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## **Summary and Conclusion**

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Textiles have the potential to be suitable barriers but they are also affected by environmental threats in the form of microorganisms. Textiles currently used in hospitals and hotels are conducive to cross infections or transmission of diseases caused by microorganisms particularly by bacteria and fungi. The human pathogenic microbes include bacteria, fungi, viruses and nematodes which are able to cause serious infections. Infectious diseases are the world's leading cause of premature deaths, killing almost 50,000 people every day. The situation is alarming both in developing and developed countries. Bacteria can multiply every 20 minutes under optimum conditions turning single bacterium into eight million bacteria within a duration of eight hours. In order to protect mankind from microbial infection, a special durable antimicrobial finish has become necessary. Health and hygiene are the primary requirements for human beings to lead their life comfortably and work with maximum efficiency. Today's health care professionals are more concerned in creating a healthy environment in which they can treat the patients well. So the application of antimicrobial finishes to the products are abundant and challenging. The antimicrobial finishes have been the current vogue that promotes a healthier and physically active life style. The antimicrobial agents are incorporated with the textile material to prevent the transmission of pathogenic microorganisms and it should be capable of counter attacking the development of odour from the bacterial decomposition of perspiration in clothing. Due to the increase in realization of health hazards and toxicity caused by synthetic drugs and antibiotics, there has been a necessity and demand for protecting the health with other reliable sources with renewed interest in the use of natural materials and other alternatives with textiles.

Ayurveda is an ancient medical treatise summarizing art of healing and prolonging life. The ayurvedic medicinal herbs are moving from fringe to main stream use with a greater number of people seeking remedies and health approaches free from harmful side effects. The use of herbal medicated products helps us to reduce the opportunity for contamination by biological toxins and infectious pathogens and thereby reduces the spread of diseases to other patients by creating a physical barrier between an infected person and a healthy individual. There are numerous numbers of medicinal plants having antimicrobial and disease curing properties.

A study has been undertaken on this context with the following objectives :

- To extract the herbal solutions from selected medicinal herbs.
- To find out the antimicrobial efficacy of the selected extracted herbal solutions against disease causing microorganisms.
- To analyze antimicrobial activity of the extracted herbal solutions against the commercial antibiotics and evaluate their shelf life.
- To optimize the parameters for herbal extraction and process of applying the extracts on cotton textile materials.
- To develop herbal antimicrobial medicated products and evaluate their performance.

The experimental procedure adopted for the study encompasses the following five phases :

**PHASE – I : Selection of Suitable Medicinal Herbs, Solvent, Material, Extraction Procedure, Optimization of Finish Process Parameters, Mordant, Finishing Methods, Microorganisms, Antibiotics and Antimicrobial Tests**

❖ **Selection of Medicinal Plants**

Indian medical history has listed a long number of medicinal herbs for healing various types of diseases, which calls for intensive researches across the globe. Considering this the herbs mentioned below were selected for a pilot study. The selected medicinal plants were collected from the Agricultural University and other herbal ayurvedic shops, Coimbatore. The detail of the selected medicinal plants are given below.

**LIST OF SELECTED MEDICINAL PLANTS**

Common name	Botanical name	Parts used	Family
Aloe vera	<i>Aloe barbadensis</i>	Leaves	Liliaceae
Marigold	<i>Calendula officinalis</i>	Flower	Asteraceae
Kuppaimeni	<i>Acalypha indica</i>	Leaves	Anacardiaceae.
Neem	<i>Azdirachta indica</i>	Leaves	Meliaceae
Yashtimadhu	<i>Glycyrrhiza glabra</i>	Roots	Solanaceae
Tanner's Cassia	<i>Cassia auriculata</i>	Flower	Caesalpiniaceae
Tridax Daisy	<i>Tridax procumbens</i>	Leaves	Asteraceae
Vetiveru	<i>Vetiveria zizanioides</i>	Roots	Graminae
Flax seed	<i>Linum usitatissimum</i>	Seed	Linaceae

For *Aloe vera* the outer portion of leaves were removed and fresh gel solution was taken by grinding. All the other parts of the selected plants namely leaves,

flowers, roots and seeds were shade dried and powdered finely and the extracts were obtained. These extracts were tested by Thin Layer Chromatography and Agar Well Diffusion Test methods for identifying the antimicrobial effectiveness of the herbs. The colour reflection and the zone of inhibition revealed the herbs with the maximum antimicrobial activity. Based on these results Aloe vera, Marigold, Kuppaimeni, Neem, Yashtimadhu and were selected for the study.

#### ❖ Selection of Solvent and Extraction Procedure

Fresh extraction method was used for Aloe vera. The dry extraction method was used for all the other plant parts which were shade dried for 48 hrs and powdered into fine particles and then mixed with solvents in the ratio of 1:10 in separate beakers. Based on the herb nature, polarity ranges and yield level of herbs, the solvents namely distilled water, ethanol and methanol were undertaken for the pilot study. After the extraction, the zone of inhibition (in mm) was analyzed by AATCC 147 Agar well Diffusion Method against *Staphylococcus aureus* and *Escherichia coli* bacteria growth and also compared with antibiotics. Based on the higher zone of inhibition, the solvents such as distilled water for Aloe vera, neem and yashtimadhu, ethanol for marigold and kuppaimeni were identified as the best solvents. These parameters were used for the final study.

#### ❖ Selection of Material

Cotton is a cool, soft, comfortable clothing fiber of the world. Properties like absorbency, ability to arrest micro-organism entry and easy care are the highlights of cotton application in the field of medicine. Considering this, cotton fabric with the following specifications 82 ends and 64 picks for 2.5 cm, 60<sup>s</sup> count, GSM 63 and plain weave was selected for the study.

#### ❖ Selection of Optimization of Finish Process Parameters for the Application of Herbal Extracts on Fabrics

Time, temperature and concentration are the three major factors influencing the antimicrobial activity against bacteria and fungi organisms. Hence the extracted herbal solutions were applied on the cotton fabrics by varying these parameters. Optimization was carried out using Box and Behnken response surface design with the above mentioned three independent variables at three levels. The combinations of these variables according to the design are shown below.

**BOX AND BEHNKEN EXPERIMENTAL DESIGN  
VARIABLES AND CODED LEVELS**

Variables	Coded levels		
	-1	0	+1
Time (mins)	30	60	90
Temperature (°C)	40	50	60
Concentration (%)	25	50	75

In Box-Behnken experimental design, 15 samples were prepared in a variety of combinations for the selected five herbs. Based on the each level, the zone of inhibition was measured and the best suited process parameters were optimized and selected for the final study as shown below.

**OPTIMIZED FINISH PROCESS PARAMETERS FOR SELECTED HERBS**

Medicinal plants	Optimized finish process parameters		
	Time (mins)	Temperature (°C)	Concentration (%)
<i>Aloe vera</i>	60	50	50
Marigold	60	60	75
Kuppaimeni	90	50	75
Neem	30	50	25
Yashtimadhu	60	50	50

❖ **Selection of Mordant, Material Liquor Ratio, Microorganisms and Antibiotics**

Alum being considered as eco-friendly mordant was used as an agent to bind the selected herbal extracts to the fabrics. The extracts were applied on the cotton fabric using the optimized finish process conditions along with the material liquor ratio of 1:10.

Many harmful infectious and blood borne bacteria and viruses such as *Pseudomonas*, *Candida*, *S. aureus* and *E. Coli* are present in hospital locations which are conducive for growth of the micro organisms. Hence, gram positive *Staphylococcus aureus*, gram negative *Escherichia coli* bacteria and *Candida albicans* and *Aspergillus niger* fungi of microorganisms were selected for the study. Antibiotics namely Penicillin for *Staphylococcus aureus*, Chloramphenicol for *Escherichia coli* were selected to evaluate the efficiency of the herbal solutions against these antibiotics.

**PHASE – II : Application of Herbal Extraction on Cotton Fabrics and Evaluate the Antimicrobial Activity against Bacteria and Fungi**

❖ **Selection of Herbal Finish Application Method**

Pad-Dry Cure and Micro encapsulation methods were selected to apply the optimized herbal solution to cotton materials. In pad- dry cure process, the optimized

percentage of concentration herbal extracts of all the five selected herbs were mixed with the mordant (alum) in the ratio of 9:1. In case of micro encapsulation, co-acervation spray drying method was followed using all the herbal extract as the core material and gum acacia as a wall material. After the finish application, the micro capsules formation of each herbal finished samples was tested under the scanning electronic microscopic analysis with different magnification.

#### ❖ **Selection of Antimicrobial Standard Testing Method**

The antimicrobial activity of pad dry and micro encapsulation finished and unfinished samples were evaluated by agar diffusion and broth dilution tests. Qualitative methods (AATCC 147, AATCC 30) (AATCC 100) for bacteria and fungi.

#### **PHASE – III : Evaluating the Antimicrobial Effectiveness, Physical and Mechanical Property, Durability and Functional Property of Herbal Extractions**

The evaluation was carried out in three different stages namely before finishing, after finishing of herbal solutions on fabrics and functional property tests.

- ❖ The Preliminary Phytochemical, Solvent, Herbal Concentrations and Antimicrobial Activity Against Antibiotic Screening tests were carried out by Thin layer chromatography and Agar well diffusion.
- ❖ After finishing, all the selected pad dry and micro encapsulation herbal finished and unfinished samples were tested using FT-IR Study, SEM Study, Antibacterial and Antifungal Assessment Tests, Subjective and Objective tests. The functional property tests were also conducted to assess the ultraviolet protection and thermal comfort in the aloe vera herbal finished fabrics, and the coolant and thermal property in the yashtimadhu herbal finished fabrics

#### **PHASE – IV : Product Development and their Performance**

##### ❖ **Selection and Construction of Products**

Based on the properties of the five herbal finished cotton material, various herbal medicated products were developed. The product details are presented below.

### DETAILS OF WEAR STUDY

S.No.	Medicinal herb	Medicated Products	Diseases/skin problems	Subjects for wear study	Age group of the subjects	Time and Duration for wear
1.	Aloe vera	Hand Gloves	UV black coating, Tanning	Traffic police, sports persons, working women	25-50 years	6 hours / 30 days
2.	Marigold	Fabric Sandles	Foot cracks	Homemakers	30-45 years	6 hours / 30 days
3.	Kuppaimeni	Bed sheets	Bed sores, skin allergies	patients	25-40 years	12 hours /60 days
4.	Neem	Head and face mask	Hair fall and black pimple spots	College students	15-25 years	6 hours / 30 days
5.	Yashtimadhu	Eye Pillow	Eye irritation and red eyes.	Software/IT professionals and computer students	21-40 years	1 hours / 30 days

#### ❖ Selection of Products for Performance Wear study

The products thus designed were analysed and approved by the Human Ethical Committee constituted at Avinashilingam Deemed University for Women, Coimbatore [Proposal number HEC.2011.20 dated 02-02-2011] and PSG Institute of Medical Sciences and Research Institutional Human Ethics Committee [Proposal Number 11/098 dated 05-05-2011]. Based upon their suggestions and recommendations only two products namely aloe vera hand gloves and yashtimadhu eye pillow were designed for protection against ultra violet rays and eye irritation. The developed hand gloves were given to 30 working women, 20 traffic police personnel and 50 sports persons who spend more than 6 to 7 hours in sunlight. The eye pillows were given to 30 Informational technology professionals and 70 computer students working for more than 8 to 10 hours on the computer. The selected subjects were requested to use the gloves for 30 days for a minimum of six hours and eye pillow for minimum of 30 minutes twice a day. A questionnaire was circulated for collecting their opinion about the performance of the product. Thus collected data was consolidated.

#### PHASE – V : Statistical Analysis

The obtained datas were statistically analyzed by analysis of variance and paired and unpaired t- Tests.

#### FINDINGS OF THE STUDY

- The dark brown and blue shades seen from the Thin Layer Chromatography (TLC) tests on the herbal solutions indicates the presence of rutin related

compounds of flavonoids and phenolic acids. These phytochemical compounds exhibit antimicrobial properties.

- The herbs aloe vera, neem, yashtimadhu, tridax daisy and flax seed against the *Staphylococcus aureus* bacteria and kuppaimeni, tanner's cassia, marigold and vetiveru showed a better zone of inhibition against *Escherichia coli* negative bacteria. The best suitable solvent and herbal concentrations are distilled water for aloe vera, neem, yashtimadhu, flax seed, ethanol solvent for marigold, kuppaimeni, tridax daisy, vetiveru and methanol for tanner's cassia in 100 µl concentrations.
- The zone of inhibition for aloe vera, neem, yashtimadhu in the aqueous media is 28, 27 and 27 mm respectively against antibiotic penicillin. The herbal extracts from marigold and kuppaimeni show better antimicrobial activity in ethanol extract as 23 mm and 22 mm. The zone of inhibition against negative bacteria in aqueous media is 27 mm, 24 mm and 25 mm in aloe vera, neem and yashtimadhu herbal extracts when compared to chloromphenical antibiotic. The marigold and kuppaimeni herbal extracts exhibit better activity in alkaline medium picturing a zone of inhibition at 24 mm and 27 mm.
- The FT-IR tests concludes the presence of antimicrobial compounds like ester, flavonols, COOH groups in all the herbal finished samples.
- The Box and Behnken optimized finish parameters such as 60 mins, 50°C, 50 per cent concentration for aloe vera ; 60 mins, 60°C, 75 per cent concentration for marigold ; 90 mins, 50°C, 75 per cent concentration for kuppaimeni, 30 mins, 50°C, 25 per cent concentration for neem and 60 mins, 50°C and 50 per cent concentrations for yashtimadhu were selected for herbal finishing onto the fabric.
- The observations of SEM study shows the morphology of all the pad dry and micro encapsulation herbal finished samples. The herbal solutions were fixed unevenly with little number of protruding fibres in pad finished samples and maximum absorption of herbal solution with reduced pore size and uniform deposition of herbal solutions in micro encapsulated samples.
- Among all the herbal finished samples, ALMF sample showed a maximum zone of inhibition (40 mm) against *Staphylococcus aureus* bacteria and YAMF showed a maximum zone of inhibition (38 mm) against *Escherichia coli* bacteria.
- The observations of antibacterial AATCC tm 100 broth dilution test proved that the Box Behnken optimized herbal concentrations shows the high absorbance

value against both positive and negative bacterias. The low absorbance value shows the higher percentage of bacterial reduction. The YAMF samples clearly show more than 80 per cent reduction against *Staphylococcus aureus* bacteria and 70 per cent reduction against *Escherichia coli* bacterias. The other herbal finished samples showed the minimum reduction of 35 – 55 per cent except KUMF sample against positive bacteria and 26 – 65 per cent of reduction against negative bacteria. The herbal pad dry and micro encapsulation finished samples in between the groups, bacterias, treatments shows one per cent level of significance. The marigold, kuppaimeni, neem, yashtimadhu finished sample reveal one per cent significance in between the bacteria and treatments except aloe vera sample. The 'F' ratio shows the maximum antibacterial activity in between groups and treatments.

- All the herbal finished samples showed a better fungal control when compared to unfinished sample. The optimized concentrations of all the selected herbal finished samples indicates the maximum zone of inhibition in micro encapsulated samples than pad dry finished samples. The sample KUMF and NEPF showed maximum zone of inhibition of 65 mm and 50 mm respectively against *Candida* fungi whereas ALMF and YAMF showed a higher zone of inhibition against the *Aspergillus niger*.
- Visual inspection proved the herbal finished samples to have good texture, general appearance, lustre and evenness of finishing when compared to unfinished sample.
- All the samples except KUPF have increased in their weight after herbal finish. The maximum and minimum increase was observed in the samples MAMF and ALPF as 15 and 1.66 respectively. The KUPF sample shows a decrease of three per cent. From the statistical analysis, it is noted that the analysis of variance of all the samples in within the groups, between the herbs, between treatments and between both herbs and treatments had significance at one per cent level.
- The fabric count of the finished fabrics has reduced. Similar fabric count as the unfinished sample is seen in the samples ALMF, MAMF and NEMF in warp direction, ALMF, KUPF and YAMF in weft direction. The maximum reduction is seen in samples MAMF, KUPF and NEPF as 3.6 per cent in warp and NEPF and MAPF as 4.6 per cent in weft. From the statistical analysis, it is noted that the analysis of variance of all the samples between groups, herbs, treatments and

both herbs and treatments showed significance at one. The 200.9837 'F' ratio shows the maximum count decrease in between treatments.

- All finished samples show an increase in thickness when compared to the original sample, except KUPF which exhibits a minimum decrease of five per cent. The sample NEMF and KUMF shows the maximum increase of 14 per cent. The statistical analysis of 'F' ratio proves one per cent significance in between the groups, herbs, treatments, separately and between both.
- The tensile strength in warp direction of sample YAMF shows the maximum increase among finished sample with 25 per cent whereas minimum increase is observed in the sample KUMF as 0.92 per cent. Reduction in tensile strength was observed to be maximum in sample KUPF with 15 per cent and minimum in sample MAPF as 3.4 per cent.
- The tensile strength of herbal finished samples has decreased in the weft direction. The maximum loss of 42 per cent is observed in NEPF and minimum of 10 per cent in KUMF sample. The 'F' ratio of 521.4916 shows that the maximum decrease of strength was seen in between the treatments in the weft direction.
- All the herbal finished samples in the warp direction show reduction in elongation when compared with unfinished sample. Sample YAPF shows the minimum decrease of 11 per cent whereas sample KUPF shows maximum decrease in elongation by 43 per cent. There is an increase in the elongation of all the samples in the weft direction after treatment. Sample KUPF showed a maximum increase of 70 per cent whereas sample ALPF indicates minimum increase with 37 per cent. The 'F' ratio of statistical analysis represents one per cent significance difference in between the groups, between the herbs, treatments, separately and both of them. In between the treatments of 'F' ratio 1028.6438 shows the maximum increase of elongation in the weft direction, this proves the enhancement of the micro encapsulated herbal finish on the fabric.
- Except NEMF all the other samples showed a reduction in weight after abrasion. From the statistical analysis it is noted that there is a significance of one per cent difference in between the groups, herbs separately, but not significant between both herbs and treatments.
- The sample YAPF has the minimum increase of 21 and ALPF has the maximum increase in fabric stiffness as 145 per cent in the warp direction. The maximum increase in fabric stiffness was observed to be 90 per cent in ALPF sample and

minimum in YAMF sample by 11 per cent. The fabric stiffness of the herbal finished samples ALMF, NEPF, MAMF, KUMF and YAPF in weft direction has decreased. From the statistical analysis of 'F' value, it is noted that there is one per cent significance in between the groups, herbs separately and between both. The 'F' ratio of 120.1768 represents the maximum stiffness in between treatments, because of the characteristics and nature of the herbal extracts deposited on the fabric surface.

- The maximum drape coefficient is seen in sample ALPF as 25.92 per cent, whereas the maximum decrease is seen in sample KUPF as 19 per cent. The KUMF, MAPF, ALMF, NEMF, MAMF has better drapability than other samples after antimicrobial herbal finishing treatment, but it has decreased for the samples YAPF, NEPF, KUPF.
- The air permeability of antimicrobial herbal finished aloe vera and kuppaimeni samples show an increase whereas marigold and yashtimadhu show a decrease, irrespective of the method of application. The maximum and minimum increase is observed in samples ALMF and YAMF as 26 and one per cent respectively.
- The absorbency rate has increased in sample YAPF by 38 per cent and reduced in sample ALMF by 38 per cent. From the statistical analysis, it is reported that there is a one per cent significance, when compared between the groups, treatments, herbs separately and between both.
- The wicking behavior of the herbal finished sample showed the maximum and minimum increase in the samples ALPF and NEPF as 116 and 9 per cent respectively.
- The antibacterial activity and durability of pad dry finished sample was limited to 15 washes but in micro encapsulated samples was extended to 25 washes. Thus, the wash durability test has proved the herbal finished samples to be suitable for the development of wash and use products.

### **Functional Properties Findings**

- In vitro study, aloe vera dry condition finished sample shows 25.95 UPF value against the unfinished sample value of 11.481 per cent. In the case of wet condition the aloe vera finished sample shows 23.974 per cent UPF factor, when compared to unfinished sample of 8.039 per cent UPF factor. In both dry and wet condition the aloe vera finished sample showed the 94 per cent UVA blocking and 96 per cent UVB blocking of sun rays respectively.

- In vivo study, proved good UV protection for thirty persons depending upon this skin tones.
- From the statistical analysis, 'T' value proved good UV protection for aloe vera finished samples. Hence, it could be concluded that aloe vera finished samples can be a successful UV protection product.
- In the thermal resistance test, the unfinished sample showed higher value of 0.0076  $R_{ct}$  when compared to aloe vera finished sample. The aloe vera micro encapsulation finished fabrics has 0.0068  $R_{ct}$  and pad dry finished shows 0.0072  $R_{ct}$  revealing that the fabric has got higher coolant properties which enhances the comfort of the wearer.
- The thermal conductivity of the yasthimadhu herbal finished sample was better than unfinished sample. The pad dry and micro encapsulation finished sample showed the value of 0.0376 and 0.066 respectively.
- The unfinished fabric sample have a higher value of 0.0153  $R_{ct}$  when compared with finished sample of 0.0080  $R_{ct}$ , indicating good coolant properties. From the statistical analysis the general and paired values are significant at one per cent level showing good thermal resistance for yashtimadhu finished sample.

## CONCLUSION

The present study on Herbal antimicrobial finishes has given clear picture on the effectiveness of antimicrobial activity against the pathogenic microorganisms of bacteria and fungi namely *Staphylococcus aureus* bacteria, *Escherichia coli* bacteria and *Candida albicans* and *Aspergillus niger* compared with antibiotics. The pad dry and micro encapsulation herbal finished fabrics were proved to be effective against micro organisms without any side effects. The selected herbal finishes has improved the physical, mechanical, comfort, absorbency properties like fabric weight, thickness, strength and elongation(warp and weft direction), stiffness(warp), drape, airpermiability, absorbency and wicking. Though there was slight decrease in the fabric count, abrasion resistance, stiffness (weft) when compared with unfinished fabrics. The special functional finishes like ultraviolet protection and thermal analysis have improved the functional properties of aloe vera and yeshitimadhu herbal finished samples. As per the human ethical committee suggestion, the herbal finished health care products were developed from aloe vera and yashtimadhu which was reported to be effective and comfortable. The aloe vera hand gloves showed very good

ultraviolet protection and yashtimadhu eye pillow produced thermal cooling effect to the human eye.

Thus modern technologies have opened new doors to use the herbs in a more effective manner. The products developed could be an eye-opener for manufacturing ayurvedic fabrics. It can also boost Indian export market by showcasing the new avenues in medical textiles. The research reveals the interlacing of ayurvedic medicine with textiles as a useful and eco-friendly product echoing the “Go Back . . . Go Green” trend.

### **RECOMMENDATIONS**

- Effect of antimicrobial finishes with other medicinal herbs on natural fabrics can be attempted.
- Preparation of suitable products based upon the properties of the herbal finished fabrics is worth attempting.
- The modification of herbal extracts into nano particles and their application could be explored.
- Development of various medicated herbal finished fabrics for skin infection can be studied.