INNOVATION PROJECT MH-307

ANTIMICROBIAL FINISHING OF TEXTILES USING ECO-FRIENDLY BIOACTIVE AGENTS

Submitted by

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Final Report

UNVERSITY OF DELHI
INNOVATION PROJECTS 2016-17
FINAL REPORT

1. PROJECT CODE: **MH-307**

2. PROJECT TITLE: **ANTIMICROBIAL FINISHING OF TEXTILES USING ECO-FRIENDLY BIOACTIVE AGENTS**

3. NAME OF COLLEGE/INSTITUTION: **Miranda House, University of Delhi**

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Research Interests: Fibre Science and Technology, Functional (Nano) coatings or finishes, Electrospunnanofibres, Stimuli responsive polymers

University of Delhi

Certificate of Originality

This is to certify that the research work carried out and the final report submitted by the Project Investigators and the students of Innovation Project having Project code **MH307** and title **ANTIMICROBIAL FINISHING OF TEXTILES USING ECO-FRIENDLY BIOACTIVE AGENTS** of **MIRANDA HOUSE** is original. Any plagiarism/academic dishonesty reported at any stage will be our responsibility.

Signatures of the all PIs

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Utilization Certificate
Innovation Project 2015-16
Project Code -MH-307

1. **Project Title: ANTIMICROBIAL FINISHING OF TEXTILES USING ECO-FRIENDLY BIOACTIVE AGENTS**

Audited Financial Statement under Innovation Project scheme

College: MIRANDA HOUSE

Project Investigators: Dr. Jyoti Arora, Dr. Simran Jit and Ms. Nutan Rani

Grant sanctioned	(in figures) Rs. 6,50,000 (in Words) Rupees six lac fifty thousand only/-			
S.No.	Budget head	Amount sanctioned	Total Amount utilized	Amount Remaining
1	Equipments/Consumables	3,92,500	3,85,409	7,091
2	Travel	49,500	49,370	130
3	Stipend	1,08,000	1,00,000	8,000
4	Honorarium	25,000	5,000	20,000
5	Stationery	20,000	19,952	48
6	Contingency	55,000	54,993	7
Total amount utilized	**Rs. 6,14,724 (Rupees six lac fourteen thousand seven hundred and twenty four only)**			
Amount Remaining.	**Rs. 35,276 (Rupees thirty five thousand two hundred and seventy six only)**			**35,276**

Certified that out of Rs. 6,50,000/- (Rupees six lac and fifty thousand) sanctioned to Innovation Project Code MH 307, out of which Rs. 6,14,724/- (Rupees six lac fourteen thousand seven hundred and twenty four only) has been utilized during the period of the project. The remaining amount Rs. 35,276/- (Rupees thirty five thousand two hundred and seventy six only) is being returned back to the University.

Signature of Project Investigators

Gupta Nandan & Associates
New Delhi
M. No. 086537
Chartered Accountants

Financial Audit Clearance
and Stamp of Chartered Accountants

Signature of Principal

Project Title and Code:

INNOVATION PROJECT MH – 307

ANTIMICROBIAL FINISHING OF TEXTILES USING ECO-FRIENDLY BIOACTIVE AGENTS

Abstract

In the recent past, the demand of consumers for hygienic clothing and active-wear has created an extensive market for antimicrobial textile products, which in turn has stimulated intensive research and development. A range of textile products based on synthetic antimicrobial agents such as triclosan, metal and their salts, organometallics, phenols and quaternary ammonium compounds have been developed. Although, synthetic antimicrobial agents are very effective against microbes and give a durable effect on textiles, they are also a cause of concern due to the associated side effects such as skin irritation, ecotoxicity, action on non-target microorganisms and water pollution. Hence, there is a great demand for antimicrobial textiles based on eco-friendly agents that not only gives the desired effects on the textile but also comply with the statutory requirements imposed by regulating agencies. There are many natural products such as chitosan, natural dyes and herbal products (aloe vera, tea tree oil, eucalyptus oil etc.) rich in antimicrobial agents. These natural products are less expensive, eco-friendly, non-toxic, do not cause water pollution and produce relatively less adverse reactions as compared to modern synthetic pharmaceuticals. Therefore, natural products can be exploited as an attractive eco-friendly alternative for textile applications. However, the investigations on the use of natural products in textiles are very limited and not well documented. Recent developments on plant based bioactive agents have opened up new avenues in this area of research. The present study presents an overview of the different natural agents that can be used as antimicrobial agents in the textile industry. Different cross-linking agents that facilitate the attachment of these agents on to the fabric have been assessed. Various methods of application of agents on to the textile were evaluated. Lastly, the durability of the finished textile to washing was analyzed. The antimicrobial textile has wide applications in medical and health care sectors.

Introduction

Textiles are an excellent substrate for growth of microbes such as bacteria and fungi. The growth of microorganisms on textiles inflicts a range of unwanted effects such as the generation of unpleasant odour, stains and discoloration in the fabric, a reduction in fabric mechanical strength and an increased likelihood of contamination (Figure 1).

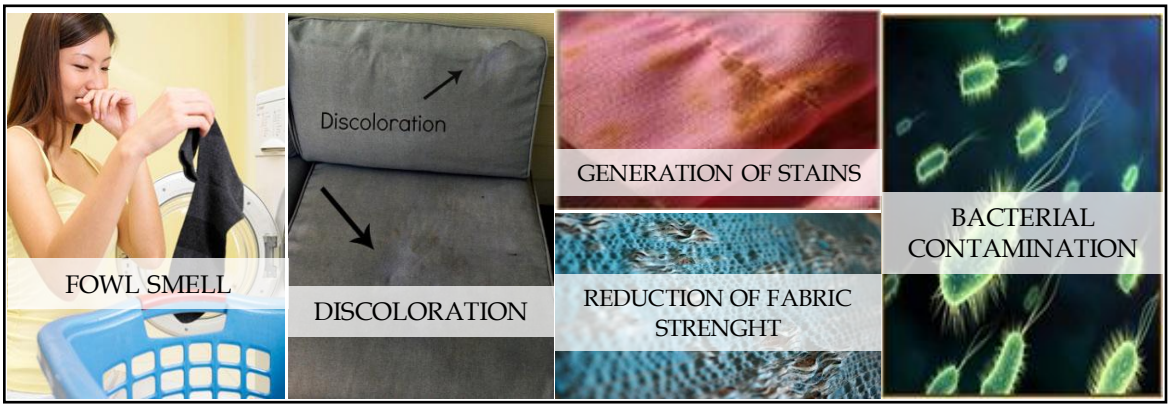


Figure 1. Repercussions of microbial growth on the fabrics.

These detrimental effects can be controlled by antimicrobial finishing of textiles using broad-spectrum biocides (Figure 2).

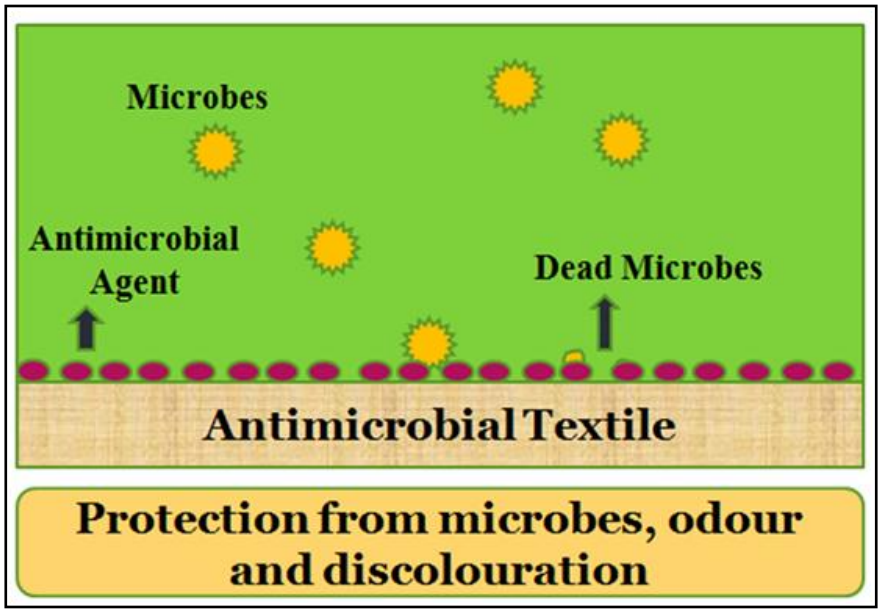


Figure 2: Mechanism of action of an antimicrobial textile on microbes

In the recent past, the demand of consumers for hygienic clothing and active-wear has created an extensive market for antimicrobial textile products, which in turn has stimulated intensive research and development. A range of textile products based on synthetic antimicrobial agents such as triclosan, metal and their salts, organometallics,

phenols and quaternary ammonium compounds have been developed. Although, synthetic antimicrobial agents are very effective against microbes and give a durable effect on textiles, they are also a cause of concern due to the associated side effects (skin irritation, ecotoxicity), action on non-target microorganisms and water pollution (Figure 3). Hence, there is a great demand for antimicrobial textiles based on eco-friendly agents that not only gives the desired effects on the textile but also comply with the statutory requirements imposed by regulating agencies. There are many natural products such as chitosan, natural dyes and herbal products (aloe vera, tea tree oil, eucalyptus oil etc.) rich in antimicrobial agents. These natural products are less expensive, eco-friendly, non-toxic, do not cause water pollution and produce relatively less adverse reactions as compared to modern synthetic pharmaceuticals (Figure 3). Therefore, natural products can be exploited as an attractive eco-friendly alternative for textile applications. However, the investigations on the use of natural products in textiles are very limited and not well documented. Recent developments on plant based bioactive agents have opened up new avenues in this area of research.

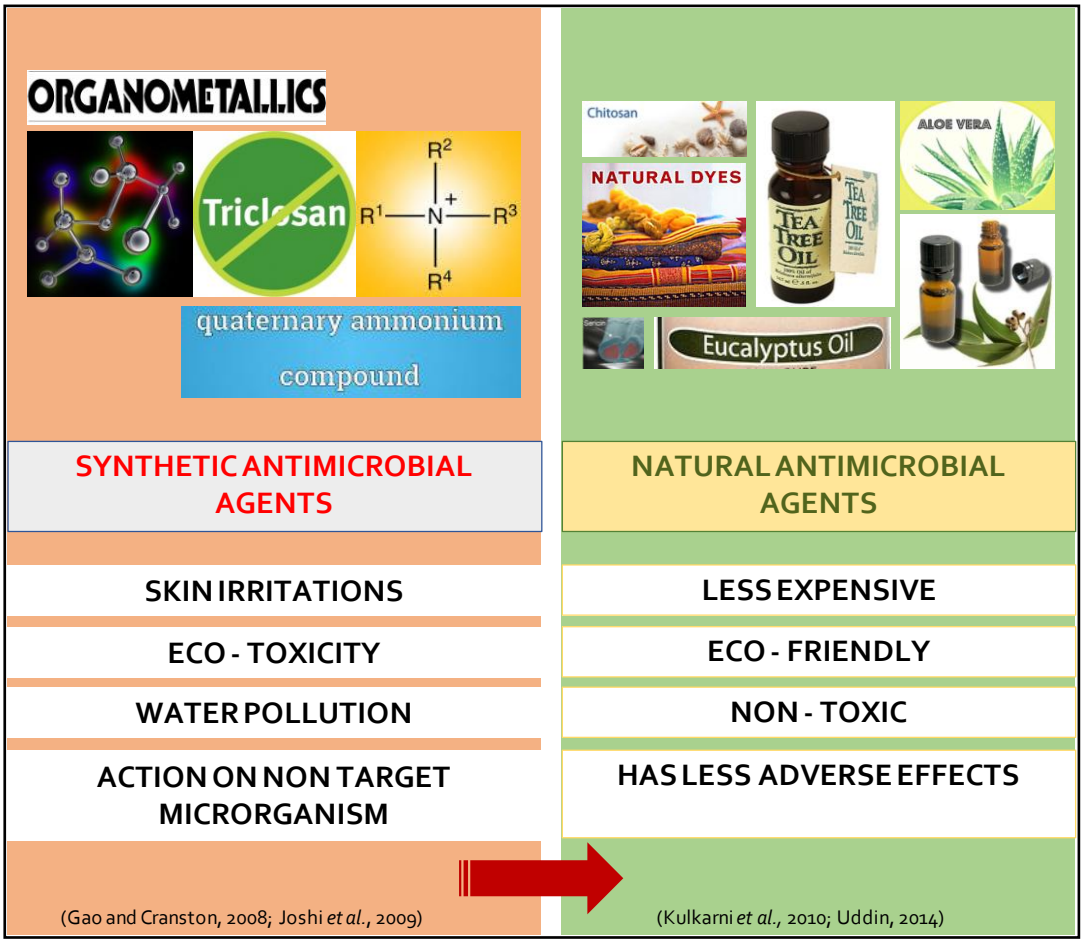


Figure 3. Natural vs. synthetic antimicrobial agents.

IMPORTANT CHARACTERISTICS OF AN ANTIMICROBIAL FINISH

The following requirements should be fulfilled to obtain maximum benefits out of the finish:

- Durability to washing, dry cleaning and hot pressing.
- Selective activity against undesirable microbes.
- No harmful effects should be produce to manufacturer, user and the environment.
- Should comply with the statutory requirements of regulating agencies.
- Compatibility with the chemical processes.
- Ease of application.
- No effect on quality of fabric.
- Resistant to body fluids.
- Resistant to disinfection/ sterilization.

NATURAL ANTIMICROBIAL AGENTS FOR TEXTILE APPLICATIONS

- Antimicrobial compounds from plants (phenolics, terpenoids, alkaloids, lectines and polypeptides, polyacetylenes)
- Chitosan-most abundant polysaccharide derived from marine shells and mollusks
- Sericin- a macromolecular protein, is a major component of silk obtained from silkworms
- Natural dyes with antimicrobial properties such as pomegranate, manjishta etc.
- Neem extract, aloe vera, tea tree oil, eucalyptus oil, azuki beans, prickly chaff flower, tulsi leaves, clove oil, onion skin and pulp extracts
- Other herbal products such as hiba oil, karanga oil, perilla oil etc.

APPLICATIONS OF ANTIMICROBIAL TEXTILES

Uniforms, defense textiles, technical textiles, home textiles (curtains, bath mats), healthcare textiles, textiles used in sports are usually given an antimicrobial textile finish (Figure 4). Another important modified form of finish is bioactive fiber, which includes chemotherapeutics in their structure (Joshi *et al*., 2009).

Figure 4. Applications of antimicrobial textiles in diverse arenas of life.

PRESENT PERSPECTIVES AND MAJOR CHALLENGES

- Synergistic combination of different bioactive agents to bring about broad spectrum inhibitory activity of microbes should be explored.
- Dissolution of natural products for textile application is a major challenge as most of these products are hydrophobic.
- The attachment of bioactive agents on to the textile surface for longer durability of antimicrobial finish is another important aspect.
- The physical and other performance properties of the textile should not be altered after the finish.
- The design of bioactive textile with slow release mechanism of the active compound for longer activity using microencapsulated neem oil or chitosan nanoparticles will be a good area of innovations in the field of biotextiles.
- All the components in a natural product do not possess the antimicrobial property. Thus, the major challenge is selective isolation of the desirable bioactive agents.

Research Problem/Hypothesis/ Objectives

Objectives
Screening of natural products with potential antimicrobial properties.
Screening of cross-linking agents to facilitate attachment of natural products on to the textile.
Application of screened products to textile material using different methods.
Determination of the antimicrobial properties of the finished textile and evaluation of treatment fastness to laundering.

Methodology

Materials: Refer Figures 5 and 6.

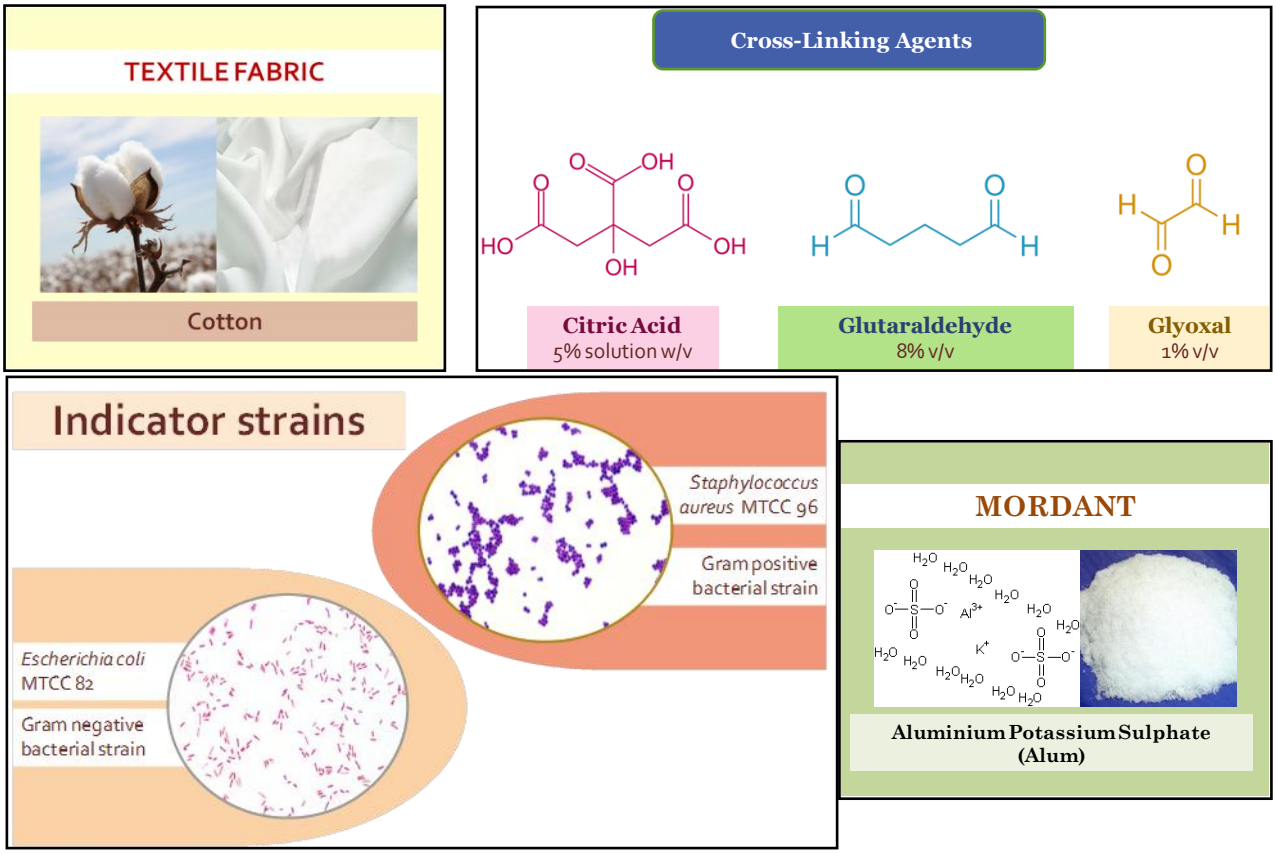


Figure 5. Textile material, cross-linking agents, mordant and indicator strains used.

Natural Antimicrobial Agents: Many natural materials were tested (refer Screening of Antimicrobial agents). Screened natural products with significant antimicrobial potential include:

- **Harda fruit powder,** *Terminalia chebula*
- **Triphala powder,** equal proportion of fruits of *Emblica officinalis*, *Terminalia chebula*, *T. belerica*
- **Dried rind of pomegranate,** *Punica granatum*
- **Chitosan**
- **Leaves of Neem,** *Azadirachta indica*

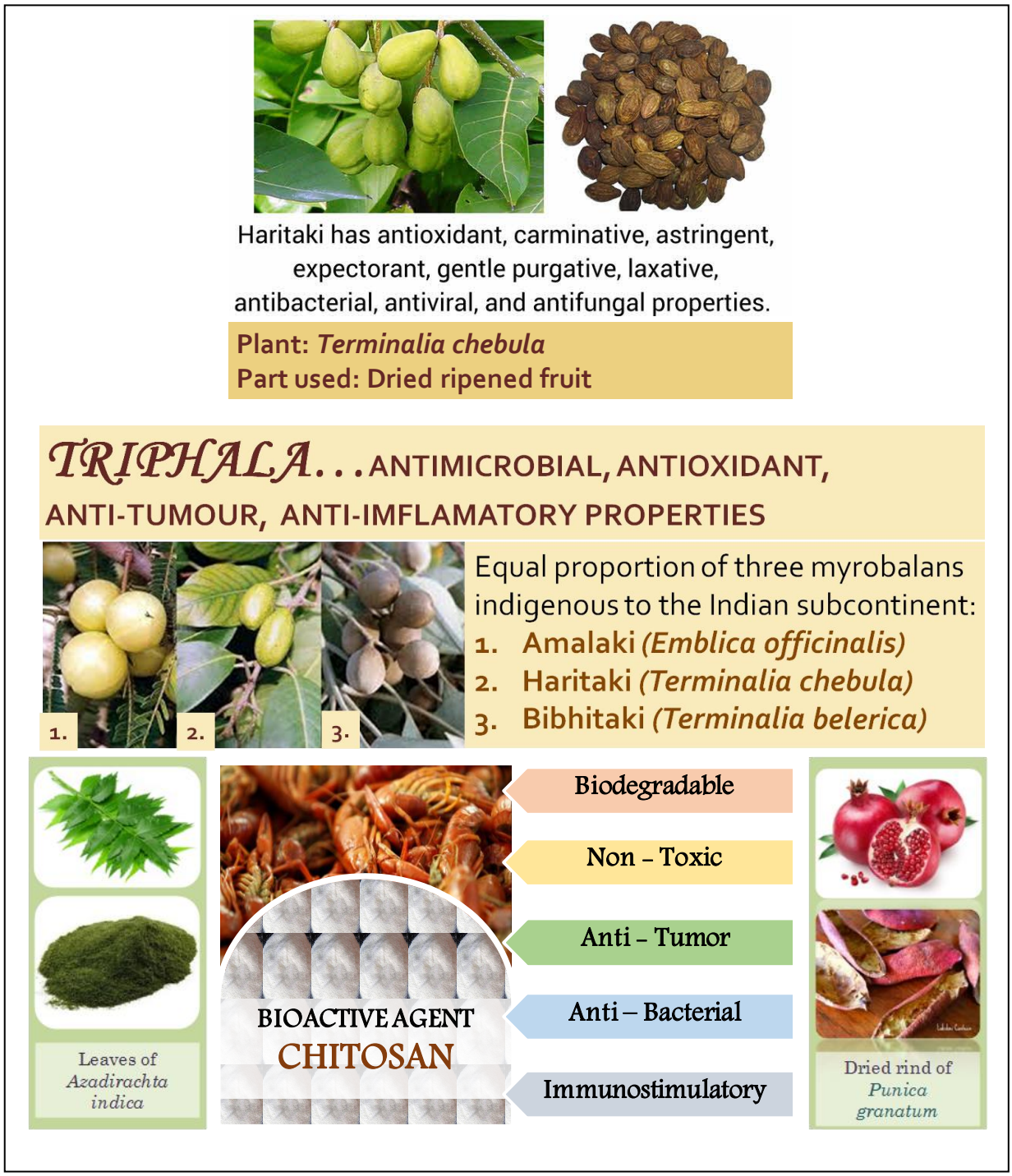


Figure 6. Natural products used for antimicrobial finishing of textile.

Methodology

I) Extraction of bioactive compounds from natural products (25% w/v)

Aqueous Extract: Weigh 25g of dried natural product and add 100 ml of water. Boil it for 45 min. Make the final volume to 100ml after boiling and sieve it through double layers of muslin cloth. This method was used for Harda and Pomegranate (Figure 7).

Leaching Extract: Instead of boiling, natural product is soaked in water and left overnight for leaching of bioactive compounds. This method was used for triphala. Ethanolic extracts were prepared in the same way for neem.

Chitosan Extract: 2.5% w/v solution of chitosan was prepared in 2% freshly prepared acetic acid. It was shaken vigorously to avoid lump formation and stored at 4˚C (Figure 8).

Figure 7. Steps in preparation of harda extract.

Figure 8. Steps in preparation of chitosan extract.

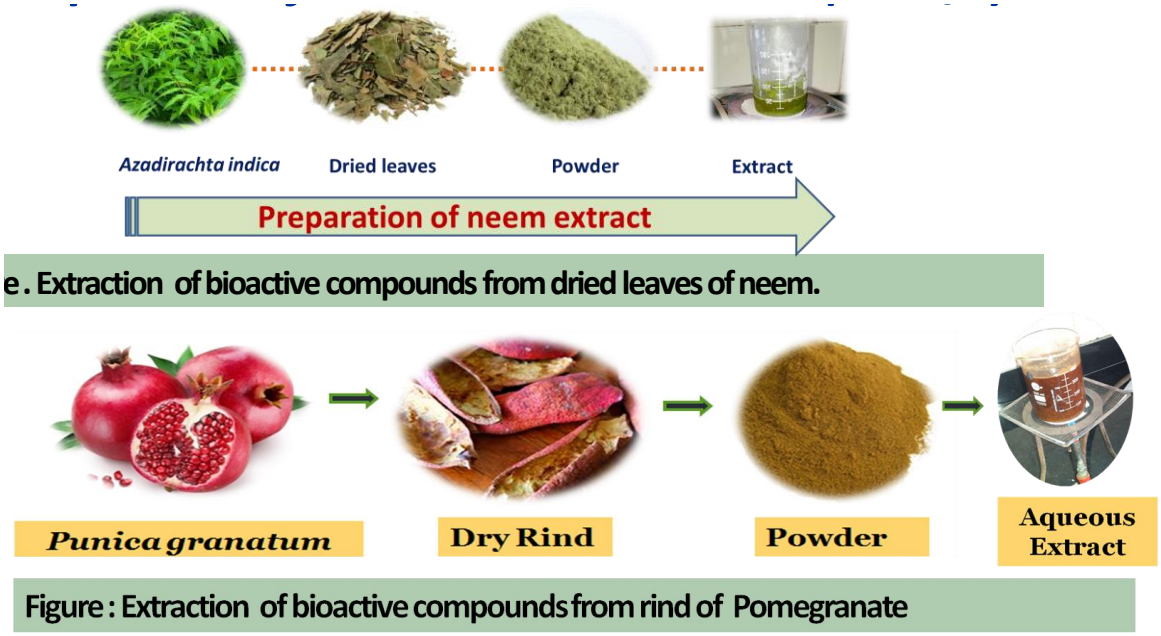


Figure 9. Steps in preparation of ethanolic Neem Extract and aqueos pomegranate extracts.

II) Evaluation of antimicrobial properties of extract

Antimicrobial potential of the extract was evaluated by disc diffusion method (Figure 10).

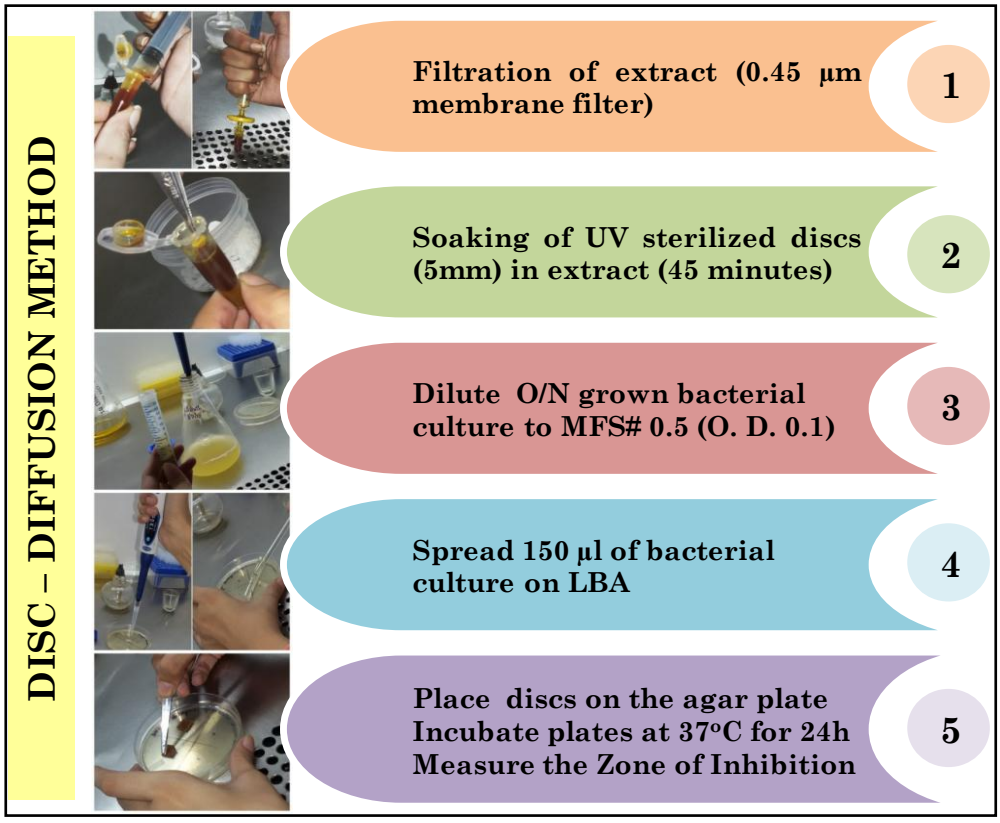


Figure 10. Disc Diffusion Method

III) Chemical Fixing of Bioactive Agents to Textile

Cotton (natural fabric) was used as textile material.

Three cross-linking agents viz., Citric acid (5%, w/v), Glyoxal (8%, v/v) and Glutaraldehyde (1%, v/v) were used to facilitate attachment of bioactive compounds on to the textile.

All the cross-linking agents were tested with and without Mordant (Aluminium Potassium Sulphate, Alum) for some natural products.

IV) Application of Natural Products on Cotton

Bioactive compounds were applied on to the cotton by Pad-Dry-Cure method using a padding mangle (Figures 11 & 12).

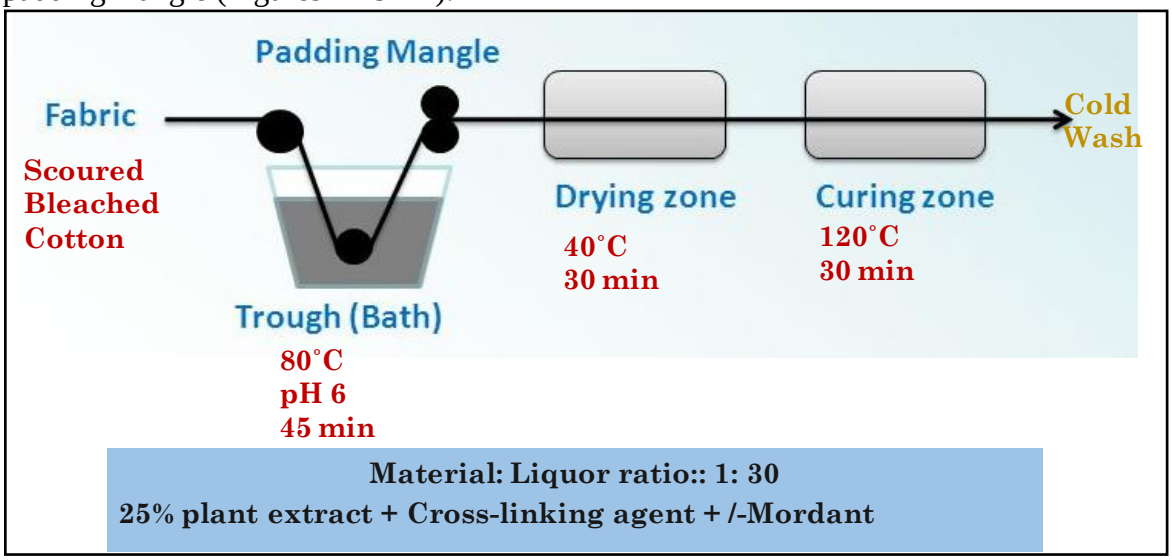


Figure 11. Textile finishing by Pad-Dry-Cure Method.

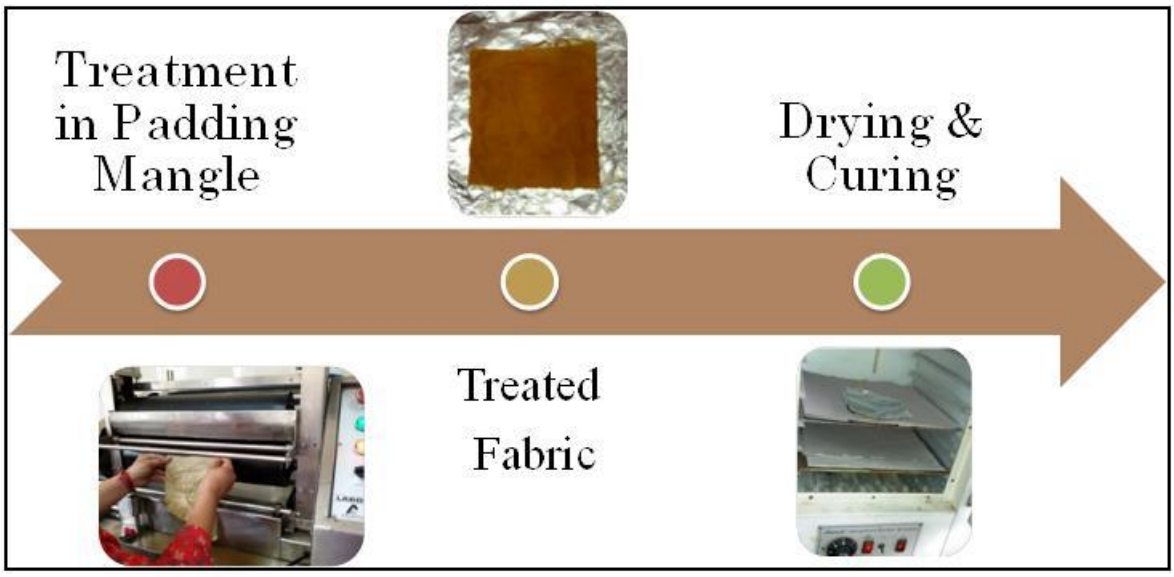


Figure 12. Steps in Pad-Dry-Cure Method.

V) Evaluation of antimicrobial properties of finished textile

Finally, the antimicrobial potential of finished textile was evaluated by diffusion method (Figure 13) and/or parallel streak method (AATCC 147) (Figure 14).

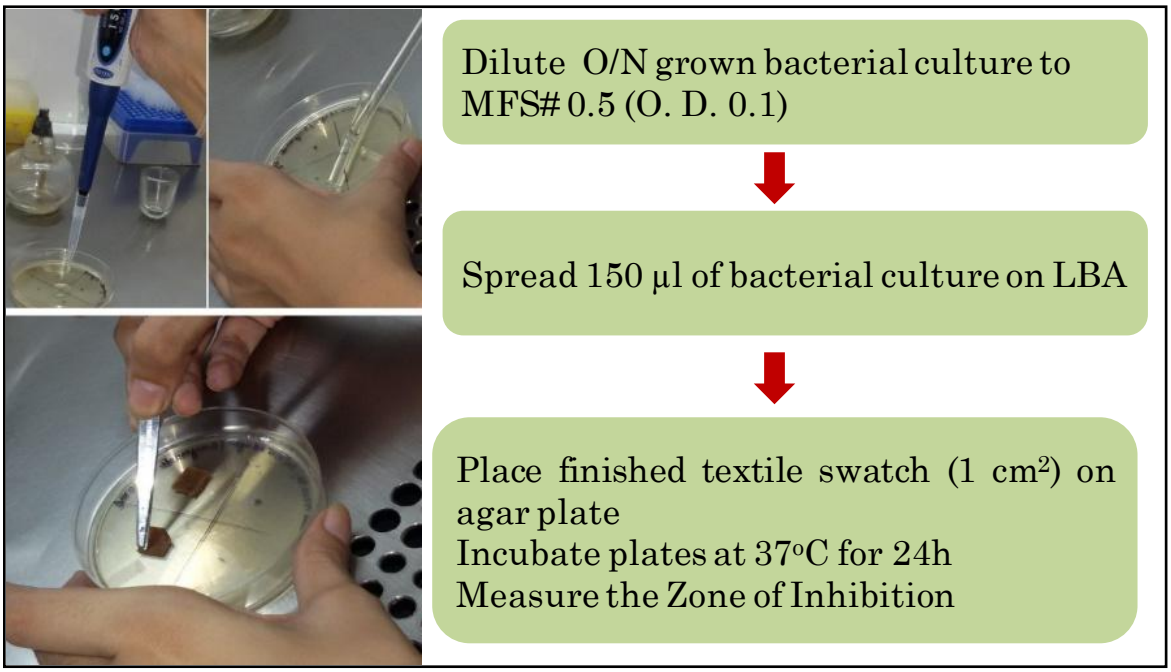


Figure 13. Evaluation of antimicrobial potential of finished textile: Diffusion method.

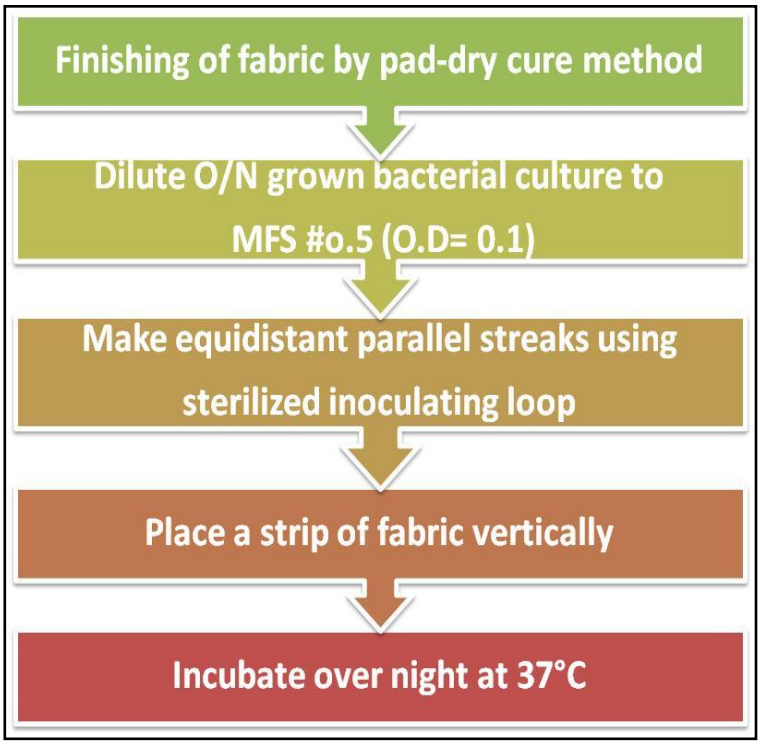


Figure 14. Evaluation of antimicrobial potential of finished textile: Parallel streak method (AATCC 147).method.

Results and Discussion

I) Screening of natural antimicrobial agents: Many natural products were screened for their antimicrobial potential (Table 1). Aqueous, ethanolic and leaching extracts were prepared and compared for their antimicrobial properties. The products were screened based on their potential to inhibit Gram-positive and Gram-negative bacteria (Table 1). The selected products (highlighted in Table 1) were used for finishing of textile material.

Table 1: Screening of potential natural antimicrobial agents.
[Values given are Zones of inhibition (mm)]

S.No.	Natural Extract	E. coli MTCC82	S. aureus MTCC96
1	Pomegranate (aq) 0.5g/ml	15	16
2..	Neem (EtOH) 0.4g/ml	13	14.75
3.	Onion (EtOH) 0.4g/ml	0	13.5
4.	Berberis (aq) 0.4g/ml	0	7.5
5.	Manjistha (aq)	0	0
6.	Chitosan (25% w/v in 2% acetic acid)	8	7.3
7.	Aloe vera (100%)	0	0
8.	Triphala (aq. 25%)	10	15
9.	Harada (aq. 25%)	16	20
10.	Ginger (aq.0.5 g/ml)	0	0

Natural agents selected for textile finishing (by pad-dry cure method):

- Pomegranate
- Chitosan
- Neem
- Triphala
- Harada

II) Antimicrobial Activity of Finished Textile: Textile material finished by Pad-Dry-Cure Method was evaluated for its antimicrobial potential by Diffusion method or Parallel

Streak method (AATCC 147). The results obtained for different natural agents are shown below:

Pomegranate

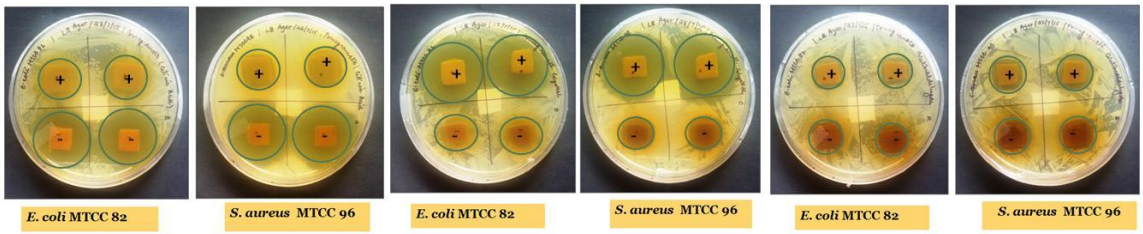


Figure : Antimicrobial potential of finished cotton against *E. coli* and *S. aureus.* (+/ - = Mordant present/ absent)

Test pathogens	Zone of Inhibition (mm)					
	Citric Acid		Glyoxal		Glutraldehyde	
	+	-	+	-	+	-
E. coli MTCC 82	15	30	36	15	16	16
S. aureus MTCC 96	18	32	38	18	17	15

Table: Zone of inhibition of finished textile against *E. coli* and *S. aureus.* (+/ - = Mordant present/ absent)

Inferences:

Finished Textile

- Effective against both gram positive and negative bacteria

Covalent cross-linking of the pomegranate extract into the cellulose matrices

- The cross-linking agent act as a bridging material for chemical bond formation between cellulose and the pomegranate compounds.
- Chemical fixation improves the endurance and efficiency of the finished textile.

Efficient Cross-linking agents

- Glyoxal in presence of mordant followed by Citric acid in absence of mordant

Azadirachta indica NEEM

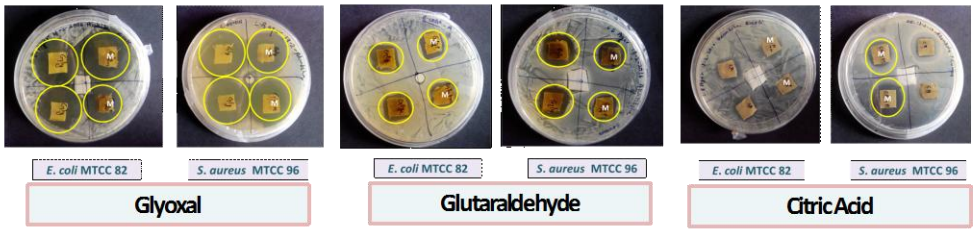


Figure. Antimicrobial potential of finished cotton against *E. coli* and *S. aureus.*
(M = Mordant present)

Test pathogens	Zone of Inhibition (mm)					
	Glyoxal		Glutraldehyde		Citric Acid	
	+	-	+	-	+	-
E. coli MTCC 82	26.5	31.5	16.6	16.5	0	15
S. aureus MTCC 96	30	28	15.5	19	17.5	14

Table . Zone of inhibition of finished textile against *E. coli* and *S. aureus.*
(+/ - = Mordant present/ absent)

Inferences:

1. Neem extract

- Effective against both gram negative and gram positive bacteria.

2. Cross-linking agent

- Glyoxal significantly increased the activity followed by glutaraldehyde against both the indicator strains.
- Citric acid did not increase the efficiency of neem.

3. Mordant

- Presence or absence did not make any marked difference in the overall activity of neem.

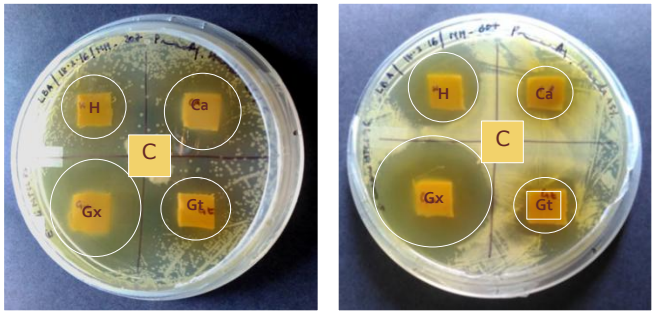
4. Finished textile

- Neem in combination with glyoxal can be used for development of antimicrobial textile.

HARDA

Test pathogens	Zone of Inhibition (mm)				
	Harda	Citric Acid	Glyoxal	Glutraldehyde	Control
E. coli MTCC 82	15.5	18	34.5	17.5	0
S. aureus MTCC 96	21	18.5	35	19.5	0

Average values taken from triplicates



E. coli MTCC 82 | *S. aureus* MTCC 96

H: Harda; C: Control; Gx: Glyoxal; Gt: Glutaraldehyde; Ca: Citric Acid

Inferences

Finished Textile

- Effective against both gram positive and negative bacteria.

Cross – linking agent

- Bridging material for covalent bond formation between cellulose and harda compounds.
- Improves the endurance and efficiency of the finished textile.

Glyoxal → Efficient Cross -linking agent

- Significantly increased the antimicrobial potential of fabric against both the indicator strains.
- In *E. coli* -a two-fold increase in zone of inhibition.

Citric acid & Glutaraldehyde → Not efficient

- Did not increase the antimicrobial potential of the fabric.

Chitosan

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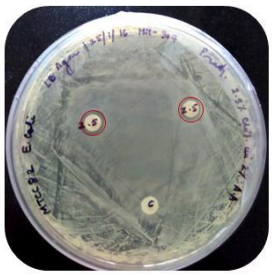


E. coli MTCC 82

S. aureus MTCC 96

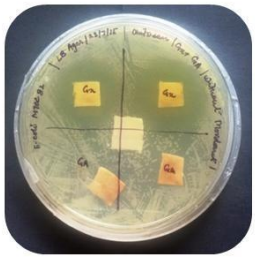
Test pathogens	Zone of Inhibition (mm)
E. *coli* MTCC 82	8
S. *aureus* MTCC 96	10

Key:
C – Control

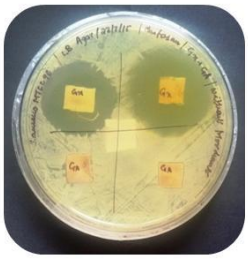
FINISHED FABRIC

E. coli MTCC 82

S. aureus MTCC 96



E. coli MTCC 82



S. aureus MTCC 96

Test pathogens	Zone of Inhibition (mm)					
	Citric Acid		Glyoxal		Glutraldehyde	
	+	-	+	-	+	-
E. *coli* MTCC 82	16.3	24.5	ND	24.5	ND	0
S. *aureus* MTCC 96	18.3	15.5	ND	31	ND	11

Inferences:

Finished Textile

- Effective against both gram positive and negative bacteria

Covalent cross-linking of the Chitosan extract into the cellulose matrices

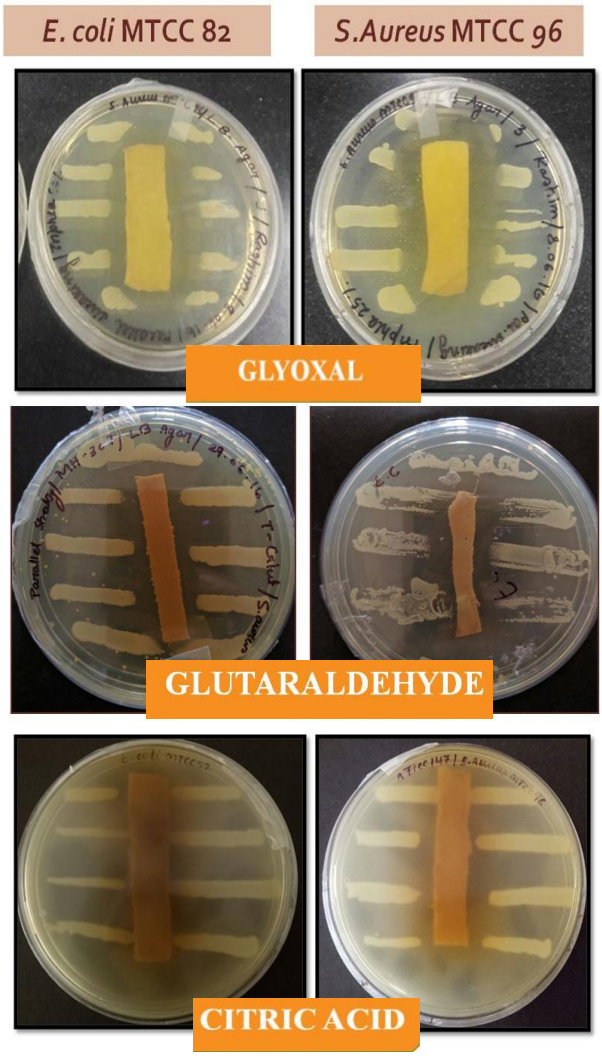
- The cross-linking agent act as a bridging material for chemical bond formation between cellulose and the Chitosan compounds.
- Chemical fixation improves the endurance and efficiency of the finished textile.

Efficient Cross-linking agents

- Overall activity of chitosan was strengthened using Citric acid or Glyoxal as a cross linking agent against both the tested pathogens.

Triphala

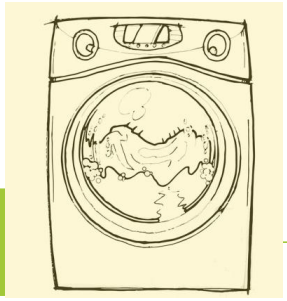
	E. coli MTCC 82	*S. aureus* MTCC 96
Glyoxal	34 mm	31 mm
Glutraldehyde	17 mm	20 mm
Citric acid	9 mm	12 mm



Inferences:

- Aqueous and ethanolic extracts of Triphala exhibit a broad-spectrum antimicrobial activity against all the microorganisms but aqueous extracts shows better activity than ethanolic extract
- By pad-dry-cure method textile was finished with triphala using padding mangle. Parallel streaking method was performed, where Triphala marks a maximum zone of inhibition of 34mm against *E.coli* MTCC 82 & 31mm against *S. aureus* MTCC 96
- Glyoxal enhances the activity of Triphala to a great extent. Glutaraldehyde and citric acid does not increase the zone of inhibition for Triphala

III) Endurance to Washing: Finished Textile was subject to washing for 10 times. After each wash the antimicrobial activity of fabric was assessed by diffusion or parallel streak method. Limitation of the naturally finished fabric is usually durability to washing is less. However, fabric finished with Glyoxal as a cross-linking agent this problem is not there and even after 7-8 washes antimicrobial properties of the fabric remain.



Durability to washing

- Cross-linking agent Glyoxal solves this problem
- Even after 7-8 washes, antimicrobial activity of the finished fabric was observed up to 80-90%.

Innovation shown by the Project:
Innovation Shown

- **Green Antimicrobial Textile**: We have developed eco-friendly antimicrobial textile by using natural products with broad-spectrum antimicrobial properties.

- **Endurance to Washing**: Natural antimicrobial agents have been applied to the textile in the presence of a suitable cross-linking agent that fixes the product on to the fabric through covalent bond linkages between the cross-linking agent and cellulose fibres. The finished fabric exhibits high endurance to laundering. The antimicrobial effect was observed even after 7-8 washes.

- **Sustainable Processes**: The use of hazardous chemicals usually employed in textile industry for finishing has been curtailed. Instead green safer chemicals and processes have been used.

- **Common Kitchen and herbal garden products (**Harda, Neem and Triphala**)** and **Biowaste products** (rind of pomegranate, Chitosan): are used for finishing of textile.

Conclusions

- **Availability of Diverse Indigenous Natural Antimicrobial Agents**: India has a rich diversity of flora and fauna. Several natural plant or animal based products have wide-ranging antimicrobial properties that can be exploited for development of antimicrobial textiles. Natural plant products like rind of pomegranate and

animal product like Chitosan that are biowaste materials can be used as efficient antimicrobial agents. Herbal formulations like Triphala and Harda also exhibit significant results (Table 1).

- **Significant Bacterial Reduction**: Antimicrobial textile significantly inhibited growth of both Gram positive (***Staphylococcus aureus* MTCC 96**) and Gram negative (***Escherichia coli* MTCC 82**) bacteria.
- **Improved Wash Durability with Cross-linking Agents**: The cellulose part in the blend fabrics is actively involved in bond formation with the active ingredients of extract. The interaction between fabric and bioactive compounds in extract can be strengthened by cross-linking agents. The active ingredients may be attached to cellulose by physical bonding and the cross-linking agent may act as a bridging material for chemical bond formation with the bioactive compounds. Therefore, the chemical fixation of the plant extract by covalent cross-linking into the cellulose matrices improves the endurance and efficiency of the resultant functionalised textile.
- **Efficient Cross-Linking Agents**: We screened three cross-linking agents for our study i.e., Citric acid, Glutaraldehyde and Glyoxal. Efficient cross – linking agent was Glyoxal followed by Citric acid and Glutaraldehyde.
- **Endurance to Laundering**: Antimicrobial textiles developed by using natural agents in association with cross-linking agents were durable to washing at least up to 8-9 washes.
- **Natural, eco-friendly product suitable for Global Market**: Textile finish with natural products through sustainable processes meets the statutory requirements imposed by regulatory agencies world-wide. Many consignments of fabrics are refused throughout the world, if the textile material is found to be carcinogenic, toxic and hazardous. Natural products being eco-freindly, non-toxic, non-carcinogenic are widely accepted on a global platform.

Future Directions:

- **High Demand in International Market:** There is a great demand for antimicrobial textiles based on eco-friendly natural products that not only gives the desired effects on the textile but also comply with the statutory requirements imposed by regulating agencies. These natural products are less expensive, eco-friendly, non-toxic, do not cause water pollution and produce relatively less adverse reactions as compared to modern synthetic pharmaceuticals. Increasing concern among people for environment in general and their personal health and hygiene, in particular are also responsible for carving out a niche in the market for green antimicrobial textiles.

- **Applications in Diverse Arenas of Life:** The finished fabric can be used on a commercial scale in several sectors such as sports, health care, military clothing, apparel, home furnishing and hospital dressings.

- **Possible Linkage with Textile Industry and Establishment of Entrepreneurial Startups**: The findings generated through this project can easily be used on a

commercial scale in textile industry where there is an increasing demand for green products. Also, ideas can be exploited to begin with on a smaller scale by establishment of entrepreneurial setup, provided suitable funds are there to begin the startup and make it a sustainable idea.

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Other Details and Achievements

Details of participation in International/ National Conferences held in India with topic, place and dates:

- A Two-Day *National Conference on Combating Industrial Pollution for Sustainable Environment- A fusion of Industrial and Scientific Efforts (CIPSE-16)* organized by Department of Chemistry, Gargi College at Gargi College from 22-23 September, 2016. Poster presentation: Jyoti Arora, Simran Jit, Nutan Rani, Rashim Malhotra, Sandipna Chakraborty, Antimicrobial Textile Finishing with a Traditional Herb, Triphala: A Green Technology.

- UGC-sponsored *National Conference in Chemistry (NCC-2016) Environment and Harmonious Development* organized by Department of Chemistry, Shyam Lal College at India International Center from 7-8 April, 2016. Poster Presentation: Simran Jit, Jyoti Arora, Nutan Rani, Akanksha Sharma, Application of Neem Leaves Extract on cotton: Development of natural antimicrobial textile.

- National Syposium on *Trends in Research and Innovations in Life Sciences at Undergraduate level* organized by Deen Dayal Upadaya College on 30 March 2016. Poster Presentation: Jyoti Arora, Simran Jit, Prerna Aggarwal, Gunjan Gupta, *Colours of Nature on Textiles: An Eco-friendly Approach; **Consolation Prize**)*

- National Conference on *Environmental Concerns of 21st Century Indian and Global context* organized by Zakir Husain Delhi College Evening from 21-22 March, 2016 at Zakir Husain college, University of Delhi. Oral Presentation: Jyoti Arora, Simran Jit, Gunjan Gupta, Prerna Aggarwal, Application of Harda (*Terminalia chebula*) for antimicrobial finishing of textiles

- National Symposium on *Man Made Diseases - An Urban Menace* organized by Department of Zoology, Maitreyi College, University of Delhi on 11-12 February, 2016. 1) Oral presentation: Jyoti Arora, Simran Jit, Prerna Aggarwal, Gunjan Gupta, *Evaluation of different cross-linking agents in antimicrobial finishing of cotton by dry rind of pomegranate*; **Best Oral Presentation Award)** 2) Poster presentation: Simran Jit, Jyoti Arora, Gunjan Gupta and Prerna Aggrawal. *Treatment of cotton textile with Chitosan for protection from microbial attack*; **Best Poster Presentation Award).**

- 56th Annual Conference of Association of Microbiologists of India (AMI-2015) and International Symposium on *Emerging Discoveries in Microbiology* organized by School of Life Sciences, Jawaharlal Nehru University, New Delhi from 7-10 December, 2015. Poster presentation: Jyoti Arora, Simran Jit, Prerna Aggarwal, Gunjan Gupta, *Antimicrobial finishing of textiles by using eco-freindly bioactive compounds derived from rind of pomegranate, Punica granatum.*

- National Symposium on *Environmental Contamination and Public Health* organized by Zakir Husain College, University of Delhi at Zakir Husain College, University of Delhi on 24 Aug, 2015. Oral presentations: 1)Jyoti Arora, Simran Jit, Anjana S. Naorem, Prerna Aggarwal and Anamika, *Development of Antimicrobial Cotton Textiles from Eco-freindly Bioactive Compounds: Applications in Medical & Health Care Sector*.

Details of Publications:

- Arora, J., Jit, S., Gupta, G.and Aggarwal, P., 2016. Application of Harda (*Terminalia chebula*) for antimicrobial finishing of textiles. Proceedings of National Conference on *Environmental Concerns of 21st Century Indian and Global context* (in press).
- Arora, J., Aggarwal, P.and Gupta, G., 2016. Rainbow of Natural Dyes on Textiles using Plants Extracts: Sustainable and Eco-friendly Processes, Green and Sustainable Chemistry (accepted, in press).

Details of workshop organized: One-day Workshop on Eco-friendly Dyeing and Finishing of Textiles was held on 6 October 2015 under Innovation Project MH 307. A total of 43 undergraduate students of different colleges of University of Delhi participated. The Workshop focused on using bioactive compounds extracted from various natural agents to provide antimicrobial finishing to textile material. It started with a lecture by Prof. Manjeet Jassal from Department of Textile Technology, IIT, Delhi, on *Antimicrobial Finishing of Textiles*. The lecture was followed by Hands on session on dyeing and finishing of textiles using natural products.

Details of Awards/ Fellowships received:

- **Consolation Prize** for poster presentation at National Symposium on *Trends in Research and Innovations in Life Sciences at Undergraduate level* organized by Deen Dayal Upadaya College on 30 March 2016.

- **Best Oral Presentation Award** and **Best Poster Presentation Award** at National Symposium on *Man Made Diseases - An Urban Menace* organized by Department of Zoology, Maitreyi College, University of Delhi on 11-12 February, 2016.

Details of curricular resource material prepared, if any:

Prepared workshop manual "Eco-friendly Dyeing and Finishing of Textiles" for undergraduate students of science, 25pp.

Details of Visit to Educational Institution

Visit to Yamuna Biodiversity Park, Delhi on 27 October 2016 to know about the plants in herbal garden and Delhi plant biodiversity in general. All the innovation project students visited the lab and learn about the rich diversity of plants of Delhi region and herbs which can be exploited for their antimicrobial potential.

MH -307 INNOVATION PROJECT TEAM

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Mentor

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Students