5

SUMMARY AND CONCLUSION

Increasing global competition in textiles has generated many challenges for textile researchers across the globe. The rapid growth in technical textiles and their end-uses has created many opportunities for the development of new innovative products in the field of medical textiles. The medical textile industries have always played an important role in the protective aspects of fabrics. The fabrics have long been recognized as a good support medium for the growth of microbes. A microbe on textile causes the unwanted effects to both the wearers and textile itself. The negative factor of the microbes has resulted in the development of innovative and hygienic finishes on textiles.

Anti-microbial textiles with improved functionality find a variety of applications such as infection control and barrier control (Rajendran et al,2016), health and hygiene commodity, especially the clothes worn close to skin and several medical applications, such as infection control and wound healing materials. Many opportunities are available to add value and improve products by incorporating novelty finishes to protect the textiles against microbial infestation. Demand for the hygienic clothing is on the rise and the green minded customers are opting for eco-friendly textile materials treated with medicinal herbs. These herbal textiles are not only permanently effective but also skin compatible and eco-friendly (Sathianarayanan et al,2010).

Designing appropriate structures for the healthcare and medical industries is the need of the hour. The wound dressing is one of the health care medical textile products which require at most attention. The antimicrobial finished wound dressing band aids reduce the growth and transmission of microorganisms. The use of standard herbal formulations for wound dressing product will determine its acceptability and commercial success. Standardized laboratory tests can provide a clear idea about the functionality of the wound dressing product.

Considering all the above factors, the present study on **"Developing Herbal Antimicrobial Finished Cotton Fabric for Wound Dressing"** was carried out to develop an antimicrobial finished cotton wound dressing band aid using polyherbal extract. Herbal components were extracted from natural plant sources and were applied onto cotton fabric samples in various ratios by different finishing methods and analyzed for effectiveness with the following objectives;

- To study the availability of wound dressing in marketand their demand
- To select the yarn for weaving fabric for wound dressing
- To select medicinal herbs
- To optimize herbal extract concentration and determination of polyherbal formation
- To treat the woven fabric with polyherbal extract and test the fabric performance.
- To develop a product and evaluation.

Experimental Procedure

The experimental procedure adopted for the study consisted of four phases as presented below;

- **The first phase consisted of literature survey, collection of information for the properties of wound dressing band aids, selection of herbs, preparation and processing of herbs, selection and testing the physical properties of yarn, weaving and assessing the physical properties of woven fabrics.**

Literature survey was carried out to select the herbal plants possessing antimicrobial effect. Plant authentication test was conducted at Tamil Nadu Agricultural University, Coimbatore. The selected herbs were then dried, garbled and ground into dry powder. Information on commercially available wound dressing band aids was studied to understand the size, price, type and properties. Based on this information an interview schedule was prepared and conducted survey among the surgeons, senior doctors and physicians, a total of fifty

members responded and the required data was collected at PSG Institute of Medical Science and Research, Coimbatore.

Based on the information on commercially available wound dressing band aids properties and opinion of the experts, 30s Ne count yarn for the warp and 10s Ne used for the weft were used. The selected yarns were then tested for the following factors as per ASTM standard methods prior to weaving;

- Count Cv% (ASTM D 1907-01)
- Evenness of yarn U% (ASTM D 1425-96)
- Yarn tenacity cN/tex (ASTM D 2256-97)
- Hariness mm (ASTM D 5647-01)
- Moisture Content % (ASTM D 2495-01)
- Yarn thickness mm (ASTM D 1425-96)
- Twist per inch TPI (ASTM D 1422/D 1422M)

The physical property of the yarn of 30sNe and 10sNe were identified based on the ASTM standard procedure. The yarns count CV% were calculated as 3.3% and 2.8%. The evenness of the yarns were identified as 12.2 U% and 12.1 U%. Similarly, the yarns tenacity and yarn hariness were identified as 18 cN/tex,12 cN/tex and 2.3mm,3mm respectively. Moisture content % of the yarns were identified as 8.5% and 7.7% respectively. The yarn thickness were identified as 0.25mm and 0.71mm. Similarly, the twist of the single yarn (TPI) 32.6(TPI), 22.7(TPI) and balance of the twist(TPI) were calculated as and 22.7(TPI) and 8.2(TPI) respectively.

Weaving of fabric with 30's and 10's count single yarns was performed at Kumaraguru College of Technology, TIFAC Core, Coimbatore. Drum winding method was followed for warp winding. 500 grams of yarn was used to weave two meter length and 18" wide fabric. Totally 8 meter fabric was woven for the study. Semi automatic Shuttle loom (Sakamoto) was used and the loom speed was set as 180rpm and the efficiency was determined as 80%. 1^x 1 plain weave structure was opted for the study. The ends per inch and picks per inch of the yarn were

noted to be 58 and 30 respectively. The cover factor was calculated as 3.86 mm and 6 mm respectively. Tappet shedding was used to weave plain woven fabric as the existing band aids were made of this structure. The woven fabrics were then desized, scoured and bleached.

- **The second phase included the extraction process of herbs with three different solvents namely Hexane, Ethyl acetate and Methanol. Qualitative Phytochemical Analysis of Herbal Extracts was also done to select best suited solvent extraction for final study.**

The herbs *Abutilon indicum, Tridax procumbenz, Cassia fistula and Cassia auriculata* for the study was selected based on their potentiality of antimicrobial nature as studied through the literature survey. The herbs were collected in and around the districts of Coimbatore and Madurai and Theni. Herbal Extraction was done in Soxhlet apparatus and the resultant extract was subjected to Qualitative Phytochemical Analysis to test the presence of Carbohydrates, Tannins, Saponins, Flavonoids, Alkaloids, Quinones, Glycosides, Glycosides, Terpenoids, Phenols, Coumarins, Steroids and Phytosteroids, Phlobatannins and Anthraquinones. Considering the results of phytochemical screening with three different solvents, Methanolic extract was opted for the final study.

- **The third phase comprised of the selection of microbial cultures, determination of Minimum Inhibitory Concentration (MIC) against selected microorganisms, polyherbal formulation and assessing antimicrobial activity, wound scratch assay in fibroblast cell line method analysis.**

Microbes such as *Candida albicans, Pseudomonas aeruginosa, Staphylococcus saprophyticus, Escherichia coli* and *Aeromonas hydrophila* were selected to conduct antimicrobial assay. The antimicrobial analysis was done using Agar Well Diffusion method. An Agar plate was prepared and the selected microorganisms were swabbed on the agar plate individually and the herbal extracts were loaded and incubated at 37^{o}c for 24 hours.

The MIC of the herbal extracts against the selected microbes were analysed by the two fold serial dilution method to identify the activity breaking point of the microbes. Each of the selected herbal extracts was dissolved in the 5% dimethyl sulfoxide to obtain 2000 µg/ml stock solutions and the samples were diluted to the concentration of 1000, 500, 250, 125, 62.5, 31.25 µg/ml. Further about 100µl of 10^5 CFU/ml of the microbes were inoculated in test tubes with nutrient bath and herbal extract samples and incubated at 37ºc for 24 hours. The MIC value had been recorded.

As per the results of MIC, microbes such as *Abutilon indicum, Cassia fistula, Cassia auriculata* showed Minimum Inhibitory Concentration at 250µl whereas, *Tridax procumbenz* showed Minimum Inhibitory Concentration at 500µl. This result formed the basis for the combination of polyherbs. The herbal extraction concentration for antimicrobial testing was confirmed based on the Minimum Inhibitory Concentration of the herbal extract.

Poly herbal extraction was prepared at the ratio of 1:1:1:2 using the sources such as *Abutilon indicum, Cassia fistula, Cassia auriculata* and *Tridax procumbenz* respectively. The contents of selected sources were mixed using magnetic stirrer and put in a double cone blender to get the blend thoroughly. Polyherbal extracts of 50 µl, 100µl, 150µl and 200µl were subjected to antimicrobial analysis in which 200µl showed good zone of inhibition. The extract was analysed by *In vitro* wound scratch assay in fibroblast cell line analysis method. The cells were grown in 24 well plates and the extract were applied to the grown cells and monitored for 1, 4, 12, 24 and at 72 hours.

- **The fourth phase involved the preparation of Micro and Nano-encapsules and fabric finishing with the selected polyherbal extract by Dip and Dry and Exhaust method. The finished fabrics were tested for its physical properties and were finally subjected to product development and evaluation.**

The herbal extracts of *Abutilon indicum, Cassia fistula, Cassia auriculata* and *Tridax procumbenz* were converted into Nanocapsules and Microcapsules. Later the extract was finished on the fabric with Dip and Drying method, and the Nanoencapsule and Microencapsule particles were applied on the fabric by exhaust method. Finally the treated fabrics were subjected to antimicrobial testing by well diffusion method.

Furthermore, SEM and FTIR testing were carried out on the polyherbal finished fabrics. The treated and untreated fabrics were subjected to physical testing such as Fabric weight, Tensile Strength(ASTM -D -5034: 1995), Sinking(AATCC 17-1994),Air Permeability (IS 11056: 1984),Water absorbency (AATCC 79:2007),Vertical Wicking (BS3424) and Water Holding Capacity(DIN 53923). Self adhesive Bandaid was developed. To assess the efficacy of developed band aid, Microbial Filteration Test and Bandaid Toxicity Test were performed.

Findings of the Study

- From the market survey, it was found that the respondents expressed that the herbal antimicrobial band aid for minor cut, burns and scratches should be made with plain woven cotton fabric of yarn count 30’s in the warp yarn and 10’s in the weft yarn.

- Hydro colloide, Hydrogel, Alginate dressing, Collagen, Foam and Cloth dressings are best for pressure ulcers, painful or nercotic wounds, high amount of drainage and venous ulcers, transplant sites, burns are injuries with large surface areas, absorbes exuades from wound surface and cover up wound respectively. Each wound dressing material was different and was used for different kind of wounds. Breathable, comfortable and antimicrobial properties are most desirable factors for wound dressing as expressed by 92% of respondents respectively. This is followed by easy wearable, effectively speading up healing prevent infection and suitable for

sensitive skin type as mentioned by 88, 84 and 80% of the respondents respectively. Considering the standard size of band aids (3/4 inch width and three inch length) three inch length and two inch width had been adopted for the study.

- Considering the percentage yield of herbal concentrate upon different solvents, Methanolic extract with respect to all the selected herbs had better yield when compared to the other solvents. With regard to minimum inhibitory concentration under serial dilution method methanolic extraction of *Tridax procumbenz* showed the breaking point at 500µg/ml whereas *Cassia fistula, Cassia auriculata* and *Abutilon indicum* show the breaking point at 250 µg/ml. Among the herbal extracts, *Cassia auriculata* (250µg/ml) indicate better zone of inhibition when compared to other herbs.
- In the case of polyherbal formulation 50 µl, 100 µl, 150 µl and 200 µl of extracts were prepared at the ratio of 1:2:1:1 *Abutilon indicum, Tridax procumbenz, Cassia fistula* and *Cassia auriculata* concentration of 80 %, in which 200 µl of poly herbal extract showed better zone of inhibition which was followed by150 µl, 100 µl and 50 µl. The Antimicrobial assessment for polyherbal finished fabric such as Dip and Dry, Microencapsulation and Nanoencapsulation against microbial pathogens were evaluated by AATCC 147 Agar well Diffusion method, and the sample NEF showed the maximum zone of inhibition as 34,33,32,35 and 29 mm against the microbes followed by MEF and DDF.
- The *In vitro* wound scratch assay in fibro blast cell line analysis method proved the development of tissue growth over the scratch ensures the healing property of the herbal extracts.
- Considering the surface morphology of the herbal finished fabric examined through Scanning Electron Microscopy analysis, the range of particle size of herbal extract is observed between 3.328µm of RSD 09 28, similarly the particle size of nanocapsules had been identified as 171.43nm to 345.25nm.

- With reference to the FTIR results the band width spectrum showed the presence of alkaloids, alkyl halides, carbohydrates groups, alkalides, acidhalides, phenolic compounds, carbohydrates, alcohols, alknes, carboxylic, ester acid, ether in various ranges proving the presence of phytochemicals which lay a base for healing property in the polyherbal extract finished fabrics.
- With reference to fabric properties, the result pertaining to weight of MEF fabric showed minimum increase as 175.02 GSM when compared to the C, DDF and NEF samples as recorded to be 174.18, 174.18 and 174.19 GSM respectively. From the analysis of Tensile Strength results obtained in the warp direction, the MEF fabric with 45.52 Kgf showed maximum tensile strength followed by DDF and NEF with 40.86 and 40.20 Kgf respectively. As far as the strength in weft direction of the fabrics, maximum strength was noted in original fabric with 58.27 Kgf, followed by MEF, NEF and DDF fabrics with 39.47 and 35.96 and 35.33 Kgf respectively. The elongation of the samples along the warp direction increased in NEF sample but decreased in the DDF and MEF samples when compared to the original as noted to be 6.53, 9.73 and 7.57 per cent respectively.
- When considering the sinking time in seconds, the herbal finished fabrics had shown reduction in sinking time than the control. The herbal extract finish has enhanced the wettability of the finished fabric. Sample DDF took two seconds whereas MEF and NEF samples have taken only 1 second to sink. The water holding capacity of the finished fabrics had increased for the herbal finished fabrics. DDF finished fabric had the water holding capacity of 70%. This was followed by MEF and NEF finished fabrics with a holding capacity of 66% and 53% respectively. From the analysis of absorbency tests it could be identified that that the control and the MEF fabric took three seconds to absorb a droplet of water. Whereas, DDF and NEF samples had taken two and one seconds respectively. The wickabilty of DDF sample was noted as 0.39 minutes along the warp and weft direction. It has increased gradually to 0.410, 0.430 and 0.440 minutes in C, NEF and MEF samples respectively.

- The air permeability of sample C and MEF is 79.3 and 79.1 c.c/cm.sq./sec respectively and hence it could be concluded that the fabrics have good air permeability.

- With regard to Bacterial Filteration test, the samples tested with *Escherichia coli* ATCC 25922, *Staphylococcus saprophyticus* ATCC 6538, *Aeromonas hydrophila* ATCC 100-2004 and *Pseudomonas aeroginosa* ATCC 100-2004 showed better filteration when compared to the control untreated sample. The Dip and Dry finished fabric show 80% to 85% of bacterial reduction whereas Micro encapsulation finished and Nano encapsulation finished samples showed more or less same bacterial reduction properties as 90% to 95% and 93% to 96%.

- With respect to Fungal Filteration test, the samples tested with *Candida albicans* for showed better filteration when compared to the control untreated sample. The Dip and Dry finished fabric showed 85% of fungal reduction whereas Micro encapsulation finished and Nano encapsulation finished samples showed more or less similar fungal reduction properties as 90% and 96%.

- During the toxicity test analysis, the antibacterial agents finished onto the sample swatches (extracts from dip-dry swatch, micro encapsulation and nano encapsulation finished swatches) did not exhibit any toxicity for the mouse fibroblast cell lines (L_{929}). All the four samples showed more than 80% of viable cells; and the percentage of cell inhibition was recorded less than 15% for the same type of samples. Thus the samples were proved to be highly biocompatible and non toxic to the users.

Conclusion

Indian history of medicinal plants has proved the use of herbs for the cure of small cuts to heavy burns. From the long list of herbs *Abutilon indicum, Tridax procumbenz, Cassia fistula* and *Cassia auriculata* are some of the common herbs that are found in abundant. These herbs are proved to have antimicrobial activity

and produce an efficacious active antimicrobial compound which is eco-friendly. Micro and nano encapsulation of these herbs confirmed the better wound healing property with higher microbial reduction. Poly herbal finished adhesive band aids did not possess any toxicity; therefore these products could be developed and effectively used.

Recommendation

- Similar studies with potential medicinal herbs could be tried to make health care products.

- Cell line assay for combination of medicinal herbs is worth attempting.

Limitations

Due to time limitation the prepared self adhesive band aid was not subjected to animal/human study.