



Research Article

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MICROENCAPSULATION OF HERBAL COMPOSITES FOR MOSQUITO REPELLENT FINISHES IN BAMBOO AND MODAL FABRICS

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ABSTRACT

Due to great demand for mosquito repellent textile materials, eco-friendly herbal microcapsules were prepared in the present research using *curcuma aromatica*, *Camellia sinensis* and *Azadirachta indica* at optimized conditions. The microcapsules were finished onto 100% bamboo and 100% organic modal fabrics. Optimization of microencapsulation process was carried out after determining the mosquito repellent activity of fabrics finished with three different concentrations of herbal capsules and three different shell materials by standard Excito-chamber method. Optimized microencapsulation was prepared using 3X herbal concentration and neem gum as shell materials. The optimized microcapsule finished fabrics showed increased mosquito repellent percentage. Maximum mosquito repellent percentage was observed for herbal extract (3X) and neem gum (3X) finished bamboo and modal fabrics against *Anopheles stephensi* mosquito (84% and 83% respectively). After 5th and 10th wash, the fabrics showed fair repellent properties (60% and 61%; 38% and 41% respectively). Microencapsulation method implied in this research was found to be a unique method for imparting the bioactive compounds of the herbal composite onto fabric materials permanently.

Keywords: Neem gum, Excito-chamber, Mosquito repellent, Herbal composite, Microencapsulation

INTRODUCTION

Mosquitoes are responsible for transmitting various diseases in any part of the nation. Hence different products like coils, lotions and liquidators are commercially manufactured to prevent mosquitoes at home. But, severe chemicals present in these commercial products causes different side-effects like nasal burnings, eye and skin irritations, eczema, nausea, etc.¹ These draw backs of commercially available chemical mosquito repellent products pave way for the development of a novel eco-friendly product like woven and non-woven mosquito repellent fabrics. Textile materials with the characteristics of mosquito repellent properties are considered as a revolutionary approach to prevent mosquitoes and diseases transmitted as vectors. This property is well studied in the present research with effective herbal finishing methods.

Among all the insect vectors of human disease, *Anopheles* is the most dreadful species of mosquitoes². In India and West Asian countries about 40 to 50% of malaria is considered as a common disease annually. World-wide, about 3 million people die each year due to diseases caused by mosquitoes³.

Mosquito repellents can be classified as chemical and herbal repellents depending on their nature of origin; and also based on their action. Chemical repellents contain neuro-toxins for mosquitoes; that disturb the nerve system and makes unconscious⁴. But long-term use of chemical repellents may cause several side effects in people and repeated use of these substances will induce resistance in mosquitoes. So, in order to overcome these limitations, the research work on natural repellents derived from plant origin are considered very promising and potential because it is safe and cheap^{5,6}.

Azadirachta indica commonly termed as neem, from Meliaceae family was reported as a natural mosquito repellent plant⁷. The plant leaves, flowers and fruits are reputed to be responsible for different repellent actions like insecticidal, pesticidal, bactericidal, fungicidal and larvicidal. Azadirachtin is a significant bioactive compound reported to be present in the plants and at a higher concentration in the seed⁸. Many research works were carried out to prove that neem plants and its parts are a natural mosquito repellent plant⁹. Many researchers have found different repellent compounds from neem like nimbin, nimitinol, gedunin, salanim, nimbidine, azadinone, nimbicidine¹⁰.

In Countries like India and other Tropical nations, simple and cheap mosquito repellent products without any adverse side effects are highly essential. Hence, mosquito repellent textiles are considered as the suitable alternative for the chemical repellents. Herbal particles and its extracts finished onto different woven textile materials thus ensure the dual requirements for the common people. These two requirements are protection against mosquitoes and the side effects caused by chemical repellents. The present research is focused on the mosquito repellent finish in textile materials using suitable techniques and herbal extracts.

Preparation and optimization of solvent extracts from *Curcuma aromatica* (Kasthuri manjal), *Camellia sinensis* (Green tea) and *Azadirachta indica* (Neem) was carried out to determine the optimum mosquito repellent finish in the selected textile materials. The prepared extracts were finished on the 100% bamboo and 100% modal fabric and the mosquito Repellence efficiency of the fabric was tested against the microencapsulated extract finished fabric. Microencapsulation is a suitable technique used in this research which deposit as small microparticles to form thin polymeric coatings on the textile materials either as solids or liquids^{11,12}. The size and shape of microcapsules; as a wall material and active substance release mechanisms influences

the significance of textile processing methods and its applications in the final products¹³.

MATERIALS AND METHODS

Fabrics used in the study

Bamboo 100% and Organic modal 100% fabrics were selected based on their significance in the environment. All the selected fabrics were considered to be eco-friendly in nature. The specification of the fabric materials was presented in Table 1. All the materials were scoured, bleached and dyed with reactive dye to attain basic preparatory process.

Table 1: Test fabrics and its parameters

Fabric parameter	Bamboo 100%	Organic modal100%
Courses per cm	22.71	22.04
Wales per cm	17.20	17.99
GSM	127	114
Tightness factor	16.01	16.01
Loop shape	1.320	1.225

All parameters were selected based on the textile standards

Herbs and shell materials

Curcuma aromatica (Kasthuri manjal), *Camellia sinensis* (Green tea) and *Azadirachta indica* (Neem) herbal powders (commercially procured from local herbal market) and three shell materials like sodium alginate (Hi Media), gum acacia (Hi Media) and neem gum was commercially procured from a local supplier at Coimbatore, Tamil Nadu, India.

Herbal composite preparation

Commercial powders of neem leaves, green tea leaves and rhizome of *Curcuma aromatica* were weighed, air-dried and reduced to coarse powder. Using 100s sieve the powders were finely sieved and packed separately before the extraction procedure. About 40g of each fine sieved powder was extracted overnight with distilled water. The distillates were freeze-dried to get dried plant extracts. Certain concentration of the plant extract was prepared by dissolving it with sterile distilled water and

filtrated through a 0.2 µm membrane filter. The neem leaf extracts were taken in a beaker and kept under magnetic stirring conditions at room temperature. During the stirring conditions, the green tea leaf extracts were slowly added at the rate of 1ml/min using a burette. Using similar conditions finally the rhizome powder extracts of *Curcuma aromatica* was added to get a final herbal composite. The herbal composite solution was then separated as three different concentrations (1X, 2X and 3X) and each concentrate was used for the microencapsulation process.

Optimization of herbal concentration and shell material for the preparation of microencapsulation solution

Two different herbal concentrations and two different shell materials were used separately to optimize the conditions for preparing microencapsulation solution. In brief, sodium alginate was dissolved in sterile distilled water to form a homogenous solution. Three herbal concentrations (1X, 2X and 3X) was added separately to the alginate solution and mixed thoroughly with a stirrer to form a viscous dispersion. The resulting dispersion was then sprayed into 0.5 ml calcium chloride (1%) solution by means of a sprayer under controlled aseptic conditions. Microcapsule droplets obtained in the calcium chloride solution were allowed to retain for 15 minutes. The obtained microcapsules were decanted and washed repeatedly with isopropyl alcohol. Finally, the microcapsules were dried at 45 °C for 12 hours.

Using the other shell materials (gum acacia and neem gum) similar procedure was carried out separately. All the three prepared microcapsule solutions were used for finishing 100% bamboo and 100% organic modal separately (Table 2). About one litre solution containing 700 grams of capsules was used to finish one meter of fabric. The fabric was immersed in the solution with 8% citric acid as a binder for 30 min under 50 °C in oven. After exhaust finishing the fabric was removed from the oven and air dried at room temperature aseptically. All the test fabric finished separately with different microcapsules was subjected to mosquito repellent property by Excito-chamber method. From the optimization studies, one best herbal concentration and one best shell material was finally selected.

Table 2: Optimization of herbal microcapsule preparation and finishing onto test fabrics

Fabrics	Herbal concentration/ Shell material (1X)*			Herbal concentration/ Shell material (2X)#			Herbal concentration/ Shell material (3X)@		
	sodium alginate	gum acacia	neem gum	sodium alginate	gum acacia	neem gum	sodium alginate	gum acacia	neem gum
100% Bamboo	sodium alginate	gum acacia	neem gum	sodium alginate	gum acacia	neem gum	sodium alginate	gum acacia	neem gum
100% Organic modal	sodium alginate	gum acacia	neem gum	sodium alginate	gum acacia	neem gum	sodium alginate	gum acacia	neem gum

*10mg/10ml, # 20mg/10ml, @30mg/10ml

Finishing the fabric with optimized herbal microcapsules

The fabric material (100% bamboo and 100% organic modal) was finished separately in the optimized herbal microcapsule solution prepared with selected herbal concentration (3X) and selected shell material (neem gum). After exhaust finishing, the fabrics were subjected to determine its mosquito repellent activity.

Mosquito Repellence Procedure (Modified Excito Chamber Method)

Repellence Behavioral tests

Specially designed excito Repellence test chambers (Fig 1) were used to evaluate the efficiency of Repellence activity as previously described by Chareonviriyaphap et al., (2002). The outer chamber of excito-Repellence testing device measures 34

cm × 32 cm × 32 cm and faces the front panel with the single escape portal. The box is composed of a rear door cover, an inner transparent glass panel with a sealed door. Laboratory tests were performed during daylight hours and each test was replicated twice. After each test was completed, the number of specimens dead and the number of specimens escaped was recorded for all the samples (before wash and after wash). The percentage of Mosquito Repellence was calculated by the following formula,

$$\text{Repellence (\%)} = \frac{\text{No. of specimens escaped} + \text{No of specimens dead}}{\text{No of specimens exposed}} \times 100$$

Testing the treated fabrics after washing

The treated fabric was washed with the recipe mentioned below in the launder-o-meter (Table-3). After the fabric washed and

dried, it was tested for mosquito repellent test to check whether the finish is durable or not. After washing the samples were tested with similar procedure used for the untreated fabric.

RESULTS

100% modal herbal finished fabric samples were tested for mosquito repellent properties using a modified excito chamber method. During this test before wash sample showed 83% of

Repellence; after 5th wash and 10th wash sample exhibited 62% and 41% respectively. In Table 3 the obtained results were evaluated using the formula given and the Repellence behaviour of the fabric was presented in percentage. Herbal extract finished modal exhibits significant repellent properties for the samples (before wash, after 5th and 10th wash), which deserve further investigation for possible use as mosquito repellent home textile materials and equivalent. Obtained results infer that after 15th wash no more repellent properties may be observed (Table 4).

Table 3: Mosquito Repellence behaviour of the fabric (Before Wash)

Fabrics	Herbal concentration/ Shell material (1X)*			Herbal concentration/ Shell material (2X)#			Herbal concentration/ Shell material (3X)@		
	1X/ sodium alginate	1X/ gum acacia	3X/ neem gum	2X/ sodium alginate	2X/ gum acacia	3X/ neem gum	2X/ sodium alginate	2X/ gum acacia	3X/ neem gum
100% Bamboo	66	68	73%	71	70	78%	78	80	84%
100% Organic modal	62	69	75%	70	74	79%	76	78	83%

Table 4: Mosquito repellence behaviour of the fabric (After Wash)

Fabric sample	Mosquito Repellent: Excito Chamber test method		
	Before Wash	After 5 th Wash	After 10 th wash
100% Bamboo finished with Herbal extracts (3X) and neem gum (3X)	84%	60%	38%
100% Modal finished with Herbal extracts (3X) and neem gum (3X)	83%	62%	41%

DISCUSSION

Most mosquito repellents are commercially manufactured and designed in such a way to have immediate action on the mosquitoes. This is mainly due to the presence of severe chemical ingredients like N,N-diethyl-3-methylbenzamide (12%)¹⁴. This chemical can repel mosquito to greater extent but with lot of adverse side-effects as described previously¹. In the present research, a search for eco-friendly approach of mosquito repellent finish on to two different textile materials were made under an optimized condition. Among the three types of shell materials, neem gum (3X) was found suitable for finishing the herbal extracts onto both bamboo and modal fabrics. Maximum repellent behaviour of herbal finished bamboo was observed for herbal concentration at 3X strength and neem gum at 3X strength. About 84% and 83% of mosquito Repellence was obtained for bamboo and modal finished with 3X herbal concentrates and 3X neem gum respectively.

Azadirachta indica used as one of the herbal constituent in the present research was reported as a powerful insect anti-feedant; disrupts metamorphosis in moth larvae even at very low concentration¹⁵. Many research work was completed and reported that neem compounds are more effective insect repellent than the widely used synthetic chemical N,N-diethyl-3-methylbenzamide¹⁶ due to the presence of various bioactive compounds as mentioned earlier¹⁰.

The mechanism of action of mosquito repellents is that carbon dioxide, excretory products and lactic acid present in sweat of warm blooded animals' acts as an attractive substance for female mosquitoes. The perception of the odor is through chemoreceptors present in the antennae of mosquitoes. The repellents block the lactic acid receptors thus destroying upwind flight and as a result, the mosquito lose contact with the host usually mosquito repellents work by masking human scent or by using a scent which insects naturally avoid¹⁷. According to this literature survey, in the present research the presence of the odor in *Curcuma aromatica* (Kasthuri manjal), *Camellia sinensis* (Green tea) and *Azadirachta indica* (Neem) must have contributed to the repellent action¹⁸.

Apart from odour, taste molecules are also reported to be involved in the mosquito repellent action. Taste of herbal particles to the insects plays a vital role in the repellent properties of herbal finished fabrics. It was reported that when mosquito tastes the skin of the host using its gustatory receptors before it bites, which induces avoidance response through the sense of taste. The reason was justified by Akin¹⁹ stating that neem and other herbal plants usually contain sulfurous compound which attributed to act as mosquito repellent. The repellent activities in the present research for before and after wash fabrics was well in accordance with the properties of odour and taste as described by Akin.

The repellent action measured in percentage was also compared with the other similar type of research works during the literature survey. Some of the significant findings of the researchers using herbal extracts as mosquito repellents are compared with the present analysis.

Ramya et al²⁰ investigated the plant extracts of *Andrographis paniculata* as mosquito repellent finish for fabric. They also compared the direct and microcapsulation application method. Samples treated by the direct application method showed about 96% efficiency, while the microencapsulated sample showed 94% efficiency. Anish Sharmila et al²¹ finished cotton fabric using citronella and lavender oil and reported 93% Repellence. Sarita Kumar et al²² examined and found remarkable repellent properties of essential oil extracted from the leaves of peppermint plant. They reported 100% protection till 150 min against the larval and adult stages of *Aedes aegypti*. Sumithra et al²³ in their study developed mosquito repellent finish for denim fabric using three natural herbs extracts of *Ricinus communis*, *Senna auriculata* and *Euphorbia herita* which were applied directly by using pad dry cure method. The results showed good efficiency of 68% Repellence in denim fabric and also highest Repellence rate of 52% even after 30 industrial washes when compared to other fabrics. Microcapsules of lemon grass synthesized by Anitha et al²⁴ showed 92% Repellence on polyester fabric and methanolic extracts exhibited 80% mosquito Repellence activity.

CONCLUSION

Increase in demand for mosquito repellent textile materials, and also due to adverse side effects caused by commercial chemical mosquito repellent agents, a novel eco-friendly approach using herbal microcapsules were prepared in the present research. Microcapsules of three significant herbs like *curcuma aromatica*, *Camellia sinensis* and *Azadirachta indica* were selected to finish the fabrics at optimized conditions. The microcapsules were finished onto 100% bamboo and 100% organic modal fabrics. Optimization of microencapsulation process was carried out after determining the mosquito repellent activity of fabrics finished with three different concentrations of herbal capsules and three different shell materials by standard Excito-chamber method. Optimized microencapsulation was prepared using 3X herbal concentration and neem gum as shell materials. The optimized microcapsule finished fabrics showed increased mosquito repellent percentage. Maximum mosquito repellent percentage was observed for herbal extract (3X) and neem gum (3X) finished bamboo and modal fabrics against *Anopheles stephensi* mosquito. Wash fastness of the fabric also showed promising repellent properties indicating the efficiency of microcapsules finished. So, the microencapsulation method is proved as a best method specifically for mosquito repellent finishes. The method implied in this research was found to be a unique method for imparting the bioactive compounds of the herbal composite onto fabric materials permanently.

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