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# Herbal functional finishes on cotton textiles to encounter bacteria and mosquitoes

**Padma Alapati and Khateeja Sulthana Shaik**

**Abstract**
Concern on synthetic usage have been increased and led to find the alternatives sources that are eco-friendly in nature. One of such kind can be found in herbal sources, considering the benefits of plant sources leafs of *Nepeta cataria, Lantana camara, Azadirachta indica, Eucalyptus obliqua* leafs and Nyctanthes Arbor-tristis flowers were selected. The Total Phenolic Content of the sources was tested and then based on local availablity Minimum Inhibitory Concentrations of *Nepeta cataria* and *Lantana camara* were analysied against *S. aurus* and *E. coli*. Later, these sources were treated on cotton textiles with direct and pad-dry-cure methods which were later tested for their antimicrobial and mosquito repellency potency which was found to be good with around 1.4 ZOI and 80 percent respectively. Fabric performance was also analysed and observed no major difference in all the parameters when compared to control ones.

**Keywords:** Plant extracts, cotton fabric, functional finishes, anti-bacterial, and mosquito repellency

## Introduction
Today's generation is more focused on health and hygiene. Owing to their low cost, with the changing decades, artificial and synthetic materials have over taken the natural resources, especially in the textile sector. These alterations in textile industries have adversely affected the environment as well as human beings with their non-biodegradable characteristics that create a pollution load. Hence, now it is necessity to have wide range of textile products finished with biodegradable finishes. The most common types of finishes given to the textiles are UV protection, sustained medicine release (antiseptic and aroma finishes) and microbial resistance etc. Due to the inherent structure, the cotton fiber facilitates the microorganisms to grow. In addition, humid and optimum temperatures occurred due to perspiration and different environmental exposures, assist microbes to aggravate (Bossard, 1997) [3].
Apart from microorganisms, mosquitoes are one such insect which are very harmful to human kind. Fradin and Day, 2002 [4], Shahid and Mohammad, 2013 [12] in their article stated that Mosquito transmitted diseases can make a person illness and can lead to death in worst cases. Folks get rid of them by using mosquito repellent sources like liquid vaporizers, smart cards, lotions, etc. Prathyusha Kantheti *et al*. (2018) [8] described that use of synthetic mosquito repellent sources are carcinogenic and poses may cancerous diseases. With the time, however, these sources least affect them as the mosquitoes are getting intelligent to sustain to repellent products. As per Krishnaveni (2009) [6] and Anuar and Yusof, 2016 [1], the key strategy to control or minimize the mosquito borne diseases, is to prevent their bites. According to Kanwar Varinder pal singh (2004) and Dr Naresh M. Saraf (2011) weather a chemical or herbal repellent, the significant role of Repellent Insecticides is to repel insects and pests than killing them. An innovative way to drive the mosquitoes away can be achieved through textile fabric with mosquito repellent property (Rajendran Ramasamy 2014) [10-11]. The people have been using plant remedies against various ailments from time immemorial without knowing their effective constituents (Selvadurai *et al.*, 2013), however, there is a drastic increase in the usage of herbal medicine was found in last few years from the developed countries.
Considering these, in the recent, scientists and researchers are keener in identifying eco-friendly functional finishes for textiles which caters to modify characteristics of the material by surface application. This created a worldwide interest to study different plant extracts. With a view to overcome the utilization of synthetic substances which can create burden to eco-system, the present study is conducted on finishing cotton fabrics with locally available plant sources with potential antimicrobial activity with good mosquito repellent efficacy.

## Methodology

### Selection and processing of herbal sources

Based on the secondary data, five herbal plant sources (leafs of *Nepeta cataria, Lantana camara, Azadirachta indica, Eucalyptus oblique* and flower of *Nyctanthes arbor-tristis*) were selected having functional properties that include antimicrobial, mosquito repellency, aroma and UV protection characteristics for textile application. These five sources are locally (in and around Hyderabad) available herbal sources were collected, cleaned from impurities and shade dried. The moisture content and yield of the sources were noted through shade dry method. Late, these were crushed, sieved for fine powder and stored aseptically for further usage. The sources were extracted through aqueous and ethanolic (70%) procedures.

### Testing of herbal extracts

These extracts were assessed for Total Phenolic Content (TPC) through Gallic Acid Equivalence method (GAE) as determined by using the Folin-Ciocalteu assay method (Singleton and Rossi, 1965). Further, two sources (*Nepeta cataria* and *Lantana camara*) were finalized to evaluate Minimum Inhibitory concentrations (MICs), Tripathi, 2013[14].

### Treatment of herbal extracts to cotton textiles

After determining MICs of the extracts, the potential concentrations were used to treat on cotton fabrics. The extracts were treated to Desized-cotton textiles (Sumithra and Raaja, 2013) [13] by means of 'Direct method' and 'Pad-dry-cure method' with and without cross linking agent (citric acid), Selvi and Rajendran, 2014 [10-11].

### Analysis of functional finished fabrics

The treated fabrics were analyzed for its Antimicrobial property through AATCC 147 method against gram positive and gram negative bacterial *S. aureus* and *E. coli*; Performance characteristics such as thickness, count, GSM, strength and elongation; and Mosquito repellent property through Cage Test method (Priyadarshinirajkumar A and Vasugi Rajaa N, 2015) [9]. The wash durability was also tested to check the efficacy of antibacterial and mosquito repellent properties.

## Results and Discussion

### Herbal source's moisture content and yield

**Table 1:** Yield of dried sources and moisture content sources

| Plant Source | Common/local Name | Raw Weight of the fresh source (gms) | Yield of dried sources(gms) | Moisture content (%) |
|---|---|---|---|---|
| *Nepeta cataria* leafs | Catnip | 100 | 27.5 | 72.5 |
| *Lantana camara* leafs | Lantana | 100 | 39.1 | 60.9 |
| *Azadirachta indica* leafs | Neem | 100 | 41.7 | 58.3 |
| *Eucalyptus obliqua* leafs | Eucalyptus | 100 | 65.1 | 34.9 |
| *Nyctanthes arbor-tristis* flowers | Parijatham | 100 | 16.7 | 83.3 |

Table 1 illustrates weights of herbal sources, before and after processing. A notable difference in the reduction of weight was found for *Nyctanthes Arbor-tristis* flowers, weighed about 16.7grams with around 83.3percent of moisture content followed by *Nepeta cataria* by 27.5grams and 72.5 percent moisture. Post weights of *Lantana camara* and *Azadirachta indica* leaf are close to each other with around 40 grams with about 60 percent moisture content. The dry weight of *Eucalyptus Oblique* leafs are 65.1grams around with the vice versa moisture content of 34.9 percent which is the least moisture content among the other four herbal sources.

### Yield of aqueous and ethanol extracted extracts

**Table 2:** Yield of extracted sources

| Plant Source | Yield of extracts (ml/50ml) with | |
|---|---|---|
| | 70% Ethanol | Distilled water |
| *Nepeta cataria* leafs | 42.5 | 40 |
| *Lantana camara* leafs | 36 | 35 |
| *Azadirachta indica* leafs | 42.5 | 41 |
| *Eucalyptus obliqua* leafs | 43 | 43 |
| *Nyctanthes arbor-tristis* flowers | 45 | 44 |

The yield of 70% ethanolic and aqueous extracted sources were noted and found similar measurements. *Lantana Camara* leafs being lowest yielded around 36ml per 50ml and highest be the *Nyctanthes Arbor-tristis* flowers. A nominal measurement of around one to one and half milliliter increase in the yield was observed in *Ethanolic* extracts for all the sources, as depicted in table 2.

### Total phenolic content of the herbal extracts

Table 3 reveals that the *Eucalyptus obliqua* extracted with Ethanol have high TPC with 72.67 mg/g GAE followed by *Nepeta cataria* (46.78 mg/g GAE) and *Azadirachta indica* (39.83), where *Nyctanthes arbor-tristis* (10.87) and *Lantana camara* (19.78) have shown moderate results. Compared to Ethonolic extracted sources, about 20 percent decrease in TPC was found for aqueous extracted *Nepeta cataria* and *Eucalyptus Obliqua* leaf sources, where the decline of about 10 percent was observed for *Lantana camara* an *Azadirachta indica* and no change was observed for *Nyctanthes arbor-tristis* flowers.

**Table 3:** Total phenolic content (TPC) of plant extracts

| Plant source | Total Phenolic Content (mg/g dried source) – (GAE) | | DMRT rating | |
|---|---|---|---|---|
| | 70% ethanol | Distilled water | Ethanol | Aqueous |
| *Nepeta cataria* | 46.78 | 29.06 | $46.78 \pm 2.49^{BC}$ | $29.06 \pm 2.04^{D}$ |
| *Lantana camara* | 19.78 | 27.41 | $19.78 \pm 1.33^{E}$ | $27.41 \pm 1.36D^{E}$ |
| *Azadirachta indica* | 39.83 | 28.81 | $39.83 \pm 0.25^{C}$ | $28.81 \pm 1.28^{D}$ |
| *Eucalyptus obliqua* | 72.67 | 52.11 | $72.67 \pm 2.38^{A}$ | $52.11 \pm 2.14^{B}$ |
| *Nyctanthes arbor-tristis* | 10.87 | 10.97 | $10.87 \pm 1.28^{F}$ | $10.97 \pm 1.37^{F}$ |

*Duncan's Multiple Range Test (DMRT)

According to DMRT results, *Eucalyptus obliqua* leaf was graded as first followed by *Nepeta cataria* leafs. As the *Nepeta cataria* and *Lantana camara* leafs are weed plant and also have high potential towards mosquito repellency, these sources were selected for further study.

**Minimum Inhibitory Concentrations**

MICs of *Nepeta cataria* and *Lantana camara* were depicted in the table 4. MIC for *Nepeta cataria* is recorded for 4$^{th}$ and 3$^{rd}$ dilution of the extract against *E. coli* and *S. aureus* respectively. MIC for *Lantana camara* is 7$^{th}$ and 8$^{th}$ dilution of the extract against *E. coli* and *S. Aureus* respectively. That means, it required 4% and 3% of *Nepeta cataria* stock solution is required to fight against *E. coli* and *S. aureus* bacteria. Hence, it can also be stated that less percent of stock solution is required to fight against Gram-positive bacteria than Gram-negative bacteria. Plate 1.1 to 1.4 also portrays the MICs for the extracts.

**Table 4:** Minimum Inhibitory Concentration of Herbal extract against cultures

| Type of culture | Herbal extract | Minimum Inhibitory Conc. (Turbidity/ no turbidity) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| *S. aureus* | *Nepeta cataria* | | | ✓ | | | | | | | | |
| | *Lantana camara* | | | | | | | | ✓ | | | |
| *E. coli* | *Nepeta cataria* | | | | ✓ | | | | | | | |
| | *Lantana camara* | | | | | | | ✓ | | | | |

**Table 2.2b:** Minimum Inhibitory Concentration of Herbal extract against cultures

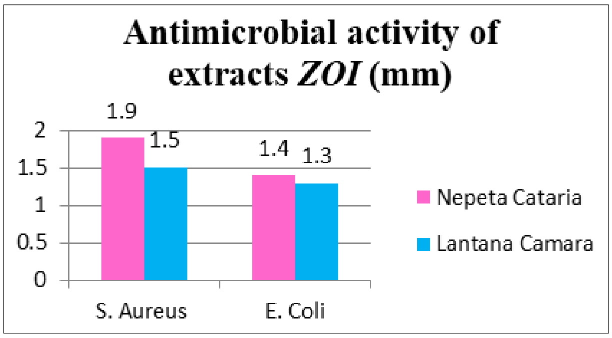
| Type of culture | *S. aureus* | | *E. coli* | |
|---|---|---|---|---|
| Source | *Nepeta cataria* | *Lantana camara* | *Nepeta cataria* | *Lantana camara* |
| MIC photo |  Plate 1.1 |  Plate 1.2 |  Plate 1.3 |  Plate 1.4 |
| MIC (%) | 3 | 8 | 4 | 7 |

**Antibacterial activity of the herbal treated samples**

Natural fibers are easy targets for microbial attack because they retain water readily and microbial enzymes can readily hydrolyze their polymer linkages. Cotton, wool, jute and flax are reported to be most susceptible to microbial attack (Yau, 1998).

**Table 2.6:** Antibacterial activity of extracts

| Name of the plant source | Antibacterial activity of extracts *ZOI* (mm) | |
|---|---|---|
| | *S. aureus* | *E. Coli* |
| *Nepeta cataria* | 1.9 | 1.4 |
| *Lantana camara* | 1.5 | 1.3 |




**2.3a:** Antimicrobial activity of the extracts

The extracts of the sources have shown extremely good antibacterial activity against *S. aureus* than *E. coli* with 1.9 and 1.4 for *Nepeta cataria* and 1.5 and 1.3 for *Lantana camara* respectively, as per the data in the table 2.6 and figure 2.3a. This depicts the presence of potential antibacterial content in the selected sources. Hence, the sources were treated to cotton fabric with selected sources and finishes which were later evaluated for Antibacterial activity, Performance characteristics and Mosquito repellent efficacy.

**Antibacterial activity of herbal treated fabrics**

The antibacterial activity of treated samples against gram positive bacteria is more than the gram negative bacteria. Compared to samples treated with pad-dry-cure method, direct method application has shown good activity with Catnip about 1.5 to 2mm *ZOI* against *S. aureus* and *E. coli* respectively and with Lantana around 1.1mm against *E. coli* and 2.5mm *ZOI* against *S. aureus*. Lantana treated samples have shown high ZOI than Catnip treated samples with around 2.4 to 2.8 for *S. aureus* and 1.1 to 1.7 mm for *E. coli*. If given a closure look, the table reveals that Citric Acid treated samples have encountered greater *ZOI* than the control samples, as shown in table 2.7 and figure 2.3b.

**Table 2.7:** Antibacterial activity of herbal treated fabrics

| Name of the plant source | Cross linking agents | Antibacterial activity of treated fabrics *ZOI* (mm) | | | |
|---|---|---|---|---|---|
| | | *S. aureus* | | *E. coli* | |
| | | Direct method | Pad-dry-cure method | Direct method | Pad-dry-cure method |
| *Nepeta cataria* | Extract without CLA | 2 | 1.6 | 1.5 | 1.4 |
| | Extract with Citric acid | 2.1 | 2 | 1.7 | 1.5 |
| *Lantana camara* | Extract without CLA | 2.5 | 2.4 | 1.1 | 1.1 |
| | Extract with Citric Acid | 2.8 | 2.5 | 1.2 | 1.2 |

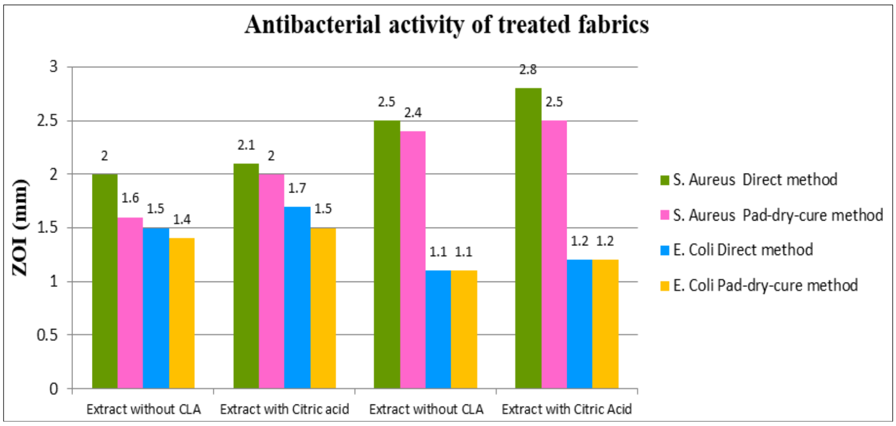



**Fig 2.3b:** Antibacterial activity of the treated fabrics

**Wash durability of herbal treated fabrics against cultures**

The herbal finished samples have high antibacterial activity, from the results, it is evident that with the repeated launderings treated samples have witnessed loss of antibacterial properties (see table 2.7a and 2.7b). Certainly, the activity against *S. aureus* has retained up to 15 wash cycles that means the samples can fight against microorganism even after ten to fifteen washes. Similarly, after wash cycles, the efficiency of Pad-dry-cure treated samples have lasted more than direct method treated samples. Though the wash durability is preserved after wash cycles, the activity against *S. aureus* is more than *E. coli*, as shown in figure 2.3c and 2.3d. Thilagavathi *et al.* (2005) conducted an experiment on development of antimicrobial textile finishes from plant species. Neem leaves, pomegranate rind and pickly chaff flowers were used on the cotton fabric. When tested for antimicrobial activity through parallel streak method (AATCC Test Method 147-1988), agar diffusion method, challenge test and digging soil test, the wash durability (2, 4, and 6 wash cycles) of the finished fabrics was noticed to be having 50 per cent of the activity up to 6 washes. A study conducted by Harini *et al.* 2007 [5], on 'Checkmate on microbes', have shown good resistant to *aureus and Staphylococcus epidermidis* even after fifty launderings for desized, scoured and bleached cotton printed cloth immersed in an aqueous solution of 15.8 per cent $Zn(OAc)_2.H_2O$, 14.0 per cent $H_2O_2$ and 13.7 per cent HOAc, padded to a wet pick up of 108 per cent undergo in-situ polymerization on cellulose.

**Table 2.7a:** Wash durability of herbal treated fabrics against *S. Aureus*

| Name of the plant source | Cross linking agents | Wash durability of treated fabrics *ZOI* (mm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Direct method | | | Pad-dry-cure method | | |
| | | 5th | 10th | 15th | 5th | 10th | 15th |
| *Nepeta cataria* | Extract without CLA | 1.2 | 0.8 | 0.1 | 1.3 | 1.1 | 0.2 |
| | Extract with Citric acid | 1.5 | 1.1 | 0.2 | 1.9 | 1.1 | 0.3 |
| *Lantana camara* | Extract without CLA | 2.0 | 1.4 | 0.5 | 2.0 | 1.2 | 0.1 |
| | Extract with Citric Acid | 2.2 | 1.5 | 0.5 | 2.5 | 1.25 | 0.8 |

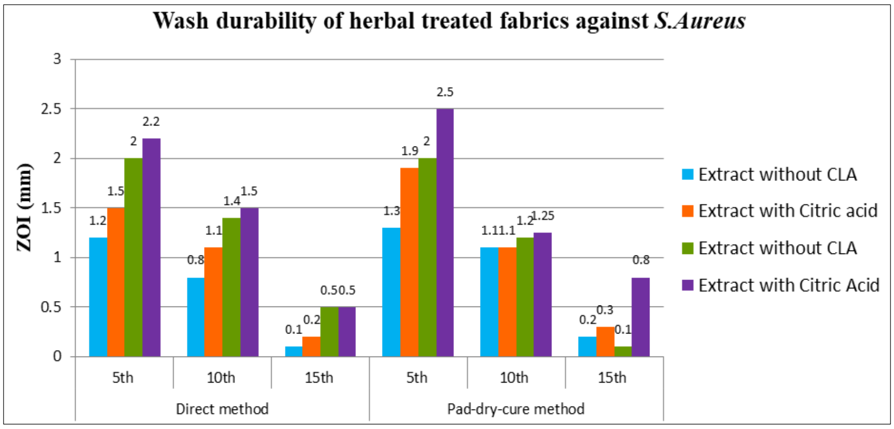



**Fig 2.3c:** Wash durability of herbal treated fabrics against *S. aureus*

**Table 2.7b:** Wash durability of herbal treated fabrics against *E. coli*

| Name of the plant source | Cross linking agents | Wash durability of treated fabrics *ZOI* (mm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Direct method | | | Pad-dry-cure method | | |
| | | 5th | 10th | 15th | 5th | 10th | 15th |
| *Nepeta cataria* | Extract without CLA | 0 | 0 | 0 | 0 | 0 | 0 |
| | Extract with Citric acid | 1.5 | 0 | 0 | 1.3 | 0 | 0 |
| *Lantana camara* | Extract without CLA | 0 | 0 | 0 | 0 | 0 | 0 |
| | Extract with Citric Acid | 1 | 0 | 0 | 1 | 0 | 0 |

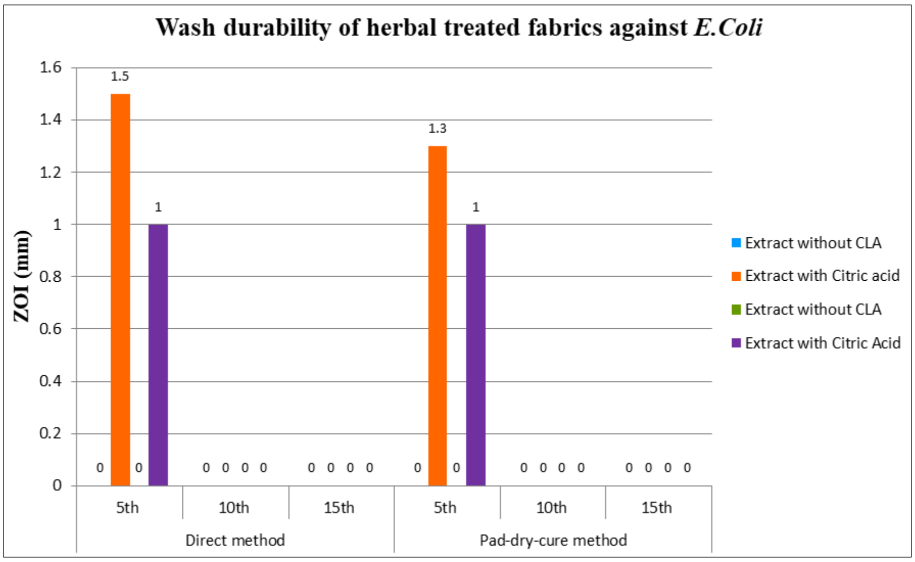



**Fig 2.3d:** Wash durability of herbal treated fabrics against *E. coli*

**Performance of the herbal treated fabrics**

**Thickness:** Least being the control sample, there was no significant difference in the thickness of the treated samples, where a surge in the citric agent samples was noted. Slight decrease in the measurement, compared to control and direct method, was observed for Pad-dry-cured samples (as in table 2.5 and figure 2.2a).

**Count:** Samples treated with both type of extracts has showed no change in the weft yarns count compared to control, whereas, there is a difference of single yarn was observed between direct method and pad-dry-cue method of warp yarns, as shown in figure 2.2b.

**GSM:** GSM of treated samples ranges between 80 and 82 for both type of treated methods and an increase in the weight was noticed for herbal treated samples applied with cross linking agents. However, a decrease in the value was observed for pad-dry-cured samples against its counterparts and control sample (as shown in table 2.5 and figure 2.2c).

**Table 2.5a:** Performance characteristics (thickness, Count and GSM) of fabric treated with herbal finishing

| Name of the plant source | Cross linking agents | Parameters | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Direct method | | | | Pad-dry-cure method | | | |
| | | Thickness (mm) | Count (no.) | | GSM | Thickness (mm) | Count (no.) | | GSM |
| | | | warp | weft | | | warp | weft | |
| | Control fabric | 0.240 | 80 | 53 | 79.05 | - | - | - | - |
| *Nepeta cataria* | Extract without CLA | 0.302 | 81 | 53 | 81.60 | 0.286 | 82 | 53 | 81.52 |
| | Extract with Citric acid | 0.306 | 80 | 53 | 82.32 | 0.288 | 81 | 54 | 81.88 |
| *Lantana camara* | Extract without CLA | 0.292 | 80 | 52 | 81.48 | 0.282 | 81 | 53 | 80.08 |
| | Extract with Citric Acid | 0.296 | 80 | 52 | 81.33 | 0.29 | 80 | 53 | 80.82 |

**Note:** CLA = Cross linking agents

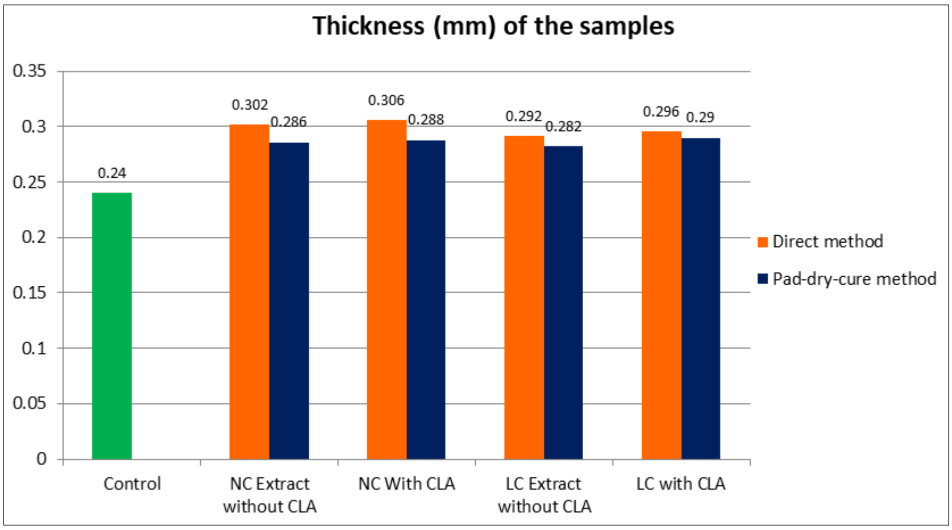



**Fig 2.2a:** Thickness (mm) of the test samples

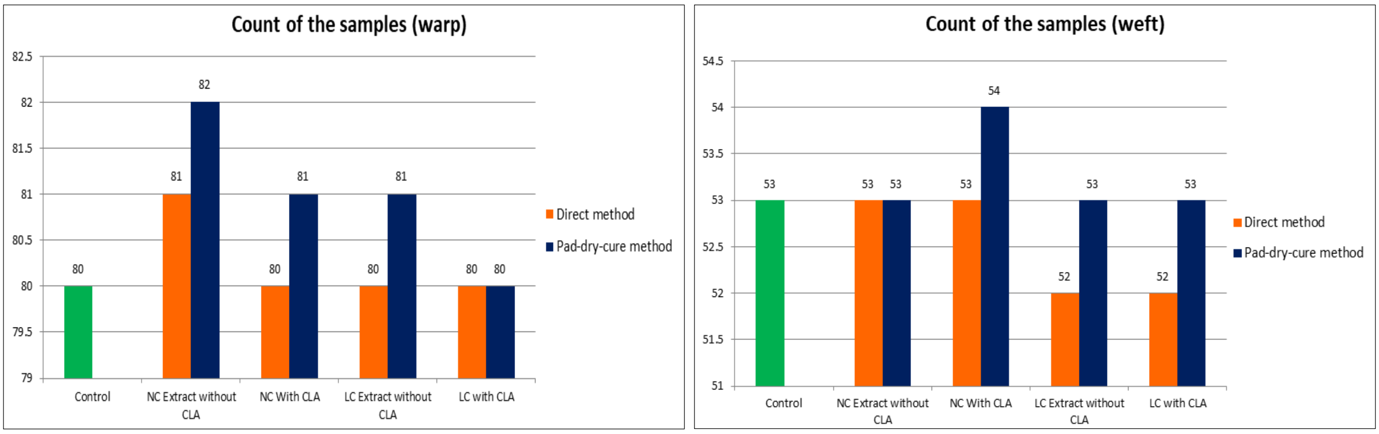



**Fig 2.2b:** Fabric Count (mm) of the test samples

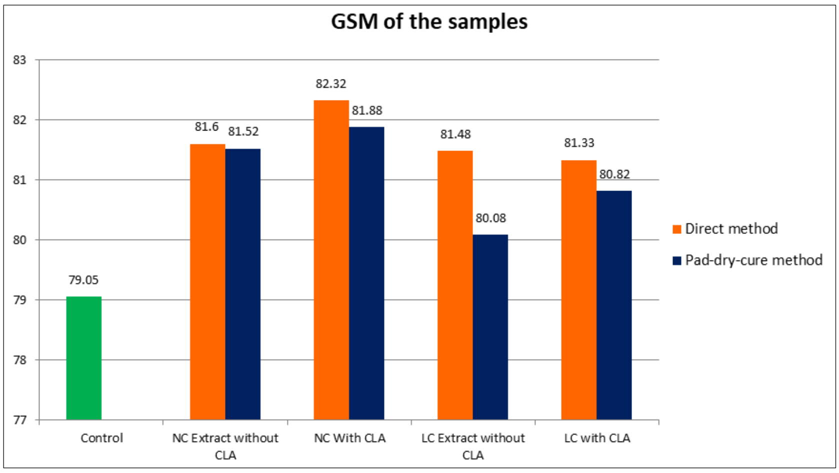



**Fig 2.2c:** GSM of the test samples

**Strength:** Strength of treated fabric was increased in both warp and weft ways, this may be due to the increase in thickness and other geometrical properties of the samples as, heavy fabrics are thicker, stiffer and stronger (Booth, 1983) [2]. Compared to direct method treated samples, pad-dry cure method treated samples have poor strength, as shown in table 2.5b and figure2.2d. The increment of temperature and time of curing, however, will adversely affect strength of the finished fabrics. Herbal treated samples along with citric acid agents have increased the strength than the control ones. Citric acid (CA) is a polycarboxylic acid used on cottons as cross linking agents, which is economical and eco-friendly. The only disadvantage is, it discolor the fabric, for instance, the researchers have found that with an elevation of the curing temperature, time and CA concentration, the yellowing of the fabric also increased. On contrary, a study conducted by Mamta Rana, 2016 [7] have found a decrease in the tensile strength by treating the cottons with marigold and nirgundi extracts with direct, microencapsulation and resin cross linking methods.

**Table 2.5b:** performance characteristics (Strength and elongation) of fabric treated with herbal finishing

| Name of the plant source | Cross linking agents | Parameters | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Direct method | | | | Pad-dry-cure method | | | |
| | | Strength (Kgf) | | Elongation (%) | | Strength (Kgf) | | Elongation (%) | |
| | | warp | weft | warp | weft | warp | weft | warp | weft |
| | Control fabric | 4.39 | 2.64 | 15.16 | 16.16 | - | - | - | - |
| *Nepeta cataria* | Extract without CLA | 4.02 | 2.78 | 14.03 | 15.32 | 4.00 | 2.53 | 14.00 | 15.20 |
| | Extract with Citric acid | 4.71 | 2.84 | 14.82 | 15.68 | 4.52 | 2.80 | 14.28 | 15.40 |
| *Lantana camara* | Extract without CLA | 4.57 | 2.53 | 15.08 | 15.96 | 4.46 | 2.35 | 14.83 | 15.77 |
| | Extract with Citric Acid | 4.94 | 2.61 | 15.13 | 16.02 | 4.79 | 2.54 | 15.01 | 15.86 |

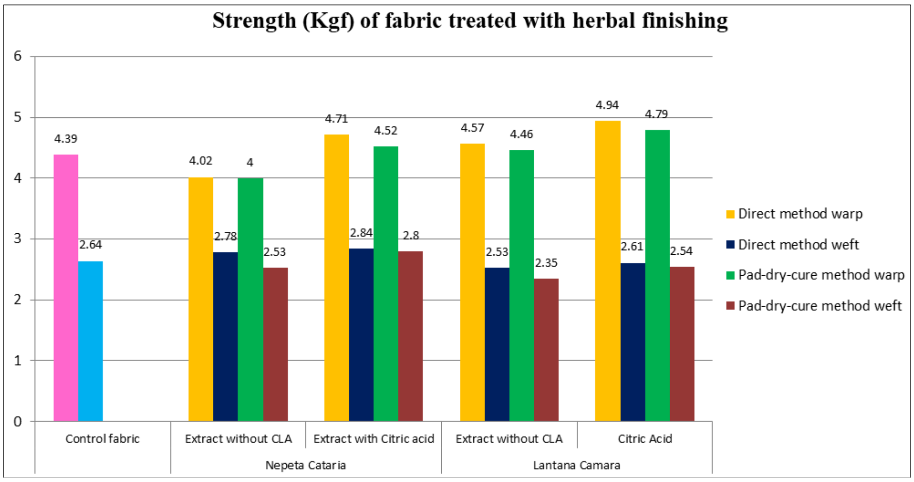



**Fig 2.2d:** Strength of the fabric treated with herbal finishing

**Elongation:** Compared to *Nepeta cataria*, *Lantana camara* has shown good elongation in both types of parameters at both directions (as shown in table 2.5b and figure 2.2e). The reduction in the elongation was may be due to stiffening of fabric with the plant source that was embedded in the fiber polymer system of the fabric. A decrease in the strength was observed as the concentration of the *Artocarpus heterophyllus Lam* Seeds starch increases (Padma Alapati and Khateeja Sulthana Shaik, 2018) [8].

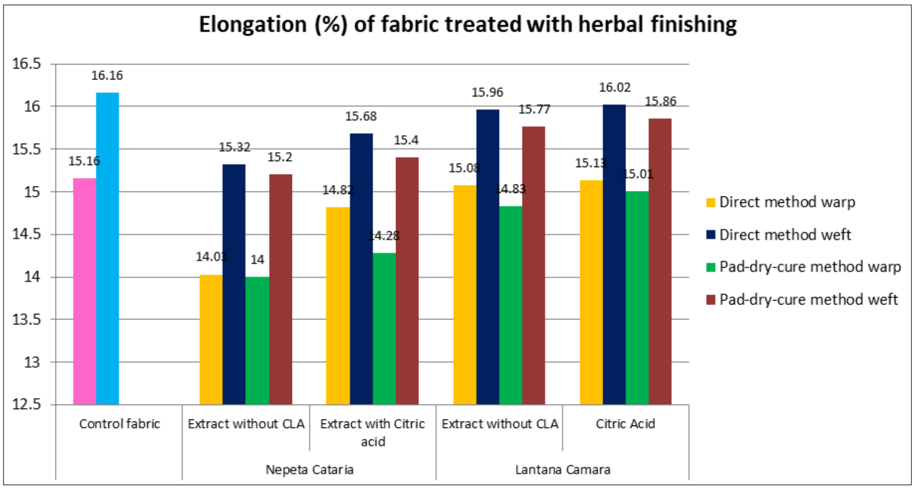



**Fig 2.2e:** Elongation of the fabric treated with herbal finishing

**Mosquito repellent efficiency**

In the table 2.8, plates 2.5 to 2.8 demonstrate the presence of mosquitoes on the test samples. The mosquitoes rested on the test samples were manually counted (as per table 2.9a and figure 2.4a) and evaluated them for mosquito repellent efficiency percentage (see table 2.9b and figure 2.4b). The repellency rates of the mosquitoes, from the table, are between 15 to 20 that are about 20 % of the mosquitoes did not fall on the untreated samples. At the same time, the repellency per percent of the treated samples has shown good results with about 80 per cent. There was not much difference was found for both type of sources as well for both type of finishes. Granch Berhe Tseghai, 2016 have studied mosquito repellency of cotton textiles treated with castor oil with pad-dry-cure method which were evaluated through cage test and found to be good, but after washing the efficiency of the treatment has frayed, so it was recommended to retreat the fabric by spraying after every wash.

**Table 2.8:** Cage test images for mosquito repellency

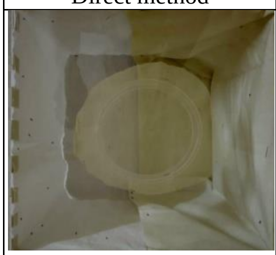
| *Nepeta cataria* | | *Lantana camara* | |
|---|---|---|---|
| Direct method | Pad-dry-cure method | Direct method | Pad-dry-cure method |
|  |  |  |  |
| Plate 2.5 | Plate 2.6 | Plate 2.7 | Plate 2.8 |

**Table 2.9b:** Mosquito repellent efficiency (%)

| Name of the plant source | Direct | | Pad-dry-cure | |
|---|---|---|---|---|
| | Control | Treated Sample | Control | Treated Sample |
| *Nepeta cataria* | 20 | 80 | 15 | 80 |
| *Lantana camara* | 25 | 75 | 20 | 75 |

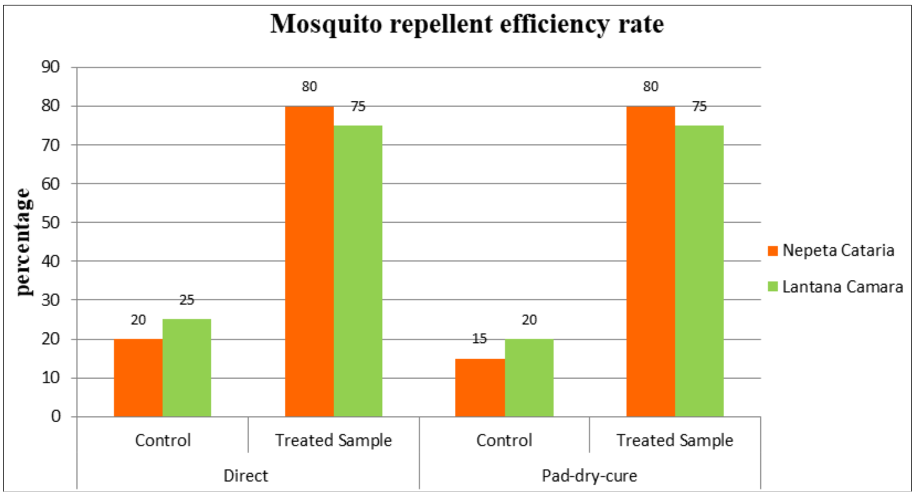



**Fig 2.4b:** Mosquito repellent efficiency rate from the herbal treated fabric

## Conclusion
Though the repellents in the market are available in many forms like spatial, chemical, natural and gadgets, considering the eco-friendliness, people are much focused on natural repellent agents. The source of the repellent should be obtained preferably from replaceable parts of the plant, such as the leaves rather than plant itself, which when removed, kill or damage can harm the environment. Hence, the present study has enlightened the use of Catnip and Lantana leaves and it was observed that Catnip and Lantana plant leaves have potential herbal composition which not only act against micro-organisms, but also can repel different insects. The study also have reveled good results of these plants against *S. aureus* and *E. coli* and also against mosquitoes.

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