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Multifunctional finishing of cotton using chitosan extracted from bio-waste

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ABSTRACT

In the current work, chitosan extracted from waste shrimp shells was used in finishing formulation for cotton fabric, along with DMDHEU and other chemicals, imparting multiple performance characteristics such as wrinkle free, antibacterial and flame retardant properties. The finished fabrics were evaluated for textile properties like tensile strength, bending length, yellowness index and functional properties like crease recovery angle, antibacterial activity and flame retardancy and also for the ecological properties like formaldehyde release. The finished fabric showed excellent crease recovery, antibacterial property and flame retardancy which were retained to a moderate extent even after 20 washes. Besides formaldehyde scavenging action, chitosan clearly showed its positive role in imparting multifunctional properties to cotton.

1. Introduction

Cellulosic fibres and especially cotton are still the most important kinds of fibre, because of their numerous advantages [1]. Dominance of cotton in textile apparel industry is due to its varied advantages such as ability to withstand the rough laundering treatments, especially under alkaline conditions; good perspiration absorption characteristics, comfort during wear, and the ability to take up the wide range of dyestuffs. However, proneness to wrinkles under even slight crushing and the retention of the wrinkles for long time give cotton garments a poor rating during the actual wear [2]. Other limitations of cotton as textile fibre includes proneness to microbial attack causing odor, discoloration, flammability, low UV resistance and high quantity of salt requirement for certain important dyeing processes. In the globalised market of textiles the apparel consumers all over the world are found to be demanding functionality in the products. An extensive work has been carried out with an aim of developing innovative textile products by treating textiles with chemical finishes to impart specific functional properties in addition of improving their aesthetic value.

In the recent years, however among the biopolymers used for functional properties, chitosan is gaining increasing importance in all the fields including textiles. On the back drop of huge amounts of crab and shrimp shells being abandoned as wastes worldwide by seafood companies, considerable scientific and technological interest in extracting chitin and chitosan from these renewable wastes is being generated [3]. Chitosan is a functional, linear polymer that can be derived by the partial deacetylation of chitin which is the most abundant natural polysaccharide on the earth after cellulose and it can be obtained from the exoskeleton of marine crustaceans, such as crabs, lobsters, shrimps and krill [4]. Chitosan comprises copolymers of glucosamine and N-acetyl glucosamine and has a combination of many unique properties such as nontoxicity, biocompatibility, and biodegradability [5]. The antimicrobial ability, coupled with its non-toxicity, biodegradability and biocompatibility, facilitate applications of chitosan in food science, agriculture, medicine, pharmaceuticals and textiles [6]. Chitosan is natural cationic polysaccharide, and is known to suppress the metabolism of bacteria when sticking to the bacterial cell wall [7]. Chitosan has been widely used in three areas of textile manufacture. These are the primary production of human-made fibre, textile fibre finishes, and textile auxiliary chemicals [8]. Various applications of chitosan in textiles have already been reported in the literature [9–22]. Application of chitosan from different sources and their antimicrobial activities has been reported [23–25]. The different modifications of chitosan and the resulting antimicrobial activity are also reported in literature [26–29].

The extraction of chitosan from waste shrimp shells and applications in antibacterial finishing of grafted bamboo rayon [30] and finishing of denim [31] were reported earlier from our laboratory. Dimethylol dihydroxy ethylene urea (DMDHEU) is the most commonly used crosslinking agent in the wrinkle free finishing of cellulosic fibres; however the release of formaldehyde is a big issue as far as user ecology is concerned. In the current work, chitosan extracted from shrimp shell waste was utilized in multifunctional finishing formulation of cotton fabric along with dimethylol

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Table 1
Recipes for finishing of cotton.

Sample no.	Dm (gpl)	M (gpl)	C (gpl)	A (gpl)	D (gpl)	Bo (gpl)
Control	–	–	–	–	–	–
1	100	10	–	–	–	–
2	–	–	5	10	–	–
3	–	–	5	20	–	–
4	–	–	10	10	–	–
5	–	–	10	20	–	–
6	–	–	20	10	–	–
7	–	–	20	20	–	–
8	–	–	–	–	20	–
9	–	–	–	–	40	–
10	–	–	–	–	60	–
11	–	–	–	–	80	–
12	100	10	5	10	–	
13	100	10	10	10	–	–
14	100	10	20	10	–	–
15	100	10	5	20	–	–
16	100	10	10	20	–	–
17	100	10	20	20	–	–
18	100	10	–	–	20	–
19	100	10	–	–	40	–
20	100	10	–	–	60	–
21	100	10	–	–	80	–
22	–	–	5	10	20	–
23	–	–	5	20	20	–
24	–	–	10	10	20	–
25	–	–	10	20	20	–
26	100	10	10	20	20	–
27	100	10	10	20	40	
28	100	10	10	20	60	–
29	100	10	10	20	80	–
30	100	10	10	20	60	10
31	100	10	10	20	60	20
32	100	10	10	20	60	30
33	100	10	10	20	60	40
34	25	10	10	20	60	40
35	50	10	10	20	60	40
36	75	10	10	20	60	40

Dm, DMDHEU; M, $MgCl_2$; C, chitosan; A, acrylic acid; D, diammonium hydrogen phosphate; Bo, boric acid.

dihydroxy ethylene urea (DMDHEU). The multifunctional properties imparted by finishing such as improved crease recovery, antibacterial property and flame retardancy were analyzed. Since durability of such finishes is always a criterion, the durability of the finishes to washing was also studied. The role of chitosan in finishing formulation as antibacterial agent, flame retardant agent in presence of phosphorous compounds and scavenger for the released formaldehyde was explored.

2. Materials and methods

2.1. Materials

Bleached cotton fabric (GSM 122.95) was obtained from Century Mills Ltd., Shrimp shells waste was obtained from local fish market to extract chitosan. DMDHEU was supplied by Clariant India Limited. Bacterial strains were obtained from Haffkins Research Institute, Mumbai. All other chemicals used were of laboratory grade and were supplied by SD fine chemicals.

2.2. Methods

The detailed method of extraction of chitosan and characterization was reported in our earlier publication. Chitosan (mol. wt. 124,999.8, degree of deacetylation, 89.06%, nitrogen content, 7.1%) so obtained was utilized for finishing treatment of cotton.

2.2.1. Finishing of cotton fabric

The finishing was carried out using two bowl vertical padding mangle. The recipes for finishing treatment are summarized in Table 1.

The cotton fabric was padded using required chemicals as per recipes with 75 ± 1% expression, dried at 80 °C for 4 min and cured at 150 °C for 5 min.

2.2.2. Characterization of finished fabric

Analysis of finished cotton fabric was done by the following methods.

2.2.2.1. FTIR analysis. The FTIR spectra of unfinished and finished fabric samples were recorded using FTIR spectrophotometer (Shimadzu 8400s, Japan) using ATR sampling technique by recording 45 scan in %*T* mode in the range of 4000–600 cm^{-1}.

2.2.2.2. Thermo gravimetric analysis (TGA). The thermograms of unfinished and finished fabric sample were recorded using aluminum pan between temperature range 30 to 500 °C and under inert atmosphere of N_2 at a flow rate of 50 ml/min (Shimadzu, Japan).