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Review Article

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Developments in Antimicrobial Textiles – Some Insights on Current Research Trends

N Gokarneshan*, VB Nagarajan and SR Viswanath

Department of Textile Technology, Park College of Engineering and Technology, India

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***Corresponding author:** N Gokarneshan, Department of Textile Technology, Park College of Engineering and Technology, Coimbatore, Tamil Nadu, India. Email: advaitcbe@rediffmail.com

Abstract

The article reviews the recent trends in the development of antimicrobial textiles. Bacterial cellulose has been produced from gram negative bacteria at the air liquid interface of sugary rich medium. The bacterial cellulose so produced can be used in making absorbent pads and nonwoven textiles. Viscose fabrics have been modified to enhance the attraction for nano metal oxides in order to impart antibacterial activity against two types of bacterial species. The treatment has lead to a unique ability to stop growth of microorganisms on the viscose fabrics are treated with acid and after treatment with nano metal oxides. Also the antimicrobial activity could endure many washes. Antimicrobial finish has been imparted to wool fabric by application of chitosan derivative through a microwave heating system.

The microwave finished wool fabric exhibits better antimicrobial activity and durability to washes in comparison with conventionally finished wool fabrics without loss in strength properties. Natural and regenerated bamboo/cotton knitted fabrics have been finished with the extracts of piper betel leaves. The finished fabrics have been evaluated for the antibacterial activity against a select range of pathogens commonly encountered in human foot wounds. The fabrics so finished have been compared with untreated fabrics and fabrics treated with commercially available antibiotics used in the treatment of foot wounds. The herbal treated fabrics have been microencapsulated to improve wash durability. Three types of antibacterial microfibers have been developed by addition of nano silver particles during melt spinning process. The bacteriostatic reduction rates ranged between 65-99% depending on the fineness of the fibres produced.

Keywords: Antimicrobial fiber; Bacterial cellulose; Viscose fabrics; Nano metal oxide; Microwave Heating; Antiseptic finishing; Herbal extract

Introduction

Recently, increasing public concern about hygiene has been driving many investigations on antimicrobial agents for textiles. Cellulose is of great importance in fundamental research and industrial applications because of its widespread occurrence, uniform high molecular structure and unique properties such as polyfunctionality, multichirality, hydrophilicity, and biocompatibility. Bacterial cellulose which is obtained from microorganisms like bacteria, fungi and algae, are preferred over plant cellulose due to advantages. It is pure cellulose aggregate which does not include any impurities, such as hemicellulose, pectin and lignin [1].

Antimicrobial agents are used to prevent serious undesirable effects on textile materials, such as degradation of coloring, staining and deterioration of the fibers, formation of unpleasant odor, as well as increase of potential health risks [2-7]. A proposal of hygienic living standard by controlling the microorganisms is necessary. Researchers have focused on the antibacterial and antifungal modifications of textiles by application of inorganic nanotechnology [8-10]. In recent years, some new techniques and methods have been studied for saving energy and eco-friendly textile processing. The use of microwave heating method in textile dyeing and finishing has been the subject of considerable importance because of various advantages such as uniformity, flexibility, less energy, and high efficiency [11-13].

Recently there has been upsurge interest in apparel technology all over the world for much demanding functionality of the products like wrinkle resistance, water repellence, fade resistance and resistance to the microbial invasion [14]. Today with the increasing awareness of environmental concerns, an important legislation on eco-toxicological considerations has been introduced. Among various finishes, development of antimicrobial textile finish is highly indispensable and relevant since garments are in direct contact with the human body. The antimicrobial property plays a vital role, as they are in directly in contact with the human skin [15]. Microfiber is a kind of synthetic fiber finer than one denier. The most common types of microfibers are made from a conjugation of polyester and polyamide [16]. Its products are environmental friendly cleaning textiles, which make a perfect cleaning without or only with a little detergent [17-19].

Microbial fiber from bacterium

Bacterial cellulose is generated as a never dried membrane in a nearly pure form that contains 99% water, of which 0.3% is bound and 98% is free water [20]. Many potential high value markets exist for thin film of bacterial cellulose, including acoustic diaphragms, artificial skin, pulp and high value paper products, artificial blood vessels, liquid loaded medical pads, super sorbers, and specialty membranes [21]. A xylinium is a gram negative, aerobic bacterium that produces cellulose in the form of interwoven extracellular ribbons as part of primary metabolism. This bacterium grows and produces cellulose from a wide variety of substrates and is devoid of cellulose activity. The fibers are formed in the membrane by cellulose syntheses and consequently secreted from a row of 50-80 pores like synthetic sites along the longitudinal axis of the cell and gives a 3D cellulosic layer [22]. The scale of bacterial cellulose production, processing and use is relatively small because of the problems associated with the selection of sufficiently efficient producers.

Cellulose obtained from bacterium A.xyilinum has opened new avenues in the field of fibers and textiles. The production of bacterial cellulose is more convenient and a relatively pure form of cellulose can be obtained with simple alkali treatment [23]. Based on the FTIR studies it is concluded that the properties of bacterial cellulose are closer to that of the pure microcrystalline cellulose. With a very high water retention capacity and tensile strength bacterial cellulose appears to be a specific substitute for plant cellulose in selected applications such as absorbent pads and in production of nonwoven textiles.

Modified viscose fabrics with antimicrobial activity

As most of the textile fabrics would undergo repeated laundering during their lifetime the washing durability of nonmaterial treated fabric is of significant importance. Polycarboxylic acids are a multifunctional organic molecules with chemical and thermal stability [24,25]. Polycarboxylic acid could form ester linkage with hydroxyl group of cellulosic fabrics at elevated temperature above 160oC [26]. They have also been used to improve the adhesion of the inorganic-organic interface [27]. Efforts have been directed towards producing permanent antimicrobial viscose fabrics by fixation of propionic acid groups at lower temperature (below100oC), as active centers, onto the cellulosic polymeric chain. The added carboxylic groups are believed to act as favorable centers for some oxides such as titanium dioxide. The efficiency of the antimicrobial activity, considering the permanent performance against selected microorganisms onto modified textile is also evaluated.

FTIR spectra of untreated viscose fabric as well as fabrics pretreated with 3-bromopropionic acid and then with nano metals show a support for the reaction between the viscose fabrics and 3-bromopropionic acid. The alkali combining capacity values increase remarkably as the amount of 3-bromopropionic acid is increased during the modification of the viscose fabrics, which supports the reaction between OH-active group of viscose and bromine halide of 3-bromopropionic acid. Investigation has revealed the ability of the introduced carboxylic groups to attract the nano metal oxides from their suspension to the fabrics [28]. The study also shows the incapability of 3-bromopropionic acid treated viscose fabrics to resist microorganism growth. A unique ability to stop growth of these microorganisms on the viscose fabric can only be attained when treated with 3-bromopropionic acid followed by after treatment with nano metal oxides. It has also been found that the ability of nano metal treated viscose fabrics to reduce the microbial growth is in the following order:

Zinc oxide>aluminium oxide>titanium oxide.

3-bromopropionic acid has a superior antifungal activity in comparison with its antibacterial activity. The added carboxylic groups to the fabrics is not only acting as attracting groups for the nano metal oxides, but also fixing these nano metal oxides to the fabrics. The viscose fabrics treated with 3-bromopropionic acid and nano metal oxides are found able to maintain high antimicrobial activity even after 30 wash cycles.

Antimicrobial finished wool fabric

Wool has been widely used as a high quality textile material, such as suiting, carpet, blankets and shawls due to its high elasticity, flexibility, wet ability, biodegradability and biocompatibility. The use of high efficient microwave heating method in wool dyeing and finishing achieving energy savings and high efficiency has been the subject of considerable interest [29-31]. Chitosan has biodegradability, biocompatibility and environment friendly nature, and has complex double helix structure with strongly reactive groups, which helps in carrying out a variety of chemical modification under appropriate conditions, to improve its solubility. Guanidinium salts have increased interest in recent years. Their derivatives with antimicrobial and antifungal activity have been investigated as medical and crop protection agents and antiseptics for industry products, food and daily necessities [32]. Guanidinylation of chitosan can not only enhance the water solubility of the chitosan, but also improve the stability of low molecular weight guanidine salt. Guanidinylated chitosan treated wool fabrics show significantly improved antimicrobial characteristics [33]. Textile finishing using microwave heating has been reported by several authors and the result showed that microwave treatment can obtain clean, environmental friendly and highly efficient heating effect in textile finishing process [34,35].

Chitosan guanidine hydrochloride with good water solubility has been prepared by the guanidinylation reaction of chitosan with thiourea trioxide. Chitosan and chitosan guanidine hydrochloride is characterized by means of FTIR and CMNR, and it is confirmed that the guanidine group is introduced into chitosan main chains [36]. Guanidinylated chitosan has good antimicrobial activity against E.Coli and S.aureus. Treatment of wool fabric with chitosan guanidine hydrochloride using conventional and microwave heating techniques has been studied. Scanning electron microscopy supports the adhesion of the chitosan guanidine hydrochloride on the surface of the wool under microwave heating. Microwave heated samples show slightly higher degree of cross linking, antimicrobial properties and durability (40 washes) than conventionally heated samples without high losses in strength properties.

Bamboo/cotton fabrics with antiseptic properties

Recognizing the importance of plant materials as antimicrobial agents, research has been initiated in the areas of producing bioactive textiles for the protection of wearer from common microbes causing cross infections. Natural antimicrobial agents are non toxic and non allergenic and do not cause and do not cause the problems of microbial resistance [37]. There is a growing interest in plants with antimicrobial activity. Scientists are increasingly becoming involved in the screening of such plants with the aim of establishing their potential antimicrobial effects and identifying the compounds responsible for the antimicrobial properties [38]. Although certain natural antibacterial agents are available at present, only few studies have been explored for their antibacterial activity on textile materials and also there is need to generate progressive and consolidated data on antimicrobial finished product of textiles particularly in the preparation of medical cloths [39]. Efforts have been directed towards development of an eco-friendly and natural antimicrobial finish on textile fabrics using the extracts of piper betel. Betel leaf has broad antiseptic properties and to date there have been no reports in the literature on the occurrence of cases of allergy to the plant. The use of betel leaf as antiseptic is increasing. The active substances in betel are phenol and its derivatives.

The phenolic derivatives contained in betel leaves have a fivefold greater antimicrobial potency than phenol itself [40-42]. As garments are subjected to washing, the wash durability of finishes is a major issue. Even though many of the herbal extracts like tulsi leaves, pomegranate, cassia senna, etc have shown good antimicrobial property after applying on textile fabrics their wash durability is poor [43]. Hence, microencapsulation has been used to fix the herbal extracts on the fabrics. The extracts have been applied to the bamboo/cotton knitted fabric by direct application method and microencapsulation method. An extensive study has been conducted to assess the antiseptic efficacy against the selected human foot wounds and their wash durability by employing standard test methods [44].

The piper betel extracts have found to have good antibacterial against the wound pathogens which acts as an antiseptic. The extracts are directly applied on to the fabric by pad dry cure method, but the only disadvantage is that the wash durability of the directly of the directly treated fabrics is poor. But the fabrics treated by micro encapsulation method show good antiseptic property and wash durability. Hence, the direct application method is suitable for the fabrics being used for single use applications like bandage gauze, surgical cloths, baby diapers, sanitary napkins, and the fabrics that need repeated launderings like garments, bed linens, socks, hospital fabrics, etc. can be microencapsulated [45]. Piper betel is easily available all over the world and there is a good opportunity for the implementation and the commercialization of the herbal extracts finished textile fabrics to act as an antiseptic products. As the extracts are purely from the natural resources, the finished fabric is eco-friendly and satisfies the social and the environmental needs.

Antibacterial microfiber

-Microfiber can trap the dust or greasy dirt inside of its special groove structure. However, if washed improperly, bacteria can grow on it after a long usage time, similar to other cleaning products. Under this context, successful antibacterial microfiber products are eagerly demanded in the market. Recently, the application of nano silver particles has been extended in a new approach to become antimicrobial agents [46-48]. The antibacterial effect of nano silver has been attributed to its small size and large surface area, which allows them to interact closely with bacteria and is not merely due to the release of metal ions in solution [49]. There are many kinds of antibacterial fibers in the market. Most of them are antibacterial finishing products. However, few studies have been reported about the preparation of antibacterial fiber through melting spinning. An innovative kind of antibacterial micro fiber has been developed by adding nano silver particles in the spinning process.

The tenacity and max strain of the newly prepared microfibers are found to be similar to other man made fibers. The fineness of the fibers is found much less than one denier, which comes in the microfiber range. In addition, most of the silver particles are found inside the fibers and the antibacterial microfibers show good spin ability, which is the key point for future mass production [50]. All the samples have a good antibacterial function; more than 99% bacteriostatic reduction rate is obtained before washing. After washing, the bacteriostatic reduction rate of 270D, 300D, and 330 D samples are found to be 65-99% for two different ranges of bacteria respectively. Although, further research about antibacterial microfiber fabrics is necessary, the investigation has provided a useful guide to the future industry production and shows a promising potential for the functional microfiber market.

Conclusion

The isolate from sugarcane juice, namely, Acetobactorxylinium produces bacterial cellulose in quantities of commercial interest. Further the production of bacterial cellulose is receiving great attention because of its benefit for environmental requirements and possesses wide application possibilities. Hence, an attempt has been made to produce and characterize bacterial cellulose from Acetobactorxylinium isolated from fermented sugarcane juice. Viscose fabrics have been modified to enhance the attraction for nano metal oxides, namely aluminum oxides, zinc oxide or titanium oxide to impart antimicrobial activity against Eschirichia Coli and Candida albicans. The findings reveal a unique ability to stop microorganism's growth on the viscose fabrics pretreated with acid followed by treatment with nano metal oxides. Antimicrobial finishes have been imparted on wool fabrics by use of microwave heating system so as to apply chitosan guanidine hydrochloride on wool fabric. Microwave finished wool fabrics gave better results as compared with conventionally finished wool fabrics. The textile finishes with added values particularly for medical cloths are greatly appreciated and the growth in the field of medical textiles and their end uses has generated many opportunities for the application of antimicrobial finishes, of which the application of piper betel extracts on natural and regenerated bamboo/cotton knitted fabrics has been recently investigated. The market importance of microfiber has been rising throughout the world and functional microfiber even makes it more outstanding. Newly developed antimicrobial fibbers show very good bacteriostatic reduction rates. Thus, the aforesaid discussions indicate revolutionary methods of development of antibacterial textiles for varied medical applications.

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