bacteria, therefore, extractives have influence on that.

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