An Investigation into the Antibacterial Properties of Bamboo/ Cotton Blended Fabric and Potential Limitations of the Test Method AATCC 147

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ABSTRACT

In this paper, the antibacterial activity of various blend ratios of bamboo and cotton fibers was assessed qualitatively. It was found that incorporation of regenerated bamboo fiber did not drastically increase the antibacterial property of the resulting fabric. In fact, limited bacteriostatic property was observed in the case of the sample containing as high as up to 75% bamboo fiber. Thus, the study supports the reports stating that the regeneration process of bamboo results in significant loss of its antibacterial properties. Pile fabric (terry towel) was also considered and it was observed that the pile area showed inferior bacteriostatic property. This is attributed to the lack of contact between the pile *portion of a* fabric and the nutrient providing medium for bacterial growth. This is considered to be an important finding that could be beneficial for the relevant industry that is involved in developing antibacterial textiles.

摑要

本文对竹棉纤维的不同混纺比的抗菌活性进行了定性评价.结果表明，再生竹纤维的加入并没有显著提高织物的抗菌性能.事实上，高达75%的竹纤维样品的抑菌性能有限.因此，这项研究支持了有关竹子再生过程导致其抗菌性能显著丧失的报道.同时还考虑了绒布（毛巾布），发现绒布区域的抑菌性能较差.这是由于织物的堆积部分与为细菌生长提供培养基的营养素之间缺乏接触.这被认为是一个重要的发现，可能有利于相关行业参与开发抗菌纺织品.

Introduction

The concept of antibacterial textiles is not new. This is reported in patent documents as early as from the 1960s (Milton and Gump 1962). In order to achieve antibacterial or bacteriostatic properties, the most common method generally is to impregnate a textile fabric with appropriate chemical compounds. Such chemicals have been used singly or as a mixture of two or more to furnish antibacterial properties in the treated material (Arain et al. 2013; Sun et al. 2001; Zhang et al. 2007). The methods employed range from simple dip coating (Onar et al. 2011) to deposition of multiple layers (Dubas, Kumlangdudsana, and Potiyaraj 2006). One of the most common elements that are used for this purpose is silver in a variety of forms (Lee, Yeo, and Jeong 2003; Rajamani, Kuppusamy, and Shanmugavadivu 2013). Detailed accounts of the mechanism of action of silver on *Staphylococcus aureus* and *Escherichia coli* are reported in the literature (Jung et al. 2008). Attempts have also been made to treat textiles with natural products that possess antibacterial properties (Joshi et al. 2009). Nowadays, almost all of the leading textile chemical and auxiliaries' manufacturers offer antibacterial chemicals that can be applied onto textile articles in the form of finishes to achieve the desired antibacterial characteristics.

Synthetic fibers/filaments that are claimed to be antibacterial in nature are also available commercially. Among the more commonly used textile fibers, bamboo fiber, which is chemically similar to all bast fibers with cellulose making up the major proportion (Yueping et al. 2010), reportedly possesses antibacterial properties (Yu-Lu 2009). A naturally occurring substance in bamboo known as "bamboo kun" is considered to be the primary source in furnishing antifungal and antibacterial properties to bamboo. It is also partly due to the same substance that the use of pesticides is not required to protect bamboo during the growth phase in fields (Waite 2009). In addition, water consumption in the process is low. Due to such properties, complimented by the recent surge in sustainability-related aspects of textiles, bamboo has drawn considerable interest of researchers in both academia and in industry (Yao and Zhang 2011).

Numerous studies report on the quality characteristics of yarns and fabrics prepared by blending bamboo with other widely used textile fibers such as cotton (Demiroz Gun, Unal, and Unal 2008; Erdumlu and Ozipek 2008; Prakash, Ramakrishnan, and Koushik 2011; Sekerden 2011; Yueping et al. 2010). In a study in which woven fabric made from bamboo fiber was compared with bamboo/cotton blend fabric, it has been shown that the fabric made from bamboo fiber has superior physical/mechanical properties including breaking strength, elongation and tearing strength (Rathod and Kolhatkar 2014). A large number of studies report on other properties such as moisture management, thermal properties and comfort properties (Majumdar, Mukhopadhyay, and Yadav 2010; Prakash and Ramakrishnan 2014, 2013b, 2013a; Prakash, Ramakrishnan, and Koushik 2012; Wu, Zhang, and Li 2009). It has been reported that bamboo fabric possesses better overall wearing comfort, hygroscopicity, air permeability and antistatic properties compared to a number of regenerated and natural fibers (Wu, Zhang, and Li 2009; Yong-Fang and Bu-Kun 2010). Owing to the properties highlighted in the preceding text, bamboo fiber is increasingly being used in commercial products that are claimed to offer certain advantages over conventional fibers (Lee 2007).

In the past decade or so, a large number of textiles manufacturers, particularly from Asia, have actively marketed bamboo textiles as antibacterial textiles. However, regarding the true nature of such products, the available scientific information is limited and conflicting (Li-Wei et al. 2008). Although a number of studies report the preparation of anti-bacterial textiles, complete characterization and particularly a detailed study of the effects of various processing treatments are not reported. Therefore, in the present study, the case of terry towel was considered and qualitative assessment of the antibacterial properties was carried out at every major stage in the product development line. This was expected to provide insight into the effects of each treatment on the antibacterial properties of the textile article. Furthermore, characterization of anti-bacterial properties of various blend ratios of bamboo and cotton fibers was also carried out and the effect of specimen surface smoothness was also examined.

Materials and methods

Blended fabric preparation

Cotton and regenerated bamboo fibers were blended on a standard, industrial scale, staple yarn production line. The yarn count was maintained at 30s while the blend ratios mentioned in Table 1 were prepared and tested. In the next step, woven fabrics from the blended yarns were prepared on

Table 1. Bamboo/cotton blend fabrics prepared and tested in the study.

S. no.	Bamboo/cotton blend ratio	Ends per inch	Picks per inch
1	22:78	54	56
2	25:75	54	54
3	50:50	54	58
4	75:25	54	54

a sampling loom. The important specifications of the blended fabrics are also provided in Table 1. As per the requirements of a conventional weaving process, the warp yarn was sized using a typical starch-based sizing solution. The antibacterial property of the prepared fabrics was tested in Grey form, after standard bleaching process and after a typical dyeing process.

Antibacterial finished fabric

The applicability of the antibacterial assessment method AATCC 147 on pile fabrics was also investigated in the present study. For this purpose, terry fabric sample was prepared on standard production-scale machinery followed by complete pre-treatment and finishing using anti-bacterial agents.

Assessment of antibacterial properties

AATCC method 147:2011 was used in the present study to assess the antibacterial properties of bamboo-cotton blended fabric as well as the terry fabric treated with antibacterial finishing agents. Nutrient agar was used as the growth media. *Escherichia coli* (ATCC® 8739™) and *S. aureus* (ATCC® 6538™) were considered as the representative gram-negative and gram-positive bacteria against which the response of the test samples was evaluated.

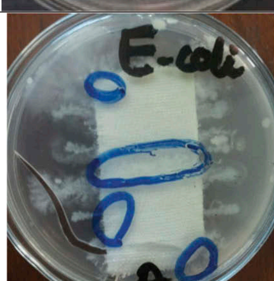
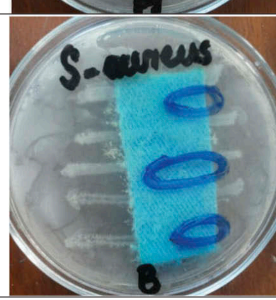
Sample	E.Coli	S.Aureus
Loom state		
H_2O_2 Bleached		
H_2O_2 Bleached + Turquoise tinted		

Figure 1. Anti-bacterial assessment of CB fabric after bleaching and after dyeing.

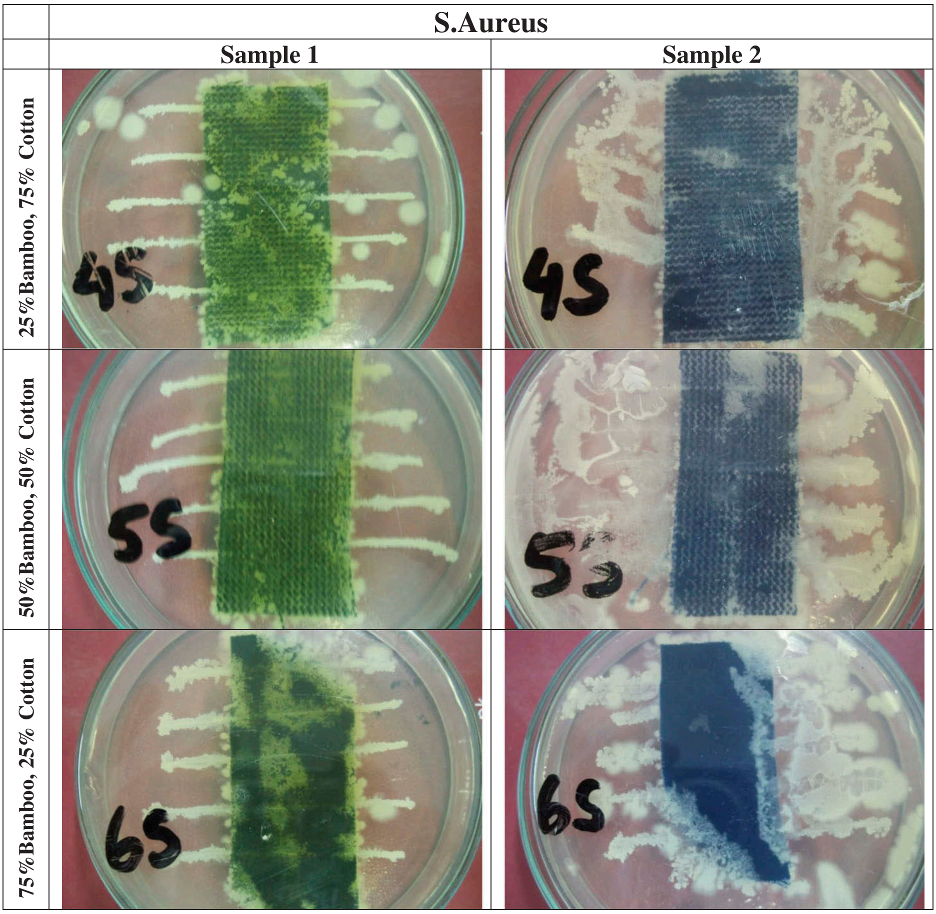


Figure 2. Response of bamboo:cotton blended fabrics against *Staphylococcus aureus*.

Results and discussion

In order to analyze the effect of a typical wet processing sequence on the antibacterial property of bamboo/cotton blended fabric, a fabric containing 22% bamboo and 78% cotton was tested in Grey form, after bleaching and after dyeing with a reactive dye. The bacterial growth on the petri plates after 24 h of incubation at 37^{o}C is shown in Figure 1. The regions where bacterial growth occurred are marked. This was required because the contrast between the bacteria and the sample was too low to make the growth visible in the recorded images. It is clear from Figure 1 that a distinguishable "zone of inhibition" was not present in any of the samples. Furthermore, the extent of bacterial growth was virtually the same for both *S. aureus* and *E. coli*. However, the growth under the bleached and under the dyed samples was slightly less compared to the loom-state fabric. This could simply be attributed to the fact that removal of sizing agent from the fabric resulted in improved contact between the bamboo fiber content in the fabric and the nutrient in the Petri plates.

The dyed samples tested as mentioned in the preceding text provided a better contrast against the nutrient and the bacterial growth could be seen clearly. Thus, in the next step, which involved the testing of blended fabrics containing higher proportions of bamboo fiber, samples were bleached and tested prior to assessment of their antibacterial characteristics. For all of the blended fabrics, two samples were tested for response against each bacterium. The petri plates inoculated with *S. aureus* and incubated for 24 h at 37^{o}C are shown in Figure 2. It is clear from the results that only the fabric

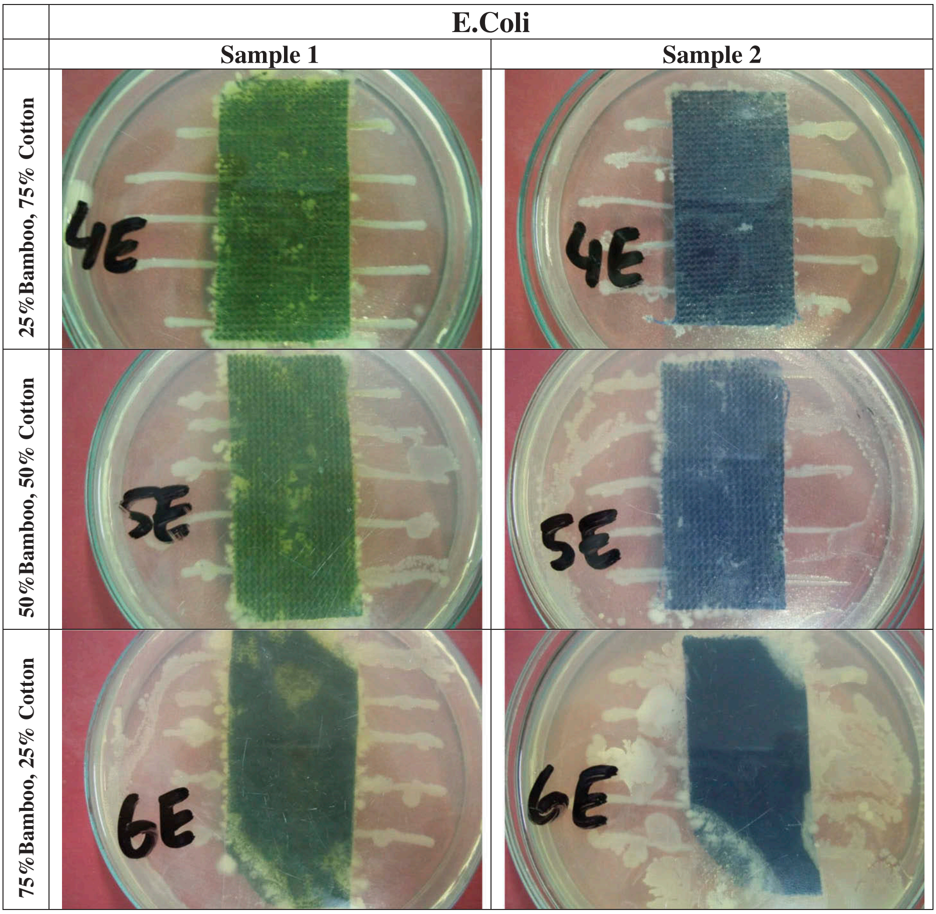


Figure 3. Response of bamboo:cotton blended fabrics against *Escherichia coli*.

containing 75% bamboo possessed antibacterial character strong enough to restrict bacterial growth under the sample. Even in this case, a distinct "zone of inhibition" did not develop around the sample.

As evident from the samples shown in Figure 3, virtually the same trend was observed in the case of testing of blended fabrics against *E. coli*. Thus, the results of our study support the argument that a considerable loss occurs in the antibacterial property of bamboo fiber during the regeneration process.

It was noticed in the present study that the construction of a fabric, in particular the weave, is a significant factor to be considered while employing the AATCC 147 method. This is because the correctness of the results is greatly dependent on proper contact between the test sample and the nutrient in petri plates. This point becomes even more important to be considered in the case of samples that do not possess very strong antibacterial characteristics. Although elaborate methods for quantitative assessment of antibacterial properties can be employed, the AATCC 147 method is widely used in the relevant industry for flat woven fabrics as well as for pile fabrics. Due to the considerably lower cost of the test, this approach is even more common in screening type trials in the product development process. Based on the observations made by the investigators regarding the influence of the flatness (or lack of it) of a test fabric on the results obtained, a terry towel fabric finished using antibacterial agents was considered and the antibacterial assessment was carried out for the pile portion as well as the non-pile portion. From the results of these tests that are provided in Figure 4, it is evident that the antibacterial effect of the pile portion was less pronounced

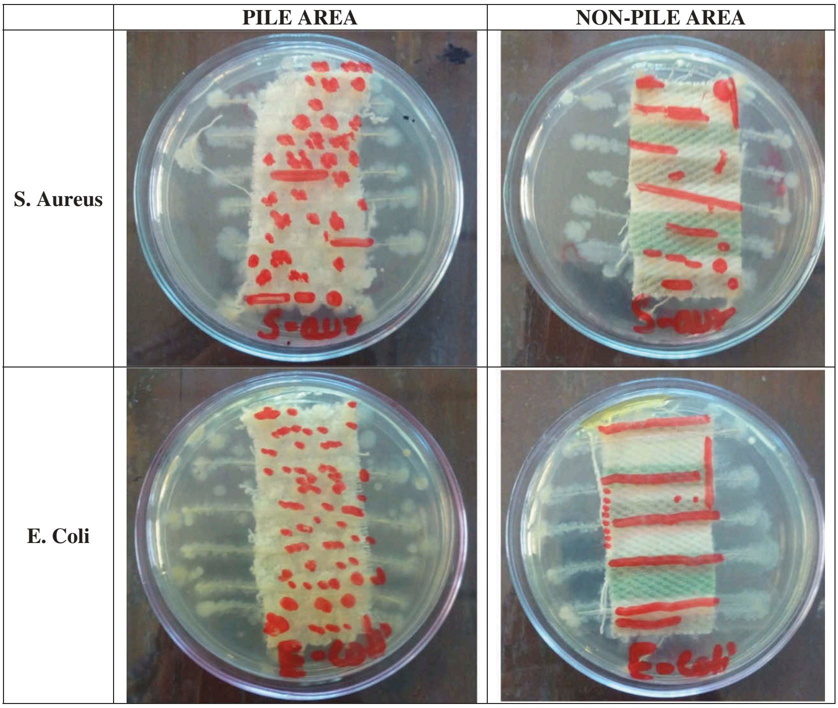


Figure 4. Response of pile portion and non-pile portion of a terry fabric treated with antibacterial agent.

compared to that of the non-pile portion of the same fabric. Given that both the pile portion and the non-pile portion were taken from the same larger piece after all the treatments, it is certain that the observed difference in the antibacterial property was not due to a difference in the intrinsic properties of the test sample. Instead, it is a clear indication of the fact that reduced area of contact resulted in an apparently inferior antibacterial character of the sample comprising of the pile portion of terry towel.

Conclusion

In this study, the antibacterial property of fabrics containing different ratios of cotton and regenerated bamboo fibers was qualitatively assessed. The results of our study support the argument that bamboo fiber considerably loses it antibacterial property during the regeneration process. Among the blend ratios that were tested, bacterial growth under the sample containing 75% bamboo was restricted; however, a clear zone of inhibition could not be identified even in this case. Another important aspect of the antibacterial assessment of textiles that is reported in this study is that if the test method AATCC 147 is considered, a flat woven structure must always be used as the test specimen. This point is of prime importance for the industry involved in manufacturing of antibacterial textiles such as towels.

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