IMPARTING PROTECTIVE PROPERTIES TO LYOCELL VIA FINISHING TREATMENTS

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Abstract:

Lyocell fabric was analysed for its protective properties against UV radiation and disease-causing microbes. Unfinished lyocell fabric afforded no protection against UV radiation and also possessed no antimicrobial activity against the two microbes investigated in this study. To improve its protective properties, lyocell was finished with a UV absorber. To enhance its antimicrobial properties, lyocell was treated with an antimicrobial agent. It was experimentally determined that an optimum UV absorber concentration of 2% of the weight of the fabric was sufficient to improve the UV properties of lyocell fabric to an excellent degree. The optimum antimicrobial concentration for excellent antimicrobial activity was found to be 0.5% of the weight of the fabric. Subsequently, lyocell fabric was finished with the optimum amount of UV absorber and antimicrobial agent in a combined multi-functional bath. The data showed that the UV protection of lyocell fabric was not negatively affected when a multi-functional bath was employed. Similarly, the antimicrobial efficiency was not reduced by multi-functional finishing treatment. Further, the finishing treatments, whether applied singly or in a multi-functional bath, were durable to laundering and to light exposure.

Key words:

Lyocell, ultraviolet, antimicrobial, finishing, multi-functional.

Introduction

Lyocell is a fibre made from wood pulp cellulose. It was first manufactured in 1987 by Courtaulds Fibres, United Kingdom. Lyocell was designated by BISFA (Bureau International pour la Standardisation des Fibres Artificielles) as belonging to a new generic class. Lyocell was also the first new generic fibre group to be approved by the U.S. Federal Trade Commission (FTC) in thirty years. The FTC defines lyocell as “a cellulose fabric that is obtained by an organic solvent spinning process”. The principal advantage of lyocell fibre is that it is naturally biodegradable. Additionally, other materials used in the fibre production process are recycled with very little loss. The desirable properties of lyocell are its dry strength, wet strength, durability, lustre and soft drape which make it an aesthetically pleasing fibre suitable for a multitude of end-uses [1].

A number of finishing treatments have been performed on lyocell to improve its properties; notable among these are enzymatic hydrolysis [2,3] and low-temperature plasma treatment [4]. Very few studies, however, have studied the protective properties of lyocell such as resistance to ultraviolet (UV) radiation and resistance to disease-causing microbes. These protective properties add value to fabrics and are important as the following discussion will attest.

In recent years, consumers have become increasingly aware of the need for sun protection, which is related to the incidence of sun-induced skin damage and its relationship with increased exposure to ultraviolet light. Elevated exposure to UV radiation can result in skin damage such as sunburn, premature skin ageing, allergies, and even skin cancer. Fabrics can provide effective protection against skin damage. A system for denoting the UV protection provided by fabrics is the Ultraviolet Protection Factor (UPF). It is very similar to the SPF rating system used for sunscreens, the difference being that SPF values are determined in vivo whereas UPF values are determined in vitro. Therefore, a fabric with a UPF of 20 only allows 1/20th of the UV radiation falling on the surface of the fabric to pass through it. UV resistance in fabrics can be incorporated by varying the weave structure, dyeing in heavy shades or applying a suitable finishing agent to the fabric such as a UV absorber [5-10].

Antimicrobial finishing of textile fabrics is another exponentially growing area in the textile and allied industries because infections, particularly those caused by antibiotic-resistant Gram-positive bacteria such as methicillin-resistant Staphylococcus aureus (MRSA) and vancomycin-resistant enterococci (VRE) are a growing concern. A critical factor for the transmission of a microorganism from a person to the environment and then to another person is the ability of that microbe to survive on an environmental surface. Antimicrobial agents impart maximum resistance to the growth of bacteria and many viruses. Antimicrobial agents primarily work in two ways. Conventional “leaching” antimicrobials separate from the textile upon contact and chemically interact with the microorganism. The result of the interaction leads to destabilisation of the microorganism, eventually killing it. A “bound” antimicrobial, on the other hand, remains affixed to the textile, and, on a molecular scale, physically penetrates the bacterial wall and complexes the biochemicals in the microorganism on contact to kill it [11].

In this study, both single-component finishing as well as multi-functional finishing for lyocell fabric were investigated. Multi-functional finishing is defined as treating textile fabrics with two or more finishing agents in a combined bath in a single step. Multi-functional finishing therefore results in savings, both in terms of energy usage as well as water consumption. The intent was to impart value-added protective properties to lyocell in terms of resistance to ultraviolet (UV) radiation and resistance to disease-causing microbes. The specific objectives of this study were to enhance the fabric’s UV protection characteristics via a finishing treatment with a UV absorber and to improve the antimicrobial properties via a finishing treatment with an antimicrobial agent. Additionally, we investigated the feasibility of a multi-functional UV and antimicrobial finishing treatment on the protective properties of lyocell fabric.

Experimental

Materials

The fabric used in this study was a plain weave lyocell fabric (Lenzing AG, Austria). UV-Sun Cell(r) (Huntsman Textile Effects, Charlotte, NC) was the UV absorber used to increase the ultraviolet protection factor of fabrics. The antimicrobial agent used was Tinosan(r) (Ciba Specialty Chemicals, High Point, NC). Staphylococcus aureus (ATCC(r) 6538, MicroBioLogics) and Enterococcus faecalis (ATCC(r) 51299, MicroBioLogics) were the two microorganisms used in this study.

Methods

Treatment with the UV absorber and UPF measurement

The UV absorber was applied by the exhaust method. The concentration of the UV absorber was varied from 1 to 4% (by the weight of the fabric). The fabric samples were introduced in a bath containing the UV absorber and circulated for 10 minutes. Glauber's salt (60 g/L) was gradually added and the temperature of the bath was increased to 70øC. Four grams per litre of caustic soda were then added and the application was continued. The total treatment time was 60 minutes. Finally, the bath was cooled and the fabric samples were rinsed and air-dried. The UPF was measured using a Labsphere(r) UV-100F Ultraviolet Transmission Analyser and calculated using equation (1) [12].

$$UPF = \frac{ED}{ED_m} = \frac{\sum_{290nm}^{400nm} E_\lambda S_\lambda \Delta\lambda}{\sum_{290nm}^{400nm} E_\lambda S_\lambda T_\lambda \Delta\lambda} \quad (1)$$

In equation 1, E_λ corresponds to the erythema sensitivity of the average human skin, S_λ is the spectral irradiance of terrestrial sunlight under controlled conditions, T_λ is the transmission spectrum of the fabric, and λ denotes the wavelength of UV radiation (between 290 and 400 nm). The numerator of the above equation describes the quantity of the UV radiation which reaches the skin if unprotected. The denominator describes the quantity of UV radiation reaching the skin protected by a fabric [13]. Fabrics with a UPF value in the range 15-24 are classified as having "Good UV Protection"; when the UPF value is between 25 and 39, a fabric is classified as having "Very Good UV Protection", and "Excellent UV Protection" classification is used when the UPF is 40 or greater [14].

Treatment with the antimicrobial agent and evaluation of antimicrobial activity

Fabric samples were introduced in the treatment beakers of an Ahiba Nuance ECO-B infrared machine containing Tinosan(r) at room temperature at a material-to-liquor ratio of 1:50. The temperature was increased to 130°C and treatment continued for 90 minutes. The treated samples were then rinsed in deionised water, air dried, and antimicrobial activity was evaluated by two methods.

For the zone of inhibition method, five streaks of the microorganisms were inoculated on nutrient agar plates (peptone 5 g/L, beef extract 3 g/L, nutrient agar 15 g/L, NaCl 8 g/L, pH 6.8 + 0.1). Fabric samples were then placed in intimate contact with the bacteria-inoculated agar. The plates were incubated for 24 h at 37°C. At the end of this period, the plates were examined for the presence of a clear area of interrupted growth underneath and adjacent to the test fabric which gave an indication of the antibacterial activity of the fabric. The evaluation of treated fabrics was done by calculating the zone of inhibition of the samples using equation (2).

$$W = \frac{(T - D)}{2} \quad (2)$$

where *W* is the width of the clear zone of inhibition in mm, *T* is the total diameter of the test specimen and clear zone in mm and *D* is the diameter of the test specimen in mm.

In the second method, the colony forming units (CFU) were enumerated using a Reichert Darkfield Quebec Colony Counter and the percent reduction in bacteria was calculated using equation (3).

$$R\% = \frac{(B - A)}{B} \times 100 \quad (3)$$

where *R* is the percent reduction in bacteria, *A* is the CFU for treated fabric and *B* is the CFU for untreated (control) fabric.

Treatment with the UV absorber and antimicrobial agent

For concurrent finishing, multifunctional baths were prepared containing the optimum concentration of the UV absorber and antimicrobial agent prior to the introduction of fabric samples. Glauber's salt (60 g/L) was gradually added and the temperature of the bath was increased to boiling. Four grams per litre of caustic soda were then added and application continued. The total treatment time was 60 minutes. Finally, the bath was cooled and the fabric samples were rinsed and air-dried.

Durability of treated fabric to laundering and light exposure

Treated fabrics were subjected to laundering at 40øC for 45 minutes in an Atlas Launder-Ometer with an material-to-liquor ratio of 1:50. The antibacterial properties and UV properties of the laundered fabrics were then quantitatively evaluated.

Treated fabrics were subjected to light fastness by exposing the samples in an Atlas Sun Test XLS+ Weatherometer chamber with the following parameters: Black Standard Temperature (BST) of 63°C, phase time of 300 minutes, irradiance (E) of 500 W/m2, and final dosage of 9000 kJ/m2. The samples were exposed front and back in the chamber on successive days. The antibacterial and UV properties of the light-exposed samples were then quantitatively evaluated.

All experimental work was done in triplicate and the reported values are the means of these values.

Results and Discussion

UV protective characteristics of lyocell after finishing with UV absorbers

Unfinished lyocell fabric had a UPF value of 0.6. A UPF value below 15 indicates negligible protection against UV radiation [13]. Mean UPF values after finishing with the UV absorber are shown in Table 1 and illustrated in Figure 1.

Table 1. UPF values of lyocell fabric after finishing with the UV absorber.

UV absorber concentration (% weight of fabric)	Ultraviolet Protection Factor (UPF)		
	After treatment	After laundering	After light exposure
Unfinished fabric	0.6	-	-
1	45.9	-	-
2	51.9	51.2	51.6
3	55.3	-	-
4	81.8	-	-

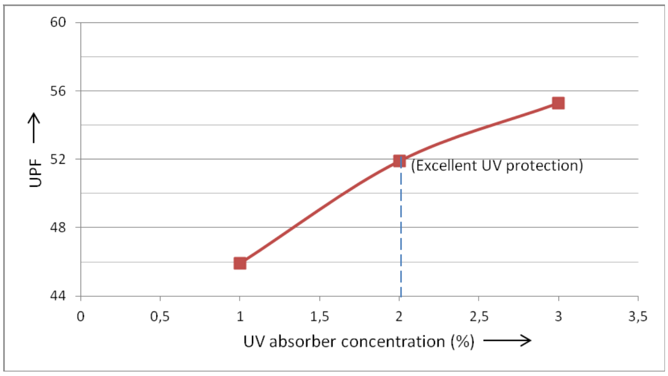

Figure 1. Relationship between the UV absorber concentration and UPF for lyocell fabric.

As observed from the data, a 2% owf treatment with the UV absorber gave a mean UPF value of 51.9 which falls in the category of "Excellent UV Protection". Values much higher than UPF 50 offer only an incremental increase in protection and, therefore, a 2% treatment with UV-Sun Cell(r) was taken as the optimum concentration to be applied on lyocell fabric for excellent protection against UV radiation. Since 2% UV-Sun Cell(r) was the optimum concentration of the UV absorber for excellent UPF values, fabrics treated with this concentration were studied for their durability against laundering and light exposure. The results are also included in Table 1. Laundering and exposure to light did not diminish the UV protection of the lyocell substrates and therefore a 2% concentration of UV absorber for lyocell fabric was sufficient both in terms of protection against UV radiation and durability to laundering and light exposure.

Antimicrobial properties of lyocell after finishing with the antimicrobial agent

Two methods were employed for analysing the antimicrobial property of lyocell fabric. For the zone of inhibition method, the evaluation showed that for unfinished lyocell fabrics, the mean zone of inhibition was zero millimetres against the two microorganisms, which meant that there were microbes growing adjacent to and underneath the fabric. The mean zones of inhibition of lyocell finished with Tinosan(r) against the two microorganisms at various concentrations studied are shown in Table 2. A treated sample exhibiting a zone of inhibition greater than 2 mm was considered as having good antimicrobial properties [15]. As is clearly evident from Table 2, the mean zone of inhibition for lyocell fabric after finishing against the two microbes was greater than 2 mm, clearly indicating that the treated substrates possessed excellent antimicrobial activity. When the antimicrobial effect of the substrate was considered in terms of concentration, the lowest

Table 2. Mean zones of inhibition of untreated and antimicrobial-treated lyocell fabric against S. *aureus* and E. *faecalis*.

Antimicrobial Concentration (% weight of fabric)	Mean zone of inhibition (mm)	
	S. Aureus	*E. faecalis*
Unfinished fabric	0	0
0.5%	10	3
1%	10	6
1.5%	10	8
2%	10	10
2.5%	10	10

concentration of 0.5% investigated in this study could be considered as sufficiently effective as the zone of inhibition was greater than the required minimum of 2 mm; additionally, there was no growth of bacteria beneath the fabric.

The second method was performed to determine the percentage reduction in the bacterial population for antimicrobial-treated samples as compared to an untreated control. This method was subsequently repeated after laundering and after exposure to light. For S. *aureus*, the percentage reduction in bacteria was 100% after treatment and after laundering and 99% after exposure to light. For E. *faecalis*, it was 99.6% after treatment, decreasing slightly to 97.7% after laundering and 98.5% after light exposure. Clearly, a concentration of 0.5% of the weight of the fabric of the antimicrobial agent Tinosan(r) was highly effective for lyocell fabric and imparted to the fabric excellent antimicrobial efficacy against S. *aureus* and E. *faecalis*.

Table 3. Percentage reduction in bacterial growth by 0.5% owf antimicrobial-treated lyocell fabrics.

Microorganism type	Percentage reduction in bacteria		
	After treatment	After laundering	After light exposure
S. aureus	100	100	99
E. faecalis	99.6	97.7	98.5

Multi-functional finishing

In the hyper-competitive global arena of the textile industry, cost is of paramount concern and so combining several processing steps to reduce time and expense is the current mantra. The synergistic effect of UV absorber treatment and antimicrobial treatment using a multi-functional treatment bath was investigated in this phase of the study. Lyocell fabrics were treated simultaneously with the optimum amount of the UV absorber and antimicrobial determined from previous experiments, i.e., 2% owf UV-Sun Cell(r) and 0.5% owf Tinosan(r). Figure 2 compares the UPF values of lyocell fabric when the UV absorber was applied as a single component to the UPF values and when the UV absorber was applied using a multi-functional bath.

As the figure shows, UPF values were not adversely impacted when a multi-functional bath was employed. The UPF value when the UV absorber was applied in a multi-functional bath was 52.9 after treatment, 54.6 after laundering, and 55.1 after light exposure. These values compare very favourably with the UPF values reported in Table 1 when the UV absorber was applied as a single component finishing treatment. Hence, UV absorbers can safely be used in a multi-functional bath

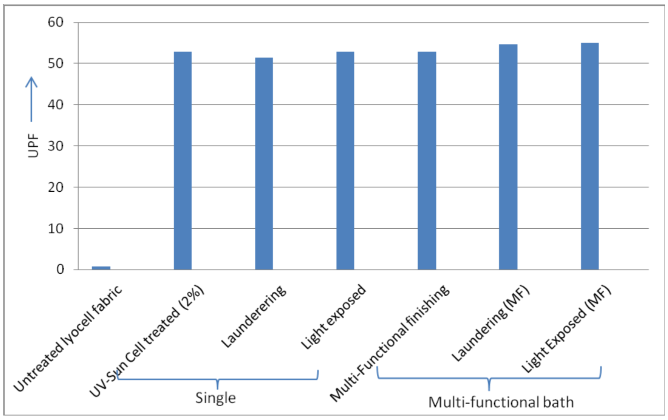

Figure 2. UPF values (single component bath versus multi-functional bath).

with no decrease in protection against UV radiation. Further, it was found that the antimicrobial activity did not diminish upon application and treatment in a multi-functional bath. The percentage reduction in bacteria remained between 97-100% against both microorganisms. Since a reduction in the bacterial population greater than 95% is an indication of excellent antimicrobial activity, it was concluded that an antimicrobial finishing treatment can be combined with a UV-resistant treatment with no apparent drawbacks.

Conclusions

Protective properties can be easily imparted to lyocell fabric with finishing treatments. A treatment with 2% owf UV absorber gave a UPF value of 51.9, which falls in the excellent UV protection category. Additionally, UV absorber-treated lyocell was found to be durable with regard to laundering and light exposure. In terms of the antimicrobial properties, the qualitative and quantitative results showed that a concentration of 0.5% owf antimicrobial agent was sufficient to impart excellent antimicrobial properties to lyocell fabric against S. aureus and E. faecalis. The antimicrobial efficacy of treated lyocell fabric was also found to be durable with regard to laundering and to light exposure.

Multi-functional finishing was performed to reduce costs and time by treating lyocell fabric with optimum concentrations of the UV absorber and the antimicrobial agent in a combined bath. The data showed no adverse effects on either the UV protective properties or the antimicrobial protective properties of lyocell fabric after multi-functional finishing. The protective properties were also retained after laundering and exposure to light.

Acknowledgements

This research was supported by the United States Department of Agriculture Multi-State Research Project S-1026 (Textile Materials and Technologies Addressing Energy, Health and other National Security Issues) via a grant to the Colorado Agricultural Experiment Station.

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