5. SUMMARY AND CONCLUSION

The summary and conclusion pertaining to the study entitled “A study on the effect of multifunctional finishes on blended denim fabrics” are summarized here.

Denim is the most preferred clothing of today’s youth. The spread of denim-wearing culture, the world over, brought with it a trend of fast changing fashions and manufacturing technology. Westerners are the major producers of denim in the past. Today, denim culture is widely prominent in the tropical and sub tropical world. Denim does not mean jeans alone; it refers to a multitude of items in apparel accessories and embellishments. With the development of infinite possibilities of yarns, fabric, finishes, weaves, dyes, a wide range of denim fabrics can be manufactured to suit the varied taste of the consumer.

The garment industry, especially the denim industry’s new drive towards high value-added products, is promoted in many countries. The garment industry is developing textiles with smart functions, using new products to provide extra comfort and thereby increasing the performance. The finishing of the denim fabrics with increased comfort and aesthetic properties is on the rise. The eco sensitiveness of the consumer is vastly improving day by day, and the finishing techniques with natural herbal products is gaining momentum.

The investigator considered all the above factors and selected the present study to satisfy the consumer by producing antibacterial, antifungal finish on denim fabric. With this objective, the following study was carried out. Antimicrobial herbal products were extracted from natural plants, using three methods. These natural herbal products were applied onto four types of denim fabric samples in various ratios and analyzed for effectiveness.

The objectives of the study were to

- To elicit information from the market and the consumer to find out the availability of denim fabric and its utility.
- To screen for the functional properties such as Antibacterial, Antifungal, Anti odor, Mosquito Repellency, micro encapsulation and nanoencapsulation from selected herbs.
- To optimize the effective herbal combination of the functional property of the selected finishes
- To finish the optimized herbal combination on the four selected denim fabrics
- To evaluate the properties after and before wash of the finished fabrics
Experimental procedure

The Experimental procedure of the study consisted of four phases with the following aspects.

Phase-1
Pilot study

Market survey, consumer survey

The market survey was carried out in 50 prominent denim shops located in and around Coimbatore. The selection was based on random sampling method.

Consumer survey was carried out with 100 teenage girls and boys in an interview schedule.

Pretreatment

Desizing of selected samples to make it suitable for further processing was done. The desizing was done for four selected samples namely A, B, C & D.

Selection of herbs

For this research, twenty healthy and live herbal plant parts were selected. The botanical names of the selected herbs are as follows: *Ricinus Communis* (leaves), *Ricinus Communis* (seeds), *Abutilon indicum* (leaves), *Solanum surattense* (Leaves), *Coccinia grandis* (Fruits), *Coccinia grandis* (leaves), *Datura metel* (leaves with fruits), *Aleo vera* (flower), *Aleo vera* (leaves), *Cardio spernum halicacabum* (Leaves), *Cissus quadrangularis* (whole plant), *Albizia amara* (Leaves), *Leucas aspara* (stem, leaf and flower), *Euphorbia hirta* (mixture of stem, leaf and flower), *Kathari flower*, *Cereus janacars* (whole plant), *Tribulus terrestris* (Whole plant), *Senna auriculata* (Leaves), *Passiflora foetida*–( Stem, Leaf and flower ) and *Poolapoo* (whole plant) were collected from different regions in and around Coimbatore district, which were authenticated by the Botanical Survey of India. These herbs were selected because they exhibited antimicrobial activity and tannic properties.

Extraction process of herbs

The extraction process was done in three stages, such as drying, grinding and extraction. Two types of extraction methods were followed: viz methanol and aqueous extraction was done for all the twenty selected herbs.

Finishing method

The selected denim fabric samples were finished with the herbal plant extraction by dip method and analysis of antibacterial activity by ENISO 20645 method was followed to find out the three best activity herbs.

Optimized parameters

After conduct of Pilot study, the following parameters were selected. Three herbs such as *methanolic extract* of *Ricinus communis*, *methanolic extract of Senna auriculata* and
aqueous extract of Euphorbia hirta, in the proportion of (1:3:2) was taken and conditioned with 20Kg/cm² Pressure, 20m/min rpm, followed by pad dry cure method.

Phase-2

Phase 2 consisted of application of multi-functional finishes in the selected samples, and verification of qualities such as anti-bacterial activity, using ENISO 20645 standard method and anti-fungal activity by AATCC 30 standard method, anti odor, mosquito repellency by dip method. The evaluation was done after 10, 20, 30 washes. The fabric was evaluated using five categories of evaluation such as visual inspection, physical, mechanical, comfort and absorbency property test. The above evaluation was done to find out the impregnation of multifunctional finishes in selected fabrics.

Selected samples

Four denim fabric samples namely Sample A, B, C and D were identified. The first three samples namely A-68%cotton+32% Polyester, B-68%cotton+32% Poly Lycra, C-68%cotton+32% core spun Lycra were blended fabrics of various combinations, whereas the sample D was 100% cotton fabric.

Finishing technique

The selected fabrics were finished with the herbal extracts using Dip method. The finished fabrics were tested for various characteristic features exhibited due to the herbal extract impregnated in it by the following criteria

Anti bacterial property - ENISO 20645 standard method
Antifungal property - AATCC 30 standard method
Anti odor property - was tested with male panelists who wore finish impregnated socks. The evaluation of anti odor activity on the finished fabrics was compared with the organoleptic evaluation of odor control for accurate value.
Mosquito Repellency property- the test was carried out with the excito mosquito repellency chamber and with the Anopheles mosquitoes.
Visual inspection- the multi-functional finished fabric (dip method) was visually inspected for the general appearance; evenness of finishes, texture and luster were analyzed.
Geometrical properties-the geometric properties such as Fabric count, Fabric weight and Fabric Thickness were analyzed.
Mechanical properties-the Tensile strength, Abrasion Resistance, Pilling Resistance of the multi-functional finished fabrics were tested.
Comfort properties -the wearing comfort of the consumer was the primary objective of this study, which was determined using the following three tests: drape coefficient test, air permeability test and crease recovery angle test
Absorbency properties-the water absorbency test, sinking test and the wickabilty test was also determined as a part of evaluation.
Phase 3

In **phase 3** the herbal extraction was microencapsulated and applied on 100% cotton denim fabric (D), which was selected as ideal sample among the four Denim fabrics in phase2, by pad dry cure method, to get the maximum antibacterial, antifungal, anti odor and mosquito repellency finishes. This was evaluated after 10, 20 and 30 washes. The evaluation was done by five categories such as visual inspection, physical, mechanical, comfort, absorbency. A scanning electron microscopy and Fourier transform infrared spectroscopy test was carried out.

**Microencapsulation**

The Microencapsulation method was followed as stated by Sathianarayanan et al.(2010). The procedure of gelatin ionic microencapsules preparation was followed, and the microencapsules prepared, were applied on 100% cotton denim fabrics. The microencapsules were applied on the fabric by pad dry cure method.

The finished fabrics were tested for various characteristic features exhibited due to the herbal extract impregnated in it by the following methods:

- **Anti bacterial property** - ENISO 20645 standard method
- **Antifungal property** - AATCC 30 standard method
- **Anti odor property** - The anti odor property
- **Mosquito Repellency property** - The test was carried out with the excito mosquito repellency chamber and with the *Anopheles mosquitoes*.
- **Visual inspection** - The microencapsulated finished fabric was visually inspected for the general appearance, evenness of finishes, texture and luster were analyzed.
- **Geometrical properties** - The geometric properties such as Fabric count, Fabric weight and Fabric thickness were analyzed.
- **Mechanical properties** - The Tensile Strength, Abrasion Resistance, pilling resistance of the microencapsulated finished fabrics were tested in the mechanical properties test.
- **Comfort properties** - The wearing comfort of the consumer was the primary objective of this study, which was determined using the following three tests: Drape coefficient test, Air permeability test and crease recovery angle test
- **Absorbency properties** - The water absorbency test, sinking test and the wickabilty test was carried out for this study.

**Scanning electron microscopy** - The scanning electron microscopy was used for confirming the binding of microencapsules and alignment on to the fabric sample as pointed out by Thilagavathi et al (2007).

**Fourier transform infrared spectroscopy test** - The main goal of IR spectroscopic analysis was to determine the chemical functional groups in the sample. Different functional groups absorbed characteristic frequencies of IR radiation.
Phase 4

In phase 4, the herbal extraction was nanoencapsulated and applied on 100% cotton denim fabric (D), by pad dry cure method, to get maximum antibacterial and antifungal activity; this was evaluated after 10, 20 and 30 washes. The evaluation was done under five categories such as visual inspection, physical, mechanical, comfort, absorbency, A Scanning electron microscopy and Fourier transform infrared spectroscopy test was carried out on the selected fabric for increased durability of the finish on the fabric.

Nanoencapsulation

The procedure for coacervation process was followed; the Nanoencapsules prepared were applied on 100% cotton denim fabrics. The nanocapsules were applied on the fabric by pad dry cure method.

The finished fabrics were tested for various characteristic features exhibited due to the herbal extract impregnated in it by the following methods:

- **Anti bacterial property** - ENISO 20645 standard method
- **Antifungal property** - AATCC 30 standard method
- **Visual inspection** - The nanoencapsulated finished fabric was visually inspected for the general appearance, evenness of finishes, texture and luster.
- **Geometrical properties** - The geometric properties such as Fabric count, Fabric weight and Fabric thickness were analyzed.
- **Mechanical properties** - The Tensile Strength, Abrasion Resistance, pilling resistance of the microencapsulated finished fabrics was tested in the mechanical properties test.
- **Comfort properties** - The comfort property was determined using the following three tests Drape coefficient test, Air permeability test and crease recovery angle test
- **Absorbency properties** - The water absorbency test, sinking test and the wickability test was carried out for this study.
- **Scanning electron microscopy** - Scanning Electron Microscope was used to identify morphological structure of specimens (fiber, yarn or fabric) under investigation. SEM evaluation was also used to know the uniformity of coating of finishing over the nanoencapsulated specimen
- **Fourier transform infrared spectroscopy test** - Fourier transform infrared spectroscopy (FTIR) was an analytical tool to identify the nature of chemicals that are coated on the fabric specimen. It also helps to know to what extent the molecules of the finishing chemicals are attached with fiber molecules of the specimen.

**Analysis of results** - The test results of various denim fabric samples on various characteristic features after application of finishes by various methods like dip method and comparative analysis of multifunctional dip method, microencapsulation and nano encapsulation were analyzed statistically using one way ANNOVA. The microencapsulation and nanoencapsulation finishes were analyzed using ‘T’ test.
Findings of the study
The information gathered from the market and consumer survey on selected shops, and consumer selected by random sampling method, revealed the following:

- the usage of denim made fabrics is in an increasing trend
- the usage of denim fabric by the teenage consumers is in the increasing way
- the preference among the denim fabrics was identified as blended and 100% cotton denim fabric
- the interview schedule analysis showed the knowledge of consumers on various finishes including antibacterial, antifungal, anti odor and mosquito repellency was improving

Hence this study was carried out to satisfy the demands of the consumers.

Identification of samples
Based on the survey, the following four samples were selected for this research work titled “A study on the effect of multifunctional finishes on blended denim fabrics”.
Sample A-68%cotton+32% Polyester,
Sample B-68%cotton+32% Poly Lycra,
Sample C-68%cotton+32% core spun Lycra and
Sample D -100% cotton

Evaluation of denim fabrics
Multi-functional finishes
Considering the pollution status in the environment by using chemical finishes and the preference shown by the consumers over eco-based finishes, the naturally available plant extracts were used as finishes in the selected fabric samples for the study.

Common plant herbs identified mostly as weeds, which had medicinal properties, as illustrated by various literatures, were selected for this study. Among the twenty herbs identified, the following three herbs were finally shorted listed, based on the various preliminary analysis and performance.

- Methanolic extract of Ricinus communis
- Methanolic extract of Senna auriculata and
- Aqueous extract of Euphorbia hirta

The plant and plant parts of the above three selected herbs were extracted using methanol and aqueous extracts, and were used as herbal finishes.

The selected samples were finished with multi-functional finishes and the performances of treated fabrics were analyzed using the following parameters:
Multi-functional finishes done by dip method, microencapsulation and nanoencapsulation technique.
Assessment of multifunctional finished samples (Dip method).

The assessment of the finished fabrics was tested for its activity against bacteria, fungi, odor and mosquitoes. The antibacterial activity was tested against common dermal pathogens namely *Staphylococcus aureus* and *Escherichia coli*. The antifungal activity was done against the fungi Aspergillus Niger. Antibacterial activity was verified with official panelists. The excito chamber was used to judge the mosquito –anopheles resistance by the fabric. The overall results after the study showed that sample D which was 100% cotton denim fabric, was exhibiting good retention of the herbal finish.

Visual inspection

Among all samples, sample A and D was judged very good in appearance and in finishing. In the case of texture, sample D showed a very good medium texture. Samples A and D after finishing exhibited a medium luster. As a whole, sample D i.e. 100% cotton denim fabric showed an overall best appearance among the samples.

Geometrical Properties of multi-functional finished fabrics

The Geometrical Properties such as Fabric count (Ne) in warp and weft direction, Fabric weight (g/m²) and Fabric thickness (mm) were tested; in case of the fabric count, in all the samples, the count in warp direction was reduced due to washing, which was minimum in sample D. The fabric count in the weft direction showed a reduction in samples B, C and D; whereas no reduction was noticed in sample A. Among B, C and D samples as a whole, the reduction was minimum in washed samples of D. To sum up, sample D showed good results for fabric count.

Fabric weight and fabric thickness of samples under study: sample A exhibited the maximum weight gain over all the other fabrics after finishing. This weight gain was noticed in sample A even after 10, 20 and 30 washes.

In the case of fabric thickness, the maximum thickness was observed in sample C, over all other samples. The increase in thickness was noted with .01 mm over sample A with 0.55 mm. Even the finished samples showed the same trend.

Mechanical properties of multi-functional finished fabrics

The mechanical properties such as Tensile strength (Kgf), Abrasion resistance (kpa) and Pilling Resistance (grey scale rating) of the finishes, was tested. In Tensile Strength, the fabrics showed variation after finishing and washing. The abrasion resistance and pilling resistance was similar in all the samples which had no thread break till 5000 cycles under slight pilling.

Comfort properties of multi-functional finished fabrics

The drape coefficient (%), Air permeability (m³/cm²/sec), Crease recovery angle (degrees), Stiffness (mg-cm) and Water repellency (spray test) characters of the samples were tested. The results showed a variation of comfort properties. Different samples showed difference
in drape coefficient, Air permeability, Crease recovery angle and Stiffness, whereas a similarity was noticed in case of water repellency.

**Absorbency properties**

The water absorbency-drop test (sec), sinking test (sec) and wickability test (minutes) - properties of the finished fabrics were evaluated as absorbency properties and in the analysis it is understood that there was no change in the absorbency rate. In sample A, B, C&D fabrics, there was a reduction identified after washes. With respect to wickability test, it was concluded that on unwashed finished sample, there was a slight increase in the wickability but a decrease in wickability was exhibited on subsequent washing processes in both warp and weft direction.

After the above evaluations sample D -100% cotton Denim Fabric, was identified as the best suited fabric for herbal extract finish and hence the latest, high profile technique of finishing namely the microencapsulation and Nanoencapsulation technique was followed for sample D.

**Assessment of Microencapsulation technique**

The herbal extracts were imparted into the selected samples using micro encapsules and the finishes were evaluated on various parameters.

The assessment of the activity of the micro encapsulated herbal extracts against Bacteria, Fungi, odor and mosquitoes were evaluated through various techniques.

As a whole, and as expected, Sample D exhibited the Anti bacterial activity well against the common human skin bacterial flora namely *Escherichia Coli* and *Staphylococcus aureus*. The sample showed good anti odor and mosquito repellent property. The qualities were retained by the fabric samples even after washing.

**Visual inspection**

The Juries expressed 100% satisfaction on the fabrics’ evenness of finishing, general appearance, medium texture and luster for the microencapsulated finished sample MD. Further it was noticed that there was no reduction in the above property after washing in evenness of finishing and luster.

**Geometrical Properties of Microencapsulated finished fabrics**

The Fabric count (Ne) in warp and weft direction, Fabric weight (g/m²) and Fabric thickness (mm) of the finished fabric was considered as the geometric properties. The fabric count analysis showed that the fabric count increased in the warp and weft directions to considerable level on washing with a shrinkage noticed because of the sample being 100% cotton. The fabric thickness and the fabric weight were found reduced after washing making the fabric light weight ,and thereby increasing the wearers comfort.

**Mechanical properties of Microencapsulated finished fabrics**

The mechanical properties such as Tensile strength (Kgf), Abrasion resistance (kpa) and Pilling Resistance (grey scale rating) of the microencapsulated finished sample were analyzed.
The tensile strength of the fabric was increased after washing, whereas there was no change in the abrasion resistance (no thread break till 5000 cycles) and slight pilling among the samples before and after washing.

**Comfort properties of multi-functional finished fabrics**

The drape coefficient (%), Air permeability (m³/cm²/sec), Crease recovery angle (degrees), Stiffness (mg-cm) and Water repellency (spray test) characters of the samples were considered as criterion for the comfort property analysis. The drapability of the sample was found increased after washes along with air permeability increase, due to washing out of starch and other material from the pores, thus resulting in wearing comfort. The maximum crease recovery was noticed in washed samples. Further the stiffness was found predominantly reduced after washing, and no change noticed in water repellency.

**Absorbency properties of Microencapsulated finished fabrics**

The Water Absorbency-Drop test (sec), Sinking Test (sec), Wickability test (minutes) were tested for the fabric to determine the absorbency nature of the finished fabric. The rate of water absorbency was found decreased after washing. There was no difference in timing noted in sinking. The wickability timing was decreased initially and later on increased with washing.

**SEM analysis of Microencapsulated finished fabrics**

The finished samples with Microencapsules were SEM analyzed and it was clear that the microcapsules were present in interstices of the fiber assembly of fabric even after 30 washes proving the adherence of the finishing in the samples.

**FTR analysis of Microencapsulated finished fabrics**

The Microencapsulation technique strongly adhered to the fabric, which shifted the frequency significantly. Moreover, most of the stretching frequencies were found to exist even after 10, 20 and 30 washes. This inferred that there was a binding between the cellulose fiber and the added microencapsules in fabrics. Hence it is found to be present even after many washes. This is strong evidence that herbal extracts were imparted in the fabric.

**Assessment of Nanoencapsulation technique**

The antibacterial activity exhibited by the Nanoencapsulated herbal extract finished fabrics against the bacterial flora *Escherichia coli* and *Staphylococcus aureus* was good; and even after thirty washes the antibacterial activity was not considerably reduced. This showed that the fabric possessed higher rate of protection, low skin irritation, high bad odor control & kills bacterial pathogens. The finished fabric possessed good antifungal activity even after 30 industrial washes, which was proved against the fungi *Aspergillus Niger*. 

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Visual inspection

All the juries appointed for the determination of the visual inspection properties of the Nanoencapsulated finished properties, commented that the finished fabric had good evenness of finishing and luster. In general appearance and medium texture, slight reduction in rating was noticed.

Geometrical Properties of Nanoencapsulated finished fabrics

The Fabric count (Ne) in the warp direction and weft direction was increased after the application of the finishes. There was no reduction noticed after washing. The Fabric weight (g/m²) and the fabric thickness (mm) were considerably decreased in the finished and the washed sample.

Mechanical properties of Nanoencapsulated finished fabrics

The Tensile strength (Kgf), Abrasion resistance (kpa) and Pilling Resistance (grey scale rating) of the Nanoencapsulated finished sample was studied. The tensile strength of the fabric was increased after washing in both the warp and the weft direction, whereas there was no change in the abrasion resistance (no thread break till 5000 cycles) and slight pilling in the sample before and after washing.

Comfort properties of Nanoencapsulated finished fabrics

The possession of drape coefficient (%), Air permeability (m³/cm²/sec) through the fabric, Crease recovery angle (degrees), Stiffness (mg-cm) exhibited and Water repellency (spray test) of the samples were considered as criterion for the comfort properties. The drapability of the sample was found increased after washes, along with air permeability increase during washing out of starch and other material from the pores, which resulted in wearing comfort. The maximum crease recovery was noticed in finished samples. Further the stiffness was found predominantly reduced after washing and no change noticed in water repellency.

Absorbency properties of Nanoencapsulated finished fabrics

The Water Absorbency-Drop test (sec), Sinking Test (sec), Wickability test (minutes) were tested for the fabric to determine the absorbency nature of the finished fabric. The rate of water absorbency was found decreased after washing. There was no difference in timing noted in sinking. The wickability timing was increased initially and later on decreased on washing.

SEM analysis of Nanoencapsulated finished fabrics

The finished samples with Nanoencapsules in the fabric were SEM analyzed to find out the adherence of the Nanoencapsulated herbal finishes in the fabric and it was noticed that the Nanoencapsules were in the fabrics even after multiple wash.
FTIR analysis of Nanoencapsulated finished fabrics

On comparison of the spectra of treated samples with untreated fabric it clearly showed the differences in stretching frequencies. The intensity of many absorption peaks reduced significantly in the treated samples, as compared to the untreated sample. Most of the stretching frequencies were found to exist even after 10, 20 and 30 washes. This inferred that there was a binding between the cellulosic fiber and the added nanoencapsulation. Hence it was found to be present even after many washes. This strong evidence showed that herbal extracts were imparted in the fabric.

Comparative study on various finishing Techniques on sample (D)

The study was carried out to identify a single finishing technique in the selected sample namely D- i.e 100% cotton denim fabrics, which can be recommended for commercial production which was the ultimate aim of this study.

The comparative study showed that the Nanoencapsulated herbal extract finished sample fabrics possessed more antibacterial activities than the other two methods of finishing. Along with the nanoencapsulated sample the microencapsulated and dip method finished samples exhibited good antifungal activity. The anti odor capacity of the fabric was analyzed for the microencapsulated fabrics with the Dip method sample, and the retention of herbal extract was more in the later. In case of mosquito repellency, the microencapsulation technique was more effective than that of the dip method finish.

Visual inspection

The panelists rated both washed and unwashed samples good in general appearance, evenness and luster, in all the types of finishes. With respect to the texture the microencapsulated and nanoencapsulated finishes were rated medium.

Comparative study on Geometric properties

The nanoencapsulated finished fabrics increased the value of fabric count in warp and in weft directions. It was observed after 30 industrial washes and hence it was superior among the three methods of finish. The fabric thickness in the nanoencapsulated finished fabrics was increased, leading to the conclusion that the Nanoencapsulation increased the fabric durability.

Comparative study on Mechanical properties

The results showed that the Microencapsulation technique increased the tensile strength of the fabric in the warp direction; whereas the Dip method increased the tensile strength in the weft direction. With respect to the other mechanical property, in the Abrasion resistance and pilling resistance the finishes showed no difference. The abrasion resistance was uniform with no thread breaking till 5000 cycles and slight pilling in pilling resistance.
Comparative study on comfort properties

The possession of drape coefficient (%), air permeability ($m^3/cm^2/sec$) through the fabric, Crease recovery angle (degrees, Stiffness (mg-cm)) exhibited and water repellency (spray test) of the samples were considered as criterion for the comfort properties. With respect to drapability, the nanoencapsulation technique was found to increase the drapability among the finishes, the air permeability was more in nanoencapsulated finished samples. The maximum crease recovery was noticed in washed samples of microencapsulated finish. Further the stiffness was found predominantly reduced after washing and finishing in three methods; and no change noticed in water repellency.

Comparative study on absorbency properties

The Water Absorbency-Drop test (sec), Sinking Test (sec), Wickability test (minutes) were tested for the fabric to determine the absorbency nature of the finished fabric. The rate of water absorbency after finishing was uniform in all the three finishes. There was no difference in timing noted in sinking. The wickability timing was decreased initially in warp direction, and in weft direction, increased on washing, in all the three finishes; by which it had been deciphered that the finish had no say, in absorbency property.

Conclusion

Plant kingdoms consist of millions of species. The uses of these plants to the human beings are innumerable. It is highly impossible for the human kind to enumerate the usefulness of the plants and its various parts. Many plants contain plenty of medicinal properties present in them. Among these, twenty commonly available plant species were selected for the study. There were natural inhibitors present in it. These characters were identified in the selected plant species and the extracts were collected. After a preliminary study, 3 plant species with desirable characters were short listed. The herbal extracts from these plants were applied on the denim fabrics by three different application methods i.e. finish. The three finishes selected were dip method, microencapsulation and nanoencapsulation. The finished fabrics were subjected to various tests such as Antibacterial, Antifungal, Antiodor, Mosquito repellency tests, along with Visual inspection, Geometrical properties, Mechanical properties, Comfort properties and Absorbency properties to identify the best finish. The adherence and long lasting nature of the finish was also tested with the SEM analysis and FTIR analysis.

After the procedure it was identified by the investigator that the finishing technique by the Nanoencapsulation method in the fabric sample 100% cotton denim fabric (sample D) possessed all the expected characters like durability of the fabric, increased fabric thickness, weight, drapability, luster, evenness and antimicrobial activity. In turn the above characters enhanced the wearing capacity of the denim fabric for an extended period without any skin/dermal irritations/infections, without any bad odor and protection from mosquitoes.
Recommendations for further study

Further study may be carried out with more plant species.

- Other structures and types of fabrics such as plain, twill and cotton, polyester can be selected for the study.
- The chemical structures of the herbal extracts can be identified and other natural materials which possess the chemicals may be used.
- Other - new finishing methods to be experimented.
- Commercial, mass production of the finished fabrics can be tried out.
- The research can be carried out with finishes of the yarn i.e. before weaving.
- Ecofriendly finishes can be applied to the eco-fabrics made of organic cotton thus producing an eco-friendly garment.