Summary and Conclusion
The growing concern for the usage of hygienic textile products has resulted in the application of antimicrobial finishes as the microorganisms such as bacteria, molds, & yeast are normally found on the skins of human producing characteristic foul odour and related infections. Soiled cloths often contain large number of microbes which multiply rapidly and cause problems when worn by people. Antimicrobial finishes for textiles have been in the market in the recent days. The aim of modern antimicrobial modifications particularly with regard to textiles is to provide very specific benefits, while at the same time complying with all medical requirements relating to safeguarding human health and the environment.

The antimicrobial textiles and related products such as briefs, shoe-insoles, socks, foot spray, shoe spray, foot powder, instant starch and sanitary pads commercially available in Coimbatore city of Tamilnadu have been evaluated to assess the efficacy of antimicrobiotics. The choice of antimicrobiotics with respect to their suitability for human use is of paramount importance when the side effects of these antimicrobials are considered for long-term use. Despite a number of chemical antimicrobials, a number of medicinal plant extracts have been used for various textile products such as apparels, medical, health care and hygienic textiles.

The present study was aimed at selecting a suitable fabric from cotton, viscose and nylon, and assessing its compatibility with chitosan, infasil and tinosan. Further the antimicrobial effect of various medicinal plant extracts such as neem, tulasi, prickly chaff flower, camphor basil, aloe vera, thumbai, portia, Mexican daisy, Indian acalypha, henna, shoe flower, thudhuvalai, onion, garlic, ginger, sweet flag, turmeric, clove, cardamom and pomegranate on cotton fabric as fabric finishes was analyzed. In this study, based on the critical evaluations of antimicrobial effects of chitosan, infasil and tinosan on different types of fabrics, only cotton treated with chitosan was found to be efficient and selected for further treatment with plant extracts. In the context of ecological and environmental threats, the most recent trend appears to be a search for and development of technologies for use of natural materials such as plant extracts for imparting antimicrobial finishing to home and medical textiles.
In the search for an antimicrobial technology designed for use in a wide range of fabrics, the fixation of chemicals using a cross-linking agent becomes imperative as mere treating with an antimicrobial agent does not last longer. In the process of evaluation the beneficial effects of eco-friendly cross linking agents were also worked out so that the antimicrobial effects can be extended over a long period. With the view to develop multifunctional textiles for medical use, cotton treated with neem/chitosan and post treated with fluoropolymers, the antimicrobial and blood repellency functions were also assessed for a dual function.

The recent introduction of microencapsulation technique as an alternative finishing method using polymers has enabled to incorporate microspheres of gelatin and alginate as wall materials entrapped with the chitosan and plant extracts such as neem, prickly chaff flower, aloe vera and pomegranate rind extract, individually as core materials for cotton fabric.

In this study both qualitative and quantitative antibacterial assays were done using parallel streak and agar diffusion methods against the test organisms such as *S. aureus* and *E. coli*. For quantitative test, the challenge test was carried out using *S. aureus* as the test bacteria. The antifungal activity and antimicrobial resistance tests were carried out. The wash durability test, physical, fastness and functional properties of the treated fabrics were also analysed.

Amongst the commercial antimicrobial textile products, the maximum zone of bacteriostasis was observed in the case of foot powder-Dr. Scholl (15 mm) and foot spray (15 mm) against *S. aureus* and foot spray-Dr. Scholl (11mm), insoles Dr. Scholl (10 mm) and foot powder Dr. Scholl (10 mm) against *E. coli* in parallel streak method. Similarly in the case of agar diffusion method the maximum zone of bacteriostasis was observed in the case of foot spray-Dr. Scholl (47 mm), insoles Dr. Scholl (43 mm) and shoe spray-ultra (43 mm) using *S. aureus* as the test bacteria. Using *E. coli* the maximum zone bacteriostasis was observed in foot spray Dr. Scholl (49 mm) and shoe spray-ultra (47 mm). In quantitative test a 100% bacterial reduction was observed in insoles-Dr. Scholl, foot spray-Dr. Scholl and sanitary pads samples. In *in vivo*
organoleptic evaluation, the socks treated with foot spray-Dr. Scholl, shoe spray-ultra and foot powder-Dr. Scholl had 100% odour control activity.

When the antimicrobial effectiveness of cotton, viscose and nylon fabrics treated with chitosan / infasil / tinosan was assayed, the cotton treated with chitosan showed the maximum zone of inhibition in parallel streak method \( i.e. 17 \text{ mm} \) against \( S. \text{aureus} \) and \( 10.5 \text{ mm} \) against \( E. \text{coli} \). In the case of agar diffusion method the maximum zone of bacteriostasis was observed in cotton treated with chitosan \( i.e. \) \( 43\text{mm} \) against \( S. \text{aureus} \) and \( 29 \text{ mm} \) against \( E. \text{coli} \). In the quantitative test the bactericidal activity was total (100%) in the case of cotton treated with chitosan against \( S. \text{aureus} \). The cotton treated with chitosan also exhibited the maximum antimycotic activity with zones of mycostasis to an extent of \( 49 \text{ mm} \) and \( 45 \text{ mm} \) against \( A. \text{niger} \) and \( P. \text{fungicola} \) respectively. None of the chemical treatments was efficient in controlling \( T. \text{viridae} \). Based on the findings it was ascertained that the cotton fabric was found to be efficient when compared with viscose and nylon for incorporating antimicrobial chemicals especially chitosan.

Based on the results of antimicrobial activity of the medicinal plant extracts on cotton fabrics, it was observed that in qualitative test using agar diffusion and parallel streak method, the cotton fabric treated with the neem, prickly chaff flower, pomegranate rind, tulasi, clove oil and aloe vera showed the maximum antibacterial efficiency. The zone of bacteriostasis was \( 17.5 \text{ mm} \) in the case of prickly chaff flower and neem extract treated fabrics, using \( S. \text{aureus} \) as the test organism and the maximum zone of bacteriostasis was observed in prickly chaff flower treated fabric \( (12 \text{ mm}) \) against \( E. \text{coli} \). In the case of agar diffusion method, the maximum zone of bacteriostasis was observed in neem extract treated fabric \( (52 \text{ mm}) \) against \( S. \text{aureus} \). Using \( E. \text{coli} \) as the test organism the maximum zone of bacteriostasis was observed in prickly chaff flower extract treated fabric \( (41 \text{ mm}) \). All other plant extracts showed minimum to moderate activity in parallel streak and agar diffusion tests against both \( S. \text{aureus} \) and \( E. \text{coli} \). The results of the quantitative test indicate that the antibacterial activity was found to be 100% in the case of neem, prickly chaff flower and pomegranate. It is interesting to note that some of the plant extracts such as henna,
shoe flower and thudhuvalai which showed only nil to moderate activity in the quantitative tests showed higher activity in the quantitative tests.

The results of the antifungal activity of the medicinal plant extract treated and untreated fabrics showed the maximum zone of mycostasis in neem (51 mm), tulasi (47 mm) and portia (46 mm) treated fabrics against *A. niger*. It was also observed that the maximum zone of mycostasis was present in turmeric extract treated fabric (45 mm) against *T. viridae* and most of the other plant extracts did not exhibit any antimycotic activity against *T. viridae*. Using *P. funiculosum* as the test organism maximum zone of mycostasis was observed in neem extract treated fabric (46 mm) followed by tulasi treated fabric (45 mm).

Regarding the use of eco-friendly cross-linking agents it was observed that the etherified DMDHEU was found to be efficient and for the slow release and enhanced durability of the antimicrobial agents. The release of free formaldehyde in the case of etherified DMDHEU was found to be less than 10ppm with in the permissible limit. The Cuen rating of DMDHEU and etherified DMDHEU was found to be the maximum (4) where as in the case of CA and BTCA it was found to be only 3 (moderately cross linked). It was also observed that CA and BTCA with suitable catalysts were found to be 100% formaldehyde free cross-linking agents. However the stability of linkage bond was lowered when this chemical forms ester linkages with cotton fabrics.

The antibacterial activity by challenge test indicated that regardless of the fluoropolymer concentration, the samples showed over 96% reduction of bacteria in chitosan treated fabrics and 95% in neem treated fabrics. However the blood repellent finish with fluoropolymer was compatible with the antimicrobial finish. The blood repellency study with synthetic blood penetrating the untreated cotton fabric, chitosan and neem treated cotton fabric without fluoropolymer was estimated to be 16.74 g, 9.17 g and 10.70 g respectively. However with fluoropolymer treatment the synthetic blood penetrating the samples started decreasing. The results of impact penetration and the spray test confirmed that both cotton treated with neem and chitosan were equally suitable for a blood repellent finish.
The cotton fabrics with gelatin microcapsules treated with chitosan and plant extracts such as neem, prickly chaff flower, pomegranate and aloe vera, as textile finishes were found to be efficient when compared to alginate confirming the steady release of the antimicrobial factors over a longer period. In this study the microencapsulation technique was perfected with both orifice-ionic gelation process and coacervation methods. The SEM analysis indicated the totality of the gelatin microcapsules with plant extracts which adhered to the fibers of the cotton fabrics. Hence the newer microencapsulation technique was found to be effective in providing multifunctional fabrics with the complete effect of microbial protection and functional performance. The results of soil burial test show that except the untreated fabric and the brief sample, all other samples (commercial / chemical / plant extract treated) showed resistance to degradation. The structural damages were clearly seen at the degraded sites of the untreated fabric where as no damages was noticed on the finished sample using SEM. This study proved that the microbial resistance provided by neem extract treated cotton fabric could enhance the wear life of the textile products. The loss in breaking strength at an interval of 4 weeks of soil burial revealed that the fabrics treated with chitosan / neem extract / dual finish / microcapsule finish showed higher percentage strength retention. It is interesting to note that in case of dual finished and microcapsule finished fabrics, this strength retention was excellent showing more than 90% even after 16 weeks of soil burial.

All the treated fabrics without washing exhibited 100% reduction of bacteria. The fabrics of chitosan treated with etherified DMDHEU, neem with etherified DMDHEU and dual finished fabrics retained >90% bacterial reduction upto 40 wash cycles, where as fabrics treated with chitosan / neem with DMDHEU retained >90% bacterial reduction only upto 30 wash cycles. It was also observed that fabrics treated with chitosan (1%) and neem (5%) without the cross-linking agent had very poor wash durability. On the other hand the dual and microcapsule finished fabrics exhibited excellent wash durability by retaining >90% bacterial reduction upto 50 wash cycles. The presence of DMDHEU and etherified DMDHEU improved the laundering durability, but the difference in the effect was only marginal.
These findings suggest that the barrier properties of antimicrobial finishes on cotton against microorganisms could be effectively achieved with the treatments without significant changes in the physical, functional and fastness properties. The tensile strength of all the treated samples was unaltered when compared with the untreated samples. A slight improvement in physical properties of cotton fabrics treated was noticed when treated with dual finish and microcapsule finish. It was also confirmed that the fastness properties of the finished samples such as acidic perspiration, alkaline perspiration and rubbing fastness were unaffected by the treatment. The surface resistivity, air permeability, bending rigidity and bending modulus were also found to be unaffected after the treatment.

Commercialization of the medicinal plant extracts as antimicrobial textile finishes can be done successfully by a systematic and scientific approach to extraction, purification and use. Optimization of the use of plant extracts on fabrics has to be achieved to minimize the investment cost. The extracts of medicinal plants such as neem, prickly chaff flower, tulasi and aloe vera were subjected to HPLC analysis and active factors were identified as azadirachtin, achyranthine, champhene and aloin respectively. The efficacy of chemical and neem extract treated fabrics was analyzed, and the process for chitosan treatment of cotton fabric was optimized as 1.0-1.5% concentration at 82-92°C and the neem extract treatment of cotton fabric was optimized as 6.5-7.5% concentration at 82-92°C based on the percentage bacterial reduction.

From the hospital field trials it was observed that the textile products used in hospitals pretreated with neem extracts didn’t produce any allergy, irritation, and disagreeable odour and unpleasantness during the trial. Dermatological tests confirm the utility of the treated materials without any discomfort and harmful effect on the skin of the users. The bacterial load on the untreated samples was rich when compared with the treated items.

The critical evaluation of antimicrobial finishes prepared from medicinal plant extracts on textile fabrics including the microencapsulation technique could possibly be designed to incorporate such active factors on cotton fabrics. Such antimicrobial finishes would definitely help the textile industry to introduce antimicrobial treated fabrics of
different nature, taking into account the ecology, environmental barriers and the health status of the users after post exposure. Medicinal plant extracts used in this study were safe and eco-friendly, as they have been shown to be free from hazardous chemicals. Thus in this study the development, standardization and optimization of medicinal plant extracts as finishes for cotton fabrics are of immense significance in the development of eco-friendly antimicrobial textile finishes for various textile products and made commercially available. As of now no such textile products treated with antimicrobial finishes are in use in India. Hence to enhance the value of different textile products this present study helps the textiles manufacturers to switch over to certain optimized use of antimicrobial textile finishes for different textile products in near future.