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Microencapsulation of lemon grass oil for mosquito repellent finishes in polyester textiles

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ABSTRACT

Health and hygiene are the primary requirements for human beings to live comfortably and work with maximum efficiency. Mosquitoes home in on people because they give off carbon dioxide, lactic acid, body odor and heat. A mosquito repellent textile protects the human beings from the bite of mosquitoes and thereby promising safety from the diseases like malarial fever. There are many natural plant products, which show mosquito repellent properties. Extracts from roots, stem, leaves, flowers, fruits and seeds of diverse species of plants exhibit mosquito repellent properties. These extracts can be used as textile finishing agents in the crude form or as microcapsules to enhance the durability and controlled release of the extracts. Lemon grass is one such plant well known for its medicinal properties. In the present study, 100% polyester fabric was finished with lemon grass oil to check for its mosquito repellent properties. The results show that, the microencapsulated polyester fabric showed highest mosquito repellent activity (92%) when compared with the fabric finished by pad dry cure method. FTIR analysis of the microcapsules finished fabric also reveals additional functional groups imparted to the fabric by microencapsulation compared to the control.

Introduction

In today's era of modernization of the textile industry, we are going through advancements of technology in every field of this industry. The world where this would lead us would be astonishingly Hitech and materialistic. To ensure our security and safety from the future hazards, we need to equally develop the technology for our protection (Kumaravel et al., 2009). Value addition in clothing has changed the global textile scenario. A novel and holistic approach of the 21st century has been the use of microencapsulation in textile finishing. Creative designers of the 21st century want to diversify their vision from visual aesthetics to performance value like sense of smell, colour change technology, phase change materials and bactericides. Market for fragrant clothing has also been expanded and due to increase in awareness about health and hygiene people increasingly want their clothing to be hygienically fresh (Karolia and Mendapara, 2005).

A mosquito repellent textile is one such textile product came out recently. It protects the human beings from the bite of mosquitoes and thereby promising safety from the diseases like malarial fever. To impart this character, a finish of the mosquito-repelling agent is given to the textile material. Thorough research and development has facilitated the applicability of certain chemicals of the textile products, which sustain this character for a reasonable period (Pani, 2008). Basically mosquito-repelling textiles are the ones, which exhibit a character of repelling mosquitoes. This feature was developed as a need in sense of protection from the mosquitoes in which the textile material is given an anti mosquito finish. This anti mosquito bite agent is capable of being used on textiles without spoiling their characteristics and has good washing fastness.

Because of global warming the distribution of mosquitoes has expanded from tropical regions to northern latitudes, and that leads to a spread in sources of viral infection from mosquitoes. It is likely that the virus, bacteria and fungus are being arrived via wild birds imported as pets and via plane or boat in an infected mosquito. As far India is concern, the populations of mosquito are found to be enormous day by day. On an overall basis, the need is for finishing textile products to protect against mosquito transmitted viral infections such as malaria, pneumonic and other diseases. Mosquitoes can be found all over the world from the Tropics to the Arctic. Some mosquitoes can be found 200 miles from their birthplace. One species of Anopheles frequently becomes frozen but after gradual thawing revives and is capable of laying eggs. Of all the harmful creatures on earth, this little "vampire" probably poses the greatest threat to mankind. There are more than 3,450 species in the culicid, or mosquito family, worldwide and mosquito-borne diseases infect about 700 million people each year and kill 3 million according to the Centers for Disease Control.

Mosquito – borne diseases such as malaria, dengue fever and yellow fever, have plagued civilization for thousands of years. There are various kinds of mosquitoes, each of which has a different habitat, behavior and preferred source of blood. About ten of these species are so numerous and such vicious biters of man and animals, that an organized mosquito control is necessary because mosquitoes are not only a nuisance as biting

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insects, but are also involved periodically in transmitting disease to humans and animals (Gulrajani et al., 2007).

The repellent properties of plants to mosquitoes and other pest insects were well known before the advent of synthetic chemicals. However, the most commonly used insect repellents are synthetic chemicals that mostly have contained DEET (N, N-diethyl-3-methylbenzamide) in their formulations. Although DEET is an effective repellent against a broad spectrum of insects, however there are disadvantages associated with the use of DEET, which stem principally from its activity as a solvent of paints, varnishes, and some plastic and synthetic fabrics. There have also been concerns over toxicity of DEET (Oshaghi et al., 2003). A variety of botanical substances have been evaluated for their repellency against mosquitoes. Thousands of plants have been tested as potential sources of insect repellents. None of the plant-derived chemicals tested to date demonstrate the broad effectiveness and duration of DEET, but a few show repellent activities. Plants whose essential oils have been reported to have repellent activity include citronella, cedar, verbena, pennyroyal, geranium, lavender, pine, cajeput, cinnamon, rosemary, basil, thyme, allspice, garlic, and peppermint. Unlike synthetic insect repellents, plant-derived repellents have been relatively poorly studied. When tested, most of these essential oils tend to give short-lasting protection, usually less than 2 hours (Fradin, 1998). Therefore, on the basis of these findings, the present study focuses on the investigation of mosquito repellency properties of lemon grass plant.

Microencapsulation is a micro packaging technique that has traditionally involved the deposition of thin polymeric coatings on small particles of solids or liquids (Karolia and Mendapara, 2005; Li et al., 2006). Microencapsulation is a rapidly expanding technology and finds greater applicability in textiles in recent years. Uniqueness of microencapsulation is the smallness of coated particles and it provides a means of packaging, separating and storing materials on a microscopic scale for later release under controlled conditions (Thilagavathi and Bala, 2007). The properties of microcapsules, size, shape, wall material, active substance release mechanism, have had to be adapted to the requirements of textile processing methods and use of final products (Voncina et al., 2009). Some of the herbal compounds obtained from plants are well known from time immemorial as antibacterial and antifungal products. These plants and tree products are applied directly on skin or wounds as paste or ticaution either for skin care or wound healing (Sayed and Jawale, 2006). These natural products are abundantly available in nature and are widely distributed. They are cheap and not processed and can be used as raw materials for required applications. Apart from dyeing these medicinal products posses distinct odor for identification. These plant products are non-irritant to skin and non-toxic. Many of these materials are skin care products. The stem, bark, leaf, root and tuber of the plants and trees can be used for special application. Lemon grass is a medicinal plant whose leaves are widely used for many applications (Premalatha and Nagarajan, 2007). Lemongrass commonly known as "East Indian Lemongrass" is a perennial and multicut aromatic grass. The prefix 'lemon' owes to its typical lemon like odor, which is mainly due to the presence of citral, a cyclic monoterpene. Lemongrass is the source of Lemongrass oil, a good source of natural citral, which is used as a basic raw material for synthesis of β-ionone used for synthesis of a number of useful aromatic compounds and Vitamin- A. Lemongrass oil is thus used as a main substitute for 'Cod liver oil' (Hebbalkar et al., 1992). The present study was focused on the preparation and optimization of aqueous and methanolic extract from lemon grass. The prepared extracts were finished on the polyester fabric and the mosquito repellency efficiency of the fabric was tested against the microencapsulated extract finished polyester fabric.

Materials and methods

Fabric selection

The fabric used as textile substrates in the present research work was 100% polyester synthetic curtain fabric. The physical properties of the chosen fabric are given below.

Count / Denier – 66's
Ends per Inch – 92
Picks per Inch – 84

Extraction of lemon grass oil

Methanolic extraction (Bandoniene et al., 2002)

According to the fabric weight, equal amount of herbs were taken. About seven grams of medicinal plants per 100 ml of methanol was taken in an airtight conical flask at room temperature overnight. After 12 hours, the solution was filtered using cheesecloth and the filtrate was kept aside for evaporation of methanol. The amount of methanol vaporized into the environment is only under permissible limits and thus does not cause damage to the environment. The solution was filtered to get the extracted solution. According to the concentration %, the finishing solution was taken from the extracted solution and was used to finish the fabric.

Aqueous Extraction

Aqueous extracts were obtained by mixing dry powdered leaves with deionised water and leaving the mixture overnight at 20-22˚C. The mixture was then filtered through four folds of cheesecloth followed by sterile filtering through a 0.2 μm filter, before use.

Preparation of Microcapsules with Lemon Grass Oil

The microcapsules of lemon grass oil extract were prepared with sodium alginate as follows:

Encapsulation by Ionic Gelation Process (Kim et al., 1988)

Microcapsules containing lemon grass extract were prepared employing sodium alginate. 3% sodium alginate (LobaChemie, viscosity – min 45 cps) was prepared. To this, 30 ml of lemon grass extract and 10 ml of Tween 20, a surfactant agent (Polyoxyethylene (20) sorbitan monolaurate, Nice, Weight per ml at 20 ˚C, Hydroxyl no. 97-113, Saponification no. 40-51) were added to the polymer solution and mixed thoroughly to form smooth viscous dispersion. This was sprayed into calcium chloride solution by means of a sprayer. The droplets were retained in calcium chloride (Rankem, 10% wt/vol) for 15 minutes. The microcapsules were obtained by decantation and repeated washing with iso propyl alcohol followed by drying at 45 °C for 12 hours. The microcapsules were then used for finishing on the selected fabrics.

Microscopic Observation of the Microcapsules

The prepared microcapsules were observed for their structure under oil immersion objective (1000 X) of light microscope.

Finishing of the fabric with the lemon grass oil extract

Pad dry cure method

The herbal lemon grass extract was finished on the fabric by pad dry cure method using a padding mangle which was run at 15 m / min, pressure of 15 kgf / cm2 to remove excess solution. The fabric was air dried and used for checking the mosquito repellency property.

Mosquito Repellency Testing

The mosquito repellency efficiency of the fabric finished with methanolic extract, aqueous extract, microencapsulated methanolic extract and microencapsulated aqueous extract by pad dry cure method were tested using the modified excito chamber method (Roberts et al., 1997).

Mosquito Repellency Procedure (Modified Excito Chamber Method)

Mosquito collection

Anopheles mosquitoes were identified based on morphologic keys and they were collected during the evening hours. All mosquitoes were starved of blood and sugar of 4 hours before the tests.

Repellency Behavioral tests

Specially designed two excito repellency test chambers (figure 1) were used to evaluate the efficiency of repellency activity as previously described by Chareonviriyaphap et al., (2002). The wooden outer chamber of excito-repellency 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 Plexiglas glass panel with a rubber latex-sealed door, a Plexiglas holding frame, a screened inner chamber, an outer chamber, a front door, and an exit portal slot. Mosquitoes were deprived of all nutrition and water for a minimum of 4 hours before exposure. Laboratory tests were performed during daylight hours only and each test was replicated four times. Observations were taken at one-minute interval for 30 minutes. After each test was completed, the number of Escaped specimens and those remaining inside the chamber was recorded separately for each exposure chamber, external holding cage, and paired control chamber. Escaped specimens and those remaining inside the chamber, for the treated samples, were held separately in small holding containers with food and water. The percentage of Mosquito repellency was calculated by the following formula,

$$\% \text{ Mosquito repellency} = \frac{\text{No. Of specimen Escaped} + \text{No. Of specimen Dead}}{\text{No. Of specimen Exposed}} \times 100$$

Figure 1. Excito chamber used for Mosquito repellency testing

FTIR Analysis of The Microcapsule Finished Fabric

The microcapsule finished polyester fabric was subjected to FTIR (Fourier Transform Infra Red spectroscopy) analysis and the results were compared with the unfinished fabric.

Wash Durability Test

The lemon grass oil extract finished fabric was then subjected to 15 industrial washes and the washed fabric was tested for its mosquito repellency efficiency using the modified excito chamber method.

Results and discussion

The lemon grass oil extract was microencapsulated using sodium alginate. The prepared microcapsules were analyzed using a light microscope to determine the structure of microcapsules (figure 2). The lemon grass oil extract was tested for its mosquito repellency efficiency. The results are presented in table 1. The results indicate that the fabric treated with microencapsulated extract by pad dry cure method has the highest mosquito repellent activity compared to fabric treated with the extract by wet type dip method

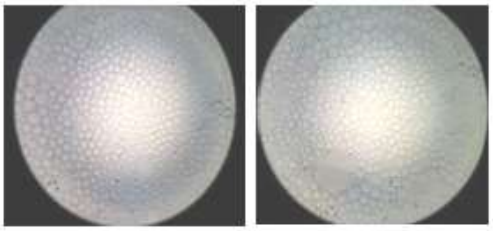

Figure 2. Microcapsules of Lemon grass oil extract under light microscope (A – Aqueous extract, B – Methanolic extract)

The results show that the mosquito repellent activity was highest for the fabric finished with microcapsules of aqueous lemon grass oil extract compared to the fabric finished with the microcapsules of methanolic lemon grass oil extract. Similar results were obtained by Oloyede (2009). But the mosquito repellent efficiency was moderate for the fabric finished with the extracts by wet - type - dip method i.e., 56% and 72% respectively for the methanolic and aqueous extracts. The mosquito repellent activity for the fabrics was determined by examining the mortality rates of the mosquitoes after exposure to the oil extracts. In all the trials, mortality was observed in escaped females from all treatments, except for the control sample. The FTIR analysis of the microcapsule-finished fabric is presented in figure 3. The results indicate that compared to the unfinished polyester fabric, the microcapsules finished fabric has additional peaks in the wavelength region of 2000 - 3600 nm^{-1}.

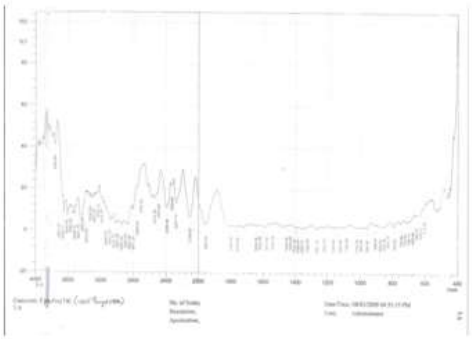

Figure 3a. FTIR pattern of unfinished polyester fabric

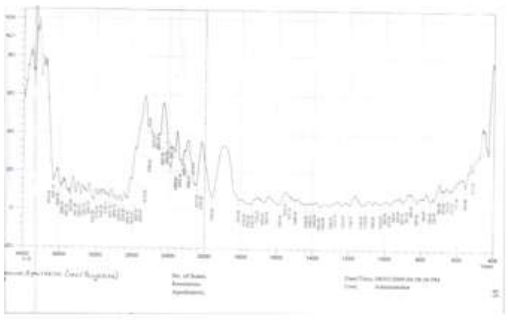

Figure 3b. FTIR pattern of microcapsules finished polyester fabric

Noosidum *et al*., (2008) compared the behavioral responses of *Aedes aegypti* females to essential oils extracted from native plants *Melaleuca leucadendron* (ML), *Litsea cubeba* (LC), and *Litsea salicifolia* (LS) by using an excito-repellency test chamber. Mortality of *Ae. aegypti* females following 24 h holding period post-contact and non-contact trials were observed. No mortality was seen in escaped mosquitoes after direct contact with essential oils ML and LS, and low mortality (2.3–20.4%) with LC. Likewise, in all non-contact trials, no mortality was observed in escaped females from all three treatments, whereas low mortality was seen in non-escaped mosquitoes exposed to LC (0–14.3%) and LS (0–17.1%). *Ae. aegypti* showed significantly higher escape rates from contact chambers treated with ML and LC compared to LS, regardless of test concentrations ($P<0.05$). Non-contact repellent responses were significantly pronounced with LS, except at the highest (6.0%) concentration.

Conclusion

Herbs are available in nature abundantly. A major part of the total population in developing countries still uses traditional folk medicine obtained from plant resources. Biologically active compounds present in the medicinal plants have always been of great interest to scientists working in this field. The application of herbal oils on apparel fabrics will give added protection from different organisms present in air. At close range, skin temperature and moisture serve as attractants for mosquitoes. The present study focused on the mosquito repellency efficiency of the lemon grass plant. Both the aqueous and methanolic extracts were finished on the polyester fabric and the mosquito repellency rate was tested by improved excito chamber method. The microencapsulated lemon grass oil extract was also studied for its repellency abilities and compared with the extract finished fabrics. The results showed 92% repellency activity for the polyester fabric finished with the lemon grass aqueous extract microcapsules. Whereas, the polyester fabric exhibited only 80% mosquito repellency activity finished with methanolic microcapsules of lemon grass leaves. From the above result the natural material, Lemongrass oil is being capable of repelling mosquito on the fabric to a greater extend. The study can thus be concluded that lemon grass oil extract exhibit significant irritant and repellent properties and deserve further investigation for possible use as active ingredients in topical skin and indoor dispersed repellent systems. In India thousands of species are known to have medicinal value and the use of different parts of several medicinal plants to cure specific ailments has been in vogue since ancient times. These herbal products are eco-friendly and quite stable for prolonged timed period. Therefore, with the above findings, it would be helpful for the scientific community in finding the right durable and reusable textiles for various medical applications.

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Table 1. Results of Mosquito repellency test for 100% Polyester fabric

S. No.	Fabric sample	No. Of specimen Exposed	No. Of specimen in the cage	No. Of specimen Escaped	No. Of specimen Dead	Mosquito Repellency in %
1	Control	25	25	0	0	0
2	Fabric sample finished with the methanolic extract by pad dry cure method	25	10	8	7	60
3	Fabric sample finished with the aqueous extract by pad dry cure method	25	6	9	10	76
4	Fabric sample finished with the microencapsulated methanolic extract by pad dry cure method	25	5	12	8	80
5	Fabric sample finished with the microencapsulated aqueous extract by pad dry cure method	25	2	6	17	92
6	Fabric sample finished with the microencapsulated aqueous extract by pad dry cure method (after 15 washes)	25	4	6	15	84