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Analysis of eco-friendly medicinal herb extracts and essential oil applications on textile products for healthcare applications

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Products such as head band, band-aid, sleep pillow, eye pillow, t-shirt and *pyjama* trouser, facial tissue and herbal tea dip were developed using woven, knitted and non-woven fabrics by treating them with medicinal herb extracts and essential oils for healthcare applications. The presence of bioactive principle compounds present in the herbal extracts and essential oils was confirmed by standard laboratory method through high performance liquid chromatography (HPLC). The woven and knitted fabrics were pre-treated naturally without using any chemicals. The pre-treated textile materials were finished with herbal extracts and essential oils by using pad-dry-cure method and micro-spraying method. The herbal extract composition has been optimized through experimental trials for all the cases. The developed eco-friendly healthcare textiles have been tested as per the AATCC test methods for their anti- microbial activity. The results show that the products are equipped with good anti-microbial activity. To confirm the healthcare potential of the developed eco-friendly healthcare textile products, a clinical trial was conducted in a nature cure centre and the subjective evaluation of the healthcare performance of the products showed good results in all the cases.

Keywords: Eco-friendly, Medicinal herbs, Naturally, Pre-treated, Anti-microbial, Healthcare textile products, Clinical trials
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Research on environment-friendly antimicrobial agents based on natural products for textile application gaining worldwide interest[1]. As consumers become more aware of hygienic and potentially harmful effects of microorganisms, the demand for antimicrobial finished clothing is increasing. Many plant extracts possessing antibacterial properties can be used as textile finishing agents in the crude form or as microcapsules to enhance the durability and controlled release of the extracts[2]. With the increasing demand for fresh and hygienic textiles, the consumption of antimicrobials is increasing day by day. Research and development activity is trying to keep pace by developing more and more effective and safe solutions[3].

Though natural colouration is known for ancient time as artisanal practice for handicrafts, paintings and handloom textiles, the chemistry of interaction of such colourants with textile materials is of relatively recent interest for producing eco-friendly textiles[4]. Prickly chaff leaves extract has been found to possess antimicrobial character due to the presence of a chemical substance called 'betaine' as identified by HPLC[5].

Presently, there is a good deal of demand for the fabrics having functional finishes in general or antifungal finishes in particular. The availability of entirely new class of antifungal agents is opening new opportunities for the treatment of fungal infections. In this regard mahonia or taming proved quite fruitful as its methanolic extract gave antifungal activity of 83.33% and good antifungal activity in terms of preventing fungal growth of *Trichoderma* a known pathogen, in dyed fabric. Earlier mahonia dye has also given quite beautiful yellow color and hue on cotton fabric. So, antifungal activity on fabric is really a value addition of cloth as well as the cloth material dyed with natural dye which will be aesthetically good. This study is like trapping new potential antimicrobial substance from our natural resource and the new development such as textile with antifungal finish would help to reduce the infection effects and possibly could comply with the statutory requirements imposed by regulating agencies[6].

With advent of new technologies, the growing needs of the consumer in the wake of health and

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hygiene can be fulfilled without compromising the issues related to safety, human health and environment. Taping new antimicrobial substances, such as, chitosan from nature can considerably minimize the undesirable activities of the antimicrobial products[7]. The recent interest in biofunctional textiles is mainly directed to the use of specific textiles in medical therapy and prevention of deficiencies in wearing comfort. A continuous demand for bioactive antimicrobial finishing has occurred recently, due to the increased health interest of the consumers. Antimicrobial activity of materials treated with antimicrobial products is tested against different strains of bacteria. Furthermore, high performance properties of the treated textiles are measured, including tensile strength and elongation, roughness, air and liquid permeability, color modification. The releasing time and rate of the drug embedded into the textile materials as antimicrobial agent can be controlled. This phenomenon takes place within a long period of time, thus the textile materials would have a minimal toxicity, compared with standard methods of exposure to drugs action. Application of new antimicrobial agents makes textile materials useful for prolonged therapeutic treatment without the genesis of germs. Microbial growth control in textiles is of great significance from the point of view of hygiene[8].

Functional textiles have opened a new vista of applications in diverse field of human life. Many of these applications are highly crucial and thus, these materials with high end performance properties are going to play paramount role in the life of modern man. Surely in the fast developing economies, the growth of such textile materials will take place at galloping rate. Not only will it act as the driving force for R&D activities, tapping hitherto untapped field of functional textiles and apparels[9].

Textile materials can be exposed to contamination with microbes (bacteria, fungi, algae) during production, usage or storage. The microbial attack of textiles leads to quality losses due to changes of colour and appearance or to reduction in strength and can result in unpleasant odour formation. Moreover, since microbes absorb to textiles there is a risk of contamination and infection[10].

In recent years, the growing demand for herbal products has led to the idea of developing "Eco-friendly healthcare textile products". The main aim of this research work is to impart medicinal value to products like head band, band aid, sleep pillow, eye pillow, T-shirt and pyjama trouser, facial tissue and herbal tea dip for healthcare purpose.

Materials and methods

Materials

The materials used for the development of eco-friendly textile healthcare products are given below and sourced within Tamil Nadu state.

Textiles

The textile materials particulars used for the development of healthcare products are as follows.

- 100% Cotton plain woven fabric with 40s Ne combed yarn in warp and weft direction having a thread density of 144 ends per inch and 72 picks per inch and a fabric weight of 144 grams per square metre.
- 100% Cotton single jersey knitted fabric with 40s Ne combed hosiery yarn having 44 wales per inch and 33 courses per inch with a fabric weight of 130 grams per square metre
- *Silk cotton* (*Bombax ceiba* L.) fibre
- Spun-bonded non-woven facial tissue made from biopolymer (Polyhydroxybutyrate)

Medicinal herbs

The medicinal herbs used for the development of healthcare products are given in Table 1.

Methods

Pre-treatment of textile materials

100% cotton woven and knitted fabrics were given pre-treatment processes to make the fabrics suitable for developing eco-friendly textile healthcare products without using any chemicals.

- Natural desizing (Woven fabrics only)
- Natural scouring (Woven and knitted fabrics)
- Natural bleaching (Woven and knitted fabrics)

Natural desizing

The material is first wetted in cold water solution containing *Sapindus emerginata* L. (*Soapnut*) seed

Table 1—Medicinal herbs used

Medicinal herbs used	Parts used
Rosemary (*Rosmarinus officinalis* L.)	Leaves and flowers
Lemongrass [*Cymbopogon citrates* (DC.) Stapf]	Leaves
Lavender (*Lavandula latifolia* Medik.)	Leaves and flowers
Sage (*Salvia officinalis* L.)	Leaves and flowers
Thyme (*Thymus vulgaris* L.)	Leaves and flowers
Aloe [*Aloe vera* (L.) Burm.f.]	Leaves
Stevia [*Stevia rebudiana* (Bertoni) Bertoni]	Leaves
Thulasi (*Ocimum sanctum* L.)	Leaves

extract 10%, a natural desizing agent and left in this bath for 24 hrs to remove the starch size present in the woven fabric.

Natural scouring

The scouring process was carried out in the solution containing 15% plantain leaf ash at the boiling temperature for 1 hr and washed several times till the material is brought to neutral *p*H.

Natural bleaching

The scoured cotton fabrics are exposed to direct sunlight with use of a natural grass base with animal manure which carries out photolytic oxidative bleaching process. No chemicals are used in this process.

Preparation of herbal formulation

Rosemary, lemongrass, thulasi and stevia leaf powder preparation

The fresh leaves of *rosemary* (*Rosmarinus officinalis* L.), *lemongrass* [*Cymbopogan citratus* (DC.) Stapf)], *stevia* [*Stevia rebaudiana* (Bertoni) Bertoni)] and *thulasi* (*Ocimum sanctum* L.) were shade dried first and subsequently sundried to bring the leaf moisture content to 10-15%. The dried leaf samples were then powdered to coarse size by using wiley mill at micro analytical laboratory.

Lavender flower powder preparation

The fresh flowers of *lavender* (*Lavandula latifolia* Medik.) were shade dried first and then, sun dried to bring the moisture content to 10-15%. The dried flowers were crushed manually into small pieces. The flower stalks and debris were removed leaving the flower part alone.

Essential oil extraction

The essential oils from flowers of rosemary (*Rosmarinus officinalis* L.), stem, leaf and flowers of sage (*Salvia officinalis* L.) and leaves & flowers of thyme (*Thymus vulgaris* L.)were extracted using steam distillation method. The essential oils from the stem and leaves of lemongrass [*Cymbopogon citrates* (DC.) Stapf)] and flowers of lavender (*Lavandula latifolia* Medik.) were extracted using clevenger apparatus and solvent extraction methods respectively.

***Aloe vera* gel preparation**

Aloe vera (L.) Burm.f. (*Aloe*) gel was the mucilaginous gel produced from the centre (the parenchyma) of the plant leaf. The gel portion of the plant was prepared by peeling the outer portion of the skin and the pericarp away. It is the preparation which is called 'pure *Aloe vera* gel'.

Confirmation of bio-active components in the herbal extracts and essential oils

The bio-active components present in the herbal extracts and essential oils are responsible for the curative property of a particular disease. The confirmation of the presence of bioactive components in the herbal extracts and essential oil was carried out using high performance liquid chromatography (HPLC).

Development of eco-friendly healthcare textile products

By using the herbal extracts and essential oil applied healthcare fabrics, seven eco-friendly healthcare textile products were designed and developed. The methodology adopted in the development process for all the products are given below:

Herbal tea dip

A tea bag (size: 5cm x 5cm) was prepared using natural pre-treated woven cotton material. The three sides of the bag except top were stitched. Equal proportion of leaf powder of rosemary, lemon grass, stevia and thulasi were filled in the bag up to one fourth capacities and running stitch was used to partially close the top of the bag. The top edge of the bag was tagged with a cotton yarn and the other end of the cotton yarn was stapled with a small paper for easy handling.

Sleep pillow

The dried kapas were broken manually to collect the silk cotton. The seeds from the silk cotton were removed and used for preparation of pillow. The pre-treated cotton woven fabric was cut into pieces (size: 30 cm x 20 cm) and the three sides were stitched. Silk cotton and lavender flower powder were mixed in the ratio of 3:1 (150 gm: 50 gm) and stuffed in to the stitched pillow and the open end was stitched.

Head band

The cotton knitted fabric with a size of 25cm x 5cm was taken for the preparation of head band. The natural adhesive prepared from the gum of *Acacia nilotica* (L.) Willd. ex Delile (*Karuvel*) was smeared on one side and kept inside another woven fabric of size 22cm x 3cm. It was smeared with 1.5 ml of 0.5% rosemary oil evenly. After the application, it was

pasted on the knitted material, covered with butter paper to avoid the evaporation of rosemary oil. The edges of the knitted band were stitched with elastic for easy use.

Facial tissue

A non-woven biopolymer material (size: 22cm x 15cm) was taken and micro sprayed with rosemary oil droplet size of 100-200 microns. Likewise, lemongrass oil was also applied on another non woven biopolymer material and the facial tissue was prepared. The process parameters are as follows:

Method	:	Microspraying
Material	:	100% non woven biopolymer (Polyhydroxybutyrate)
Herbs used	:	Lavender and lemongrass oil (100 ppm each)
Temperature	:	Room temperature
Time	:	12 hrs at room temperature

Band aid

Water proof flexible fabric was used for preparing band aid. Band aid of various shapes viz., square, circle and rectangular was prepared and pasted on the flexible fabric using natural adhesive prepared from 100 gram of gum of *Acacia nilotica* (L.) Willd. ex Delile (*Karuvel*) mixed with equal volume of water, heated at boiling temperature and allowed to cool at the room temperature. Before pasting, it was dipped in *sage* (*Salvia officinalis* L.) oil and covered with butter paper. Similar procedure was adopted for the preparation of band aid with *thyme* (*Thymus vulgaris* L.) oil.

T-Shirt and Pyjama trouser

The pre-treated cotton knitted fabric was used for the development of t-shirt and *pyjama* trouser. The pre-treated material was treated with *Aloe vera* gel extract using pad-dry-cure method. The process conditions are as follows:

Method	:	Pad – Dry-cure
Material	:	100% cotton fabric
Herbal used	:	*Aloe vera* gel extract
Wet pick-up	:	80% owm
M: L ratio	:	1:10
Temperatur	:	Room temperature
*p*H	:	6.8-7.0
Drying with curing	:	12 Hours at room temperature

Eye pillow

The pre-treated cotton knitted fabric was cut into 8cm diameter pieces (4 Nos). The eye pillow was stitched to about 3/4th of the circumference and pre-treated woven cotton fabric was micro sprayed with lavender oil (100 ppm) and stuffed into it. The remaining portion was also stitched. The two parts of the eye pillows were joined together by stitching. The edges were also stitched with an elastic band for easy wearing.

Testing of eco-friendly healthcare fabrics

The developed healthcare fabrics for t-shirt, *pyjama* trouser, band-aid material and facial tissue material have been tested as per "AATCC" (American Association of Textile Chemists and Colourists) standards. The antimicrobial activity was ascertained by quantitative method as recommended by AATCC, the combined AATCC 100 and Hohenstein modified test methods: Challenge test–JIS L 1902. The presumptive screenings of fabrics were carried out using agar diffusion method (AATCC 147) and further confirmed by calculating the percentage reduction of bacteria using Shake flask test.

Clinical trials

The performance of the developed healthcare textile products was evaluated by conducting clinical trials in a nature cure centre by giving it to patients of both genders with various health complaints. The duration of the clinical trials varied from 1-3 weeks according to the nature of the disease and the patients were instructed to use the wearable healthcare products in contact with their body for an average duration of 8-10 hrs. The patients were instructed to carry out the washing of the washable healthcare textile products (t-shirt and *pyjama* trouser) with natural non–ionic detergents like soap nut powder and dry them in shadow to retain the medicinal properties. They were also instructed to keep them in a cool and dry place prior to use. Detailed feed back from the patients and the doctor were collected regarding the performance and comfort aspects of the healthcare products. The subjective evaluation of the healthcare textile products' healthcare performance was carried out by the doctor, who has specialization in alternate medicines as well as bio-medical analysis, after complete check-up of the patient's past health records and the health records obtained after clinical trials and rated as poor (0); Fair (1); average (2); good (3); very good (4) and excellent (5) and expressed as a percentage. Apart from the healthcare performance of the products, comfort

aspects of the products, and general comments about the products were also recorded from every patient.

Results and discussion

Test results of presence of bio-active components in the herbal extracts and essential oils

The presence of bio-active compounds present in the herbal extracts and essential oils was confirmed by testing it in high performance liquid chromatography tester and the test results are given in Table 2. The test results confirmed the presence of bio-active components in the herbal extracts and essential oils.

Evaluation of antimicrobial activity in eco-friendly healthcare fabrics

Agar diffusion test

The agar diffusion test (AATCC 147) is a preliminary test to detect the diffusive molecules of the herbal treated fabrics which are having antimicrobial activity. In this test, a microbial culture is spread evenly on the top of an agar plate containing medium that will support its growth.

The antimicrobial activity determined by agar diffusion method is presented in Table 3. The assessment of antibacterial activity for eco-friendly healthcare fabrics by agar diffusion method showed that the t-Shirt and *pyjama* trouser made up of knitted fabrics had a high activity of 34, and 25 mm diameter of zone of inhibition against both the bacteria *S. aureus* (gram +) and *E. coli* (gram -). Band aid fabric showed 24 and 23 mm diameter of zone of inhibition against the bacteria *S. aureus* (gram +) and *E. coli* (gram -), followed by facial tissue with 19 and 16 mm diameter of zone of inhibition against the bacteria *S. aureus* (gram +) and *E. coli* (gram -), respectively. The reason for the higher antimicrobial activity in knitted fabrics when compared to other fabrics may be due to the low twist present in the yarn in the fabric which might have enabled the good penetration of herb extracts. The preliminary test results using agar diffusion test method showed that the developed healthcare products are equipped with good antimicrobial activity.

Challenge test

The antibacterial activity of the healthcare fabrics assessed by the challenge test (Combined AATCC 100 & Hohenstein modified test) is given in Table 3. The assessment of antibacterial activity for healthcare products by challenge test showed that T-Shirt and *Pyjama* trouser made up of knitted fabrics had a high bacterial reduction of 80%, and 65 % for *S. aureus* and *E. coli,* respectively. Similarly, facial tissue had a per cent reduction of 78 and 63 against S. *aureus* and *E. coli,* respectively. Band aid had a per cent reduction of 72 and 69 against S. *aureus* and *E. coli,* respectively. The challenge test results confirmed the good antimicrobial property of the developed healthcare products.

Evaluation of healthcare performance of eco-friendly health care textile products using clinical trials

The clinical trial was conducted in a nature cure hospital. The various eco-friendly healthcare textile products like herbal tea dip, head band, sleep pillow, facial tissue, band aid, t-shirt and *pyjama* trouser and eye pillow were tested for their healthcare performance against the selected diseases. The results of the clinical trials are given in Table 4. The clinical trial results for all the seven healthcare products show that the healthcare performance was noticed to be good in all the cases. The patients did not experience any discomfort while using the healthcare textile

Table 2—Presence of bio-active components in the herbal extracts and essential oils

S. No.	Herb	Essential oil/ extract (%)	Active components	Result
1	Rosemary	1-2.5	Camphor	Present
2	Lemon grass	1–1.25	Citral	Present
3	Lavender	1	Linalool	Present
4	Sage	1-1.5	Camphene and linalool	Present
5	Thyme	5% extract	Thymol	Present
6	Aloe	10% extract	Aloin and Aloe-emodin	Present
7	Thulasi	2 - 2.5	Epicatechin	Present

Table 3—Assessment of antibacterial activity in healthcare textiles

S.No	Healthcare textiles	Agar diffusion test		Challenge test	
		Zone of inhibition (Dia. in mm)		Per cent of bacterial reduction	
		S. aureus	*E. coli*	*S. aureus*	*E. coli*
1.	Knitted fabric material (T-shirt & *Pyjama* trouser)	34	25	80	65
2.	Band aid material	24	23	72	69
3.	Facial tissue material	19	16	78	63
4.	Untreated Control	0	0	0	0

Table 4—Clinical trial results on the performance of healthcare textile products

Duration of the Clinical trial (week)	Number of people used the healthcare products	Health problem	Healthcare products given	Average healthcare performance of products (%)
Wearable healthcare textile products				
2	3	Headache	Head band	66.7
1	4	Insect bite	Band aid	70.0
1	5	Darkness around eye	Eye pillow	56.0
3	6	Crinkling of skin	T -shirt & *Pyjama* trouser	70.0
Non-wearable healthcare textile products				
1	5	Digestive problem	Herbal tea dip	88.0
1	3	Sleeplessness	Sleep pillow	60.0

products. In the case of wearable healthcare textile products, the product has to be in direct contact with the wearer's skin for at least 10 hrs per day (especially during sleeping) for getting good results. The duration for getting significant healthcare performance results will vary between 1 to 3 weeks depending upon the nature of the disease. The confirmation of the presence of bio-active components present in the herbal extracts and essential oils by HPLC test, the anti microbial assessment of the treated fabrics and clinical trial results confirmed the healthcare performance of the developed products. Apart from the above reasons, the pharmaceutical and emotional effects of aroma emitted from the herbal extracts/essential oils may also influence the healthcare performance of the healthcare products[11].

Durability of the developed healthcare products

The products such as facial tissue and herbal tea dip were developed as one time use (disposable type) products. The head band, sleep pillow and eye pillow can be used till the presence of applied herbal extracts and essential oils fragrance (aroma) exists in the product. The t-shirt and *pyjama* trouser can be used till the natural colour of the applied herbal extracts exists in the product. As per the clinical trial results, complete fading of the natural colour present in the t-shirt and *pyjama* trouser occurred after 10 washes for an average use of 10 hrs per day by the patient. The band-aid has to be changed once in every day till the healing of insect-bite takes place. The healthcare performance durability of the healthcare textile products depends on the amount of time one uses the product. To enhance the durability of the products and retain the medicinal property, the products should be kept in a cool dry place prior to use.

Conclusion

The clinical trial results of the developed healthcare textile products show that the subjective evaluation of the healthcare performance was found to be good in all the cases. Further, these products have not shown any side effect to any of the patients during clinical trials. The confirmation of the presence of bio-active components present in the herbal extracts and essential oils by HPLC test, the antimicrobial assessment of the treated fabrics and clinical trial results confirmed the healthcare performance of the developed healthcare products. Apart from the above reasons, the pharmaceutical and emotional effects of aroma emitted from the herbal extracts/essential oils may also influence the healthcare performance of the developed products. This work can be extended for developing healthcare textile products for customized applications with low cost. This approach adopted in the research work can be taken as a support therapy for healthcare applications. However more trials and further investigations are required for this therapy to ensure its wide application.

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