

Microencapsulation of different Herbal extracts and finishing onto Bamboo fabrics – Evaluation of Antibacterial and Anti-Odour properties

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Abstract

As microcapsules were gaining lot of interest in the field of medical textiles, the present research was aimed to develop meditech textiles using bamboo fabrics finished with five different types of medicinal herbs in the process of microencapsulation method. Herbal microcapsules were prepared and finished onto bamboo fabric samples using Pad-dry cure process. Finished fabrics were subjected to antibacterial activity using standard EN ISO 20645 test method against *Escherichia coli* and *Staphylococcus aureus*. Also to prevent odour from physical activities, anti-odour activity was determined using Swiss standard SNV 195651 method. Test results of antibacterial activity of microcapsules finished fabrics revealed good inhibitory action against both test bacteria. Aromatic efficiency of herbal microcapsules finished fabrics also showed significant results after testing as per swiss SNV 195651 standards. Both finished and unfinished control fabric samples were statistically evaluated using F value. Statistical evaluation determined that there was no significant difference (p=1) between finished and control fabrics in terms of anti-odour efficiency. Physical properties such as air-permeability, tensile strength and absorbency between finished and unfinished fabrics did not showed any significant difference indicating that the nativity of the fabric was not altered even after finishing with herbal microcapsules. The present study would be considered highly significant by providing an eco-friendly and sustainable products for developing medical textile products and smart home textile products.

Keywords: Herbal microcapsules, Pad-dry cure, Antibacterial activity, Anti-odour activity, Air-permeability.

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Introduction

Natural dyes are the colorants derived from plants, invertebrates, or minerals and these dyes have emerged as biocompatible, environment-friendly, and non-toxic substitutes, and their facile applications could validate the concept of pollution-free dyeing of textile materials (Ibrahim et al., 2010). During the last few decades, the growing consciousness about eco-friendly textiles has compelled the textile industry to use natural dyes without employing toxic mordants in the dyeing process (Rehman et al., 2022).

Antimicrobial applications using natural dyes are also gaining more importance to establish and commercialize healthcare textiles in different fields like medical industries which included hospitals, healthcare sectors, diagnostic laboratories, adult home care centres, food and beverage units, education sectors, surgical centre, medical equipment manufacturing sectors etc. Since these zones are highly sensitive to microbial attack, the need for antimicrobial textiles are highly significant among the workers and people associated with these sectors. From commercial point of view, many synthetic antibacterial agents were used for finishing and constructing antimicrobial textiles. In earlier stages even though these fabrics proved to be highly efficient in retarding and protecting the workers from microorganisms, in later stages the microbes become more resistant to these synthetic antibacterial agents. Current studies reported the exponential rise in multi-

drug resistant bacteria on repeated use of these synthetic antibiotics (Spellberg et al., 2013). Ghane et al., (2022) reported that bacterial resistance to antimicrobials is a major global issue today. Shastry and Rekha, (2021) investigated that microbes produce biofilms to become resistant to antibiotics and disinfectants. Shin and Kim, (2022) highlighted that a novel approach is highly essential to combat with biofilm producing antibiotic resistant bacteria. And hence need for an alternative drug is essential.

Hence, developing a novel antibacterial agents that has a dual function of preventing the process of drug resistance and improving the properties of antimicrobial textiles against infectious disease are highly essential. From different literature survey, the emphasis of World Health Organization on the replacing antibiotics with natural ingredients was noticed (Son et al., 2022). The organization instructs the researchers to use rich reservoirs of useful compounds from nature to replace chemical and synthetic antibacterial agents (Bulut et al., 2021). The natural compounds shall be processed in the pharmaceutical industry for the production of natural antimicrobials with the very negligible side effects (Yonjalli et al., 2020).

Based on these concept, in our present study, different herbs were selected. Herbal extracts were developed on solvent based extraction process and made into microcapsules using standard methods for imparting durable antimicrobial finishes. Antimicrobial finish is an

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important property required in Meditech textiles (Sonu Rani and Alka Goel, 2023). Microencapsulation of antimicrobial agents is gaining popularity in medical textiles all over the world. In microencapsulation process, microcapsules containing an antimicrobial agent adhere to the textile using a binding agent. Under microencapsulation process, tiny particles or droplets are surrounded by a coating to give small capsules, which can impart functional properties (Hammad et al., 2011).

Based on the application significance of microcapsules, the present research was aimed to employ antibacterial and anti-odour finishes on to bamboo fabric materials by

imparting herbal microcapsules and also to investigate its efficacy using textile standard methods.

Materials and Methods

Procurement of Fabrics

100% Bamboo fabrics (180GSM) was procured from Textile processing Unit, Pallipalayam, Erode, Tamil Nadu. Fabric was washed using non-ionic detergent solution under room temperature to remove debris and other impurities. Washed fabrics were dried under shade in a closed chamber and cured for 10 min at 80C.

Bamboo Fabrica



Fabric Pretreatment

All desized fabric materials was cut in to 10cm X 10cm and processed further for pre-treatment steps. Five series of steps were carried out to pre-treat all the nine fabrics separately as follows, Soaking fabrics in water @ 70°C for 20min, Rinsing in running water @ 50°C, Relaxation and drying @ room temperature, Non-Ionic detergent (Machine washing) and Shade drying. Initially, the fabrics were soaked in normal fresh water at 70°C for 20min. The washed fabrics were rinsed well in the

running water to remove surface dirt and other impurities. All the fabrics were squeezed (relaxed) gently in hand and dried at room temperature. To improve excess starchy like components from fabric surface and interstices, non-ionic detergent (sodium lauryl sulphate – 1% (10g/L) was used. Washing was done in a normal washing machine kept at low speed for 10min. Washed fabrics were relaxed in hand and shade dried for 120min.

Fabric Pre-treatment using non-ionic detergent



Selection of Herbs

Arasampattai, Thandrikai, Parangipattai, Vadhanarayana and Parpadagam are selected based on their biomedical properties as per literature survey. All the selected herbal powders were collected from Tamil Nadu Agriculture University, Coimbatore, Tamil Nadu. The dried herbs were arranged separately in aluminum trays and oven dried at 40°C to 50°C for 24h until the moisture content reach below 10%. The dried parts were sieved using metal sieve and finally stored at room temperature prior soxhlet extraction.

Soxhlet extraction of herbs

Extraction of each herbs were carried out using a standard Soxhlet method. In the Soxhlet extraction method, finely ground sample - Arasampattai powder was placed in a porous bag or “thimble” made from a strong filter paper or cellulose, which is placed, in thimble chamber of the Soxhlet apparatus. Extraction solvent (Ethanol) was heated in the bottom flask separately, vaporized into the sample thimble, and condensed in the condenser and drip back. When the liquid content reached the siphon arm, the liquid contents was emptied into the bottom flask again and the process was continued. The powdered herbs were filled in the thimble and placed in the soxhlet extractor. The extractor had been filled with solvent solution of ethanol

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and the temperature of 60°C was set and left for 6 hours. Slowly and steadily the temperature was increased up to 100°C. The extract from the thimble was collected in the round bottom flask kept in the heating mantle below by passing through a side arm tube. Similar protocol was

carried out for all the selected herbal powder to get the ethanolic extracts separately. After completion of soxhlet experiments, all the ethanol extracts of herbal powders were stored in brown amber bottle at room temperature.



Soxhlet extractor and extraction process
A: Extract present in Thimble
B: Extract collected back in the flask

Antibacterial screening of herbal extracts

The antibacterial activity of the ethanolic extracts of all the selected herbs were determined against the test organisms using the standard well diffusion method. All the test cultures (*Escherichia coli* and *Staphylococcus aureus*) were inoculated in a sterile Nutrient broth* and allowed to attain the growth for 24 to 48 hours. Sterile Mueller-Hinton Agar* plates were prepared and allowed to solidify. About 0.1% inoculum suspensions of the test organism (*Escherichia coli* and *Staphylococcus aureus*) were swabbed uniformly over the agar surface separately. Under sterile conditions, 6mm wells were cut on the agar surface of each NA plates. About 20µl of each herbal extract fractions (prepared using DMSO) were loaded into the well and the plates were incubated at 37°C for 24h. The antibacterial activity was evaluated in terms of zone of inhibition around the wells in all the inoculated NA plates. The inhibition clear zones were measured and recorded in millimeter.

Preparation of different finishing agents - Microencapsulation of herbal extracts

Microencapsulation was done using the selected herbal extract as core material and gum acacia as wall material. 50 gram of wall material was allowed to swell for half an hour by mixing with 500ml of hot water. To this mixture, 50ml of hot water was added, stirred for 15min maintaining the temperature between 40°C and 50°C. Ten millimeter of core material was added and stirred at 300-500rpm for further 15min followed by drop wise addition of 20% sodium sulphate solution (10ml) for 5-10min. The stirrer speed was reduced and then 5ml of 17% formaldehyde was added. The stirrer was stopped and mixture was freeze dried to obtain fine microcapsules of herbal extract. About 300ml of microcapsule thus obtained was further subjected for finishing the fabrics. The finishing procedure is as follows.



Addition of gum acacia

Addition of sodium sulphate

Addition of formaldehyde

Finishing all the agents on to different fabric materials using Pad-Dry cure process

About 300ml of prepared microcapsules was stored at 4°C prior to finishing the fabrics. The capsules were brought to room temperature and finished onto Bamboo fabrics. The fabrics were finished with microcapsule solution by using a standard dip and dry method. The fabric was padded in a solution containing microcapsule

solution in the ratio 1:3 (1mt fabric: 300ml microcapsules) at 40°C using 8% citric acid (binder) concentration. For 1mt fabrics, about 300mL of microcapsules was used for finishing. The wet pickup was adjusted to 100%. The padded fabric was dried at 80°C, and then cured at 140°C to 160°C for 5min in the hot air oven. The fabrics were finally used for further experiments.

Finishing, Drying and Curing of Bamboo fabrics using microcapsules – Dip dry method



Evaluation of fabrics with different functional properties

Determining the Antibacterial activity of microcapsule finished fabrics (EN ISO 20645 test method)

The test specimens (microcapsule finished) were cut into pieces (20mm in diameter) and its antibacterial activity was tested using standard EN ISO 20645 test method. All the test cultures (*Escherichia coli* and *Staphylococcus aureus*) were inoculated in a sterile Nutrient broth (Composition g/L: Peptone: 5g; Yeast extract: 5g, Beef extract: 3g, Sodium chloride: 5g; Final pH - 7.0 ± 0.2) and allowed to attain the growth for 24 to 48 hours. Using sterile 4mm inoculating loop, one loop full of culture (*Escherichia coli* and *Staphylococcus aureus*) was transferred by swabbing all around the surface of the Mueller-Hinton agar plate (Composition g/L: Acid hydrolysate of Casein: 17.5g; Starch: 1.5g, Sodium chloride: 5.0g, Agar 17.0 g; Final pH - 7.0 ± 0.2) and also covering the central area of the petridish. For each test organism, separate Mueller-Hinton agar plates were used in a sterile zone. 20mm test fabric swatches from each herbal dyed samples were placed on to respective plates in which already the bacterial cultures

were swabbed. All the inoculated plates were incubated at 37°C for 24 hours. The test plates were examined for the clear zone of inhibition around the dyed fabrics. The zone of inhibition around each type of fabric specimen was measured in millimeter (mm).

Determining the Aroma/Anti-odour of microcapsule finished fabrics

In order to identify the efficiency of the charcoal finished fabrics on controlling the odour caused by test microorganisms (*Escherichia coli* and *Staphylococcus aureus*) artificial sweat studies was conducted. Artificial sweat was prepared as per the AATCC Test Method 15-2002 (Table-1) and pH was adjusted to 4.3. Odour causing bacteria *Escherichia coli* and *Staphylococcus aureus* were inoculated on the prepared artificial sweat separately and incubated for 24 hrs. About 2ml of the artificial sweat was sprayed on the test swatch. The samples were sealed in a petri dish to prevent oxidation. Then the odour intensity was determined by sensory evaluation. Five subject persons were used for the evaluation and the odour was determined using the grades given in Table-2.

Table-1: Preparation of artificial sweat

S. No.	Chemical composition	Concentration(% (w/v))
1	Sodium chloride	1.0

2	L-Histidine	0.097
3	Manosodium Phosphate (NaH ₂ PO ₄)	0.025
4	Disodium Hydrogen Phosphate (Na ₂ HPO ₄)	0.1

Table-2: Grades and their inference

S. No.	Grades	Inference
		Artificial Sweat Studies
1	1	No odour formation
2	2	Not unpleasant
3	3	Slightly unpleasant
4	4	Unpleasant
5	5	Very unpleasant

Physical properties

Air-permeability test (ASTM D 737-96 test method)

Air permeability of fabric is the volume of air measured in cubic cm passed per second through 1 sq. cm for the PCM finished fabric sample at a pressure of one cm. head of water. Air permeability can be measured using an instrument called Shirley Air Permeability Tester. Air permeability was determined in accordance with Test Method ASTM D-737-96. The conditioned specimens in the standard atmosphere for testing textiles, 21 ± 1°C and 65 ± 2 % relative humidity was tested unless otherwise specified in a material specification or contract order. The test specimens were carefully handled to avoid altering the natural state of the material. Placed each test specimen onto the test head of the test instrument, and performed the test as specified in the manufacturer's operating instructions. Read and recorded the individual test results in SI units as cm³/s/cm²

Tensile strength test (ASTM D 5035-2006 test method)

Tensile strength is the measure of the resistance of the fabric tensile load or stress in either warp or weft direction. It is the strength shown by a specimen subjected to tension as distinct from torsion, compression, or shear. Elongation defines the length to which a fibre may stretch before breaking. A sample of 12" X 2" was taken for the test. The tensile strength of the fabric was determined by cloth tensile strength tester. Tensile strength is performed using cut strip method. This test is used for treated or heavily sized fabrics. Three readings for every sample were taken and the average was calculated.

Absorbency or Wicking test (AATCC TM 197)

Water or Moisture absorbing abilities of the microcapsules finished fabric sample was studied using AATCC TM 197 standard test method. The method describes the vertical wicking properties of microcapsules finished fabric. The principle of the study describes that, Vertical Wicking of Textiles, is used to

measure "the ability of vertically aligned fabric specimens to transport liquid along and/or through them" Wicking rate is a particularly important property that measures a fabric's ability to remove sweat/liquid from contact with the skin. The wickability of microcapsules finished fabric was evaluated by time for wetting. During the analysis, the fibre samples were conditioned in a standard atmosphere of 22°C under 65% relative humidity for 24 hours. The pre-measured size (1.5cm x 5cm) of each test mounted on the glass slides was kept at immersed condition inside a reservoir containing distilled water. The wicking height of the advancing liquid front as a function of time was recorded by visual observation after 5 minutes. Using a standard ruler scale, the colour of water absorbed on the fibre surface was measured for each sample and the values were recorded.

Results and Discussion

Antibacterial screening of herbal extracts

Antibacterial activity of each medicinal herbs were carried out using standard well diffusion method. A known concentration of each herbal extract (100ug/ml) was tested its inhibitory activity against test bacteria *Escherichia coli* and *Staphylococcus aureus*. During the analysis, five different herbs were selected based on their ability to inhibit the growth of test bacteria at significant level. The inhibition of growth of bacteria was measured in millimeter and presented in Table-3. During the analysis it was observed Parpadagam extracts revealed maximum zones of 20.3 ± 1.05mm against *Escherichia coli* and 21.9 ± 0.57mm against *Staphylococcus aureus*. Followed by Vadhanarayana extracts exerted inhibitory zone size of about 19.9 ± 0.57mm and 20.6 ± 0.75mm against the respective test organisms. Parangipattai extracts provided 17.6 ± 0.75mm and 18.6 ± 0.75mm; Thandrikai and Arasampattai extracts exhibited zones of 15.3 ± 1.05mm, 15.9 ± 0.57mm; and 13.6 ± 0.75mm, 14.3 ± 1.05mm against *Escherichia coli* and *Staphylococcus aureus* respectively (Fig. 1).

Table - 3: Antibacterial screening of herbal extracts

S. No.	Herbal extracts	Zone of inhibition (mm)	
		<i>Escherichia coli</i>	<i>Staphylococcus aureus</i>
1	Arasampattai	13.6 ± 0.75	14.3 ± 1.05
2	Thandrikai	15.3 ± 1.05	15.9 ± 0.57
3	Parangipattai	17.6 ± 0.75	18.6 ± 0.75
4	Vadhanarayana	19.9 ± 0.57	20.6 ± 0.75
5	Parpadagam	20.3 ± 1.05	21.9 ± 0.57

Fig. 1: Antibacterial screening of herbal extracts



Escherichia coli

Staphylococcus aureus

Evaluation of fabrics with different functional properties

Antibacterial activity of herbal microcapsules finished fabrics

Antibacterial activity of all fabric samples finished with microcapsules of different herbal extracts were presented in Table - 4.

Table-4: Antibacterial activity of the herbal microcapsules finished fabrics

F. No	Fabrics	Zone of inhibition (mm)				Statistical Analysis			
		<i>Escherichia coli</i>		<i>Staphylococcus aureus</i>		<i>Escherichia coli</i>		<i>Staphylococcus aureus</i>	
		C	F	C	F	F value	Significance	F value	Significance
BHM 1	Arasampattai	0	28	0	27	842.5	0.000*	825.4	0.000*
BHM 2	Thandrikai	0	31	0	30				
BHM 3	Parangipattai	0	32	0	31				
BHM 4	Vadhanarayana	0	34	0	33				
BHM 5	Parpadagam	0	36	0	35				

*Significant at 5% level

Bamboo fabric finished with Arasampattai microcapsules (BHM1) showed 28mm and 27mm of inhibitory zones against *Escherichia coli* and *Staphylococcus aureus* respectively (Fig. 2). Thandrikai microcapsules finished bamboo fabrics (BHM2) exerted 31mm and 30mm of inhibitory zones against *Escherichia coli* and *Staphylococcus aureus* respectively (Fig. 3). Inhibitory zone size of about 32mm and 31mm were found evident for the bamboo fabric finished with Parangipattai microcapsules (BHM3) against respective test organisms, *Escherichia coli* and *Staphylococcus aureus* (Fig. 4). Bamboo fabric finished with Vadhanarayana microcapsules (BHM4) exhibited 34mm and 33mm of inhibitory zones against *Escherichia coli* and *Staphylococcus aureus* respectively (Fig. 5). Parpadagam microcapsules finished bamboo

fabrics (BHM5) revealed 36mm and 35mm of inhibitory zones against *Escherichia coli* and *Staphylococcus aureus* respectively (Fig. 6).

Among these five fabric samples, Vadhanarayana microcapsules (BHM4) finished swatches exhibited maximum inhibitory zone size.

Fig. 2: Antibacterial activity of Bamboo fabric finished with Arasampattai microcapsules (BHM1)



Escherichia coli

Staphylococcus aureus

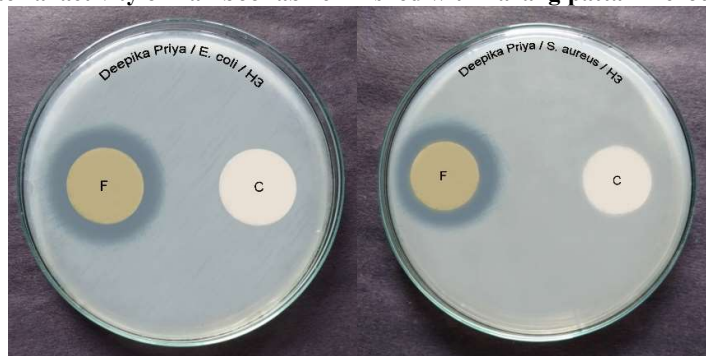
Fig. 3: Antibacterial activity of Bamboo fabric finished with Thandrikai microcapsules (BHM2)



Escherichia coli

Staphylococcus aureus

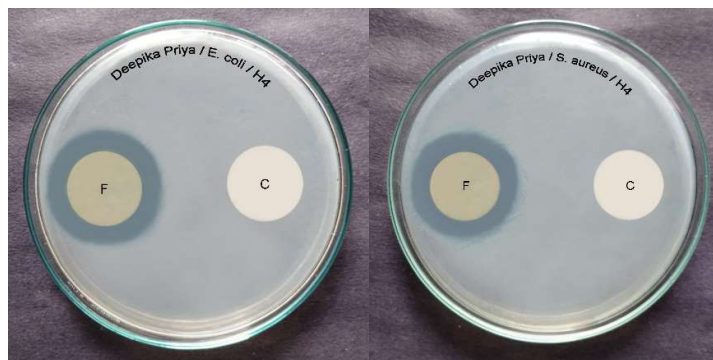
Fig. 4: Antibacterial activity of Bamboo fabric finished with Parangipattai microcapsules (BHM3)



Escherichia coli

Staphylococcus aureus

Fig. 5: Antibacterial activity of Bamboo fabric finished with Vadhanarayana microcapsules (BHM4)



Escherichia coli

Staphylococcus aureus

Fig. 6: Antibacterial activity of Bamboo fabric finished with Parpadagam microcapsules (BHM5)



Escherichia coli

Staphylococcus aureus

To prove that herbal microcapsules has antibacterial activity, the control unfinished fabric was also subjected to similar experimental protocol. All control samples did not exhibited inhibitory zones against the respective bacterial strains which indicated that only herbal microcapsules finished samples have exhibited antibacterial activity. Difference between finished and control samples expressed in terms of zone of inhibition was statistically calculated using one way ANOVA (Statistical package of social sciences, Windows-7) with 5% significant level. The statistical results revealed that there was significant difference in inhibitory zones in terms of antibacterial activity between the finished and control fabrics (F=842.5 for *Escherichia coli* and F=825.4 for *Staphylococcus aureus*).

Antibacterial activity of the microcapsules finished fabric expressed in this present research was reviewed from the literature survey. The herbal extracts of Arasampattai, Thandrikai, Parangipattai, Vadhanarayana and Parpadagam used for finishing had proved to contain different types of significant biological compounds like alkaloids, flavonoids, terpenoids, steroids, phenols and glycosides (Senthilkumer and Manivannan, 2016). These phytochemical compounds were proved to be attributing for different biological properties like antimicrobial activity (Tiwana et al., 2024) and anti-oxidant activity (Sharmila et al., 2025).

In our present research five different herbal sources used for finishing the bamboo fabrics showed good antibacterial activity. Sumithra (2017) highlighted that

eco-friendly products are highly beneficial to our health as also to the environment; also extended that these products improves quality of our lives as these green products are made from natural raw materials.

The researcher used medicinal herbs such as *Tribulusterrestris* – Whole plant, *Cissusquandrangularis* – Whole plant, *Leucasaspara* - Stem, Leaf and flower, *Passiflorafoetida* – Stem, Leaf and flower and *Cereus janacaru* – Whole plant have been selected for finishing 100% cotton fabric using dip-dry method. The finished fabrics have been tested for its antimicrobial activity using standard test method ENISO 20645. The research concluded that *Tribulusterrestris* finished fabric revealed good inhibitory zones ranging from 19mm to 21mm. In comparison to this work, in our present research, the antibacterial activity (ENISO 20645) were analyzed for microcapsule finished fabric samples. The results revealed that inhibitory zones ranging from 30mm to 38mm were obtained for all the test samples with excellent biological properties. Thus the results obtained in our present study was found well supportive with the results of Sumithra and Vasugi Raaja (2020) in terms of antibacterial activity.

In another study, Sumithra and Vasugi Raaja (2014) focused on imparting extracts of *Ricinus communis*, *Senna auriculata* and *Euphorbia hirta* as composite on denim fabrics. The antimicrobial efficiency of composite finished denim fabric samples were evaluated using EN ISO 20645 test method. The herbal composite finished fabric revealed inhibitory zones of 25mm and 29mm against respective *Escherichia coli* and

Staphylococcus aureus. In comparison with the results of Sumithra and Vasugi Raaja (2014), the antibacterial activity results obtained in our present study was found well supportive as similar range of inhibitory zones.

Aromatic efficiency of herbal microcapsules finished fabrics

Aromatic efficiency of herbal microcapsules finished and unfinished control fabric samples were statistically evaluated using F value. Difference between finished and control samples was presented in Table-5. From the Table, it was evident that there was no significant difference statistically ($p - 1$) between finished and control fabrics in terms of aroma when tested as per Swiss standard SNV 195651.

Table-5: Aromatic efficiency of herbal microcapsules finished fabrics

F. No	Fabrics	Samples Aromatic efficiency		Statistical analysis	
				Between Control and Finished	
		Control	Finished	F-Value	Significance
BHM1	Arasampattai	1	1	F - 1	p - 1
BHM2	Thandrikai	1	2		
BHM3	Parangipattai	1	1		
BHM4	Vadhanarayana	1	2		
BHM5	Parpadagam	1	1		

1 - Very pleasant 2 - Pleasant 3 - Not unpleasant 4 - Unpleasant 5 - Very unpleasant

Anti-odour activity results obtained in the present research was compared with the literature survey. The concept and model of anti-odour properties exhibited by the fabrics finished with different types of agents like silver, zeolite, activated carbon, essential oils, herbal extracts, chitosan, etc were well described. As reported, different types of bacteria and yeast were involved in causing odour in human bodies. Anti-odorant molecules in textiles thus control the growth of odour-causing bacteria arising in clothing that are used as daily basis. Normally these bacteria would generate unpleasant odour, but by controlling their growth, treating with suitable chemicals, prevents the formation of these odours and keeps fabrics fresher longer. More specifically, these chemicals can be applied at the manufacturing level which create bonds into fabric or just bind with fabric by coating. It then kills bacteria by puncturing their cell membranes. Once the bacteria are dead they can no longer produce any kind of noisome smell that enable fabrics to ascertain their freshness (Richter et al., 2017).

Geethadevi and Maheshwari (2020) used cypress oil and thyme oil mixtures to finish bamboo and tencel fabrics in three combinations like (1:1), (2:1) and (1:2). The result showed essential oil combination (2:1) showed very good to excellent interpreted value for deodorant activity. In comparison to this work, in our present research the anti-odour properties were analyzed for fabric samples treated with herbal microcapsules. The results revealed that all five types of herbal capsules finished fabrics provided excellent anti-odour properties. The results obtained in our present study was found well supportive with the results of Geethadevi and Maheshwari (2020) in terms of odour control.

Sumithra M and Vasugi Raaja (2020) carried out an anti-odour finish on cotton fabrics using the extracts of medicinal herbs such as *Ricinus Communis* (leaves and seeds), *Datura metel* (leaves with fruits), *Aloe Vera* (flower), *Abutilon indicum* (leaves), *Solanum surattense* (Leaves), *Coccinia grandis* (Fruits and leaves), *Aloe vera* (leaves), *Cardio spermum halicacabum* (Leaves), using dip-dry method and highlighted that the finished fabrics enhanced the wearing comfort properties and prevented bad odour. In comparison to this work, the herbal microcapsules finished samples also prevented the odour and this study found well supportive with the results of Sumithra and Vasugi Raaja (2020) in terms of odour control

Huong and Thinh (2019) studied the anti-odour properties of wool fabric treated with colorants from ground coffee residues. The researchers claiming that ground coffee residues are considered as biomass and organic wastes that can be used for further applications due to their deodorant properties. The purpose of this study is to confer anti-odour treatment on 100 % wool fabric by bi-functional dyeing process with the colorant extracted from ground coffee residues. The treated wool fabrics were evaluated for anti-odour effect; and the results confirmed that the samples could prevent odour caused by strong onion extract concentrations. The results obtained in our present study was found well supportive with the results of Huong and Thinh (2019) in terms of odour control.

Physical properties

Physical properties of herbal microcapsules finished fabric samples were tested and compared with unfinished control fabrics based on air-permeability test, tensile strength test and wicking test. In Table-6, the values obtained separately for each test were recorded.

Table-6: Physical properties of herbal microcapsule finished fabrics

F. No	Physical properties	Tensile strength (MPa/kgf)		Air-permeability (cm ³ /cm ² /sec)		Wicking height in (cm)		Inference
		Control Bamboo	Microcapsules finished	Control Bamboo	Microcapsules finished	Control Bamboo	Microcapsules finished	
BHM 1	Arasampattai	36.6	35.6	102.9	100.3	2.8	2.7	No significant difference
BHM 2	Thandrikai	34.9	33.3	104.3	103.9	2.6	2.5	No significant difference
BHM 3	Parangipattai	35.3	34.9	103.6	101.6	2.9	2.7	No significant difference
BHM 4	Vadhanarayana	38.6	37.6	102.3	101.9	2.8	2.6	No significant difference
BHM 5	Parpadagam	36.3	35.6	103.3	102.9	2.5	2.4	No significant difference

The tensile strength and air-permeability of microcapsules finished fabric samples did not showed significant difference on their respective values when compared to control unfinished plain fabric samples. This indicated that the herbal microcapsules after finishing on to the bamboo fabrics did not altered or changed the nativity of the fibres.

The vertical wicking test was done for the unfinished and finished fabrics. Bamboo fabric finished with Arasampattai microcapsules (BHM1) showed wicking height of 2.7cm. Thandrikai microcapsules finished fabrics (BHM2) exerted wicking height of 2.5cm. Parangipattai microcapsules (BHM3) finished samples revealed wicking height of 2.7cm; Vadhanarayana and Parpadagam microcapsules (BHM4 and BHM5) exhibited wicking height of 2.6cm and 2.4cm respectively. When compared to finished samples, unfinished also showed almost similar absorbency in terms of height in centimetre. This indicated that the microcapsules finished for antimicrobial and anti-odour control properties does not have any impact on the absorbency of the fabrics. The nativity of the fabric was not altered significantly.

Conclusion

Microencapsulation method was currently providing more durable finishes in the field of medical textiles,

hence in the present research bamboo fabrics were finished with five different types of medicinal herbs in the form of microcapsules. Finished fabrics were subjected to antibacterial activity and the results showed good inhibitory zones against *Escherichia coli* and *Staphylococcus aureus*. Anti-odour activity was also investigated for the finished fabrics and results were found satisfactory with no statistical difference. Physical properties such as air-permeability, tensile strength and absorbency between finished and unfinished fabrics did not showed any significant difference indicating that the nativity of the fabric was not altered even after finishing with herbal microcapsules. The present study would be considered highly significant by providing an eco-friendly and sustainable products for developing medical textile products and smart home textile products. To conclude that, the herbal microcapsules used for finishing the fabrics would be considered highly significant for the development of eco-friendly and sustainable products.

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