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Development of Eco-Friendly Finish for Cotton and Wool Fabrics using *Neem* Plant Extract

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ABSTRACT

There are many prospects for the application of new finishes due to the fast rise of technical fabrics and their end uses like medical and healthcare applications. In the present study, an Eco-friendly agent is extracted from *Neem* leaves with methanol is used to apply finish on cotton and woollen fabrics to investigate the effect of anti-microbial activity on both. Cotton fabrics were treated with 3, 6, 9 and 12% *Neem* leaf extract and extract with 8% citric acid (CA) separately at a fabric-to-liquor ratio of 1:20 using the dip-dry-cure method. These finished samples were subjected to an antimicrobial activity test. It was found that the treated cotton fabric showed excellent anti-microbial activity at a higher concentration of *Neem* leaf extract. The treated and non-treated fabrics were characterized by Fourier Transform Infrared spectroscopy (FTIR) and this analysis showed that there were characteristic absorption bands of *Neem* leaf extract appearing in the spectra of the treated fabric. TGA and SEM were studied to identify the loss of weight of fabric on temperature and the surface morphology of treated and non-treated fabric.

Keywords : *Neem*, Microencapsulated, Cotton, Wool, Herbal

INTRODUCTION

Eco-friendly clothing is an approach for sustainable development after globalization. All over the world the economic growth has been rapid especially in the developing countries where the environmental issues are not considered as priority, but it is a big threat for the entire world. Sustainability is the word which can save the planet in the future. Today with increase in population, the use of synthetic products and their wastes has also increased causing hazardous impact on the environment. This has drawn the attention of organizations and policy makers for sustainable development. The most suitable definition of sustainability recommended by the World Commission on Environment and Development is to 'meet the needs of the present without compromising the ability of future generation to meet their needs and desires'. In recent year, a wide range of environmental organizations have created public awareness in the issues of climate change and the depletion of natural and human resources. However, various information and new-social media educate consumers to change their buying decision based on the willingness of the newly selected brand to help and save the environment and adhere to social conformity rules. As a result, consumers have started to utilize the products that address environmental and social issues. Eco-friendly literally means earth-friendly or not harmful to the environment. This term most commonly refers to products that contribute to green living or practices that help conserve resources like water and energy. Eco-friendly products also prevent contributions to air, water and land pollution (Ali *et al.,* 2010).

The rapid growth in technical textiles and their end-uses has generated many opportunities for the application of innovative finishes. Any operation (chemical or mechanical) for improving the appearance or usefulness of fabric is known as finishing. It can change a fabrics aesthetic and/or physical properties, as well as its texture

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and surface characteristics. Novel finishes of added value for apparel fabrics are also greatly appreciated by a more discerning and demanding consumer market. Among various chemical finishes, antimicrobial finish has got great importance due to its relation with healthcare and medical textiles. Antimicrobial textiles with improved functionality find a variety of applications such as health and hygiene products, specially the garments worn close to the skin and several medical applications, such as infection control and barrier material.

Antimicrobial agents inhibit the growth or kill microbes to control their negative effect e.g. odour, staining and deterioration. Microbes are the tiniest of creatures, which cannot be seen by the naked eye. They consist of a variety of micro-organisms like bacteria, fungi, algae and viruses etc. There are various antimicrobial agents used as textile finishes that can be classified as synthetic and natural agents.

Some of the herbal compounds obtained from plants are well known from time immemorial as antibacterial and anti fungal products. These plants and tree products are applied directly on skin or wounds as paste or in caution either for skin care or wound healing. These natural products are abundantly available in nature and are widely distributed. They are cheap and not processed and can be used as raw materials for required applications. A part from dyeing; these medicinal products posses distinct odour for identification. These plant products are non irritant to skin and non toxic. Many of these materials are skin care products. The stem, bark, leaf, root and tuber of the plants and trees can be used for special application. *Neem* is a medicinal tree whose bark, stem, leaf, root and fruit can be used for antibacterial and anti fungal action.

Engaging in eco-friendly habits or practices by being more conscious of how we use the resources is need of the day. Clothing is something that is required by all human beings. It is one of the most fundamental requirements needed to survive. Clothing uses a lot many chemicals and many consumers never know about in their lifetime. On an average, six hundred dyes and chemicals are used in the production of clothes, the most common being, *alijarin*, benzo and chlorolane. These chemicals have effects on the consumer’s body, such as rashes and allergies and other major skin problems along with lung and kidney problems. Chemicals in clothes can also cause prostate, pancreas, liver and bladder cancer.

Many special and functional properties can be imparted to the fabrics by microencapsulating the core material. This core material can be any substance having a special function to perform for the fabric. Encapsulation has allowed moisturizers, therapeutic oils, and insecticides to be incorporated into fabrics. Microencapsulation of anti-microbial agents is also gaining popularity in sportswear and medical textiles. This technique has a vast application in various fields like textile finishes, industrial chemicals, agro chemicals, food additives, flavours and essences, pesticides and herbicides, sealants, cosmetics, nutraceuticals, pharmaceuticals and adhesives (Umer, 2011).

Therefore, in the present prevailing conditions of climate change and increasing health hazards in the form of different environmental pollutants, industrialization etc., it is imperative and necessary to study the effect of herbal finishing on antimicrobial activity of the fabric. ‘Go – Green!!!’ is a slogan adapted by various environmentalist organizations to protect the planet. Due to spreading awareness, now it is being adapted by textile industrial sector. Therefore, keeping the above facts in consideration, the present research will be planned to study the effect of herbal agents on cotton and woolen fabrics.The eco-friendly agents which are not only help to reduce effectively the ill effects associated with microbial growth but also comply with the statutory requirements imposed by regulating agencies. The present research work is aimed at developing an eco-friendly antimicrobial finish from *neem* plant for textile application.

Objectives of the study:

1. To apply the standardized *Neem* finish on cotton and wool fabric using different techniques at optimized conditions.

2. To observe the effect of finish on selected physical and mechanical properties of the substrate.

3. To study the antimicrobial efficacy of finishing agent on cotton and wool fabric.

METHODOLOGY

This section deals with the type of raw material and various instruments used in the study. The details of materials and methods are given below:

Selection of fabric for the study:

Antimicrobial finish was applied on 100 % cotton and 100% wool fabric. The fabric was scoured and bleached.

a) Fabric count: Fabric count is the number of warp yarns (ends) and weft yarns (picks) per inch of fabric (Booth, 1964).

b) Fabric weight: Fabric weight is defined as weight of known area of the fabric and then computing the weight per unit area.

c) **Enzymatic scouring**:

1. Cotton fabric: Cellulase enzymatic scouring was carried out by using the optimized standard conditions such as concentration 0.5g/1; temperature 60^0 C; pH 5; time 30 minutes and material to liquor ratio 1:30. Acetate buffer was used to maintaining the pH. Objective of enzymatic scouring was to remove impurities from the grey cotton fabric and enhance the absorbency of antimicrobial agents of the treated cotton fabric.
2. Wool fabric: Protease enzymatic scouring was carried out at optimized standard conditions concentration 0.5g/1; temperature 40^0C; pH 9; time 30 minutes and material to liquor ratio 1:30. Phosphate buffer was used to maintaining the pH. Objective of protease enzymatic scouring was to remove impurities from the grey wool fabric with minimum strength loss and weight loss.

Identification and screening of plant sources:

Neem plants were selected for the present study and various literatures were reviewed for screening for their antimicrobial properties. This herbal plant was selected and standard screening methods were used to study the antimicrobial properties of these selected identified plant sources. Soxhlet and Maceration methods were used for Optimization of *Neem* extract with Ethanol on the basis of review studied for developing anti-microbial finishes. Thilagavath *et al.* (2005) revealed that the various herbal species were screened for their antimicrobial activities by employing preliminary (qualitative) antimicrobial tests. Methanolic extraction procedure was followed for extracting the active substances from herbs. Antimicrobial efficacy was assayed by AATCC (agar diffusion and parallel streak) method and Hohenstein modified challenge test. The *Neem* leaves (*Azadirachta indica*), prickly chaff flower (*Achyranthus aspera*), tulsi leaves (*Ocimum basilicum*) and pomegranate rind (*Punica granatum*) were found to exhibit antimicrobial activity against the strains of *Staphylococcus aureus* and *E. coli*. *Neem* ranked first followed by pomegranate and prickly chaff flower.

Test organisms used in the study:

Test organisms *Staphylococcus aureus* (ATCC 6538) and *Klebsiella pneumoniae* (ATCC 4352) used in the study evaluating antimicrobial activity of plant extract were procured and tested at Chemical Laboratory of NITRA Ghaziabad.The details of instruments used in this research are listed in Table 1.

Extraction of plant material:

The active ingredients of *Neem* are found in all parts of the tree but in the present study leaves have been taken for extraction process. Fresh mature green leaves were collected, washed and allowed to dry in hot air oven at 40^0 C temperature. After complete drying they were made into a fine powder by crushing and grinding. Dry powder was weighted and subjected to organic solvent to get the concentrated extract. Extraction was carried out by soxhlet extraction plant as per standard.

– **Soxhlet extraction process:** The powdered raw material was packed in the body of the soxhlet extractor. The methanol was placed in the flask. When extraction solvent was boiled on heating the flask, it got converted in to vapours. These vapours entered in to the condenser through the side tube and got condensed in to hot liquid which falls on the column of the *Neem* leaves powder. When the extractor was filled with the solvent, the level of siphon tube also raises up to its top. The soluble active constituents of the *Neem* remain in the flask while the solvent was repeatedly volatized. The solvent containing active constituents was collected from the flask and transferred to the beaker which was placed on the water bath in order to evaporate the solvent. At last the solidify mass of the extract of *Neem* was obtained. The extract obtained was weighted and percentage yield was calculated in terms of air dried powder weight of the plant material.

Determination of antimicrobial activity:

a) ***Preparation of Disc*:**

Twenty five sterilized discs of 6 mm in diameter were soaked in different concentrations 3, 5, 7 (gpl) of each plant extract for 24 hrs at the room temperature.

Next day these discs were dried at room temperature under sterile conditions.

b) ***Preparation of culture broth:***

The cultures used for the broth included *Klebsiella pneumonia* (-ve) ATCC 4352 and *Staphylococcus aureus* (+ve) MTCC 737. Pure culture of *E coli* and *Staphylococcus aureus* were inoculated in the nutrient broth and incubated at 37ºC for overnight. The turbidity of the above culture was adjusted equivalent to 0.5Mc Farland std. by taking absorbance at 430 nm.

c) ***Preparation of plates:***

Tryptone Soya Agar (TSA) plates were prepared and incubated at 37°C for 24hrs prior to test for sterility check. The plates of *Klebsiella pneumonia* and *Staphylococcus aureus*were prepared using sterile swab. During the process, the sterile swab were dipped in the culture broth (*K pneumonia* and *S. aureus*), excess of liquid from the swab was removed and marked the streak three times on TSA plate.

d) ***Placing of disc:***

Prepared discs were placed on the prepared plates of *Klebsiella pneumonia* and *Staphylococcus aureus.* In each culture plate, three discs were placed at 60°C to each other. For each dilution, plates were prepared in duplicate. The plates were incubated at refrigerated temperature (4ºC) for 4-5hrs. The plates were shifted to the incubator and incubated at 37°C for 18-30 hrs. After incubation period the clear zone was measured in mm using a scale. This clear zone represented the zone of inhibition.

e) ***Determination of yield percentage:***

Percentage yield of extract was calculated in terms of air dried powder weight of the plant material using the following formula:

$$\text{Yield percentage (\%)} = \frac{w}{W} \times 100$$

where,

w = Weight of extract (grams)

W= Weight of air dried plant parts in powder form (grams)

f) ***Direct application of antimicrobial finish:***

On the basis of weight of the fabric, quantity of herbal extract and citric acid used as cross linking agent were calculated. The material to liquor ratio was taken as 1:20. Acetic acid was used to maintain pH 5-6. The samples were immersed in the finish bath for 30 minutes. After that the fabric was placed in trough containing the solution of herbal extract for 5 minutes and passed the fabric through the herbal solution. Samples were passed between two rollers of pneumatic padding mangle at a pressure of 2.5 psi and uniformly squeezed. The fabric was dipped in the solution and passed again between the rollers of padding mangle to give a wet pick of its maximum take up. It was known as two dip two nips operation. The fabric was sent for subsequent drying and curing operation after it left the padding mangle. The fabric was dried at 80^{o}C for 3 minutes and cured at 120^{0}C for 2 minutes on a curing chamber (Santosh, 2009).

g) ***Preparation of microcapsules and its application:***

Microencapsulation is a process by which very tiny droplets of liquid or particles of solid are covered with a continuous film of polymeric material. Micro-capsulation was done using herbal extract as core material and gum acacia as wall/sheath material. Ten grams of acacia powder was allowed to swell for 15 min in 100 ml of hot water. To this mixture, 50 ml of hot water was added and stirred for 15 min maintaining the temperature between 40^0 and 50^0. One and half gram of core material (herbal extract) was slowly added under stirring conditions. Stirring was continued for another 15 minutes and then 10 ml of 20 % sodium sulphate and 6 grams of citric acid was added. The stirring was stopped and mixture was freeze dried in a freezer to develop microcapsules. Fabric was immersed in the microcapsule solution and padded through padding mangle. The treated fabric was dried at 80^{0}C for 5 minutes (Sathiyanarayan *et al.,* 2010).

Study the effectiveness of antimicrobial finish on morphology and selected fabric properties:

a) ***GSM (IS: 1964: 1970):***

The weight (GSM) is defined as the weight of specimen in one square meter of length. The samples were conditioned to maintain moisture equilibrium in standard atmosphere for 24 hours and then weighed. The principle of weighing grams per square meter of specimen is expressed in Test Method IS: 1964: 1970. The fabric was layed on a smooth surface. Square swatches of 25 x 25 cm were marked with the help of template. Swatches were then cut and conditioned. Weights of standard swatches were taken to an accuracy of 0.5 g (Nadiger and Subramanium, 2001).

The GSM was calculated by using the following formula:

25cm x 25cm = 'a' grams

Weight/square meter = 16 x 'a' grams/meter square

b) ***Fabric Thickness (BS 2544:954):***

The principle of the measurement of the fabric thickness is expressed in test method BS 2544:954. Using this method, the thickness of the fabric was measured with a Thickness Tester consisting of a graduated dial gauge of 10 mm capacity with a least count of 0.01 mm. The pressure foot is 5 cm^2 in area and a pressure from 20-100g/cm^2 *i.e.* a load of 100 g to 500 g can be applied. It has a base and a frame which is heavy enough to be stable, supporting a stationary circular plate or anvil, to fix it. The sample rests on this plate. A vertical sliding circular foot, with accurate surface rests on the top of the specimen. The later turns a dial pointer thus, giving the thickness of the sample under measurement *i.e.* the distance between the foot and the anvil. The measurements must be made at five different portions of the fabric is calculated by taking the mean of the five measurements.

c) ***Bending Length and Flexural Rigidity (ASTM- D1388- 64):***

Bending length is the length of the fabric that will bend under its own weight to a definite extent. It is the measure of the stiffness that determines draping quality. The bending length of the fabric was determined by the Stiffness Tester using ASTM- D1388- 64 test method.

Bending length $C = Lf_1(\theta)$

where $f_1(\theta) = 41^{1/2^\circ}$

also, $41^{1/2^\circ} = 1/2$

therefore, $C = L/2$

L = Mean length of the overhanging portions.

$$W = \frac{\text{Average weight of samples}}{\text{Average area of samples}} \text{ g/cm}^2$$

Flexural rigidity in warp direction (G_1)

$(G_1) = W_1 \times C^3 \times 10^3$ mg/cm

Flexural rigidity in weft direction (G_2)

$(G_2) = W_2 \times C^3 \times 10^3$ mg/cm

Overall flexural rigidity (G_0)

$$(G_0) = \sqrt{G_1 \times G_2}$$

d) ***Crease Recovery (ASTM 1295-67):***

The wrinkle recovery was determined on the 'Shirley Crease Recovery Tester' using ASTM 1295-67 test method. Samples were cut both in warp and weft directions from all the fabrics with a template measuring 5 cm x 2.5 cm and were tested after conditioning. The test specimen was carefully creased by folding in half and was placed between the two glass plates. The specimen was creased for 3 minutes under 2 kg weight. The specimen was removed and transferred to the fabric clamp on the instrument and allowed to recover from the crease for 3 minutes. As it recovered the dial of the instrument was rotated to keep the free edge of the specimen in line with the knife edge. The recovery angle in degrees was noted from the engraved scale. The mean values of 10 readings were calculated.

e) ***Tensile Strength (IS -1969 -1985):***

Samples of size 325 x 60 mm each were cut from warp as well as weft direction of the fabrics. The yarns were unraveled from both sides to obtain sample of uniform width. This was done to get uniform results. Prior to the test, the specimens were conditioned for moisture equilibrium from dry side and test was carried out in standard atmosphere of 65 ± 2 per cent relative humidity at 27 ± 2^0C temperature.

For testing a specimen was held between two clamps of the tensile strength testing machine in such a manner that the same set of yarns was gripped by both the clamps and a continual increasing load was applied longitudinally to the specimen by moving one of the clamps until the specimen ruptured. Value of breaking strength of the test specimen was read from the indicators on the machine.

f) ***Whiteness Index:***

The whiteness index of control, treated and microencapsulated cotton samples was calculated by using Hunter Lab Calorimeter (Color Flex spectrocolorimeter). It is based on the principle of reflectance the instrument gives. The Color Flex performs integration of the reflectance/transmittance values over the visible spectrum to arrive at CIE *tristimulus* L, a, b values. The opponent-colour scale gives measurements of colour in units of approximate visual uniformity throughout the colour solid. Thus, in the Hunter scale, L measures lightness and varies from 100 for perfect white and zero for perfect black, approximately, as the eye would evaluate it. The chromacity dimensions (a and b) give understandable designations of colour as follows:

'a' measures redness when positive, grey when zero and greenness when negative.

'b' measures yellowness when positive, grey when zero and blueness when negative.

Test specimens were passed between the plates of colorimeter and plate was inside the instrument L, a and b values displayed on the computer screen was noted down and whiteness index were calculated with the help of following formula.

$$\text{WI (Whiteness Index)} = \frac{L \times (L - 5.72b)}{100}$$

g) ***Moisture Regain (IS: 199-1973):***

Test specimen was drawn randomly from the lot and weighed. It was then placed in the drying oven at 105^0C to 110^0C for one hour and weighed again to record oven dry weight. Per cent moisture regain was calculated as follows (Grover and Hamby, 1988).

$$\text{Moisture Regain per cent} = \frac{(a - b)}{b} \times 100$$

where,

a = original weight in grams of the test specimen

b = original dry weight in grams of the test specimen

Study the efficacy of antimicrobial finish on cotton and Wool:

The efficacy of the finish was analyzed by washing all finished samples with pre-determined number of washing cycles in 'Launder-o-meter' by using standard test ISO:6330-1984E. The fabric samples were then subjected to microbial testing and the bacterial growth was analyzed after 5, 10, 15 and 20 washing cycles.

Statistical analysis:

The data was coded, tabulated and statistically analyzed. One way *ANNOVA* test was used to study parameters.

RESULTS AND DISCUSSION

The present research was conducted to impart the antimicrobial finish on cotton and Wool fabrics. To achieve the objectives, extraction was carried out from selected plant (*Neem*) using soxhlet process, conditions of extraction were optimized. Direct application and microencapsulation techniques were used to impart antimicrobial finish. Effectiveness of antimicrobial finish was determined in terms of different washing cycles and checked microbial resistance at different washing levels. The effect of antimicrobial finish on physical properties of cotton and wool fabrics was examined for both plant extracts applied using direct application and microencapsulation techniques. The results obtained were discussed under following subheads:

Identification and screening of plant sources:

Neem plant was identified through various literatures and screened for their antimicrobial properties. The common names and biological names of these selected herbal plants have been given in Table 1. *Neem* plants are rich chemically and have traditional and pharmacological properties and has been used for the study. *Neem* extracts also have more than 300 active compounds e.g. azaadirachtin, salannin and nimbin etc. which have diverse medicinal activities (Joshi *et al.,* 2009).

Every plant has its own medicinal value. *Neem* was selected for study having good antimicrobial resistance to *Staphylococcus aureus* and *Klebsiella pneumoniae*. The microbial resistance of these plants was checked by Disk method (Baver *et al.*, 1966).

Soxhlet extraction of plant sources and optimization of conditions for extraction:

Soxhlet extraction of plant source:

Neem (*Azadirachta indica*): Fresh mature green *Neem* leaves were collected, washed and dried in hot air oven at 40^0C temperature. After complete drying, these were prepared into fine powder by crushing and grinding.

Table 1 : Instruments used in the study

Name of equipment	Manufacturer	Purpose
Crease Recovery Tester	*Texlab* Industries Ahmedabad	Wrinkle Recovery
Electronic Balance 200B	Adair Dutt Instruments Pvt. Ltd. Calcutta	Weight per unit area of fabric (GSM)
Fabric Stiffness Tester	Paramount Instruments Pvt. Ltd., New Delhi	Fabric stiffness and bending length
Freeze dryer	FTS,USA	Microcapsule drying
Hunter Lab Colorimeter	Hunter Lab	Whiteness Index
Hot air oven	Labmaster Instruments Pvt. Ltd, Ambala	Drying the finished material
Launder-o-meter	Prolific Engineers Noida UP	Wash fastness
Magnetic stirrer	Bamstead International, USA	Homogenizing the mixtures
Tensile Strength Tester	Prolific Engineers Noida UP	Tensile Strength
Thickness Tester	Paramount Instruments Pvt. Ltd., New Delhi	Fabric thickness

Powder of *Neem* was placed in a thimble of soxhlet apparatus. Sample was extracted in a Soxhlet extraction system using 250 ml of various solvents viz. n- Methanol, ethanol and Chloroform solvents. The crude extract solutions obtained and rotary evaporator used to remove the solvents and completely dried in an atmospheric oven. High temperature treatment was avoided to minimize the component degradation (Kumaro and Masitah, 2007). Extract was then stored at room temperature before weighing gravimetrically to determine the yields. Plant sources including *Neem* and *Aloevera* were extracted in soxhlet using methanol (Raut *et al* 2012), and methanol (Nisarg *et al.,* 2012), respectively for application on cotton fabric to assess the antimicrobial property.

Optimization of extract concentration:

Optimization is the selection of a best element (with regard to some criteria) from some set of available alternatives. The conditions for extraction of plant sources were optimized. The parameters included for extraction were concentration and time which were optimized on the basis of their antimicrobial activity against *Staphylococcus aureus* and *Klebsiella pneumoniae*, medium and temperature were kept constant (Jeyachandran *et al.,* 2009, Raut *et al.,* 2012, Nisarg *et al.,* 2012 and Joshi *et al.,* 2011). The antimicrobial activity of plant extracts was tested with Disk diffusion method for both cotton and wool fabric.

The antimicrobial activity regarding optimization of extract concentration against *Staphylococcus aureus and Klebsiella pneumonia* has been shown in Table 2. It can be interpreted from the Table 2 that *Neem* showed antibacterial activity at 5g/l concentration and at more. It can be concluded that, higher concentration of plant powder more is the antimicrobial activity, but it also depends upon antibacterial properties of the plant. Joshi *et al* (2009) tested the antimicrobial activity of four plants (*Neem*, *Tulsi*, Clove and *Datiwan*) and found that Clove was most effective against *Samlonellatyphi* and *Staphylococcus aureus*bacteria.

Neem showed no antibacterial effect against *Staphylococcus aureus* for 3g/l and 5g/l concentrations when used for wool fabric as data showed in Table 2. S*taphylococcus aureus* had the quite zone of inhibition diameter of on both *aloe* leaf and root extract respectively at 100 µl, whereas the ethanol extract had significant effect on the zone of inhibition of *S. aureus*. At 100 µl of the ethanol extract, the highest zone of inhibition of aloe leaf ethanol and aloe root ethanol, susceptibility against gram-positive bacteria

Table 2 : Antimicrobial activity of plant extracts against *Staphylococcus aureus* and *Klebsiella pneumonia* bacteria for different concentrations on Cotton and wool Fabric

Neem	Concentration		
	3g/l	5g/l	7g/l
	Susceptible/ resistant	Susceptible/ resistant	Susceptible/ resistant
Cotton	Susceptible	Resistant	Resistant
Wool	Susceptible	Resistant	Resistant

Percentage yield of plant extracts:

Percentage yield of plant extracts in terms of air dried powder weight of the plant material. The yield percentage of *Neem* extract was found to be of 21.5% which is maximum yield attained from soxhlet extraction with ethanol at 90/ °C.

Preliminary data of the Fabric:

Pure cotton and wool fabric were used for this study. Fabric thread count (number of warps and wefts) was determined using pick glass. Table 3 indicates that the thread count of cotton sample was 56x43 ends and picks per inch. The weight is defined as the weight of specimen in one square meter of length and of cotton it was found to be 284 g/m^2.

Table 3 : Preliminary data of the fabrics used in study

Fabric	Fabric count		Fabric weight (g/m^2)
	Warp (mean)	Weft (mean)	
Cotton fabric	56	43	284
Wool fabric	60	59	260

Whereas another fabric taken for study is wool having thread count of 60 x 59 ends and picks per inch. The weight of wool fabric is found to be 260g/m^2

Determination of physical properties of untreated and treated fabrics:

The physical properties have greater influence and play an important role in determining the quality of the fabric. There is not always a clear isolating line between physical and performance properties. The physical properties were assessed to determine the appearance, performance and serviceability of the fabric. The test samples were assessed for fabric weight, thickness, tensile strength, bending length, crease recovery, moisture regain using standard test methods.

Effect on GSM of fabric after different application methods:

The weight (GSM) is defined as the weight of specimen in one square meter of length. When *Neem* extract was applied using direct and microencapsulation treatments, with GSM there is significant decrease (<0.01) b/w direct and microencapsulated method. The GSM value of control cotton sample was 148 g/m^2 which increased to 162.33 g/m^2 when direct treatment with *Neem* extract was applied. When microencapsulation treatment was given to the cotton fabric, the GSM of sample was 121.34 g/m^2.

In case of wool fabric, GSM of untreated sample observed was 188.66 g/m^2 which increased to 198.16 g/m^2 when direct treatment was given in case of *Neem* extract. The GSM significantly decreased to 165.33g/m^2 after *Neem* microencapsulation treatment at 5% level of significance (<0.01) whereas in case of direct application on wool the GSM decreases to 172.98g/m^2 of *Aloevera* extract and microencapsulation technique resulted significantly decrease in GSM (<0.01) level of significance as compared to untreated sample.

Effect on thickness of Cotton fabric after different application methods:

Fabric thickness is defined as perpendicular distance through the fabric, which determines the dimension between the upper and lower side of the fabric. The effect of herbal finish on fabric thickness has been explained in Table 5. The fabric thickness of untreated sample was approximately 0.534 mm.The fabric thickness of untreated sample was approximately 0.534 mm. The fabric thickness increased to 0.682 mm and 0631 mm after giving the direct and microencapsulation treatment with *Neem* extract, respectively.

The thickness of *Neem* treated wool fabric using pad-dry-cure method was 1.80 mm. When microencapsulation treatment was given, the thickness of fabric increased to 1.326 mm as compared to untreated sample. While in case of direct *Neem* extract applied 1.77 mm while it becomes 1.66 mm when microencapsules were applied. It can be concluded from the Table 4 that, the thickness of fabric significantly improved after giving the herbal finishing treatments at 5 % level of significance. As compared to untreated sample, the fabric thickness significantly increased (<0.01) after giving direct application of extracts with pad-dry-cure method and microencapsulation treatments.

Table 4 : Effect on GSM of cotton and wool fabric after different application methods with *Neem* extract

Application method	GSM (g/m^2) Cotton	GSM (g/m^2) Wool
Untreated	148.00 ± 2.00^b	188.66 ± 1.52^b
Direct application	162.33 ± 2.08^a	198.16 ± 2.05^a
Microencapsulation	121.34 ± 0.58^c	165.33 ± 1.15^c
P value	<0.01	<0.01

Values having different superscripts from a, b to c differ significantly coloumn wise in application method
(*) significant at α=0.05
(**) significant at α=0.01

Table 5 : Effect on thickness (mm) of Cotton and wool fabric after different application methods

Application method	Cotton	Wool
Untreated	0.534 ± 0.01^c	0.345 ± 0.02^c
Direct application	0.682 ± 0.01^a	1.80 ± 0.01^a
Microencapsulated	0.631 ± 0.01^b	1.326 ± 0.13^b
P value	<0.01	<0.01

Values having different superscripts from a, b to c differ significantly column wise in application method
(*) significant at α =0.05
(**) significant at α=0.01

Effect on bending length of cotton and wool fabric after different application methods

Fabric bending length is a measure of the interaction between the fabric bending rigidity and weight. It is evident from the Table 6 that, when *Neem* extract was not applied on fabric, the bending length was 3.28 cm in warp and 1.43 cm in weft direction. After the direct treatment of *Neem* extract on cotton fabric, the bending length decreased to 1.22 cm in warp and increased (1.49 cm) in weft direction. When microencapsulation treatment of *Neem* extract was given to the fabric, the bending length further decreased to 1.65 cm in warp and increased (1.70 cm) in weft direction.

The bending length of warp and weft directions was 1.89 cm and 1.60 cm respectively when *Neem* extract was directly applied on wool samples by pad-dry-cure method. It decreased to 1.28 cm in warp direction and increased in weft direction i.e. 2.15 cm after giving the microencapsulation treatment.

It can be concluded from the Table 6 that bending length had non-significant decreased when different

Table 6 : Effect on bending length (cm) of cotton and wool fabric after different application methods

Application method	Bending length (warp) cm	Bending length (weft) cm	Bending length (warp) cm	Bending length (weft) cm
	Cotton	Cotton	Wool	Wool
Untreated	3.28 ± 0.02[a]	1.43 ± 0.03[c]	3.28 ± 0.03[a]	1.43 ± 0.03[b]
Direct application	1.22 ± 0.01[c]	1.49 ± 0.01[b]	1.89 ± 0.03[b]	1.28 ± 0.02[c]
Microencapsulated	1.65 ± 0.02[b]	1.70 ± 0.05[a]	1.60 ± 0.08[c]	2.15 ± 0.03[a]
P value	<0.01	<0.01	<0.01	<0.01

Values having different superscripts from a, b to c differ significantly coloum wise in application method
(*) significant at α=0.05 (**) significant at α=0.01

finishing treatments were given to the wool fabric in warp direction. Bending length of fabric in weft direction increased after giving direct and microencapsulation treatments. There was significant interaction between plant sources and treatments given to the fabric. The results are in line with Joshi *et al.* (2007) who developed antimicrobial finish for polyester/cotton blended fabric using extract of *Neem* seed and in other study bending length were more or less same before and after treatment of *Neem* extract (Premalatha and Nagarajan, 2007)

Effect on Crease recovery of Cotton and Wool fabric after different application methods:

The measure of crease recovery is the angle at which the sample recovers from creasing**.** The crease recovery of treated and untreated cotton (warp + weft) sample has been depicted in Table 7. The crease recovery of untreated fabric was found to be 80^0. After giving the direct *Neem* treatment by pad-dry cure method, the crease recovery angle increased to 117° and it was 115° after giving microencapsulation treatment using *Neem* extract on cotton fabric. This shows that fabric has become rigid after giving both finishing treatments.Non-significant difference was observed between *Neem* extract application through direct method whereas significance shown at 1% level in microencapsulation method.

The Table 7 depicted that crease recovery angle of

Table 7 : Effect on crease recovery of cotton and wool fabric after different application methods

Application method	Crease recovery (warp+weft) (^{0})	
	Cotton	Wool
Untreated	80 ± 2.00[b]	89.33 ± 2.51[b]
Direct application	117 ± 1.00[a]	280.33 ± 4.04[a]
Microencapsulated	115 ± 1.5[a]	280.33 ± 4.50[a]
P value	<0.01	<0.01

Values having different superscripts from a, b to c differ significantly coloumn wise in application method
(*) significant at α=0.05 (**) significant at α=0.01

wool fabric when directly applied *Neem* extract angle becomes 280^0. When *Neem* extract microcapsules were applied to the wool fabric with pad-dry-cure method, the crease recovery angles same as in direct method.

Effect on moisture regain of fabric after different application methods:

It is evident from the Table 8 that moisture regain of untreated sample was 0.44 %. Maximum moisture regain 6.30 % was observed, when *Neem* extract was directly applied on cotton fabric by pad-dry-cure. Moisture regain increased to 10.28 % as compared to untreated sample when microencapsulation treatment of *Neem* extract was given on cotton Fabric. Hence there is a significant increase in the moisture regain percentage of various applications with *Neem* extract on Cotton fabric as compared to untreated samples. From the findings presented in the Table 8, it can be concluded that a significant increase in moisture regain of fabric was observed after giving direct treatment *Neem* at 5% and microencapsulation treatments as compared to untreated sample still had good antibacterial property and its inhibitory rate over 99 per cent.

Table 8 : Effect on moisture regain of Cotton and Wool fabric after different application methods

Application method	Cotton	Wool
Untreated	0.44 ± 0.02[c]	0.49 ± 0.02[c]
Direct application	4.81 ± 0.04[b]	8.14 ± 0.02[b]
Microencapsulated	6.30 ± 0.20[a]	10.28 ± 0.03[a]
P value	<0.01	<0.01

Values having different superscripts from a, b to c differ significantly column wise in application method
(*) significant at α=0.05
(**) significant at α=0.01

Effect on tensile strength of cotton and wool fabric after different application methods:

Tensile strength is the resistance of a material to breaking under tension. It is evident from the Table 9

Table 9 : Effect on tensile strength of cotton and wool fabric after different application methods

Application method	Tensile strength (kg)				
	Warp		Weft		T value
	Cotton	Wool	Cotton	Wool	
Untreated	25.06 ± 1.00^{a}	37.18 ± 1.61^{a}	25.06 ± 1.00^{c}	37.18 ± 1.62^{a}	-0.369^{NS}
Direct application	36.09 ± 1.00^{a}	27.16 ± 0.23^{b}	27.01 ± 2.00^{b}	11.59 ± 0.53^{a}	-0.337^{NS}
Microencapsulated	35.40 ± 0.70^{a}	26.57 ± 0.33^{b}	27.59 ± 0.42^{a}	20.51 ± 0.83^{b}	2.899*
P value	<0.01	<0.01	0.121	<0.01	

Values having different superscripts from a, b to c differ significantly column wise in application method
(*) significant at α=0.05 (**) significant at α=0.01

that tensile strength of untreated cotton fabric was 25.06 kg in warp direction. When *Neem* extract was directly applied by padding mangle, the tensile strength of fabric increased to 36.09 kg as comparison to untreated fabric. It further decreased to 35.40 kg after giving the microencapsulation treatment in warp way. While when *Neem* extract is directly applied to the weft direction the tensile strength of cotton fabric decreased 27.04 as compare to warp direction to whereas in case of microencapsulation of *Neem* extract no significant difference found in comparison to the direct treatment in weft direction.

It is also indicated from the Table 9 about wool fabric in warp direction that, tensile strength was 27.16 kg after direct application of *Neem* extract and it reduced to 26.57 kg after giving microencapsulation treatment. Hence, the tensile strength of treated fabric decreased as comparison to untreated sample. Data given in Table 9 also showed tensile strength of wool fabric in weft direction treated with *Neem* extracts using different finishing techniques. The tensile strength of untreated fabric was 37.18 kg. When *Neem* extract was directly applied with padding mangle the tensile strength of sample was decreased 11.59 kg and 20.51 kg after microencapsulation treatment.

Effect on whiteness index of fabric after different application methods:

Whiteness index plays a vital role in the luster of end products. Whiteness index of untreated fabric was found to be 72.24 and it decreased to 62.79 after giving the direct treatment using *Neem* extract. When microencapsulation treatment was given, the whiteness index further decreased 60.83. Here whiteness index of treated cotton fabric decreased as compared to untreated sample at (<0.01) level of significance.

Hence, whiteness index of treated fabric decreased after giving both direct and microencapsulation treatments using both extracts on wool and cotton as compared to untreated sample at 5 % level of significance given in Table 10.

Table 10 : Effect on whiteness index of cotton and wool fabric after different application methods

Application method	Whiteness index	
	Cotton	Wool
Untreated	72.26 ± 1.15^{a}	60.27 ± 0.57^{b}
Direct application	62.73 ± 0.75^{b}	50.66 ± 1.15^{c}
Microencapsulated	60.88 ± 0.50^{b}	69.25 ± 0.72^{a}
P value	<0.01	<0.01

Values having different superscripts from a, b to c differ significantly column wise in application method
(*) significant at α=0.05 (**) significant at α=0.01

Determination of microbial resistance on untreated and treated fabric:

Efficacy of Direct finish of Neem extract on Cotton and Wool Fabric:

The efficacy of the Direct Cotton samples was assessed by testing antimicrobial activity after 5, 10, 15, 20 launder-o-meter washing cycles. The results have been depicted in Table 11 that all the samples of cotton shows resistance to antimicrobial activity against both the bacteria. From the study done by Hooda *et al.* (2013), it was observed that *Neem* has been found effective against bacterial growth on wool fabric even after 20 washing cycles (79.28%). Joshi *et al.* (2011) tested the antimicrobial activity of four plants (*Neem*, *Tulsi*, Clove and *Datiwan*) and found that Clove was most effective against *Samlonella typhi* and *Staphylococcus aureus* bacteria. Therefore, bacterial growth increased after every washing cycle. Hence, the antimicrobial activity of microencapsulated sample shown in Table 12 significantly reduced after every washing cycle.

Efficacy of microencapsulated finish of Neem Extract on Cotton and Wool Fabric:

The efficacy of the microencapsulated samples was

Table 11 : Efficacy of Antimicrobial activity of *Neem* extract on Cotton and wool fabric with direct application at different wash cycles

Fabric	Cotton		Wool	
Bacteria	*S aureus*	*K pneumoniae*	*S aureus*	*K pneumonia*
Without Wash	Resistant	Resistant	Resistant	Resistant
After 5 Washes	Resistant	Resistant	Resistant	Resistant
After 10 Washes	Resistant	Resistant	Resistant	Resistant
After 15 Washes	Resistant	Resistant	Resistant	Resistant
After 20 Washes	Resistant	Resistant	Resistant	Resistant

Table 12 : Efficacy of Antimicrobial activity of *Neem* extract on Cotton and wool Fabric with Microencapsule application at different wash cycles

Fabric	Cotton		Wool	
Bacteria	*S aureus*	*K pneumoniae*	*S aureus*	*K pneumonia*
Without Wash	Resistant	Resistant	Resistant	Resistant
After 5 Washes	Resistant	Resistant	Resistant	Resistant
After 10 Washes	Resistant	Resistant	Susceptible	Susceptible
After 15 Washes	Resistant	Resistant	Susceptible	Susceptible
After 20 Washes	Resistant	Resistant	Susceptible	Susceptible

assessed by testing antimicrobial activity after 5, 10, 15, 20 launder-o-meter washing cycles. The results have been depicted in Table 12. In case of cotton treated with both extracts the results shows the resistance of antimicrobial growth even after 20 washes but in case of wool fabric finish will revive only till 5 wash-cycles, after 5 washes majority of the wool sample shows the growth of microbes onto it which further shows susceptible results. So wool fabric is less resistance to these two types of bacterial growth as compare to cotton fabric with *neem* extracts of plants.

Conclusion:

– The antimicrobial activity of *Neem* extract with 7g/l concentration against *Staphylococcus aureus* and *Klebsiellapneumoniae* bacteria was significantly effective on cotton and wool fabric.

– The GSM of treated fabrics with both the extracts increased after giving direct extract application by pad-cure-method and microencapsulation finishing techniques.

– The thickness of treated fabric significantly increased after giving the herbal finishing treatments.

– Bending length and flexural rigidity of treated fabrics decreased in warp direction and increased in weft direction. Whereas, crease recovery of the treated samples increased in both warp and weft direction as comparison to untreated sample. Hence, the fabric got stiffer after application of finish.

– Moisture regain of treated fabric significantly increased as compared to untreated sample.

– The tensile strength of treated fabric using direct and microencapsulation finishing treatments both in warp and weft direction got decreased as comparison to untreated sample for both fabrics at 5 % level of significance.

– Elongation of fabric significantly increased after giving direct and microencapsulation treatments of extracts in warp direction as compared to untreated sample. Whereas, elongation of the direct and microencapsulated treated samples significantly reduced in weft direction.

– Whiteness index of treated fabric using direct and microencapsulation finishing treatments got decreased as comparison to untreated sample of wool and cotton at 5 % level of significance.

– The efficacy of the microencapsulated samples was assessed by testing antimicrobial activity after 5, 10, 15, 20 launder-o-meter washing cycles. The bacterial growth was maximum on unwashed samples of cotton and wool and this bacterial growth becomes susceptible after 5 wash cycles. Hence, the antimicrobial activity of direct and microencapsulated samples significantly reduced after every washing cycle.

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