International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 11 | Nov 2019 www.irjet.net p-ISSN: 2395-0072

Review Study on Antimicrobial Finishes on Textiles – Plant Extracts and Their Application

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Abstract: *Medical textiles are one of the major areas of technical textiles showing promising future in terms of innovations. Antimicrobial property of textiles will find application not only in medical sector, but also in health and hygiene products. Presence of microbes in textiles has many detrimental effects like bad odors, discolouration, spots and stains on textiles. Synthetic antimicrobial agents give efficient performance and durability but they are harmful to the environment. Therefore, research and development of plant based antimicrobial agents is given lot of importance now days. The objective of this article is to review the research done over a long period of time in developing eco-friendly antimicrobial textile finishes and to present the various sources from which the antimicrobial agents were extracted. This article also gives a brief view of the research happening in development of antimicrobial textiles, methods of application and impact of these treatments on health and environment.*

***Key words**: antimicrobial agents, gram positive bacteria, gram negative bacteria, pad-dry-cure, nanotechnology, cross linking, microencapsulation, bactericidal, biocide*

1. INTRODUCTION

Technical textiles have found rapid growth and demand in recent years due to the innovations being made in imparting novel properties of added value to textiles. In the recent scenario the awareness for healthy life style has increased multifold creating demand for health and hygiene products. The ancient Egyptians applied antimicrobial finishing to textiles by means of herbal extracts and spices to preserve mummies. There is a great scope for production of textiles and apparel that provide protection against microbes.

This article is an attempt to review the recent developments in the area of imparting antimicrobial finishes to textiles from plant extracts. The article presents the research findings, their plant sources, methods of applications and extent of durability.

Microbes are omnipresent. They multiply rapidly under suitable conditions such as, heat, humidity and food. The microorganisms could be pathogenic and non-pathogenic. Pathogenic microbes will grow in textiles that come in contact with human body. They adhere to the fiber, multiply quickly and finally they damage the fiber [10]. Even if the microbes are non-pathogenic, they can cause undesirable colour changes, stains, foul odor and degeneration of textile fibers. The natural fibers provide favorable conditions for growth of microbes. They consist of starch, protein and fats or oils may be added during the finishing, which provides food for microbes [4]. The synthetic fibers and blend, when come in contact with human body, readily absorb perspiration and encourage microbial growth. In the current scenario of increased demand for hygienic products, there is a need for application of antimicrobial finishes to textiles.

A microbe consists of outer protective cell wall made of polysaccharides [11, 26]. A semi permeable membrane protects the intracellular components, enzymes and nucleic acids. The presence of this membrane and cell wall gives protection to the microbe and helps in functioning [29]. Any antimicrobial agent (chemical or natural) acts up on the cellular performance and integrity of the membranes of microbes [15]. Thus, based on the mode of action, antimicrobial agents can be classified as [11, 15]

1. Bactericidal – inhibits cell growth
2. Biocidal – kills the microbe

A lot of scientific investigations are going on in developing durable antimicrobial agents since a long time. Synthetic antimicrobial agents are very effective in imparting protection against a wide range of microorganisms. They are durable and last for several laundry treatments like bleaching and washing. But they might destroy desirable microbes and cause water pollution also. Due to the present environmental conscious scenario, strict regulations are enforced by governments. This has created necessity for research in developing eco-friendly antimicrobial textile finishes prepared from plant extracts, essential oils and other natural products [33].

Availability of wide surface area and ability to absorb and retain moisture facilitates growth of microbes on textiles. In order to minimize and arrest the growth of microbes, extensive research is encouraged and promoted to develop antimicrobial textiles over the past two decades.

1.1 Antibacterial activity

Most of the antibacterial agents act by coagulation of protein and by leaching of the microbes. They move to the microbe and poison them. But durability of such antimicrobial agents is short term. Some antimicrobial agents act by forming molecular bonds with textiles and break the membranes of the microbes. These categories of antimicrobial agents are durable. Antimicrobial treatments are given as value addition finishes. They are applied to inhibit undesirable odors, stains and spots due to growth of fungi, mildew etc.,

An ideal antimicrobial product should have following qualities [9]

- Should show activity against wide range of microbes
- In the presence of organic material, acids and alkalis and it should be active
- Should penetrate deep in to the structure of the fabric
- Should not interfere with performance of other finishes
- Should not alter the performance and aesthetic properties of the textile
- durable during laundering and finishing operations
- eco friendly
- nonirritant for skin of the user
- should be inexpensive and safe to use
  Antimicrobial properties are imparted to textiles by treating with chemicals or natural extracts to inhibit the growth of microbes such as bacteria, virus and fungi.

Most of the antimicrobial agents used for commercial production of antimicrobial products are biocides. They inhibit the formation of cell wall, protein synthesis, nucleic acid synthesis and metabolic processes. Commonly used chemical antimicrobial agents are Triclosan, Quaternary Ammonium Compounds (QACs), metals and metallic salts (copper, zinc, cobalt and silver) [29].

1.2 1.2 Plant based antimicrobial agents

Imparting antimicrobial properties involves, treating with antimicrobial agents at the finishing stage or incorporation of biocides in to synthetic fibres before extrusion. Triclosan and other chemical agents can cause skin irritation, non-biodegradable and bio accumulators [29]. Triclosan is banned by European governments [12].

Most of the pathogens have developed resistance to chemical antimicrobial agents. A lot of scientific investigations are going on in developing durable antimicrobial agents since a long time. Synthetic antimicrobial agents are very effective in imparting protection against a wide range of microorganisms. They are durable and last for several laundry treatments like bleaching and washing. But they might destroy desirable microbes and cause water pollution also. Due to the present environmental conscious scenario, strict regulations are enforced by governments. This has created necessity for research in developing eco-friendly antimicrobial textile finishes prepared from plant extracts, essential oils and other natural products [6]. Therefore, as an alternative to inhibit microbial growth, natural antimicrobial agents are extensively studied.

1.3 1.3 Plant sources having antimicrobial properties and their application to textiles

India has a vast history of plants having medicinal properties being used for treating various ailments by Ayurveda. Various parts of plants such as roots, stems, leaves, flowers, fruits and seeds have medicinal and anti-microbial properties [4]. Most of these medicinal plants contain compounds like flavonoids, alkaloids, polypeptides, Phenolics, Polyacetylenes, Terepenoids etc., which have anti-microbial properties. These compounds serve the function of defense against microbes, insects and herbivores. Some of these compounds give flavor to the plant, odor and coloured pigments.

1.4 1.4 Methods of application of antimicrobial agents [28]

Application of antimicrobial agents is done by different methods.

1.4.1 Pad-dry-cure method: Most common method is pad-dry-cure method. The active agent can be incorporated in to synthetic fibres before extrusion. Direct application is the simplest and oldest method applied by pad-dry-cure method but not durable.

1.4.2 Nanotechnology: Application by nanotechnology is more durable process.

1.4.3 Microencapsulation: the process which solid particles or liquid droplets of antimicrobial agents are covered with a continuous film of polymeric material. This process is more economical compared to direct method. This process does not harm the environment and slowly releases the antimicrobial agent.

1.4.4 Cross-linking: application of cross-linkers to make intermolecular covalent bridges between polymer chains [19] is known as cross-linking. Combination of cross-linking and microencapsulation was found to perform well.

1.4.5 Modification of fibre surface: this process enables strong adhesion of antimicrobial agents to the surface of textiles. This can be achieved by UV radiation, treatment with enzymes, and use of plasma technology, chemical modification and several other techniques.

Natural dyes obtained from plant sources like turmeric, pomegranate and henna etc. were found to have antimicrobial properties along with colouring compounds. Gupta [6] etal have found through their study of antimicrobial properties of eleven natural dyes against Gram positive and Gram-negative bacteria. They found that these natural dyes consist of tannins, which are responsible for antimicrobial properties against many bacteria and fungi [6]. Tannins are water soluble; polyphenols, found in various parts of plants.

1.5 Research done on antimicrobial finishing with natural agents:

K.A.Hammer etal[3] (1999) have studied the antimicrobial properties of 52 plant oils and extracts against various Gram positive, Gram negative bacteria and yeast such as *Acinetobacter baumanii, acromonasver* by agar and broth dilution methods. It was found that bay, lemon grass and oregano inhibited growth of microbes at concentrations of less than 2.0% (v/v). The essential oils of evening prime rose, sweet almond, sage, apricot kernel, pumpkin, and macadamia did not show any antimicrobial activity, even at higher concentrations (2.0%). Inhibitory activity against *C.albicans* and *E.coli* was given by thyme oil and against *Staphylococcus aureus* was given by vietver oil. Their study has proved that a wide variety of essential oils and plant extracts have inherent antimicrobial properties. The data obtained on antimicrobial property of plant oils and extracts, may vary from one investigation to another. The properties of plant extracts vary according to local climate and environmental conditions and some plants with same common names might belong to different species. The method of extraction and method of assessment of results may also vary from one study to other.

R.K.Sarkar etal[4](2003) conducted a study on antimicrobial activity of neem oil, clove oil, tulsi oil and karanja oil. The oils were added to size baths in various concentrations. The stability of size paste was evaluated after adding natural and synthetic preservatives separately. The size paste was applied by padding. Along with antimicrobial agent, cross-linking agent like KVSI and curing was carried out at 150 °F for 90seconds. The resistance to microbial attack on cotton fabric was tested by soil burial test. Among the four oils tested, clove oil showed better antimicrobial function. The clove oil+KVSI combination showed better results than clove oil alone. Antibacterial activity of the four oils was tested by Zone of Inhibition method also. The clove oil+KVSI combination showed better resistance bacteria.

Skergetet etal [5] (2003) found that onion showed antimicrobial activity against a wide range of bacteria such as *B.cereus, P.flouresences , E.niger*and *E.coli*. It was observed that inedible parts of onion showed better antimicrobial activity.

Neem (*Azadirachta Indica*) is found all over India. It has medicinal, insect repellant, antimicrobial antifungal, anti-viral and virucidal properties. Main compounds that showed antimicrobial activity are azadirechtin, salannin and meliantriol. The neem oil, bark extract and seed extract are proved to have antimicrobial properties. M.Joshi etal [10] (2007) have investigated antimicrobial property of neem seed extract (Neemazal Technical) and glyoxal/glycol was used as a cross linking agent. Aluminum sulfate as catalyst, tartaric acid as catalyst activator and ethylene glycol as co-reactive additive were used for cross linking. Methanol was the solvent for Neemazol. Optimum seed extract concentration was found to be 5% (w/v) for good antimicrobial function. The treated blended fabrics (Polyester/Cotton) retained antimicrobial property against Gram positive bacteria was more than against Gram negative bacteria and the antimicrobial property was retained up to five machine washes.

Onion is a good source of sulphur compounds, flavonoids and fibre. Chen.C and Chang.WY [8] (2007) have studied the antimicrobial activity of onion on cotton. The fabric was preptreated with oxygen plasma and onion pulp was grafted at 70 °C for dilution. The time of grafting had proportionate influence on zone of inhibition values.

L.Ammayyappan and J.Jeykodi Moses [14] (2009) conducted study on antimicrobial activity of aloe Vera, chitosan and curcumin (turmeric) individually and in combination with each other on cotton, wool and rabbit hair. Cotton samples were semi-bleached with hydrogen peroxide as pretreatment. Wool and rabbit hair were treated with formic acid. The antimicrobial agents were applied by exhaustion method. Aloe Vera showed better antimicrobial activity compared to chitosan and curcumin. Aloe Vera in combination with chitosan and curcumin showed improved antimicrobial activity. The pretreated fabric samples retained antimicrobial activity up to twenty-five wash cycles.

Sathiyanarayanan etal [17](2009) have studied antimicrobial properties of plant extracts for application on cotton fabric. The fruit rind of Punic granatum, leaf extract of Ocimum Sanctum was applied by different methods viz. resin crosslinking, direct application, micro encapsulation and combinations of these methods. They found that all the methods of application, except direct method showed good durability against washing up to 15 cycles. It was observed that components present in plant extracts such as Eugenol, phytol and Germacrene are contributing to the antimicrobial properties. The application antimicrobial agents by microencapsulation and resin treatment showed change or decrease in physical properties of cotton, such as crease recovery angle and tensile strength.

Study carried by Dahhamet etal[16] (2010) on antimicrobial activity of different parts of pomegranate exhibited that among peel, seed, juice and whole fruit, the peel extract showed best antibacterial activity against *S.aureus* and *A.niger*. The antibacterial activity of cotton fabric was tested by dip method followed by exhaust method. The exhaust method was found to be more effective against gram positive and gram-negative bacteria.

S.Mahesh etal [20] (2011) have studied the antimicrobial activity of neem (A*zadiracta indica*) leaves, pomegranate (P*unica granatum*) fruit rind and turmeric (*Curcuma longa*) rhizome. The neem leaves, pomegranate fruit rind and turmeric were found to yield methanolic extracts of 38%, 42% and 29% respectively. The exhaust method was found to be more effective than dip method for application on cotton fabrics. It was found that antimicrobial activity of neem and turmeric was found to be not as effective as pomegranate. The natural extracts showed more antibacterial activity against gram negative bacteria than gram positive bacteria.

Vyas etal [22] (2011) studied the antimicrobial properties of neem and aloe Vera combination and observed that the combination was more durable to washing even after 15 cycles. They found that the methanolic extract of neem showed better durability to washing than aloe Vera even after 15 cycles.

Antimicrobial property of eucalyptus oil was tested by Ben Fadhel.B etal [23] (2012) eucalyptus oil is well known for its medicinal and cleansing properties, the essential component being Eucalyptol which shows good anti-fungal and antimicrobial properties. They have tested antimicrobial activity of two different varieties of eucalyptus viz. *E.cinera* and *E.odorata* by applying on wool cotton fabric. The antimicrobial activity against *E. coli, S.aureus* and was more on wool samples than cotton samples. It was found that the antimicrobial activity has decreased over the period of time with increase in number of washing cycles. Among the two fabrics, wool showed better wash durability.

A study was conducted by Ganesan etal [27] (2015) on antibacterial properties of neem extract. They have applied neem extract on medical textiles by direct application and microencapsulation. It was found that the durability of antimicrobial finish given by direct method to washing was poor but application by encapsulation showed good durability to washing even after 15 cycles.

A study on antibacterial properties of basil on diapers was conducted by Rajput etal [8] (2017) and they compared the results with antimicrobial activity of synthetic antibacterial agents such as titanium dioxide, silver nano particles and zinc nano particles. It was found that the antimicrobial activity of natural agents was as good as synthetic agents.

Aloe Vera (*Aloe barbadensis*) is used as a skin care application for thousands of years. Aloe Vera gel is used to treat wounds, burns and has cosmetic as well as medicinal uses. It has polysaccharides having different molecular weight such as glucomannan, galactogalacturan and glucolactomann. Aloe Vera has acemannan, a long chain polymer having randomly acetylated linear D-mannopyransoyl that imparts antibacterial, antifungal and antitumor properties [15].

A study was conducted by Thangamani. K and Periasamy.R [34] (2017) on herbal finishing of natural fibres viz. cotton, bamboo and soya bean fabrics for testing their antibacterial activity. They have selected *Terminalia chebula*, *Ocimumtennuflorum* (tulsi) *Coleus aromaticos* and *Aloe barbadensis* , Asteraceae, and *Cymbopoganflexuosus* (lemon grass oil) as herbal antimicrobial agents. The antimicrobial methanol extracts of these herbal sources were applied directly on fabrics by pad-dry-cure method. They found that cotton and bamboo fabrics traded with *Asteraceae* showed zero antimicrobial activity. But soya bean fabric showed good activity on microbes. It was observed that cotton fabric treated with lemon grass oil showed best antimicrobial activity against both gram positive and gram-negative bacteria.

Chitin is a natural biopolymer derived from marine shells and mollusks. Chitosan is obtained by deacetylation, by removing acetyl groups (CH3-CO) leaving reactive –NH3 group from linear molecular chain of chitin. Chitosan is soluble in dilute acetic acid and does not require toxic solvents to dissolve as in case of chitin. Chitosan has polycationic nature and binds with negatively charged macromolecules on the cell surface of bacteria. Chitosan can be used not only as antimicrobial agent, also for other functions such as improving of dyeing process, as antistatic and deodorant finish to textiles. [33]

Pushpalatha etal [25] (2013) have conducted research on application of antimicrobial finish to woven and knitted cotton fabrics by using combination of microcapsules from plant extracts with gum sources. The best feature of microencapsulation is the core antimicrobial agent moves to the outer layer when the fabric comes in contact with water in laundry process, thus improving the antimicrobial property of the fabric. The leaves of pomegranate (*Punica granatum*), tanner's cassia (i) and periwinkle (i) were powdered and by nano particle nucleated microencapsulation technique, microcapsules were prepared. The leaf powders were used as core material for microcapsules and the combination of gums of gum Arabic (*Gum acacia*), guaar plant seeds (Guar gum) and bagawathi gum as wall materials. The antimicrobial property of these micro capsules was found to be more against *E. coli* than against *S.aureus*. 5% concentration of wall materials with core plant extracts showed more activity than 10% concentration.

J.Banupriya and V.Maheshwari [24] (2013) have investigated the antibacterial property of champaca (*Michelia alba*) on cotton fabric. A comparative study was made between conventional method of application and herbal method. The conventional method consists of application of antimicrobial agent by padding and exhaustion. The herbal method involves application of herbs by padding with three roll padding machine for five minutes, drying and curing after padding.

El-shafei etal [37] (2015) have studied the effect of Neem and Tulsi essential oils on cotton, modified cotton and cationic cotton. They have modified the cotton by usingcationized agent – 3-chloro-2-hydroxypropyl trimethyl ammonium chloride (Quat-188) and modified during the carboxymethylation process. Then the samples were treated with Neem and Tulsi extracts as essential oils with silicon micro emulsion for imparting soft hand to the fabric. They tested the physical properties of the samples, such as tensile strength, elongation, roughness, wickability to test the changes after treating with antimicrobial agents. They found the finishing properties were improved after treatment and the antimicrobial performance also increased.

Ibrahim etal [31] (2017) studied the antimicrobial and softness properties of aloe Vera leaf gel extract on cotton fabric. Methanol was used for extraction of gel and Luteal Hit Plus was used as wetting agent for imparting viscosity. Pad dry method showed best antimicrobial activity than coating method.

Saravnan and Bharathi Dhurai [33] (2017) conducted a survey with dish cloths to investigate the microbial growth at normal kitchen environment with normal temperatures. It was found that the fabric supports the growth of *Staphylococcus, Klebsiella* and *Shigella* species. Plant extracts such as Curry Leaf (*Murrayakoenigii*), Pomegranate peels, Banana peel, Casein and Cyclodextrin were studied for antimicrobial activity. The powdered extracts were applied to cotton fabric by pad-dry-cure method. The antimicrobial activity of Banana peel, Casein and Cyclodextrin extracts was found to be more than Curry Leaf and Pomegranate extracts.

A study was conducted by Priya Jaiswal etal [35] (2017) to develop cotton fabrics with antimicrobial properties. Curry leaves (*Murrayakongii*) and ginger (*Zingiber officinalis*) was applied by pad-dry-cure method. The cotton fabric was tested against gram positive (*Scureus, B.subtiles, B.Pumilus*) and gram negative (*Pseudo, Candida, E.Coli*) bacteria.it was found that as the concentration of anti-microbial extracts increased, the antimicrobial activity also increased. There was no undesirable change in physical properties of treated samples. Antimicrobial activity herbal treated cotton samples has improved.

Jyoti. V.Vastrad and Shameenbanu.A.Byadri [36] (2018) have conducted a study to develop antimicrobial finish for cotton fabric using *E.globulous, T.cordifolia* and *T.procumbers* leaf extracts. The samples treated with 10% ethanol extracts were applied by pad-dry-cure method. It was observed that the plant sources gave resistance against both gram positive and gram-negative bacteria.

1.5 Antimicrobial textiles

Many attempts at developing antimicrobial textiles are going on. Sericin, the silk gum has good antibacterial, UV resistant, moisturizing and oxidative properties. [32] Yamada & Matsunaga and Wakabayashi and Sugioka developed sericin modified polyester [32]. Acetobactroxylinium, the sugar cane juice isolate was found to produce bacterial cellulose in commercially viable quantities. Gokarneshan etal [10] produced bacterial cellulose from fermented sugar cane juice.

The bacterial cellulose can find application in making of absorbent pads and nonwovens. To impart antibacterial property, viscose fabrics were modified to increase the attraction for nano-metal oxides. Wool fabrics were given microwave finish to impart antimicrobial property. The piper betel leaf extracts were applied to give antimicrobial finish to natural and regenerated bamboo/cotton knitted fabrics and microencapsulation treatment was given to improve the wash durability of antimicrobial property. By adding nano- silver particles during melt spinning, three types of antibacterial microfibers have been developed. Their bacteriostatic reduction rates range varied from65-99% based on the fineness of fibers.

1.6 Impact of antimicrobial agents – health and environment [29]

Antimicrobial textiles may have prolonged durability due to inhibited growth of microbes. Lesser number of laundry cycles, less usage of water and detergents. But the antimicrobial treatments should be durable and should not be lost in was water causing accumulation of these antimicrobial agents in water bodies. Therefore, production and disposal of these antimicrobial textiles has a great impact on environment.

Strict ecological legislations are being imposed for industrial waste disposal. Conventional methods of application can be replaced by more efficient process like plasma treatment that are a better substitute for chemical processes and will have less impact on environment. Usage of green modifying antimicrobial agents such as chitosan, cyclodextrin and sericin etc, should be considered.

There is a need to address the potential health hazards associated with antimicrobial applications. Some pathogens are developing resistance against antimicrobial agents. The impact of these phenomena depends on type of antimicrobial agent, diffusion and frequency of use. These factors will influence exposure of humans to these resistant microbes. Certain no-harmful bacteria may be perished causing imbalance in the microbe eco-system and causing extinction of some bacteria.

2. CONCLUSION

A wide variety of plant sources are available in nature having antimicrobial properties. Many research studies have been made to develop eco-friendly antibacterial textile finishes, finding their application in healthcare textiles. Most of the plant extracts are complex bio-mixtures [32] and their composition also varies depending on the location, climate and also the method of extraction being used. Standardizing the extraction and application process of the antimicrobial finishes for commercial purposes is also a challenging task. An efficient antimicrobial agent should stop the growth of bacteria and fungi, should last for the life of the fabric by withstanding bleaching and washing, should not have any undesirable effects on fabric (discoloration, strength, softness), should not cause skin irritation or allergies and should be compatible with other finishes and dyes [4] .The durability of plant extract antimicrobial finishes is less compared to synthetic finishes. This area needs focus while conducting research.

REFERENCES

[1] Scalbert. A, “Antimicrobial properties of tannins”, Phytochemistry, vol.30, Dec. 1991, pp. 3875-3883.

[2] Russell A.D, Furr. R, Maillard. J.Y, “Microbial susceptibility and resistance to biocides”, ASM News **1997**, vol. 63, pp.481-487.

[3] Hammer. K. A, Carson C. F, Riley T. V, “Antimicrobial activity of essential oils and other plant extracts”, Journal of Applied Microbiology, vol. 86, Nov., 1999, pp. 985-990.

[4] Sarkar. R. K, purushottam De & Chauhan. P. D, “Bacteria-Resistant Finish on cotton fabrics using natural herbal extracts”, Indian Journal of Fibre & Textile Research, vol. 28, Sept., 2003, pp. 322-331.

[5] Skerget.M, Majhenic.L, Bezjak.M, &Kenz, “Antioxidant, radical scavenging and antimicrobial activities of red onion (Allium cepa.L) skin and edible part extracts”, Chemical and biochemical engineering quarterly, vol. 28, 2003, pp.322-331.

[6] Gupta. D, Khare. S. K. &Laha. A, “Antimicrobial properties of natural dyes against gram-negative bacteria”, Coloration Technol, vol. 120, April, 200, pp. 167.

[7] Deepti Gupta and Somes Bhaumik, “review article – Antimicrobial treatments for textiles”, Indian Journal of Fibre & Textile research, vol. 32, June 2006, pp. 254-263.

[8] Chen.C, Chang. WY, "Antimicrobial activity of cotton fabric pretreated by microwave plasma and dyed with onion skin and onion pulp extractions", Indian journal of Fibre& Textiles Research, vol .1, 2007, pp.122-125.

[9] Deepti. G & Bhaumik. S, "Antimicrobial treatment for textiles", Indian Journal of Fibre & Textile Research, vol.32, 2007, pp. 254-263.

[10] Joshi. M, Wazed Ali. S, Rajendran. S, "Antibacterial Finishing of Polyester/Cotton Blend Fabrics Using Neem (*Azadirachtaindica*): A Natural Bioactive Agent", Journal of Applied Polymer Science, vol.106, June, 2007, pp.794-800.

[11] Gao, Y, Cranston, R, "Recent advances in antimicrobial treatments of textiles", Textile Research Journal, vol.78, Jan., 2008, pp. 60–72.

[12] Blackburn R.S, "Sustainable Textiles:Life Cycle and Environmental Impact", Uk: Woodhead Publishing Limited , 2009.

[13] Joshi. M, Wazed Ali. S. &Purwar. R, "Eco friendly antimicrobial finishing of textiles using bioactive agents based on natural products", Indian journal of Fibre & Textile Research, vol. 34 Sept., 2009, pp. 295-304.

[14] Ammayyappan. L &Jeyakodi Moses. J, "Study of Antimicrobial Activity of Aloevera, Chitosan and Curcumin on Cotton, Wool, and Rabbit Hair", Fibres and polymers, vol.10, Feb., 2009, pp.161-166.

[15] Rahman, M.A.; Ahsan, T.; Islam, S, "Antibacterial and antifungal properties of the methanol extract from the stem of argyreia argentea", Bangladesh J. Pharmacol, vol. 5, 2010, pp. 41–44.

[16] Dahham.S.S , Ali.M.N , Tabassum.H, Khan, "Studies on antibacterial and antifungal activity of pomegranate (Punicagranatum L.)", American Eurasian Journal of Agricultural & Environmental Sciences, vol.9, March, 2010, pp. 273-281.

[17] Sathiyanarayanan. M.P, Bhat. N. V, Kokate. S &Walunje. V. E, "Antibacterial finish for cotton fabric from herbal products", Indian Journal of Fibre & Textile Research, vol. 35, March, 2010, pp. 50-58.

[18] Simonic.B, Tomsic.B, "Structures of novel antimicrobial agents for textiles – a review", Textile Research Journal, vol. 80, 2010, pp. 1721-1737.

[19] Joshi.M ,Purwar.R, WazedAli.S and Rjendran.S, "Antimicrobial Textiles for Health and Hygiene Applications Based on Eco-friendly Natural Products", Medical and Health care Textiles, Woodhead Publishing, 2010, pp. 84-92.

[20] Mahesh. S, Manjunatha Reddy. A. H & Vijaya Kumar. G, "Studies on Antimicrobial Textile Finish Using Certain Plant Natural Products", International Conference on Advances in Biotechnology and Pharmaceutical Sciences (ICABPS'2011), Bangkok, Dec., pp. 253-255.

[21] Michigan State University, "Antimicrobial Resistance Learning Site", Michigan State University: East Lansing, MI, USA, 2011.

[22] Vyas, S. K., Ingale, S. V., Mukhopadhyay, S. and Saraf, N, " Aloe Vera and Neem as Antimicrobial Agents" , 2011, Retrieved from http://www.scribd.com/doc/55162242/1469

[23] Ben Fadhel. B, Assi. A, ladhari. N, Deghrigue.M, Chemli.R and Joly.J.P, " Antibacterial effects of two Tunisian Eucalyptus Leaf extracts on wool and cotton fabrics", Journal of The Textile Institute, vo.l 103, Nov.,2012, pp.1197-1204.

[24] Banupriya. J & Maheshwari. V, "Comparative Study on Antibacterial Finishes by Herbal and Conventional Methods on the Woven Fabrics", Journal of Textile Science & Engineering, vol. 3, March, 2013, pp.1-12.

[25] Pushpalatha. K,Dr.Anitha. D &Dr.Sarada Devi, "Antimicrobial micro Encapsulated Cellulosic textiles", International Journal of Science and Research, vol. 4, March, 2013, pp.882-884.

[26] Windler.L, Height. M, Nowack. B, "Comparative evaluation of antimicrobials for textile applications", Environ. Int., VOL. 53, 2013, PP.62–73.

[27] Ganesan.P, Vrdhini K.J, "Herbal treated microbial resistant fabrics for health care textiles" Indian J. Nat. Prod. Resour., VOL.6, March, 2015, pp. 227-230.

[28] Benjamin Tawaiah, William Badoe, Shaohai Fu, "Advances in the development of Antimicrobial Agents for Textiles: The Quest for Natural Products: Review", FIBRES & TEXTILES in Eastern Europe, vol.24(117), 2015, pp.136-149.

[29] Diana Santos Morays, Rui Miranda Guedes and Maria Ascensão Lopes, "review - Antimicrobial Approaches for Textiles: from Research to Market", Materials, vol.9, 498, 2016, pp.1-21.

[30] Gokarneshan. N, Nagarajan.V. B& Viswanath. S.R, "development in Antimicrobial textiles – Some Insights on Current Research trends", Journal of Scientific & Technical Research, vol.1, Jan, 2017 pp.230-233.

[31] Ibrahim. W, Sarwar. Z, Munir. & Azeem. A, "Aloe Vera Leaf Gel Extract for Antimicrobial and Softness properties of Cotton", Journal of Textile Science & Engineering, vol. 7, March, 2017, pp. 1000301-1-6.

[32] Rajput. A, Ramachandran. M, Gotmare. V.D, Raichurkar. P.P, "Resent Bioactive Materials for Development of Eco-friendly Diapers: An Overview", Journal of Pharmaceutical Sciences and research, vol. 9(10), Oct., 2017, pp.1844-1848.

[33] Saravanan. M & Bharathi Dhurai, "Comparison of Natural Agents to Develop Antibacterial Kitchen Textiles", International Research Journal of Pharmacy, vol. 8, July, 2017, pp.93-99.

[34] Thangamani.K and Periasamy. R, "STUDY ON ANTIMICROBIAL ACTIVITY OF COTTON, BAMBOO AND SOYABEAN FABRICS WITH HERBAL FINISHING", International Research Journal of Pharmacy, vol.8, May, 2017, pp.115-120.

[35] Priya Jaiswal, Agya Preet, Simran, Garima Goel, "Antimicrobial Activity of Herbal Treated Cotton Fabric", International Journal of Engineering and Technology, vol.4, August, 2017, pp.39-43.

[36] Jyoti.V.Vastrad and Shameenbanu.A.Byadgi, "Eco-friendly Antimicrobial Finishing of Cotton Fabric Using Plant Extracts", International Journal of Current Microbiology and Applied Sciences, vol.7, Feb., 2018,pp.2284-292.

[37] El-Shafei.A, Elshemy.M and Abou-Okell.A,"Eco friendly finishing agent for cotton fabrics to improve flame retardant and antibacterial properties", carbohydrate polymers, vol. 118 (0), 2018, pp.83-90.