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Long-lasting UV protection and mosquito repellent finish on bamboo/tencel blended fabric with microencapsulated essential oil

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In this study , bamboo/tencel 50:50 blended fabric has been used for microencapsulation finishing by essential oil combination using exhaustion method in order to enhance the wash durability of the fabric. The three shell materials, namely sodium alginate, *Acacia arabica* and *Moringa oleifera* gum and three core materials like thyme oil, cypress oil and grapefruit oils in combination of 2:1:1 have been used. Then the fabrics are tested for functional properties like UV protection and mosquito repellency, and also the fabric is analyzed for allergic test. The result shows that the *Moringa oleifera* shell finished fabric has very good activity in both the functional property and there is no allergic reaction found. The durability can also be achieved up to 30 washes by using *Moringa oliefera* gum material as compared to other two.

Keywords: *Acacia arabica*, Bamboo/tencel fabric, Cypress oil, Grapefruit oil, Microencapsulation, Mosquito repellent

1 Introduction

The problems of ozone depletion in the upper atmosphere have led to increased problems of exposure of the skin to UV radiation. A special finish has been developed that protects human underlying tissues from UV radiation. The rays in the wavelength region of 150-400 mm are known as ultraviolet radiations.

This wavelength region is further divided in to UVC (100-280), UVB (280-315) and UVA (315-400). The most important UV source is the sun and thereby almost every living organism is exposed to UV radiation[1,2]. To ensure our security and safety from the future hazards, we need to develop the mosquito repellent finished textiles also a part of protective textiles[3,4]. Most plants contain compounds that are used in preventing attack of phytophagous insects. These chemicals fall in to several categories, including repellents, feeding deterrents, toxins, and growth regulators. Natural smelling repellents are preferred because these are a secure and trusted way of mosquito bite prevention[5]. Instead of using various chemicals separately, a single bath finish having the multi-functional properties can be produced using natural products. Essential oils are the highly concentrated extracts from herbs, plants and flowers. They are used in single or in combination to bring about soothing and curative process in mind and body. Aroma oils have a calming, stimulating, pain reducing and mood enhancing effects. The scents of lavender, rose, citrus or vanilla have a good way to meet important psychological and emotional need. Recently consumer's expectations are very much higher; they expect their clothing to perform multiple functions from aesthetic to basic protection from the elements[6].

Mosquito repellents based on essential oils (EO) are being developed as an alternative to DEET (N,N-diethyl-m-methylbenzamide) that causes toxic reactions, and damage to plastic and synthetic fabric[7] . Textile materials containing more than one kind of fibre are termed as blend, union or mixture. The reasons for developing such fabric unions may be to modify/confer aesthetic properties or to develop a material with specific physical characteristics. The characteristic properties of lyocell are soft handle, lusture and moisture absorbency that makes it suitable for a blend or union fabric. Lyocell is defined as a cellulosic fibre that is produced by regenerating cellulose into fibre from out of solution in an organic solvent. It is 100% natural in origin as it is made from wood pulp and is fully biodegradable[8]. Microencapsulation is a well-established method for preparation and properties. Uses of individually encapsulated novel small particles, shows significant improvements in tried-and-tested techniques relevant to micro and macro particles. It was used in a wide

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variety of industrial, engineering, pharmaceutical, biotechnology and research application[9]. Fabrics treated with microencapsulated citronella oil presented a higher and longer lasting protection from insects compared to fabrics sprayed with an ethanol solution of the essential oil, assuring a repellent effect higher than 90% for three weeks[10].

In this study, the UV protection and mosquito reppellent activity of finished bamboo/tencel 50:50 fabric in various oil combinations has been investigated. Also the wash durability and allergic tests are studied.

2 Materials and Methods

2.1 Materials

Bamboo/tencel (50:50) fibre blended fabric, using the following specifications of yarn and fabric: yarn counts 40s, fabric type single jersey, 22.7 courses/cm, 18.54 wales/ cm and 121 GSM, was prepared. Fabric was blended considering the fibre property; for example, elongation is more in bamboo fibre which is good for knitting. Tencel fibre has more strength and excellent absorption, which is best for comfort and durability of fabric. Bamboo/tencel fabric was bleached with hydrogen peroxide and dyed with reactive dye to attain the basic preparatory process.

2.1.1 Herbal Oils and Wall Materials used for Microencapsulation

Herbal oils like thyme oil, cypress oil and grape fruit oil with 100% concentration were selected for this study. Thyme was chosen for its good antibacterial, antifungal and antiviral property, whereas cypress oil was used for its good aroma and reducing nervous tension. Grape fruit oil helps in uplifting the mood, reducing stress and depression, also it helps for toning the skin, tissues and for body care treatments. These oils were mixed together in various combinations and the final combination used was 2:1:1 (50%:25%:25%) due to its good functional activity.

2.1.2 Selection of Shell Material for Microencapsulation

The three natural gum materials such as sodium alginate, *Acacia arabica* and *Moringa oleifera* were used as a shell material to enhance good durability.

2.2 Methods

2.2.1 Microencapsulation by Ionic Gelation Method

Microcapsules were prepared by orifice- ionic gelation method. The three shell materials were separately dissolved in purified water to form a homogeneous solution. The mixture of active substances like thyme oil, cypress oil and grapefruit oil with a combined ratio of 2:1:1 was added to the solution and mixed thoroughly with a stirrer to form a viscous dispersion. The resulting dispersion was then added separately. About 3% of shell material was sprayed into 0.5 mL calcium chloride solution by means of a sprayer. The droplets were retained in calcium chloride for 15 min to harden the capsules. The microcapsules were obtained by decantation and repeated washing with isopropyl alcohol followed by drying at 45°C for 12 h. The microcapsules were then used for finishing on the selected bamboo/tencel blended fabric.

2.2.2 Finishing

Fabric sample was finished with the prepared oil filled microcapsules separately using the exhaustion method. The fabric was finished according to the following recipe with 8% citric acid (cross-linking agent) and 1L of solution containing 700 g of capsules. The fabric was immersed in the solution containing 8% citric acid and microcapsules for 30 min at 50 ºC in water bath. After finishing, the fabric was removed, squeezed and dried at 50 ºC in oven.

2.2.3 Laundering

The durability of finishing is one of the main factors while laundering. The microcapsules finished bamboo/tencel fabric were analyzed for their wash durability by subjecting the sample to washing. The durability of UV protection and mosquito repellent activity of the finished fabric samples was evaluated after several wash cycles. The treated fabric samples were washed with 5% neutral soap solution for 20 min and dried according to the laundry test AATCC 124 method. The washed samples were tested for the retention of UV protection and mosquito repellency after 10, 20, 30 launderings.

2.2.4 Testing and Statistical Analysis

The fabric samples were tested for UV protection property (AATCC 183:2010), mosquito repellent property (repellency behavioral test) and allergic reaction test (contact allergy testing) then wash durability of microencapsulation finished fabric for 10, 20 and 30 washes was evaluated. Statistical analysis used was ANOVA to analyze the significant difference between treated and washed fabric.

2.2.5 UV Protection Assessment of Finished Fabric

The standard test method as mentioned before was used to determine the ultraviolet radiation blocked or transmitted by textile fabrics intended to be used for UV protection. In this method the fabric property was tested with the specimens in both dry and wet status.

The transmission of ultraviolet radiation (UV-R) through a specimen was measured on a spectrophotometer at known wavelength intervals. The per cent blocking of UVA and UVB radiation was also calculated.

2.2.6 Repellency Behavioral Tests

Specially designed two excito repellency test chambers were used to evaluate the efficiency of repellency activity (Fig.1). The wooden outer chamber of excito-repellency testing device measures 34 cm × 32 cm × 32 cm and faces the front panel with the single escape portal. The box is composed of a rear door cover, an inner plexiglas glass panel with a rubber latex-sealed door, a plexiglas holding frame, a screened inner chamber, an outer chamber, a front door, and an exit portal slot. Mosquitoes were deprived of all nutrition and water for a minimum of 4 h before exposure. Laboratory tests were performed during daylight hours only and each test was replicated four times. Observations were made at 1 min interval for 30 min. After each test was completed, the number of escaped specimens and those remaining inside the chamber was recorded separately for each exposure chamber, external holding cage, and paired control chamber. Escaped specimens and those remaining inside the chamber for the treated samples were held separately in small holding containers with food and water. The efficiency of mosquito repellency was calculated using the following equation:

$$\text{Efficiency of mosquito repellency (\%)} = \frac{\text{No. of specimen escaped} + \text{No. of specimen dead}}{\text{No. of specimen exposed}} \times 100$$

Fig. 1—Exito chamber [for mosquito repellency test]

2.2.7 Anti-allergic Test-Patch Test (Contact Allergy Testing)

Volunteers representing three males and three females were used for the contact allergy testing. The fabrics were patched on the normal skin and observed for the specified period of time for the development of the symptoms, leading to contact dermatitis allergy. Non hairy part of the skin of the subjects was selected and the surface of the skin was cleaned with cotton swabs dipped in clean water. The patches of the fabric sample were made and plastered on the surface of the cleaned skin. The site of patching was observed for any immediate allergic response. The observations were made up to 24 h for the symptoms such as reddishness, rashes, and irritations. The time of observation may be extended for another 24 h to confirm the effect.

3 Results and Discussion

3.1 Ultraviolet Protection Factor

The ultraviolet protection factor in terms of percentage blocking is mentioned in Table 1. According to the standards of AATCC 183 the percentage of UV between 93 and 96 is graded as good, between 96 and 97 as very good and between 97 and 99+ as excellent. The treated and washed fabric is evaluated. All the finished fabric has a good activity. The value is graded for all the three finished fabrics. Among the three shells the result found was good, very good and excellent. All the fabric has a UV protection activity. The fabric treated with *Moringa oleifera* shell filled with an oil combination has an excellent activity compared to other two, which forms a layer on the fabric and thus the rays do not penetrate into the fabric. Hence, by the microencapsulation technique the durability of UV protection can be enhanced up to 30 washes.

3.2 Mosquito Repellent Test

Table 2 shows mosquito repellent test results. The fabric has been treated with microencapsulated oil combination as a core with natural gum as a shell material and is analysed. The result shows that the microencapsulation technique with herbal oil combination and natural gum as a wall material can improve the mosquito repellent activity. The capsules made by *Moringa oleifera* shell material can improve the mosquito repellent activity. The capsuless made by *Moringa oleifera* shell material

Table 1—UV protection factor

Sample	Dry per cent blocking				Wet per cent blocking			
	Control	10 wash	20 wash	30 wash	Control	10 wash	20 wash	30 wash
Sodium alginate								
UVA	92.947	89.960	91.510	91.954	91.922	93.434	92.502	93.245
UVB	94.669	92.160	93.372	92.959	96.395	97.229	97.498	97.581
Acacia arabica								
UVA	93.593	92.088	89.295	89.295	92.680	93.900	93.366	93.366
UVB	95.404	94.448	91.972	91.972	97.539	98.316	97.614	97.614
Moringa oleifera								
UVA	94.341	91.313	92.814	92.814	92.176	92.970	93.455	93.454
UVB	95.677	93.998	94.963	94.963	96.832	97.550	97.817	97.816

Table 2—Effect of mosquito repellency on treated fabric

Shell material	Fabric sample	No. of specimen exposed	No. of specimen in the cage	No. of specimen escaped	No. of specimen dead	Mosquito repellency, %
Control fabric	Untreated	25	23	2	0	0
Sodium alginate	0 Wash	25	10	9	6	60
	10 Washes	25	11	8	6	56
	20 Washes	25	13	7	5	48
	30 Washes	25	14	7	4	44
Acacia arabica	0 Wash	25	8	9	8	68
	10 Washes	25	9	10	6	64
	20 Washes	25	11	10	4	56
	30 Washes	25	12	8	5	52
Moringa oleifera	0 Wash	25	4	12	9	84
	10 Washes	25	5	11	9	80
	20 Washes	25	7	10	8	72
	30 Washes	25	10	9	6	60

Table 3—Allergic reaction evaluation control and treated fabric

Subjects	Control fabric	Fabric Sample-1 (*Acacia arabica*)	Fabric Sample-2 (*Moringa oleifera*)	Fabric Sample-3 (Sodium alginate)
Subject 01 (Male / 21 yr)	-	-	-	-
Subject 02 (Male / 30 yr)	-	-	-	-
Subject 03 (Male / 35 yr)	-	-	-	-
Subject 04 (Female / 22 yr)	-	-	-	-
Subject 05 (Female / 25 yr)	-	-	-	-
Subject 06 (Female / 29 yr)	-	-	-	IR

Interpretation : (-) Negative reaction, (IR) Irritant reaction, (+) Positive reaction, (++) Very positive reaction.

can protect the oil for longer duration than the other two shell material and it shows the good activity. The percentage of mosquito repellency is enhanced up to 60% even after 30 washes.

3.3 Allergic Reaction Test

Table 3 shows no allergic reaction found in the microencapsulated finished fabrics, except a little irritation found in only one person for sodium alginate treated fabric. Thus, natural gum material and natural oil treated fabrics show no allergic reaction. The result shows that microencapsulation technique is most suitable for durable finishing and there is no allergy formation.

4 Conclusion

The application of microencapsulation on bamboo/ tencel 50:50 fabric with oil combination (thyme oil, cypress oil and grapefruit oil) and natural shell material as used in this study has

successfully resulted in UV protection activity and mosquito repellent activity for longer duration. Among the three shell materials, *Moringa oleifera* finished fabric shows good activity, durability and there is no allergic reaction on skin found.

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