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RESEARCH ARTICLE

A COMPARATIVE STUDY ON MICROENCAPSULATED ESSENTIAL OILS FOR MOSQUITO REPELLENT FINISHED COTTON FABRICS

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ABSTRACT

Mosquitoes are of leading public health concern because many species are vectors of diseases and they transmit parasites and pathogens, which continue to have an overwhelming impact on the human health. They are the main cause of spreading the deadly diseases like malaria, dengue, filariasis and chickungunya. A mosquito repellent textile is a textile product, which protects the human beings from the bite of mosquitoes and thereby promising safety from the mosquito borne diseases. To impart this character, a finish of the mosquito-repelling agent is given to the textile material. The main objective of the study was to develop an Eco friendly, efficient mosquito repellent finished fabric using essential oils; (Lemongrass, Thyme and Lavender).The essential oils were finished onto the cotton fabrics (Pure mercerised cotton fabric and Plain weave cotton fabric) by microencapsulation using pad dry cure method. Today's textile industry makes use of microencapsulated materials to enhance the properties of finished goods. The microcapsules binding on to the fabrics were confirmed by scanning electron microscopy analysis and the presence of chemical functional groups were confirmed by FTIR analysis. Thyme oil microcapsules treated fabric showed maximum antibacterial activity.The comparison between Microencapsulated oil finished cotton fabrics (pure mercerised cotton fabric and plain weave cotton fabric) were evaluated for mosquito repellency efficiency against *Aedesaegypti* using a Mosquito Repellency Behavioral test. Wash durability test for the finished fabrics will be evaluated by subjecting the finished fabric to 3 washes followed by repeating the Mosquito Repellency Behavioral test to check its efficiency.

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INTRODUCTION

Recently, there has been a great interest in apparel industry all over the world for demanding functionality of textiles such as wrinkle resistance, soil release, and water repellency, flame retardant. A mosquito repellent textile is one such functional textile product came out recently. It protects the human beings from the bite of mosquitoes and thereby promising safety from the mosquito borne diseases **(Anitha R *et al.*, 2011).**Health and hygiene are the primary requirement for human beings to live comfortably and work with maximum efficiency. Thus to protect the mankind from pathogens and to avoid cross infection, a special finish like antimicrobial finish has been given to the fabric material using essential oils **(Thilagavathy *et al.*, 2007).**

Mosquitoes are members of the family of nematocerid flies. In particular, many species of female mosquitoes are blood-sucking pests and carriers of dangerous diseases like West Nile Virus disease; Malaria, Dengue Fever, Chickungunya, Zika virus disease, St. Louis encephalitis Lyme disease etc (**Vigneshkumar Murugan *et al.*, 2012) .** Mosquito borne diseases are prevalent in more than 100 countries, infecting 300-500 million people and causing about 1 million deaths every year. In India, more than 40 million people suffer from mosquito diseases annually **(Bhupen Kalita *et al.*, 2013**). As far India is concern, the populations of mosquito are found to be enormous day by day. Dengue Hemorrhagic Fever and Dengue fever are the most common mosquito-borne viral diseases that affect a wide range of people in the world. It is caused due to the bite of an infected Aedes Mosquito. It is a threatening disease as there is no proper vaccine or treatment yet found **(Patel E K *et al.*, 2012)**

At present, controlling the mosquito is one of the utmost importances due to increase in number of mosquito borne illnesses. The most commonly used repellents are lotions, coils and liquidators which are limited in their function due to various reasons. This has necessitated the development of mosquito repellent textiles **(Ramya K *et al.*, 2014)**. A mosquito repellent is a substance that are applied on human skin, clothing or other surfaces that prevent mosquitoes from sitting or crawling on that surface. There are of synthetic chemical origin and naturally available .Compound which posses repellency against mosquitoes Plant-derived repellents usually do not pose hazards of toxicity to humans and domestic animals and are easily biodegraded. Compared to synthetic compounds, which pose environmental threat, lethal effects on non target organisms and also resistance of mosquitoes to insecticides have increased during the last five decades

In this study essential oils like Lemongrass (*Cymbopogon citratus* or *Andropogon citratus)*, Thyme (*Thymus vulgaris)*and Lavender oil (*Lavandula angustifolia*)oil are used which are

well known for its medicinal properties, good antibacterial, antifungal and antiviral property.

Coating of oil gets easily oxidized, and is removed easily when exposed to sun light. This problem could be overcome by coating the fabrics with microencapsulated oil. The microencapsulated repellent released slowly by disturbing the coated fabric material because of microencapsulation. The present study is to develop an eco friendly mosquito repellent and antibacterial fabric by treating them with natural essential oils like lemongrass, thyme and lavender individually .The application of repellent and antimicrobial finish was done by using microencapsulation technique.

MATERIALS AND METHODS

Collection of samples

Essential oils such as Lemongrass, Thyme and Lavender oil were purchased from the organic shop. Fabric material -Pure mercerised cotton fabricand Plain weave cotton fabric were purchased from commercial textile shop and Mosquito eggs (*Aedes aegypti*) were collected from Entomology Research Institute, Loyola College, and Chennai.

Preparation of microcapsules by ionic gelation process

An equal proportion of sodium alginate and oil were prepared. To this, 3 ml of Tween 20, were added and mixed thoroughly to form smooth viscous dispersion. The mixture was sprayed into calcium chloride solution using a syringe and the droplets were retained in 10% calcium chloride for 15minutes.Then microcapsules were obtained by decantation and repeated washing with isopropyl alcohol followed by drying at 45 °C for 12 hours. The microcapsules were then used for finishing on the selected fabrics.

Fabric treatment by pad dry cure method

The fabrics were immersed for 30 minutes in the binder solution 8% Citric acid (8gms of citric acid in 100ml of distilled water). After 30 minutes the microcapsules were padded on the fabric and dried at 80- 85 ºC in the oven for 5 minutes and cured at 150 ºC for 2 minutes.

Scanning electron microscopy analysis

The SEM analysis was mainly studied to identify the finished and unfinished molecules present in the fabric sample. The microcapsules finished samples were analyzed to confirm the binding of microcapsules and alignment on to the fabric samples

FTIR analysis

The types of compounds which were present in the oils were identified by different wavelengths using FTIR spectrophotometer PERKLIN ELMER SPECTRUM VERSION 10.4.00.The FTIR graph representing the corresponding

curves and wavelengths for different functional groups present were recorded.

Antimicrobial activity test

Preparation of overnight cultures:

10ml of nutrient broth was prepared and sterilized using autoclave. The selected bacteria for antimicrobial study were individually inoculated into different test tubes under aseptic conditions and were incubated at 37 ºc for 24 hrs.

Preparation of MHA plates for antimicrobial activity:

1000 ml of MHA medium was prepared and sterilized at 121º C for 15 minutes .30 ml of medium was poured into each of the plates and were allowed to solidify.0.5 ml of culture from nutrient broth was swabbed on the plates and left undisturbed for 10 -15 minutes.

The microencapsulated fabrics were cut in to small pieces and placed onto the agar plates. Then the plates were incubated at 37º C for 24 hrs. The zones of inhibition were measured in mm after 24hrs.

Rearing of mosquitoes

Day 1

The filter paper containing the mosquito eggs (*Aedes aegypti*) are placed in a plastic tray with ~300 ml distilled water. A pinch of food (Yeast powder) is added to the tray.

Days 2-3

The eggs were hatched to larvae. The larvae were fed every day with food

Days 5 – 8

The pupae start developing at this stage. The pupae are introduced into rearing cage to avoid escape of adults.

Days 9 -11

The pupae were allowed to emerge to adult. The adults were feed with a cotton wick that is soaked with 10% sucrose solution is given every day to the adult by carefully removing the net to avoid escaping of adult mosquitoes.

Mosquito repellency test

The mosquito repellency test of treated fabrics was carried out by modified WHO/ CTD/ WHO PES/lC/96 standard test method **(Amol G *et al.*, 2015)**

- An excito repellency chamber consists of two cubicle chamber attached together with a hole in the central wall was made (Figure 1).
- Walls of right side of the chamber are covered with microcapsules treated fabric
- *Aedes aegypti* mosquitoes were collected from the rearing cage and released to the right side of the chamber using aspirator and repellency was tested against 10 mosquitoes in excito repellency test

chamber for 30 min time interval duration. The repellency was noted for every 5min.

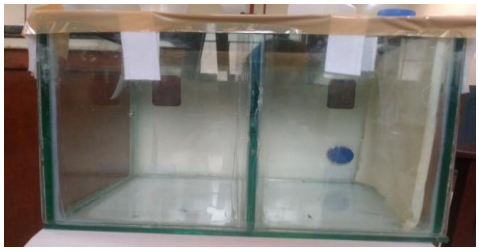


Figure1. EXCITO REPELLENCY CHAMBER

Mosquito Repellency was calculated using following formula:

% Efficiency of the mosquito repellency =

No. of specimen escaped + No. of specimen dead

---------- X 100

No. of specimen exposed

Wash durability Test:

The microcapsules treated fabrics are subjected to 3 hand washes using mild detergent and again the percentage of mosquito repellency efficiency was repeated and the results were noted.

RESULT AND DISCUSSION

Evaluation of microcapsules treated fabrics

SEM has been used to analyze the shape, size and distribution of microcapsules on the treated fabrics. The SEM photographs shown in figure 2 & 3 indicates that the microcapsules produced are of small spherical shape and uniform size distribution. As a result it is clear that the capsules are firmly binded on the surface of the cotton fabrics.

Figure 2. PURE MERCERISED COTTON FABRICS

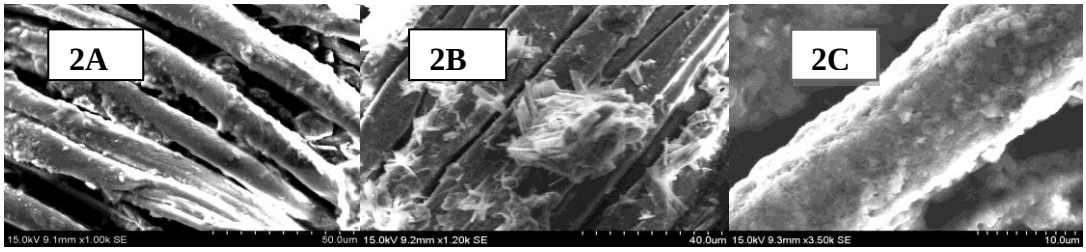
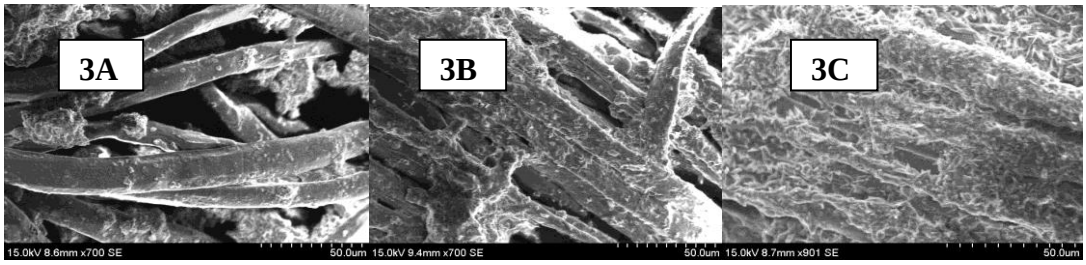


Figure 3.PLAIN WEAVE COTTON FABRICS



SCANNING ELECTRON MICROSCOPY ANALYSIS – A. LEMONGRASS OIL, B.THYME OIL, C. LAVENDER OIL MICROCAPSULES FINISHED COTTON FABRICS

FTIR Analysis

The Fourier Transform Infrared Spectrum (FTIR) were analysed using **PERKLIN ELMER SPECTRUM VERSION 10.4.00.**This technique provides information about the various chemical groups present in the fabric specimen. In this study unfinished cotton fabrics were compared with the microcapsules

The FTIR analysis of the control mercerised cotton fabric was represented in Figure 4.The results indicated the presence of peaks at wave lengths of 668.13cm.$^{-1}$, 724.28 cm $^{-1}$, 1015.16 cm $^{-1}$, 1237.65 cm $^{-1}$, 1714.27 cm^{-1} . on comparing unfinished Pure mercerised cotton fabric with microcapsules finished Pure Mercerised cotton fabric, the lemongrass oil microcapsules finished has additional peaks at wave length of 2500 cm $^{-1}$ - 3000 cm^{-1}., thyme oil had additional peaks at 3432.83cm $^{-1}$, Lavender oil ha additional peaks at 1018.41 cm $^{-1}$ shown in Figure 4A,4B and 4C.

The FTIR analysis of the control plain weave cotton fabric is represented in Figure 5.The results indicated the presence of peaks at wave lengths of 1000 cm $^{-1}$ - 1500 cm $^{-1}$, 2500 cm $^{-1}$ - 3000 cm $^{-1}$.On comparing unfinished plain weave cotton fabric with microcapsules finished pure mercerised cotton fabric, Lemongrass oil microcapsules finished fabric has additional peaks at 1205.85cm $^{-1}$, 1225.52cm $^{-1}$, 1256.89 cm $^{-1}$, 1225.52 cm $^{-1}$, 1297.78 cm $^{-1}$, 1370.87 cm $^{-1}$, 1415.70cm $^{-1}$, 1452.24 cm $^{-1}$, 1547.58cm $^{-1}$, 1585.61 cm $^{-1}$, 1680.62 cm $^{-1}$, 3394.62 cm $^{-1}$.Thyme oil 600 cm $^{-1}$ - 1000 cm $^{-1}$, 1000 cm $^{-1}$ - 1500 cm $^{-1}$, 1500-2000cm $^{-1}$.Lavender oil 719.64cm $^{-1}$, 860.41 cm $^{-1}$, 995.4cm $^{-1}$, 1151.58 cm $^{-1}$, 1261.63 cm $^{-1}$, 1485.84cm $^{-1}$,1708.81 cm $^{-1}$shown in Figure 5A,5B and 5C.

The results of FTIR stated that the essential oil microcapsules finished fabrics posses functional chemical groups which confirms the presence of O-H and C-C bonds and characteristics of higher absorbency and thermal property compared to the unfinished fabric

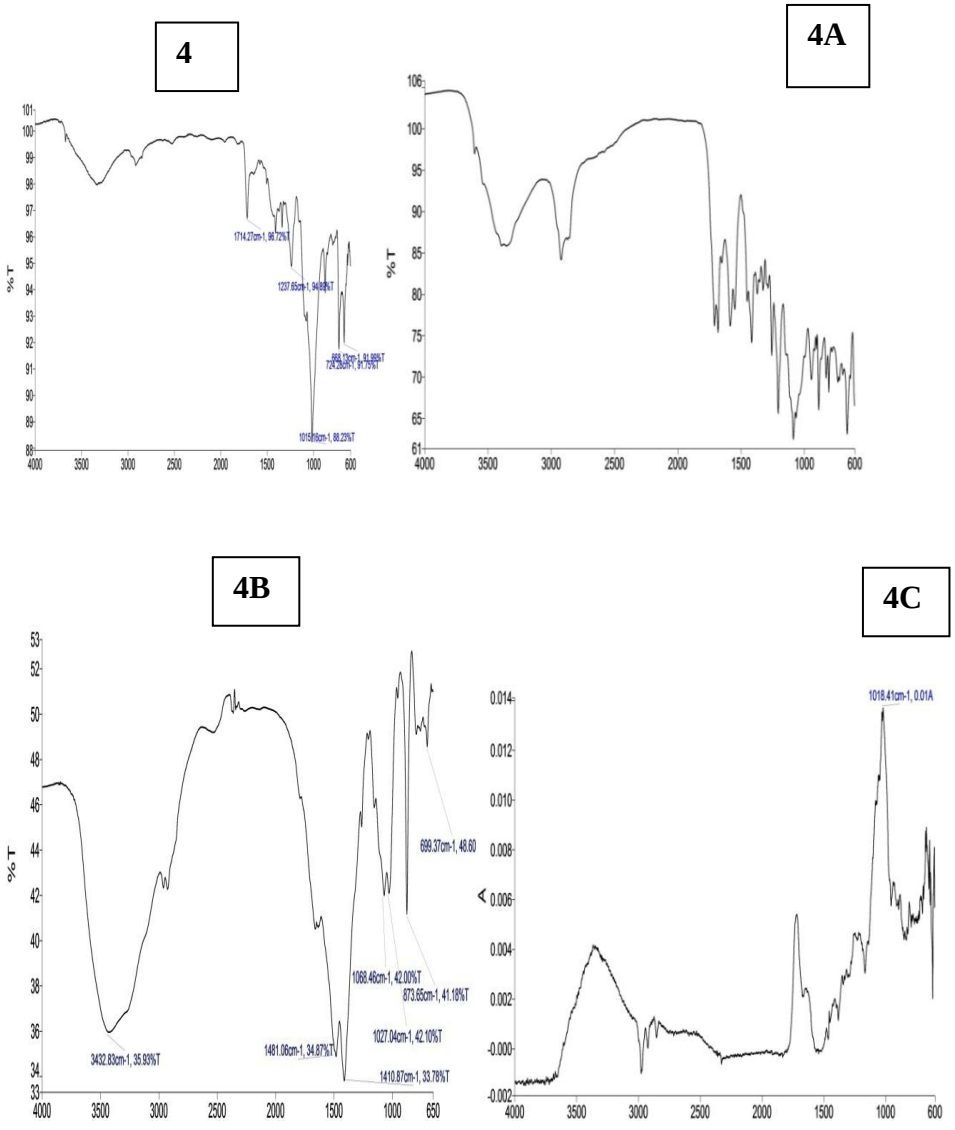


Figure4. FT-IR ANALYSIS PERKLIN ELMER SPECTRUM VERSION10.4.00 – A. LEMONGRASS, B. THYME and C.LAVENDER OIL MICROCAPSULES FINISHED ON PURE MERCERISED COTTON FABRICS.

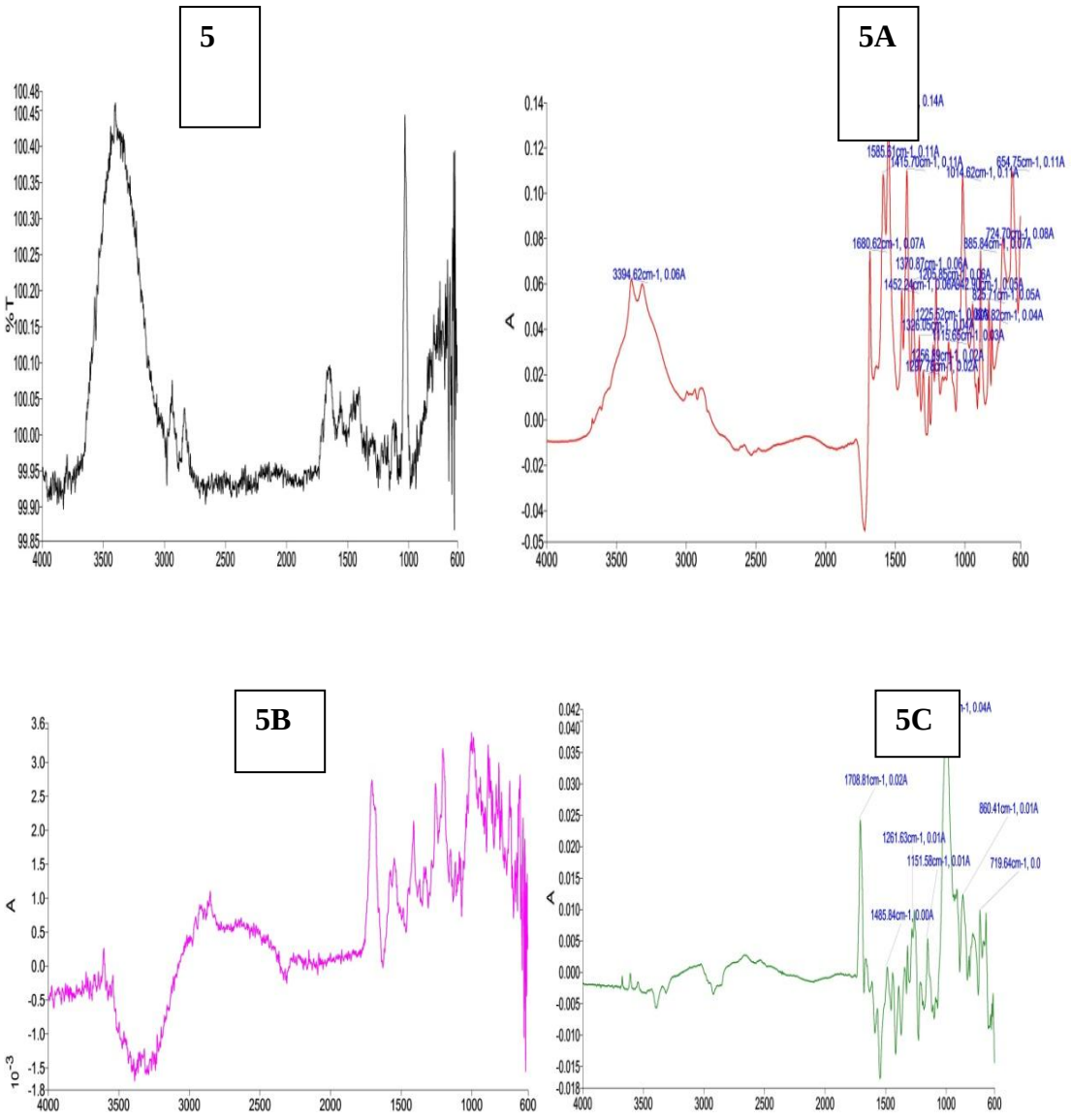


Figure 5. FT-IR ANALYSIS – A. LEMONGRASS, B. THYME and C.LAVENDER OIL MICROCAPSULES FINISHED ON PLAIN WEAVE COTTON FABRICS COTTON FABRICS

Antibacterial activity

Table 1 Show the comparison of antibacterial efficacy in terms of zone of inhibition (qualitative analysis for Lemongrass oil, Thyme oil and Lavender oil of pure mercerised cotton fabric against gram positive and gram negative organism *Staphylococcus aureus, Bacillus cereus, Escherichia coli, Salmonella typhi, Pseudomonas sp.* It is revealed that thyme oil microcapsules showed maximum zone of inhibition about 18.5mm, 14.5mm, and 9.5mm against *Bacillus cereus, Salmonella typhi, Staphylococcus aureus* compared to lemongrass

and lavender oil. Whereaslemongrass oil microcapsules finished fabric was found to exhibit maximum zone of inhibition about 7mm against *Pseudomonas sp*and 5mm for lavender oil against *Salmonella typhi.*

Table 2 Show the comparison of antibacterial efficacy in terms of zone of inhibition (qualitative analysis for Lemongrass oil, Thyme oil and Lavender oil of plain weave cotton fabric against gram positive and gram negative organism *Staphylococcus aureus, Bacillus cereus, Escherichia coli, Salmonella typhi, Pseudomonas sp.* It is revealed compared to lemongrass oil and lavender oil, Thyme oil microcapsules finished plain weave cotton fabric showed maximum zone of inhibition about 12mm, 13mm, 11mm, 14.5mm and 11.5mm against all the 5 organisms.

On comparing both the fabrics it is found that thyme oil microcapsule finished on plain weave cotton fabric showed good antibacterial efficiency against gram positive and gram negative organism *Staphylococcus aureus, Bacillus cereus, Escherichia coli, Salmonella typhi, Pseudomonas sp* compared to lemongrass and lavender oil.

Table 1 :ANTIMICROBIAL EFFICACY OF PURE MERCERISED COTTON FABRIC

		ZONE OF INHIBITION (in mm)				
S.NO	SAMPLE	*Staphylococcus aureus*	*Bacillus cereus*	*Escherichia coli*	*Salmonella typhi*	*Pseudomonas sp*
1	LEMONGRASS OIL PURE MERCERISED COTTON FABRIC	6.5	14	3.5	7.5	7.5
2	THYME OIL PURE MERCERISED COTTON FABRIC	9.5	18.5	4.5	14.5	5.5

3	LAVENDER OILPURE MERCERISED COTTON FABRIC	6.5	7	5.5	5	0

Table 2: ANTIMICROBIAL EFFICACY OF PLAIN WEAVE COTTON FABRIC

		ZONE OF INHIBITION mm				
S.NO	SAMPLE	*Staphylococcus aureus*	*Bacillus cereus*	*Escherichia coli*	*Salmonella typhi*	*Pseudomonas sp*
1	LEMONGRASS OILPLAIN WEAVE COTTON FABRIC	7	10.5	6.5	6	6
2	THYMEOIL PLAIN WEAVE COTTON FABRIC	12	13	11	14.5	11.5
3	LAVENDER OIL PLAIN WEAVE COTTON FABRIC	5	5.5	4.5	5.5	0

Mosquito repellency test

Figure 6A, B,C and D shows mosquito repellenttest results before and after 3 washes. The fabric has been treated with microencapsulated oil such as lemongrass, thyme and lavender on mercerised cotton fabric and plain weave cotton fabric.

The results show that lemongrass oil microcapsules finished on both mercerised cotton fabric and plain weave cotton fabric exhibited maximum of 60% repellency in 5mins.But the efficiency was reduced to 10 % after 3 washes.

Whereas lavender oil microcapsules treated fabric showed maximum repellency of 30% for mercerised cotton fabric and 50 % for plain weave cotton fabric and the efficiency was retained upto 30 % for mercerised cotton fabric and 20% for plain weave cotton fabric due to the sustained release and firm binding of the encapsulated lavender oil on the surface of the cotton fabrics.

Thyme oil microcapsules treated fabrics showed lesser efficiency before and after wash than the other two oils.

This shows that the microencapsulated lavender oil finished fabrics have a high retention of the repellent activity whencompared with the lemongrass and thyme oil.

Figure6A.MOSQUITO REPELLENT EFFICIENCY OF PURE MERCERISED COTTON FABRIC

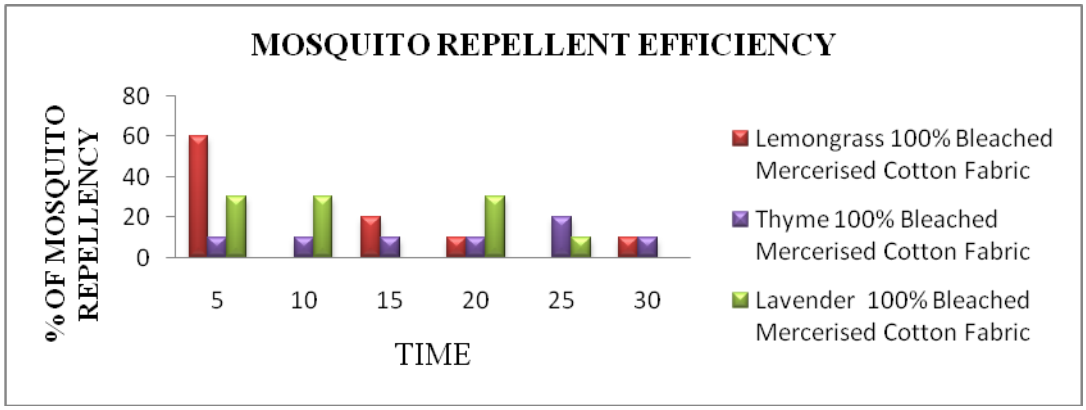


Figure 6B.MOSQUITO REPELLENT EFFICIENCY OF PLAIN WEAVE COTTON FABRIC

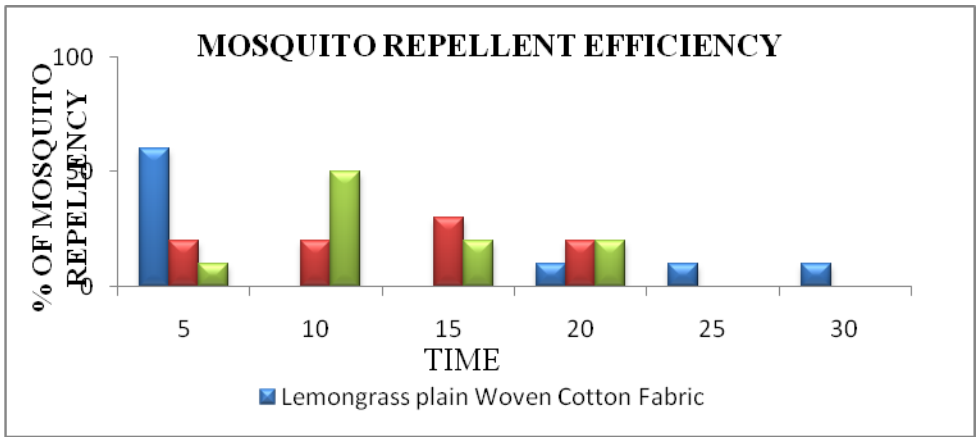


Figure 6C:WASH DURABILITY MOSQUITO REPELLENT EFFICIENCY OF PURE MERCERISED COTTON FABRIC

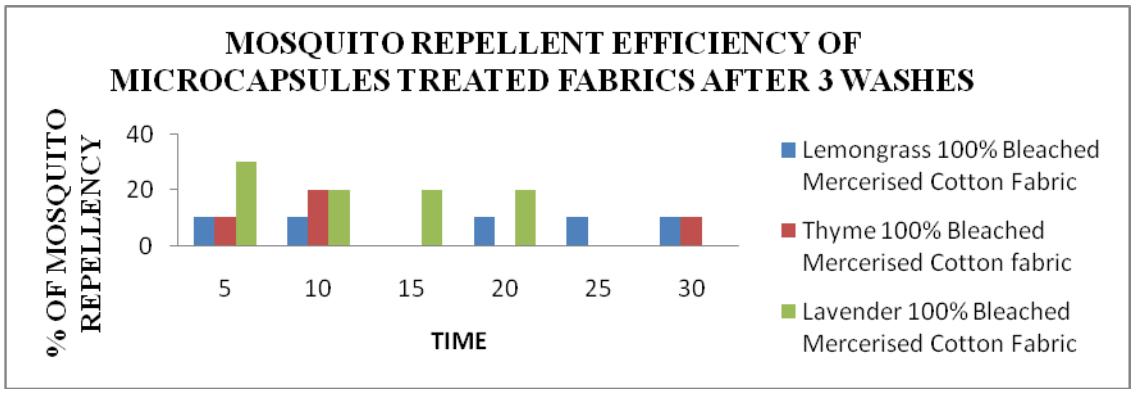
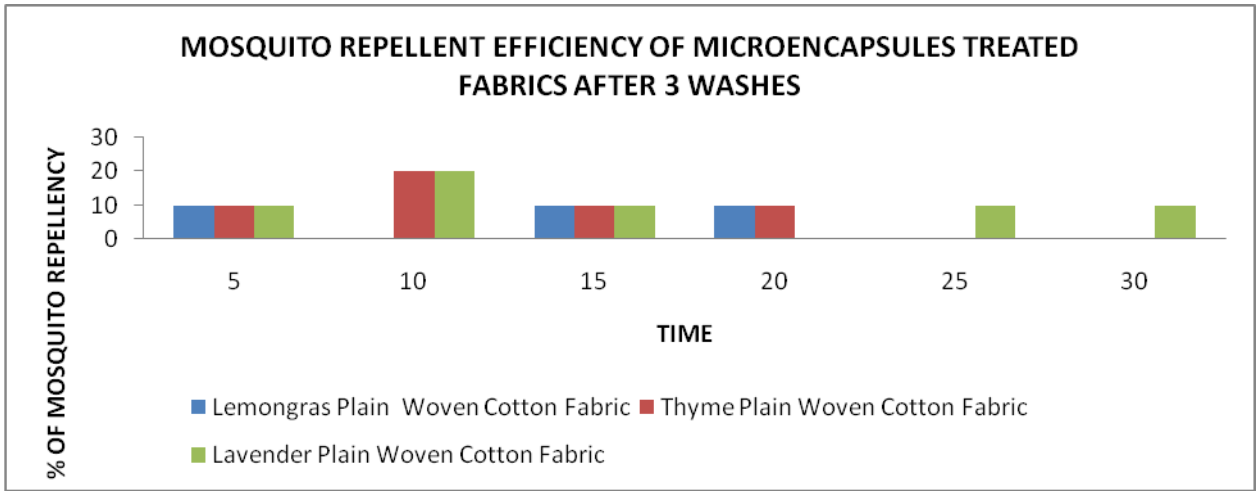


Figure 6D: WASH DURABILITY MOSQUITO REPELLENT EFFICIENCY OF PLAIN WEAVE COTTON FABRIC



CONCLUSION

Today world is moving into the ecofriendly era. There is a vast resource of natural antimicrobial and mosquito repellent agents which can be used for imparting an antimicrobial and mosquito repellent finish to textile materials. This work has given a idea of using finishing the cotton fabrics with naturally available essential oils to enhance the antimicrobial and mosquito repellency efficiency.

The spherical shape and uniform distribution of the microcapsules were synthesized and microencapsulated onto the fabrics by pad dry method. Presence of functional groups of the oils was confirmed by FTIR analysis, by comparing the microcapsules treated fabrics with unfinished fabrics. Antimicrobial activity against Gram positive and Gram negative organisms, Thyme oil microcapsules treated

plain weave cotton fabric fabrics were found to exhibit maximum inhibitory effect against *Staphylococcus aureus, Bacillus cereus, Escherichia coli, Salmonella typhi, Pseudomonas sp* compared to lemongrass and lavender oil.

The mosquito repellency activity was checked using *Aedesaegypti*mosquitoes, Lavender oil has found to have good mosquito repellent property before and after wash by microencapsulation method. This may beto the sustained release and firm binding of the encapsulated lavender oil on the surface of the cotton fabrics. Vector borne diseases are one of the major problems in developing countries. To avoid such sort of disease transmission to humans can be avoided using mosquito repellent fabrics. This form of naturally extracted oil mosquito repellent finishes is very safe and ecofriendly and protects from mosquitoes.

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