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TULSI EXTRACT MOSQUITO REPELLENCE FINISHES APPLIED ON COTTON FABRICS WITH PAD DRY CURE AND MICROENCAPSULATION

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Mosquito-borne diseases pose a major public health concern worldwide. There are some preventive measures, such as sprays, creams, roll-ons and coils, as traditional methods that have both synthetic chemicals and plant-based ingredients to reduce the transmission of mosquito-borne diseases. To improve prolonged mosquito repellent with minimal harmful chemicals, researchers have shifted towards mosquito repellent textiles such as bedsheets, curtains, clothing, etc., with natural plant-based extracts. The main objective of this research was to develop a mosquito repellent finish using Tulsi (*Ocimum tenuiflorum*) plant extract. Bleached 100% cotton fabric was dyed in black colour using reactive dye to attract more mosquitoes, and the dyed fabric was used as the control sample. Tulsi leaf extract and Tulsi powder extract were applied separately to dyed cotton fabrics using the Pad-Dry-Cure method. Samples treated with Tulsi leaf extract and Tulsi powder extract exhibited 60% and 90% repellence, respectively. Due to the greater repellence behaviour of Tulsi Powder, the sample treated with Tulsi powder was subjected to washing cycles, and repellence was dropped to 10% after ten washing cycles. To enhance the mosquito repellence behaviour, fabric samples were treated with microencapsulated Tulsi at 20ml and 30ml concentrations of Tulsi powder extracts. Fabric treated with microencapsulated 20ml of Tulsi extract showed 50% initial mosquito repellence, which reduced to 20% after ten washing cycles. In contrast, a fabric sample treated with microencapsulated 30ml of Tulsi extract exhibited 90% initial repellence, reducing to 40% after ten washing cycles. After ten washing cycles, the Pad-Dry-Cure-treated sample showed a gray scale rating of 1-2, and the microencapsulated sample that used 30ml Tulsi extract showed improved performance with a gray scale rating of 3-4 for colourfastness. Fourier Transform Infrared (FTIR) spectroscopy confirmed the presence of bioactive compounds of Tulsi on the fabric surface after being subjected to repeated washing cycles. Therefore, it is recommended that the microencapsulation method with 30ml Tulsi extract as a mosquito repellent finish for cotton fabrics, based on the results obtained in this research work. However, further investigations are to be carried out varying parameters such as the concentration of Tulsi, fabric types and application method to enhance the effectiveness of mosquito repellence.

Keywords: Tulsi, *Ocimum tenuiflorum*, mosquito repellent finishes, Fourier Transform Infrared (FTIR), microencapsulation

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INTRODUCTION

Mosquito-borne diseases such as dengue, malaria, chikungunya and yellow fever-like diseases pose significant health risks. According to the World Health Organisation, over 700 million people are infected, and more than 700,000 have died due to these diseases. In tropical countries like Sri Lanka, mosquitoes get favourable conditions like warm, high humidity and seasonal monsoons for breeding, which ultimately lead to dengue fever, one of the most serious mosquito-borne diseases recorded in Sri Lanka. In 2017, it was reported that over 186,000 cases and 440 deaths as the largest record.

Traditional methods of mosquito control, such as creams, roll-ons, and sprays, which are made from citronella, clove, babul, eucalyptus, cedarwood, peppermint, cinnamon, lemongrass, etc., often rely on synthetic chemical repellents. But they may cause adverse skin reactions like irritations, allergies, environmental concerns and also require re-applications to maintain long-term effectiveness. Due to these reasons, it has been focused on the mosquito repellent textile products such as mosquito repellent clothing, blankets, bedsheets, curtains, etc. that are more effective, long-lasting and safer to use even for sensitive people [Afaf Farag et al., 2011]. While producing mosquito repellent clothing, it uses plant-based extractions as well as DEET (N, N-diethyl-m-toluamide), permethrin, and picaridin, like non-eco-friendly and non-biodegradable synthetic agents. These synthetic agents have toxicological profiles that cause tingling, burning, and itching on human skin [Norris & Coats, 2017] and contribute to environmental pollution. In response, the researchers have turned to plant-based extracts to develop mosquito repellent cloth [Tseghai, 2016].

Tulsi (*Ocimum tenuiflorum)* plant is one of the best mosquito repellent plants, which is also known as holy basil in English and has been used for ayurvedic medication for over 3000 years. It belongs to the Lamiaceae family and is rich in compounds such as eugenol, linalool, ursolic acid and carvacrol, which have mosquito repellent effects. Therefore, there may be a possibility of applying Tulsi extract on fabrics as finishes to provide a sustainable and eco-friendly solution for mosquito repellency. This research study focused on the application of Tulsi extract on 100% cotton fabrics using the Pad-Dry-Cure method and microencapsulation method and assessed the mosquito repellency property and colour fastness property.

METHODOLOGY

The following steps were carried out in this research work.

1. Scoured and bleached 100% cotton fabric (GSM=108.67g/m^2) was dyed in black colour to attract mosquitoes.
2. Bioactive compounds were extracted from Tulsi leaves and dehydrated Tulsi powder using methanol and the evaporation method.
3. Dyed cotton fabric samples were treated with Tulsi extracts obtained through different extraction methods using the Pad-Dry-Cure method and microencapsulation method.
4. Initial mosquito repellency was tested using the chamber test method.
5. Colour fastness to washing was done ISO 105 C06 standard, and FTIR analysis was carried out to find the fastness properties and chemical interactions of Tulsi-treated fabric samples.

Preparation of cotton fabric

Cotton fabric was subjected to scouring and bleaching to prepare the substrate for dyeing. Then the fabric was dyed in black colour to enhance its attractiveness to mosquitoes using a dye bath containing 4% reactive dye in black colour, 2 ml/L of wetting agent, 60 g/L of salt, 18 g/L of soda ash and 200 ml of distilled water. Dyeing was carried out at 60˚C for 90 minutes under continuous agitation to ensure even dye uptake.

Methods of Tulsi extractions

Method A– 10g of fresh Tulsi leaves were treated with 100ml of methanol, and the solution was extracted from the evaporation process after two weeks.

Method B– Fresh Tulsi leaves were dehydrated and ground into powder. 10g of Tulsi powder was mixed with 200ml of methanol, and the solution was kept at room temperature without exposure to sunlight for two weeks. The solution was extracted from the evaporation process.

Pad-Dry-Cure method

Pre-treated and dyed cotton fabrics were treated with 20ml/*l* of extracted Tulsi solution with 1*ml*/*l,* citric acid ($C_6H_8O_7$), 30g/*l* salt (NaCl) & 1ml/*l* wetting agent using the Pad-Dry-Cure technique. Then the fabric was dried at 100˚C. The curing process was done at 160˚C temperature for 03 minutes.

Microencapsulation

Tulsi extracts made from method B were mixed with 3% of the solution with sodium alginate. The prepared solution was sprayed into a calcium chloride solution to form droplets, and the droplets were retained for 15 minutes in calcium chloride to harden the capsules through ionic gelation. The microcapsules were collected by decantation and washed thoroughly with isopropyl alcohol, followed by drying at 45ºC for 12 hrs.

Application of microencapsulated Tulsi to the fabric

The dyed cotton fabric was immersed in the microcapsule solution at a temperature of 50°C. After 30 minutes of duration, the fabric was removed and squeezed to remove excess liquid. Then it was dried at 80°C for 5 minutes, and the fabric was cured at 120°C for 2 minutes to fix the microcapsules onto the fabric.

Preparation of the excito chamber

The excito chamber was made with a front and an exit panel, occupied with a single escape portal. The chamber was built up with a screened inner chamber, a glass holding frame and a door cover. Dimensions of the chamber were 34 cm x 32 cm x 32 cm, and a small camera was installed inside the chamber to observe the behaviour of mosquito reactions. The behaviour of mosquito was observed in terms of the number of mosquitoes that escaped to another space and the mosquitoes that remained inside the chamber, which was filled with treated product. The observation is recorded after 10 and 30min exposure. Figure 1 shows the illustrated representation of the prepared excito chamber.

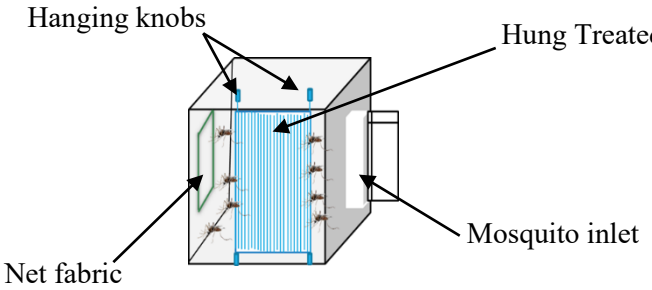


Figure 1: Excito chamber

TESTING OF TREATED FABRIC

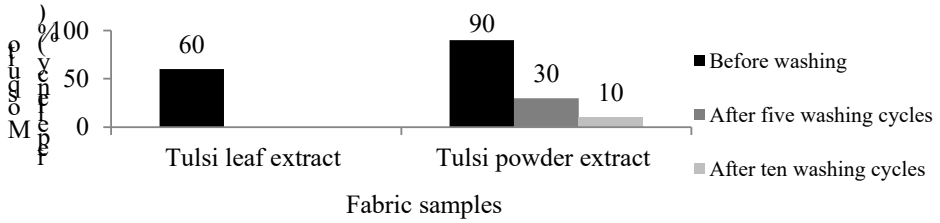
Repellency test: The experiment included untreated dyed cotton fabric as the control sample. Then, two samples were prepared by treating with Tulsi leaf extract and Tulsi powder extract by the Pad-Dry-Cure method, and mosquito repellence was tested before washing. The powder extraction method was then selected as the best extraction method. Then two samples were prepared by microencapsulated Tulsi powder extract at 20ml and 30ml, and mosquito repellence was tested before washing and after ten washing cycles.

The percentage of repellence was calculated using the following formula [Anuar & Yusof, 2016],

$$\text{Mosquito Repellence (\%)} = \frac{\text{no. of mosquitoes escaped + no. of mosquitoes dead x 100}}{\text{no. mosquitoes inlet}}$$

RESULTS AND DISCUSSION

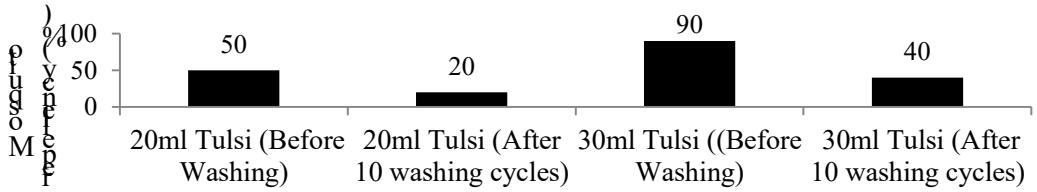
Untreated dyed cotton fabric sample attracted more mosquitoes with minimal escape behaviour, and it exhibited 0% mosquito repellence, which confirmed that dyed untreated cotton fabric (without applying Tulsi extract) has no repellence effect. The dyed cotton fabric treated with Tulsi leaf extract using the Pad-Dry-Cure method exhibited 60% mosquito repellence, while the fabric treated with Tulsi powder extract using the Pad-Dry-Cure method exhibited 90%. The reason could be the more bioactive compounds in the powdered form of Tulsi. Due to the high mosquito repellence of fabric treated with Tulsi powder extract, it was subjected to washing cycles. After five washing cycles, repellence dropped to 30% and after ten washing cycles, repellence was 10%. These results indicate the weak binding affinity of bioactive compounds. The reason would be that the extracts are only coated on the surface of the fabrics without any bonding or fixation to the fabric structure, and due to this, the Tulsi extracts are removed during repeated washings. Further, the colour fastness to washing test was carried out to evaluate the durability of the treated sample after ten washing cycles, and it showed a gray scale rating of 1-2, indicating poor



wash fastness properties. Figure 2 shows the mosquito repellence percentage of fabric samples treated with the Pad-Dry-Cure method compared to the control sample.

Figure 2: Mosquito repellency of fabric samples treated with Pad-Dry-Cure method

Therefore, the microencapsulation method was investigated to improve the mosquito repellence ability. It was used Tulsi powder extracts for microencapsulation due to the high concentration of bioactive compounds in the powdered form. Figure 3 shows the mosquito repellence behaviour of cotton fabric samples treated with



microencapsulated Tulsi at 20ml and 30ml concentrations of Tulsi powder extracts before and after 10 washing cycles. The sample treated with 20ml extracts exhibited 50% initial repellence, and it decreased to 20% after ten washing cycles. In contrast, the fabric sample treated with 30ml extracts exhibited 90% initial repellence, and it decreased to 40% after ten washing cycles. The findings indicate that increasing the concentration increases the mosquito repellent effect before and after washing. The reason would be the higher extract volume and greater retention of bioactive

compounds such as eugenol, ursolic acid and linalool of Tulsi on the fabric. To evaluate the colour stability of the sample, which used encapsulated 30ml of Tulsi extract, was tested, and it showed 3-4 gray scale values after 10 washing cycles. It ensures that the microencapsulation method did not affect the shade of the fabric.

Figure 3: Mosquito repellency of fabric samples treated with the microencapsulation method

Figure 4 shows the FTIR (Fourier Transform Infrared) spectroscopy analysis for cotton fabric treated with 30ml of Tulsi extracts before and after 10 washing cycles. It shows the treated sample with microencapsulated Tulsi, before being subjected to the washing, showed peaks around 3300cm^{-1}, 1600 cm^{-1} and 1200 cm^{-1}, and these indicate the presence of O-H stretching, C=C stretching, and C-O stretching, which are present in Tulsi bioactive compounds. Those peaks were still detected on treated cotton fabric after 10 washing cycles. These results show successful of the microencapsulation method, and they indicate that the microencapsulation method helps in the retention of Tulsi bioactive compounds, which supports the sustained mosquito repellent of the fabric after repeated washing.

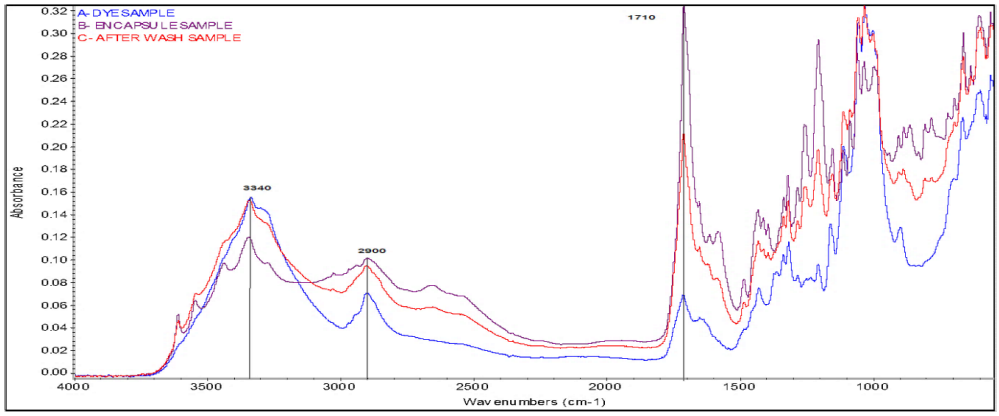


Figure 4: FTIR results of cotton fabric treated with 30ml of Tulsi extracts with microencapsulation

CONCLUSIONS

This research was carried out to investigate the mosquito repellency behaviour of Tulsi extract applied on cotton fabrics using Pad-Dry-Cure and microencapsulation methods. The sample treated with Tulsi leaf extract showed poor mosquito repellency compared to the sample treated with Tulsi powder extract when using the Pad-Dry-Cure method to apply. But the sample treated with Tulsi powder extract showed poor wash durability and colour stability after ten washing cycles.

To improve the mosquito repellency and wash durability, the microencapsulation method was applied. It was used 20ml and 30ml concentrations of Tulsi powder. According to the results of mosquito repellency before washing and after washing, it was confirmed that the higher extract concentration enhances both initial efficacy and wash durability due to the retention of bioactive compounds of Tulsi such as eugenol,

ursolic acid and linalool. Furthermore, the sample treated with 30 ml microencapsulated Tulsi showed good colour stability after ten washing cycles with a gray scale rating of 3-4. According to the results of FTIR analysis, it confirmed the presence of bioactive compounds of Tulsi on the treated fabric sample with microencapsulated Tulsi powder after repeated washing cycles. These findings will be very useful to develop a durable, more effective, sustainable alternative to synthetic repellents. Further studies can be carried out by changing the concentrations.

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