

**Comparative study on Antimicrobial activity of *Solanum trilobatum* extract
on Tencel cotton woven fabric**

By

Yasmin Fathima B

(21PBX012)

**A Thesis Submitted to the
Avinashilingam Institute for Home Science and Higher Education for
Women, Coimbatore-641 043**

**In Partial Fulfillment of the Requirements for the Degree of
Master of Science**

In

Bio Textiles

MAY 2023

**Comparative study on Antimicrobial activity of Solanum trilobatum
extract on Tencel cotton woven fabric**

By

Yasmin Fathima B

(21PBX012)

A Thesis Submitted to the
Avinashilingam Institute for Home Science and Higher Education for Women,
Coimbatore-641 043

In Partial Fulfillment of the Requirements for the
Degree of Master of Science


In

Bio Textiles

May, 2023

Certified as Bonafide Research Work


Signature of the Head of the Department


Signature of the Guide

Head, Dept. of Textiles and Clothing
Avinashilingam Institute for Home
Science and Higher Education for Women,
Coimbatore - 641 043, Tamil Nadu, India.

DECLARATION

I declare that the dissertation entitled "**Comparative study on Antimicrobial activity of *Solanum trilobatum* extract on Tencel cotton woven fabric**" submitted by me for the degree of Master of Science (M.Sc.) is the record of work carried out by me during the period from 2022 to 2023 under the guidance of **Dr. R. PRABHA, M.Sc., Ph.D., SLET.**, Assistant Professor, Department of Textiles and Clothing, Avinashilingam Institute for Home Science Higher Education for Women, Coimbatore -642043 and has not formed the basis for the award of any Degree, Diploma, Associate ship, Fellowship, Titles in this University or any other similar institution of higher learning.



Signature of the Candidate


CERTIFICATE FROM THE SUPERVISOR

I certify that dissertation entitled “**Comparative study on Antimicrobial activity of *Solanum trilobatum* extract on Tencel cotton woven fabric**” submitted for the degree of Master of Science (M.Sc.,) Bio Textiles by **YASMIN FATHIMA B (21PBX012)** is the record of project work carried out by her during the academic year 2022 to 2023 under my guidance and supervision and this work has not formed the basis for the award of any Degree, Diploma, Associate ship, Fellowship, Titles in this University or any other similar institution of higher learning



Asst. Professor (Sen)

Signature of the Supervisor with Designation



Signature of the HOD

Head, Dept. of Textiles and Clothing
Avinashilingam Institute for Home
Science and Higher Education for Women
Coimbatore - 641 043, Tamil Nadu, India

ACKNOWLEDGEMENT



ACKNOWLEDGEMENT

First and foremost the investigator places her humble salutations and prayer to the **ALMIGHTY GOD** for his uncountable blessings showered upon her throughout the study.

The investigator owes her respectful gratitude to **Late Dr. (Thiru) T.S. Avinashilingam**, Founder and First chancellor of Avinashilingam Institute for Home Science and Higher Education for Women Coimbatore, for providing this temple of learning to do this research. The investigator regards her reverential gratitude to **Late Hon. Colonel Dr. (Tmt.) Rajammal P. Devedas, M.A., M.Sc., Ph.D (Ohio State), Hon D.Sc. (Madras, Hon D.H.L.(Oregon State), Hon. D.H.L.(Ohio State), D.S.C.(Kanpur), Hon. D.Sc.(Northern Ireland)**, Former Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for being a perennial source of inspiration for conducting the study.

The investigator is grateful to **Prof. S.P. THYAGARAJAN**, chancellor of Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing an opportunity infrastructure and all the amenities to conduct the study in the university.

The investigator owes her special thanks to **Dr.(Mrs) V. BHARATHI HARISHANKAR Ph.D., FRSA**, Vice Chancellor of Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing all the amenities required for the conduct of the study.

The investigator records her gratitude to **Dr. (Mrs) S. KOWSALYA, M.Sc., M.Phil., Ph.D.**, and Registrar, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for extending all help for the smooth conduct of the study.

The investigator records her respectful gratitude to **Dr. (Tmt) N. VASUGI RAAJA, M.Sc., M.B.A., M.Phil. (Madras), Ph.D.**, Dean, Faculty of Home Science, Professor and Head of Department of Textiles and Clothing, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for constant encouragement which have helped in the successful completion of this study.

The investigator records her gratitude to **Dr. K. KALAIARASI M.Sc., M.Phil., Ph.D., SLET.**, Associate Professor and Head Department of Textiles and Clothing, Avinashilingam Institute of Home Science and Higher education for Women, Coimbatore, for constant guidance and encouragement which have helped in successful completion of this study.

The investigator feels extremely proud and privileged for having worked under the guidance of her esteemed guide, **Dr. (Tmt) R. PRABHA, M.Sc., Ph.D., SLET.**, Assistant Professor, Department of Textiles and Clothing, Avinashilingam Institute of Home Science and Higher education for Women, Coimbatore, for her constant motivation, keen interest, untiring patience, innovative ideas, suggestion, constant love and easy approach throughout the study.

She also wishes to thank all the **TEACHING, NON TEACHING STAFF** and **STUDENTS** of the department of Textiles and Clothing who helped her to carry out the research work. She acknowledges her special thanks to **Avinashilingam Institute of Home Science and Higher Education for Women, Bharat Ratna Prof. C.N.R. Rao Research Centre** for the facilities and guidance provided.

The investigator gratefully acknowledges the encouragement, timely help and support received from her friends. She expresses her deepest sense of gratitude to her **Beloved Parents, Family Members and Friends** for extending their support without them the study would never have been seen the light of the day.

CONTENT



CONTENT

CHAPTER NO.	TITLE	PAGE NO.
	LIST OF TABLES	
	LIST OF FIGURES	
	LIST OF PLATES	
	LIST OF APPENDICES	
1	INTRODUCTION	1
2	REVIEW OF LITERATURE	
	2.1 Eco-Friendly Textiles	10
	2.2 Cotton	11
	2.3 Tencel	14
	2.4 Blended Fabric	18
	2.5 Herbs	19
	2.6 Herbal/ Ayurvedic Dyeing	20
	2.7 Special Finishes	24
	2.8 Antimicrobial Finishes	26
	2.9 Microorganisms	29
	2.10 Finishing Test Methods	31
3	METHODOLOGY	
	3.1 Literature Review	39
	3.2 Selection of Fabric and Herb	39
	3.3 Collection of Fabric and Herb	40
	3.4 Pre-treatment of fabric	40
	3.5 Authentication of Herb	42
	3.6 Processing of Herb	43
	3.7 Herbal Extraction by Rotary Shaker	44
	3.8 Testing of Herbal Extraction	44
	3.9 Application of Herbal Extract on Tencel Cotton Fabric	48
	3.10 Evaluation of Finished Fabric	49

CHAPTER NO.	TITLE	PAGE NO.
	3.11 Statistical Analysis	56
	3.12 Nomenclature	56
4	RESULTS AND DISCUSSION	
	4.1 Optimization Test Result of Herbal Extract	63
	4.2 Evaluation of Antimicrobial Finished Fabric	64
5	SUMMARY AND CONCLUSION	88
	BIBLIOGRAPHY	92
	APPENDIX	

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
I	Recipe for Desizing	41
II	Recipe for Scouring	41
III	Recipe for Bleaching	42
IV	Taxonomy of Solanum trilobatum	43
V	Recipe for Herbal extraction	44
VI	Phytochemical Analysis of Herbal Extract	46
VII	Recipe for Exhaust method	48
VIII	Recipe for Spray drying method	49
IX	Nomenclature	56
X	FTIR Analysis	63
XI	Fabric weight	64
XII	Fabric Thickness	65
XIII	Fabric count (warp and weft)	66
XIV	Fabric Stiffness (Warp and weft)	67
XV	Fabric Tensile strength (warp and weft)	69
XVI	Fabric Elongation (warp and weft)	70
XVII	Fabric Abrasion Resistance	72

TABLE NO.	TITLE	PAGE NO.
XVIII	Drop test	73
XIX	Fabric Sinking Test	73
XX	Fabric Wicking test	74
XXI	Colourfastness to Washing	76
XXII	Colorfastness to Crocking	77
XXIII	Antimicrobial Activity in Finished Fabric	77
XXIV	Fabric durability test	78

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
1	Manufacturing Process of Cotton	12
2	Manufacturing process of Tencel	16
3	Classification of Natural Dye	22
4	FTIR Analysis for solanum trilobatum	80
5	Fabric Weight (GSM)	80
6	Fabric Thickness	81
7	Fabric Count (warp and weft)	81
8	Fabric Stiffness (warp and weft)	82
9	Fabric Tensile Strength (warp and weft)	82
10	Fabric Elongation (warp and weft)	83
11	Fabric Abrasion Resistance	83
12	Fabric Drop Test	84
13	Fabric Sinking Test	84
14	Fabric Wicking Test	85
15	Colour Co-ordinates graph	85
16	Colour Strength	86
17	Anti-microbial Activity in finished fabric before and after Washing (Escherichia coli)	86
18	Anti-microbial Activity in finished fabric before and after Washing (Staphylococcus aureus)	87

LIST OF PLATES

PLATE NO.	TITLE	PAGE NO.
1	Fabric Pre-treatment	57
2	Herbal Plants for Authentication	57
3	Herb Processing	58
4	Herbal Extraction	58
5	Phytochemical Screening	59
6	Exhaust method of finishing	59
7	Spray drying method of finishing	60
8	Fabric Evaluation	61
9	Antimicrobial Test	79
10	Anti-microbial Activity in finished fabric before and after Washing	79

LIST OF APPENDICES

PLATE NO.	TITLE
I	Plant Authentication Certificate
II	Fabric Samples

INTRODUCTION



1. INTRODUCTION

Textile has retained a crucial area in human lifestyle, from the ancient generation to the today's contemporary world. Within the current market, the textile Sector is one of the worldwide Industries (Raghibir et al.,2005). The history of Textile manufacturing may be traced back to the year 2000 BC. Textile manufacturing has become one of the large-scale financial activities providing tremendous employment, next to agriculture. The Indian textile and apparel industry provides a treasured wealth of workmanship both professional and semi-professional workforce which is the main contributor to the development of textile units (Tanton et al.,2013).

Textiles play a great role in our daily lives, and everybody desires to know something about textiles. The earliest times, people use textiles for their modesty, warmth, accessories and to show their wealth/status. Textiles are still used for those functions; everyone is an ultimate client. A Textile is any type of material made from different fibers or extended linear materials such as thread or yarn. The manufacturing of textiles is a historical craft, where the speed and scale of production were altered almost beyond popularity by mass manufacturing and the introduction of modern manufacturing techniques (Thomas, 2006).

The textile industry is continuously striving for revolutionary manufacturing techniques to improve product quality and it is also essential that these products are developed in an environmentally friendly way. Besides the traditional characteristic of dressing people, textiles now offer to wear comfort and safety in dangerous environments. The most crucial necessities for protective wear are barrier effectiveness and thermo-physiological comfort for the wearer. Textile finishing chemicals are used to transform a textile cloth into a technical textile with functional properties. In the textile industry, finishing is generally accomplished in the very last stage of fabric processing, because of which the textiles gain numerous functional traits. A wide form of finishing chemicals is available in the marketplace that meets or exceeds the expectations of purchasers. Novel finishes supplying high-value addition to the textile fabric are substantially appreciated by a more demanding client marketplace (Sangwan et al., 2006).

It is broadly perceived that the end uses for technical textiles will retain to boom every year and the change of commodity fiber and fabric properties by innovative finishes can be a cheaper path to excessive overall performance than by using a high-price fiber with inherent

performance properties. The functional finishes can also be implemented in clothing fabric, household textiles, and technical textiles to boost their attraction to purchasers and stimulate growth in niche markets (Roshan, 2014).

Eco-friendly products show benefits to both health and also for our environment. Using green products that are made from natural raw materials improved our quality of life. The production of these products shows minimum harm to our environment. In ancient days textiles were first developed for carrying food, shelter and later only used for clothing. Cotton is the most popular natural fiber admired by people all over the world for its charming feel, comfort and versatility (Malik, 2007).

India is a country with extreme humidity and temperature. People of India mostly use garments made from natural fibers. It may be cotton or cotton blend and it suits perfectly for India's environment and health. The Fabrics made of cotton are very popular in Tropical region Like India (Anita, 2011).

Fibers are mostly available in nature. Since ancient times, people have been constantly dependent on fibers and fibrous for warmth, protection, shelter, coverage and Packaging. In prehistoric times, man depends on animal skin and fur for their protection and warmth ness. Later man found staple and filament fibers from animals and plants. Using his imagination, the man started to twist or spun fiber together to form yarn or thread. The yarn or thread was then subjected to mechanical methods such as interlacing or weaving to obtain strong, staple, flexible, warm, highly comfortable and usable products known as fabric (Frings, 2002).

Natural fibers are more vulnerable to microbes than manmade fibers. Simultaneously, human skin supports the growth of the microorganism, due to its metabolic side products which include basic and acidic (urine and perspiration), even though it is possible that the maximum important barrier to prevent microorganisms from entering the body. Our skin is too infected with countless microorganisms. These microorganisms are almost present everywhere in the environment. NASA Scientists have found microorganisms to a depth of 11km from the sea and at a height of 32 km. These microbes can multiply effectively in a few conditions like a humid environment, dirt, damp areas, perspiration or fiber and receptive surfaces like fabric or skin (Menezers et al., 2007).

Cellulose fibers are included in the group of high comfort fibers. One of the essential developments in regenerated cellulosic fiber technology is the “TENCEL Fibre Process” which is the recorded trademark of Courtaulds Fibres Ltd Company that uses N-methyl-morphine-N-oxide (NMMO) that is used to dissolve cellulose. The generic name for Tencel is Lyocell (Yilmaz 2010). The reason for its current emergence on the market is that Lyocell fiber has the advantage of being used in a less contaminant spinning process than the one for conventional viscose (Yilmaz et al.,2010).

Tencel is a man-made fiber which is manufactured in an eco-friendly process from wood pulp. Tencel is a cellulose fiber, made from wood pulp shows a unique combination of the most appropriate properties of natural fiber and man-made fiber. Tencel is warm like wool, absorbent like cotton, strong like polyester, cool like linen, and soft like silk. The Eco-friendly manufacturing of Tencel shows less environmental impact and tremendous environmental credentials with improved physical properties such as stretches, strength, and absorbency more than cotton. It resists machine washing, quick Dry and resists wrinkling (Achwal,2000).

Lyocell is produced from wood pulp using a solvent-spinning process. More than 99% of the solvent is recycled within the process, making fiber production environmentally accountable. The standard fiber produced is 1.4 dtex, 38 mm, but it can be produced in a range of linear densities and staple lengths. The fiber has a smooth surface and a round cross-section, giving high luster in the raw state (Badr et al.,2016).

It is yarn dyed and absorbs color much better than most other cellular fibers. It drapes well luxurious, wrinkleless, soft, absorbent, much more resistant to ripping, breathable, and very comfortable to wear. In a dermatological study, wearing a Tencel significantly improves comfort and promotes a feeling of well-being. During the weaving process, the size paste in form of starch is applied to the yarn, so that it can withstand stress and strain during the weaving on the loom. If the same size paste remains on the grey fabric it will be really difficult to dye the fabric and hence in the de-sizing process, the size is removed from the grey fabric so that it should get uniform dyeing and finishing in further processing (Diepgen and Schuster, 2006).

The next pre-treatment after desizing seems to be the Scouring process. The process of removing natural (oil, wax, fats, gum, etc) as well as added impurities (during the fabrication process) to produce hydrophilic and clean textile materials is called scouring. It is a very vital process of wet processing. The main purpose of scouring is to remove impurities from textile

materials. The purpose of scouring is to make the fabric highly absorptive condition without undergoing chemical or physical damage significantly, to produce a clean material by adding alkali, to remove non-cellulosic substance in the case of cotton, to make the textile material suitable for the subsequent bleaching operations. “Bleaching for white” is carried out by treating the raw cotton successively with boiling limewater, caustic soda and cold dilute bleaching powder solution and finally washing with cold water. The bleaching process decolorizes the natural cotton pigments and removes any residual natural trash components not completely removed during ginning, carding or scouring. After pre-treatment of the fabrics, special treatment and finishes are given to the fabric to enhance its properties (Roda, 2008).

Natural fibers like cotton are more affected by bacteria compared to synthetic fibers because the bacteria that becomes trapped within the fabric can start to break down and degrade your clothes. The fibers of cotton are made completely of cellulose, a natural component of plants and bacteria can consume this substance and break down the clothes. Cotton is good at absorbing sweat, so that means there are bacteria deep inside the cotton fibers and the bacteria can quickly multiply due to their massive food source i.e. your clothes. So not only will the bacteria in your sweat make your natural workout clothes smell bad, but they will also degrade them over time until they fall apart. To overcome from the above problem of textiles, the fabric is subjected to various technologies. Finishing is one of the recent technologies introduced in the Textile Industry. Fabric finishing is a series of mechanical and chemical processes that are performed on woven fabrics to improve the overall quality and essentially make them presentable to the market. There is a vast amount of finishing processes and treatments. An important note is that the different processes vastly change raw woven to make them workable for the textile market. A big focus for fabric finishing is around color, texture and more recently a fabric’s properties and performance relating to things like UV resistance, antibacterial qualities and anti-static to name a few (Sanjay, 2013).

One of the special finishes is an Anti-bacterial finish. Anti-bacterial compounds are used in an eco-friendly way. The environment-friendly compounds have a good degree of durability with the expected level of performance in anti-bacterial finishing. The human body generates sweat during various conditions of activity leading to sensory and thermal excitation. The bacterial contamination of sweat results in a smell that can generate from various parts of the body like the armpit, forearm, arm, back and forehead. The natural anti-bacterial compounds are used in 9 eco-friendly ways. The environment-friendly compounds have a good

degree of durability with the expected level of performance in anti-bacterial finishing (Naresh et al., 2007).

Bacteria are unicellular organisms that can grow very fast under warm and moist conditions. It can be divided into two groups - Gram-positive and Gram-negative. Anti-bacterial textiles continue to increase the popularity as the demand for fresh-smelling, skin-friendly and high-performance fabric. This finished fabric can minimize the transfer of microorganisms on the wearer by creating a physical barrier (Srikanth, 2010).

Traditional medicinal systems like Ayurveda and Siddha, mention the use of plants in the treatments of various human ailments. India has about 45,000 plant species and among them, several thousand have been claimed to possess medicinal properties. Over the past decade, substantial progress has been made in research on natural products for the treatment of severe diseases like AIDS and cancer. Ayurvedic herbal products are creating a niche amongst the general population very rapidly. The fabrics dyed and finished with these may get curative therapeutic properties and become a protective functional textile (Gupta and Bhaumik, 2007).

Solanum trilobatum is one of the medicinal plants commonly available in different parts of the world and this plant is used in the Indian system of medicine to cure various diseases in humans and animals. Phytochemical screening of this plant extract proved the presence of major bioactive drugs such as sobatum, solasodine, tomatidine, disogenin and solaine in various parts of the plant including leaf, stem, root, flowers and berries to treat various diseases like tuberculosis, respiratory problems and bronchial asthma. Bioactive compounds have been tested for anti-microbial, anti-inflammatory, antioxidant, cytotoxic, anti-diabetic and immunomodulatory activities. We have reviewed the selected bioactive compounds and phytochemicals from *Solanum trilobatum* in treating a tumor, cancer cells and other diseases also involve in upsurging immunity (Balakrishnan et al., 2015).

Anti-bacterial finish causes the fabric to inhibit the growth of microbes. The humid and warm environment found in textile fiber encourages the growth of microbes. Infestation by microbes can cause cross-infection by pathogens and the development of odor where the fabric is worn next to the skin. In addition, stains and loss of fiber quality of textile substrates can also take place (Nayak et al., 2014).

A wide range of textile products is now available for the benefit of the consumer. Initially, the primary objective of the finish was to protect textiles from being affected by microbes, particularly fungi. Uniforms, tents, defense textiles and technical textiles such as geotextiles have therefore all been finished using antimicrobial agents. Later, the home textiles, such as curtains coverings, and bath mats came with an antimicrobial finish. The application of the finish is now extended to textiles used outdoors, the healthcare sector, sports and leisure wear. Novel technologies in antimicrobial finishing are successfully employed in the non-woven sector, especially in medical textiles. Textile fibers with built-in antimicrobial properties will also serve the purpose alone or in blends with other fibers. Bioactive fiber is a modified form of the finish, which includes chemotherapeutics in its structure, i.e., synthetic drugs of bactericidal and fungicidal qualities. These fibers are not only used in medicine and health prophylaxis applications but also for manufacturing textile products of daily use and technical textiles. The field of application of bioactive fibers includes sanitary materials, dressing materials, surgical threads, materials for filtration of gases and liquids, air conditioning and ventilation, construction materials, special materials for the food industry, pharmaceutical industry, footwear industry, the clothing industry, automotive industry, etc (Barker and Midgley, 2007).

Numerous new cleaner and greener methods have been developed as a result of growing environmental concerns and requests for environmentally friendly textile processing. Only a few of the technologies that science has developed for environmentally friendly textile processing. Using tiny particles or droplets encased in a coating, the process of micro-encapsulation creates miniature capsules with a variety of beneficial features. In the future, consumers desire that novel and unique effects will always be present. But more importantly, in an ever-increasing desire for convenience, the consumer will require that fabric properties are inherent in the garment, e.g. fresh odor and softness. Consumers will expect these properties to last the lifetime of the garment and not involve routine intervention in the form of the never-ending addition of washing aids and fabric conditioners. The desire for a healthier and more productive lifestyle will continue to generate a market for textiles that promote “well-being”. Textiles that “interact” with the consumer, reducing stress and promoting comfort and relaxation, are possible through active delivery from microcapsules. In the last decade, the textile industries have concentrated on developing performance fabrics with added value for sports and outdoor applications, as well as novel medical textiles (Chellamani et al., 2006).

Various methods have been used for the antimicrobial finishing of textile materials depending on the particular active agent and fiber type. In general, two different antimicrobial finishing methods can be distinguished. Antimicrobial agents can be either applied in an after-treatment process or incorporated into the polymer solution before extrusion or into the spinning bath. Substance embedded within the fiber structure has to migrate to the fabric surface and should be slowly released during when microbes come into contact (Heine et al.,2007).

The incorporation of multifunctional values with herbal extracts in textile material has become a special area of interest in recent years. Fibers, yarns, fabric and other structures with added functional value have been created for a variety of applications. Textile resources and techniques have become a significant platform for high-tech inventions. Increasing global competition in the textile sector has generated many challenges for textile researchers across the globe (Tayade and Adivareka, 2014).

Considering these aspects in mind the present study on “**Comparative study on Antimicrobial activity of *Solanum trilobatum* extract on Tencel cotton woven fabric**” has attempted to finish the Tencel cotton fabric with herbal extracts and compared to identify the effect of the fabrics against the antimicrobial property.

Aim of the study

The research aims to develop antimicrobial finishing on Tencel cotton using herbal extract of *Solanum trilobatum* using the Exhaust method and Spray drying method.

Objectives of the study

- To investigate the various fabric and herbal source through Literature Review.
- To select the suitable fabric and herbs for finishing.
- To collect and process the herbal extract and do the optimization of extract.
- To finish the pre-treated fabric with herbal extract by Exhaust method and Spray Drying Method.
- To evaluate and compare various parameters and microbial properties of finished fabric.

REVIEW OF LITERATURE



2. REVIEW OF LITERATURE

The literature pertaining to the study on, “**Comparative study on Antimicrobial activity of *Solanum trilobatum* extract on Tencel cotton woven fabric**”. This chapter provides general information on the type of fibers used in this study such as cotton and Tencel. A succinct literature review on Antimicrobial finishing on textiles and its effects has been included. As this research work focuses on an anti-bacterial finish using solanum trilobatum herb, a thorough literature review on the characteristics of different natural finishes used has been provided in this chapter.

2.1 Eco-Friendly Textiles

2.1.1 Introduction of Eco-Textiles

2.1.2 Advantages of Eco-Textiles

2.2 Cotton

2.2.1 Introduction of Cotton

2.2.2 History of Cotton

2.2.3 Manufacturing Process of Cotton

2.2.4 Properties of Cotton

2.2.5 Application of Cotton

2.3 Tencel

2.3.1 Introduction of Tencel

2.3.2 History of Tencel

2.3.3 Manufacturing Process of Tencel

2.3.4 Properties of Tencel

2.3.5 Application of Tencel

2.4 Blended Fabric

2.5 Herbs

2.5.1 Introduction of Herbs

2.5.2 *Solanum trilobatum*

2.5.2.1 Introduction of *Solanum trilobatum*

2.5.2.2 Botanical Description of *Solanum trilobatum*

2.5.2.3 Medicinal Properties of *Solanum trilobatum*

2.6 Herbal/ Ayurvedic Dyeing

2.6.1 Introduction of Ayurvedic Dyeing

- 2.6.2 History of Ayurvedic Dyeing
- 2.6.3 Classification of Natural dye
- 2.6.4 Application of Herbal Dyeing
- 2.6.5 Medicinal Properties of Herbal Dyeing

2.7 Special Finishes

- 2.7.1 Introduction of Special Finishes
- 2.7.2 Importance of Finishing
- 2.7.3 Types of Finishing
- 2.7.4 Methods of Application

2.8 Antimicrobial Finishes

- 2.8.1 Introduction of Antimicrobial Finishes
- 2.8.2 History of Antimicrobial Finishes
- 2.8.3 Origin of Antimicrobial Textiles
- 2.8.4 Requirement of Antimicrobial Finishing
- 2.8.5 Characteristics of Antimicrobial Application
- 2.8.6 The different methods of Antimicrobial application
- 2.8.7 Evaluation of the activity of treated textile material

2.9 Microorganisms

- 2.9.1 Introduction of Microorganisms
- 2.9.2 Bacteria
 - 2.9.3 Types of Bacteria
 - 2.9.3.1 *Staphylococcus aureus*
 - 2.9.3.2 *Escherichia coli*
- 2.9.4 Anti-Fungal
- 2.9.5 Effect of microbes on Textiles and Human

2.10 Finishing Test Methods

- 2.10.1 AATCC 30 – Antimicrobial Textile
- 2.10.2 Durability of Antimicrobial Textiles

2.1 Eco-Friendly Textiles

2.1.1 Introduction of Eco-Textiles

The use of eco-friendly natural dyes on textiles has become a matter of significant importance because of the increased environmental awareness to avoid some hazardous synthetic dyes (Rungruangkitkrai and Mongkholrattanasit, 2017). The coloring of textiles, wood, leather, and other natural commodities with dyes from plants and other natural products is receiving increasing attention. The textiles colored with natural dyes may be one or a combination of factors that attracts people's preference for naturalness, environmental friendliness, lower toxicity, antibacterial/anti-allergic/deodorizing/anti-cancer properties, harmonizing natural shades, or just the novelty (Lee and Kim, 2016).

The awareness of environmental pollution associated with processing and releasing synthetic dyes has led to reviving a new demand for dyeing with naturally extracted dyes (Sinha et al., 2016). Natural dyes are more eco-friendly than synthetic dyes which can exhibit better biodegradability and generally have higher compatibility with the environment (Elnagar et al., 2014). The world over consumers has realized the importance of eco-friendly, biodegradable natural dyes, which everyone encourages and prefers. Natural dyes have no health hazards or disposal problems but on the contrary act as health care (Srivastava et al., 2019).

'Eco' is an abbreviation of ecology, which means the relationship between organisms and their habitats, or humans and their homes in the global sense. 'Eco-friendly' refers to a friendly relationship between humans and their habitats. In other words, humans taking good care of the environment in which they live. The eco-friendly agents not only help to effectively reduce the ill-effects associated with microbial growth on textile material, but also comply with the statutory requirements imposed by regulatory agencies. Textiles are one of the major industrial sectors where use of water, energy and polluting chemicals are very high, and due to increased health and environmental issues, people have become more environmental conscious. Eco-friendly processing trends are becoming more and more popular. Government agencies are placing more restrictions on the control of the quality of effluents. Under these circumstances, processors are looking for eco-friendly alternative chemicals for processing (Joshi et al., 2019).

2.1.2 Advantages of Eco- Textiles

- The herbal sources in the dyeing do not have any pollutants as they are natural sources. The dyeing process is completely eco-friendly.
- The Herbal clothes are light and breezy and are cool in summer and warm in winter (Gupta et al., 2013).
- Herbal clothes improve health conditions (Jain, 2014)
- Natural dyes are eco-friendly, less pollution generation, non-toxic, nonallergic, and biodegradable (Rubia and Bhardwaj, 2016).
- High diversity of rich and complex natural dye colors.
- Different colors go well together and rarely clash.
- They do not depend on non-renewable materials.
- Allow for endless experimentation and replication of ancient techniques. (Senthil Kumar et al., 2015).

2.2 Cotton

2.2.1 Introduction of Cotton

Cotton is an important natural fiber crop in the textile industry and the economic pillar of many developing countries (Yuhuan et al., 2019). Cotton is a cellulose-based natural fiber that originated from the cotton plant and is extensively used for manufacturing textile goods of various types around the globe (Paul et al., 2017). Cotton has been a fundamental natural resource since the origin of various civilizations and today it remains one of the groups of most important plant species for mankind. It is the most widely used natural fiber and the sixth largest source of vegetable oil (Wegier et al., 2016).

2.2.2 History of Cotton

The word cotton is derived from “Quton” which means a plant found by conquered land. The origin of cotton is a legend, it is older than history. It is originated in India and mentioned in “Rig Veda”, written nearly 3,500 years ago. The woven cotton fabric was found in the excavation of Mohenjo-Daro, which is dated back to the third century B.C (Sekhri, 2017).

Cotton was cultivated by inhabitants of the Indus Valley civilization by the 5th millennium BCE- 4th millennium BCE. The Indus cotton industry was well developed, and some methods used for cotton spinning and fabrication continued to be used until the modern

industrialization of India. Well before the Common Era, the use of cotton in textiles had spread from India to the Mediterranean and beyond. Cotton has been spun, woven, and dyed since prehistoric times. Hundreds of years back in the Christian era cotton textiles were woven in India with matchless skill and spread to the Mediterranean countries (Rastogi, 2018).

2.2.3 Manufacturing Process of Cotton



(Rastogi, 2018)

Figure 1

Manufacturing Process of Cotton

The seed cotton goes into a cotton gin. The cotton gin separates seeds and removes the “trash” (dirt stems and leaves) from the fiber. In a saw gin, circular saws grab the fiber and pull it through a grating that is too narrow for the seeds to pass. The roller gin is used with longer staple cotton. A knife blade, set close to the roller, detaches the seeds by drawing them through teeth in circular saws and revolving brushes clean them away. The ginned cotton fiber, known as lint, is then compressed into bales which are about 1.5 m tall and weigh almost 220 kg (Naik, 2018).

Bales of cotton are unwrapped, unstrapped, and allowed to condition and bloom before processing. The bales are arranged on the floor as a lay-down, which contains 30 to more than 70 bales. After being selected, the bales are placed on the mill floor in a specific order to ensure a consistent and uniform product throughout and between processing runs. The surface fibers are skimmed off via a top feeder or plucker that utilizes revolving fingers and suction to remove a small layer of fiber from the top of each bale in the laydown as it traverses across all the bales. The opening process breaks down clumps of compressed fiber into smaller tufts to ease cleaning. The smaller tufts are then transported pneumatically through one or more coarse cleaners that are similar in design and function to cylinder cleaners in the gin plant. Progressively finer cleaning is performed with a fine opener to further reduce tuft size and remove smaller trash particles. After opening and cleaning, the fiber is transported to the carding machine (Christopher et al., 2017).

The second step in the yarn manufacturing process is carding. The blow room transfers the open cotton to this section through a pipeline for further processing. Carding is the heart of the spinning mill and in this section, maximum cleaning of cotton is done. In this stage the cotton is unwrapped and the fibers are separated individually. In this section, the material is collected in a can in the form of rope (called a sliver). This section also describes the technical point, critical success factor, and preventive action and describes the defects rate which affects the yarn quality (Gupta and Bharti, 2019).

Combing cotton is done using a comber machine that combs the cotton fiber to remove short fibers and some hard-to-remove residual foreign material such as seed coat fragments and neps. Ring-spun yarn is produced from roving. Roving is prepared by further drafting drawn slivers to reduce the weight of the material being fed to the spinning frame. The process of drafting individual slivers down to a finer state is known as roving and is performed on a roving frame known as a speed frame. Drawing is a process of further parallelizing the fibers and evening out variations through blending. The drafting action reduces the weight per unit length of the sliver, thus necessitating the use of multiple slivers. The drawn sliver is collected in a can for further processing. Fine-count yarns are made from combed cotton which allows the production of fine fabrics (Christopher et al., 2017).

Spinning is the costliest step in converting cotton fibers to yarn. Currently, over 85% of the world's yarn is produced on ring frames which are designed to draft the roving into the desired yarn size or count and to impart the desired amount of twist. The amount of twist is proportional to the strength of the yarn. The ratio of the length to the length fed can vary on the order. Bobbins of roving are placed onto holders that allow the roving to feed freely into the drafting roller of the ring-spinning frame. Following the drafting zone, the yarn passes through a "traveler" onto the spinning bobbin. The spindle holding this bobbin rotates at high speed causing the yarn to balloon twist is imparted. The length of yarn on the bobbins is too short to use in subsequent processes and is doffed into "spinning boxes" and delivered to the next process, which is spooling or winding (Khurana, 2018).

2.2.4 Properties of Cotton

- Cotton has a high tensile strength making it strong, durable, and less likely to rip or tear. It is 30 percent stronger when wet, withstanding many items of washing in hot water.

- Cotton clothing is soft and easily stretches making it a comfortable fabric to wear. Due to its softness and comfort, it is often used as underwear and undershirts according to the International Forum for Cotton Promotion (Peterman, 2017).
- It wrinkles easily. Withstands heat, detergents, and bleach, about 20% stronger when wet than dry, will shrink unless treated and can be damaged by mildew.
- It can be damaged by prolonged exposure to sunlight and long staple cotton can be woven into smooth almost silky fabrics.
- Cotton fiber produces a flexible and porous cotton fabric with soft yet strong, durable, and comfortable properties (Neella et al., 2017).
- Cotton has some advantageous properties such as good tensile strength, smoothness, wicking properties, and availability (Paul et al., 2017).

2.2.5 Application of Cotton

- Due to their unique softness, breathability, warmth, comfort, and biodegradability cotton fabrics are commonly used in daily life (Shaojin et al., 2017).
- It finds extensive usage in home textiles. The cotton products include towels, sheets, pillowslips, bedspreads, upholstery, and table linens.
- It also has innumerable industrial applications such as medical, surgical, and sanitary supplies (Sekhri, 2019).
- Blouses, T-shirts, sweaters, robes, undergarments, and even sheets or blankets mainly originated from natural cotton fiber.
- The medical product such as bandages and gauze are also produced from cotton. In addition to that cotton cloth is the best choice of fabric when it comes to baby/children's clothing (Peterman, 2017).

2.3 Tencel

2.3.1 Introduction of Tencel

The first commercial product of the lyocell category was brought out under the brand name "Tencel". Fibre had initial commercial success in Japan mainly in indigo denim and specialty niche products (Chavan and Patra, 2017). Tencel is a man-made cellulosic fiber of the lyocell generic fiber type (Beti et al., 2015).

The lyocell was later developed into a full-scale commercial process for producing staple cellulose, with “Tencel” as its brand name (Zhang et al., 2018). Regenerated cellulose fibers are increasingly used in apparel production driven by the continuous improvement of their inherent qualities and the introduction of new brands in the market like Tencel (Yilmaz et al., 2015).

Tencel fiber is a kind of regenerated cellulose fiber produced in a way called the “solvent spinning method”. This product mainly uses coniferous wood pulp as raw materials. Tencel fiber is also known as “green fiber and eco-friendly fiber”. Tencel fiber is a kind of biodegradable fiber (Ya Wang et al., 2019).

Tencel or Lyocell is a sustainable fiber, regenerated from wood cellulose. It is similar in hand to rayon and bamboo both are regenerated fibers. However, Tencel is one of the most environment-friendly regenerated fibers for several reasons. Tencel fibers are grown sustainably and are now popular in the United States, Japan, and other countries mainly to produce high fashion (Hasan et al., 2017) .

2.3.2 History of Tencel

Kaoerzi company has been researching cellulose fiber production with the NM-MO solvent method since 1978. In 1981, the company used amine oxide as a new solvent to spin; the experiment showed that the spinning method is feasible. In 1987, the continuity of largescale plants was established. Tencel products can be decomposed, the solvent of which is nontoxic, and it also has a high recovery rate. So, it is regarded as the third generation of regenerated cellulose fiber. Because of its unique properties, it has been applied to a variety of goods in many fields. The whole of Asia has also appeared an upsurge in Tencel development (Ya Wang et al., 2019).

Lyocell is the generic term for “regenerated cellulosic fibers” which are obtained using a different organic solvent. The abbreviation CLY stands for lyocell and it is derived from the Latin word “lying”, meaning “dissolvable”, and “cell”, another Latin word meaning “cellulose”. The term lyocell, dating back to 1989, has its genesis in the Greek words lying (dissolve) and cell (cellulose) (Regina et al., 2019).

2.3.3 Manufacturing Process of Tencel

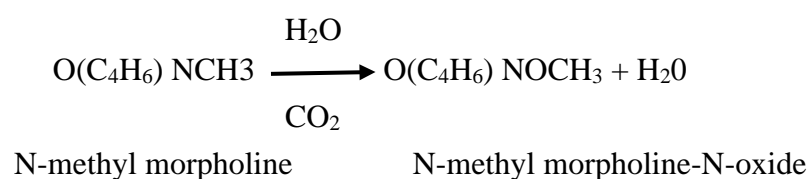


Figure 2

(Hasan et al., 2017)

The Manufacturing process of Tencel

The starting material for lyocell and viscose are the same, i.e. wood pulp, but the manufacturing process is different. Lyocell is manufactured by a direct dissolving process using an organic cyclic polar solvent, namely N-methyl morpholine-N-oxide (NMMO). This solvent is non-toxic and is easily regenerated. NMMO has higher cellulose dissolving capacity than other organic polar solvents like DMSO, DMF, DMAC, NOMA, HMPA, etc. The NMMO solution used is a 50:50 mixture of solvent and water. The trade name of this solvent is AM and the common name is an amine oxide. The melting point of the monohydrate solvent is about 76°C. NMMO can be produced from N-methyl morpholine and hydrogen peroxide as per the following reaction:



Wood pulp is dispersed in concentrated aqueous NMMO and dissolved under the exertion of intensive shear forces and simultaneous evaporation of water. The pulp used is an industrial dissolving pulp, having a DP of 750, with 96% cellulose. The starting point of the process is a suspension of approximately 13% cellulose, 20% water, and 67% NMMO. Dissolution of cellulose in NMMO is done at 120°C (temperature more than 125-130°C being unsafe for NMMO), resulting in a highly viscous solution. The solution is filtered and then extruded into a water bath through fine jets. As the solvent is washed out, the fibers formed into fine filaments are collected as two, from which the staple fiber is produced. The surplus water is evaporated and the remaining concentrated NMMO is recycled into the process (Chavan and Patra, 2017).

2.3.4 Properties of Tencel

- Tencel fiber has the advantages of both natural and synthetic fiber. Tencel fiber has good hygroscopicity, permeability, and performance, its wearing comfort is much better than polyester, and its feels, gloss, and drape are all good.
- The strength of Tencel fiber is higher than that of cotton and viscose fiber; it also has advantages such as being warm, soft, and comfortable; in addition, Tencel has good performance and dimensional stability; it can be blended with other natural fiber and synthetic fiber (Wen et al., 2017)
- Cellulosic fibers like Tencel are hygroscopic, water-absorbing, and breathable.
- High absorbency, warm and dry (as an insulation layer), high heat capacity.
- Cool and dry to the touch, can actively reduce temperature, and has neutral electric properties (Firgo et al., 2016).
- Strongly retards bacterial growth and is gentle to the skin.
- Tencel has a very high absorption capability, a unique nano-fibril structure, and a very smooth surface (Esra, 2017).
- Tencel fiber has high strength, which contains water in its structure as a source of heat capacity that helps in the human body's temperature regulation (Basit et al., 2018).

2.3.5 Application of Tencel

- Tencel is an acceptable fabric in health care and medical environments and is used for post-operative ladies' underwear (Ming and Xiao-Man, 2021).

- Lyocell fibers have the characteristics of high strength, soft and silky handling, luster and bulky touch, biodegradability, high absorbency, and easy processing (Borbély, 2018).
- Tencel fabric is used for industrial purposes such as in automotive filters, ropes, abrasive materials, bandages, and protective suiting material.
- Tencel is used in a variety of applications, including men's wear, sheets, and blankets. Since it is absorbent and dries quickly, it is also suitable for towels (Hasan et al., 2017).
- It is also used in making bandages, baby wipes, oil filters, and carpeting for cars, as well as conveyor belts and plastic parts.
- In powder or fiber form, this material is used in making specialized papers, as an additive for building materials, and in making foam mattresses (Murray, 2016).
- The Tencel fabrics are used to produce home textile products, sleeping products, a variety of apparel, and industrial products such as conveyor belts and medical dressings (Zhang et al., 2018).

2.4 Blended Fabric

Blending is the technique to combine fibers which emphasizes the good qualities and minimizes the poor qualities of the fibers. Blending also makes the fabric manufacturing process economical. In blends of polyester/ viscose and jute blend with cotton, the synthetic fibers provide crease recovery, dimensional stability, tensile strength, abrasion resistance, moisture absorption, and drapability (Bhardwaj and Juneja, 2017).

Blending of different fibres is a very common practice in the spinning industries. The blending is primarily done to enhance the properties of resultant fibre mix and to optimise the cost of the raw material. Tencel-cotton blend has better mechanical properties. Blending is one of the methods to create novel combinations in many ways. Blending also provides a fabric which has different aesthetic properties and can be put into different kinds of new uses, thus opening the way for product diversification. Blended Fabrics are made up of blended yarns. Blended yarns contain fibers of different composition in fixed proportions (Kilic and Okur, 2019).

2.5 Herbs

2.5.1 Introduction of Herbs

The Various medical plants have been used for years in daily life to treat diseases all over the world (Maham et al., 2018). The tribal and rural populations of India largely depend on medicinal plants for their health care (Cyriac et al., 2017). The roots, flowers, leaves, seeds and bark herbs are used to make the dyes. The natural herbs are generally found in very beautiful and distinct shades. Most of the herbs used in ayurveda are procured locally or regionally where they are grown organically and are extracted and applied by age old safe ancient methodology (Mamta and Rani, 2015).

The medicinal uses of plants and plant parts are an age-old practice. Ancient literature indicates that therapeutic use of plants was being practiced since 5000-4000 B.C, (Kumar and Satapathy, 2012). Traditional herbal medicines are an important part of the healthcare system in India. Plants have been used in virtually all cultures as a source of food, clothes, shelter and without doubt, medicine, and have a very significant role in human civilization. Medicinal plants are the local heritage with global importance. There is now an ever-increasing interest and demand for herbs and herbal products worldwide. Herbal medicine, also called botanical medicine or Phytomedicine, refers to the use of seeds, berries, roots, leaves, bark, or flowers of any plant for medicinal purposes (Chhetri et al, 2013). Many efforts have been made to discover new antimicrobial compounds from various kinds of sources such as microorganisms, animals and plants. One such resource is folk medicine. Systematic screening of these may result in the discovery of novel effective compounds (Tomoko et al., 2012).

2.5.2 *Solanum trilobatum*

2.5.2.1 Introduction of *Solanum trilobatum*

In traditional Indian medicine, *Solanum trilobatum* L. is a well-known medicinal herb that is used to treat respiratory diseases such as chronic bronchitis and tuberculosis. The decoction of entire *S. trilobatum* has been reported as treatment for cancer and as anti-tumour agent. *S. trilobatum* leaf extract, on the other hand, has been used to treat respiratory problems such as chronic bronchitis, asthma, cough, tuberculosis, and febrile infections. There has been a lot of data pointing to antimicrobial capabilities, anti-inflammatory, antioxidant, antidiabetic, hepatoprotective and free radical scavenging activities (Shilpha et al., 2013).

2.5.2.2 Botanical Description of *Solanum trilobatum*

Botanical name	: <i>Solanum trilobatum</i> .
Genus name	: Solanum.
Species name	: Trilobatum.
Family	: Solanaeace.
Order	: Solanales.
Common name	: Climbing Brinjal, Purple-fruited pea Eggplant. (Balakrishnan et al., 2015).

2.5.2.3 Medicinal Properties of *Solanum trilobatum*

The therapeutic efficacy of *S. trilobatum* combined with *Solanum xanthocarpum* in bronchial asthma proved their effectiveness. It has efficacy similar to deriphylline but comparatively much less than salbutamol, which is preferred choice of medicine for the treatment of bronchial asthma. Through an antioxidant defense mechanism, ethanolic extract of *S. trilobatum* demonstrated a hypoglycemic effect in the alloxan-induced diabetic mice models. The majority of secondary metabolites with therapeutic qualities, such as alkaloids like soladunalinidine and tomatidine, are found in its leaves. Sobatum, solamarine, solasodine, solaine, and diosogenin are among the bioactive substances found in *S. trilobatum*. Furthermore, sobatum isolated from *S. trilobatum* has shown effectiveness against toxicity studies in rat models. Despite of having recorded evidence of numerous pharmacological actions of *S. trilobatum* in health and disease, as well as its long-standing use in Indian medicine, genomes and metabolomics research on this medicinal plant is lacking (Rajkumar et al., 2015).

2.6 Herbal/ Ayurvedic Dyeing

2.6.1 Introduction of Ayurvedic Dyeing

The word Ayurveda is composed of the two different Sanskrit words. It is divided by Aye and Veda. The “*aye*” means life and “*Veda*” is known as knowledge. Ayurvedic dyeing process was developed by the age-old dyeing methods, since Indus Civilization. The plants or herbs are having various benefits and fabrics dyed with herbs are used for various treatment of diseases like diabetes, skin infections, eczema, psoriasis, asthma, arthritis, and general health problems. The herbal fabric is 100% organic and completely free from synthetic chemicals and biodegradable (Jyothirmai and Panda, 2016).

Ayurvastra clothing is made from organic cellulosic fabric that has been previously treated with Ayurvedic oils and herbs, which accelerate health and cure various diseases depending on the blended oils and herbs. These fabrics also have anti-inflammatory properties. The best time of its usage is when the body is at rest like during sleep, meditation, or relaxation because the functions of the body are mainly diverted towards healing activities. Hence, Ayurvastra cloth is generally used in mats meant for sitting and sleeping, pillow covers, bed sheets, towels, sleepwear, and clothes used during meditation and prayers (Minocheherhomji et.al, 2015).

The herbal dyes are used on organic cotton, natural cotton, silk, wool, linen, jute, hemp etc with their natural blends (Aggarwal, 2018). The herbal treated fabric is eco-friendly and renewable source of textiles and it is free from chemicals, detergent, and pollution (Jayapriya and Bagyalakshmi, 2013). Nowadays the consumers around the globe have interest for sustainable development, environment friendly products and the natural healing has increased demand for safe and organic clothes (Hopenow 2018).

2.6.2 History of Ayurvedic Dyeing

The term Herbal textile is derived from the Ayurvastra. The Ayurvastra is a branch of Ayurveda. The word “*ayur*” is for Health, “*Veda*” means Wisdom, and “*Vastra*” is also called as cloth or clothing (Kolte et al., 2015). The core principles were rooted in the Veda, which is an ancient book of Hinduism. Ayurveda text is also known as oldest and most famous for Charaka Samhita and Susruta (Rockefeller, 2015).

Ayurveda is one of the holistic systems of medical science and it is the oldest healing which is almost used before 5000 years back. This Ayurveda system of medicine has shaped ancient land in India. Ayurveda gives treatment for various disease and it is divided into eight branches of medicine such as principles of preventive healthcare for the entire family (Kulam Svastyam Kutumbakam), treatment of addiction (Sangakara Chikitsa), purification and rejuvenation treatments (Panchakarma Chikitsa), the ayurvedic approach to diet and weight loss (Sthaulya Chikitsa), musculoskeletal system treatments (Vatavyadhi Chikitsa), promotion of self-healing and resistance to disease (Svabhaavoparamavaada), male and female infertility (Vajikarana) and beauty and cosmetic treatments for men and women (Saundarya Sadhana). As far as herbal remedies and treatment of disease are concerned, Ayurveda principles are used

to prevent and treat the illness. It also helps in maintaining and balancing our body, mind, consciousness, diet, and lifestyle (Poonam, 2015).

2.6.3 Classification of Natural Dye

The natural dyes can be obtained from different sources. The natural dyes have wide range of shades and it can be obtained from various parts of plant such as roots, bark, leaves, flowers, and fruits (Saravanan et al, 2018). The natural dyes classification is shown in the Figure 3 (Singh and Srivastava, 2015).

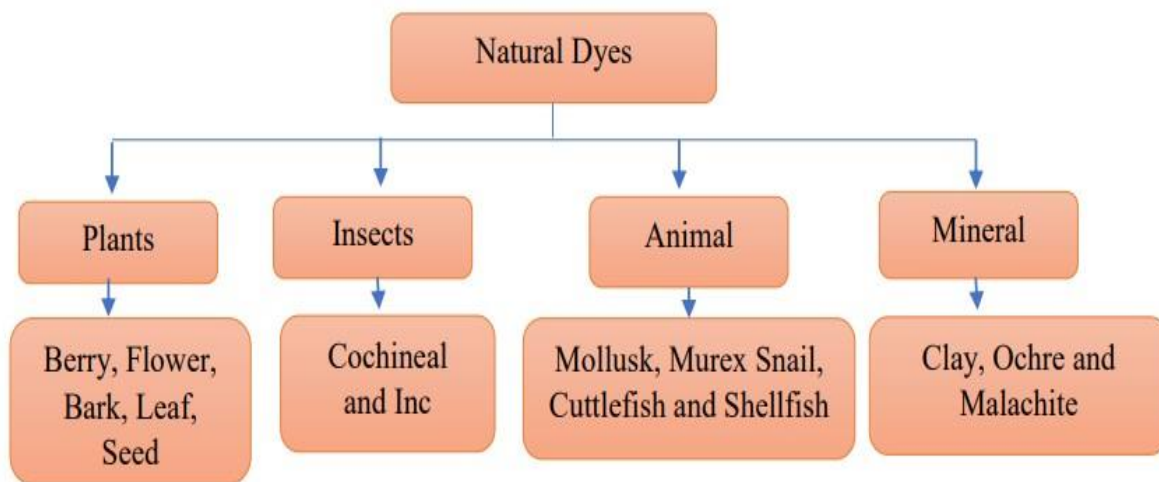


Figure 3

Classification of Natural Dye

2.6.3.1 Plant Dyes:

The different parts of plants such as roots, nuts and flower are the sources of coloring pigment and dyes. E.g.: The henna (Orange red) from the leaves of the henna plant, Catechu (Brown) from resin sticky substance from the plant of acacia tree. Fustic (Yellow) from the wood of fustic plant and Logwood (Black) from the core (heart) of the log wood tree (Korankye, 2016).

2.6.3.2 Animal Dyes:

The red mouthed rock shell is one of the main sources of Tyrain purple. Phoenician purples and biblical blues are the most royal and sacred of all ancient dyeing which is produced from Levantine sea snails of the family Muricidae. The major source of animal dyes are produced from the secretion of insects and dried insect bodies (Shanmathi and Soundri, 2016).

2.6.3.3 Mineral Dyes:

The mineral dyes are used to fix or improve the colorfastness of vegetable dye. The natural dye is more appropriate which has covered all dyes derived from natural resources. Some minerals are also used to give a colouring matter (Mutasim et al., 2018).

2.6.4 Application of Herbal Dyeing

- The herbal textiles are often used in bed coverings, under garments, towels, meditation cloths and sleepwear.
- The herbal cloth is utilized for others purpose like coir mats, mattress, door mats and carpets (Kolte et al., 2015).
- Apart from ayurveda, clothes such as sarees, T-shirts, trousers, dhotis, nightwear, inner wears, caps for healing headaches, cooling caps, bandage masks are produced. The herbal garments are used for home linen. They are also used for window curtains, bed sheets, turkey towels, and coir mats (Jain, 2018).

2.6.5 Medicinal Properties of Herbal Dyeing

- Herbs used for Ayurveda cure allergies and has antimicrobial, anti-inflammatory properties (Saluja, 2014).
- Ayurveda is extra smooth and good for transpiration that helps in recovering from various diseases (Jain, 2015).
- The herbal cloth is used to treat broad range of diseases such as skin infection, eczema, asthma, arthritis, and insomnia (Rangari et.al, 2016).
- The herbal cloth is used to relieve general body aches, stimulate weight loss, and strengthen the immune system. It is also used for mood enhancing, calming, and cooling (Jyothirmai, 2016)
- The fabric also helps in conditions such as rheumatism, arthritis, blood pressure, diabetes and respiratory conditions, such as asthma.
- The fabric has been found very helpful for people suffering from ailments like hypertension, heart ailments, diabetes, asthma and breathing problems (Minocheherhomji et.al, 2015).
- Diseases such as sleeping disorders, arthritis, HIV aids, anaemia depends upon the herb used to make the dyes. It is also used for boosting immunity.

2.7 Special Finishes

Speciality finishes include antimicrobial, fragrances, flame retardants, and many others. Special functional finishes represent the next generation of the finishing industry. Many functions can be achieved through current finishing technology. And, as with all emerging technologies, continued sharing of ideas and research findings will help create more and better opportunities to enhance textiles through functional finishes (Mwnezes and Choudhari , 2017). Now, there is a good deal of demand for the fabrics having functional/specialty finishes in general protecting human being against microbes (Klaus, 2021). Due to functional textiles apparels having added values and specific end uses (Kumar and Teli, 2017). Functional textiles and clothing provide the expected traditional properties, e.g. appearance, social identification, attraction, protection against cold, easy-care, as well as some new properties and functions of thermo-conducting, deodorant, avoidance of unpleasant odors, antibacterial and antifungal protection (Coman et.al, 2018).

Special finishes are a combination of chemical and mechanical finishes. These finishes are mainly applied or performed on textiles to improve the properties of fabric / fibres as per end use. The finishes that in addition to aesthetic values in terms of appearance handle and feel additional technological properties as per the requirement of the consumer are called specialty finishes. Some of the special finishes that are gaining popularity are the following : wrinkle resistant finish, anti-microbial finish and flame retardant finish (Goyal and Deshpande, 2016).

2.7.1 Introduction of Finishing

Fabrics are finally finished by treating with chemicals to impart special characteristics like stiffening, crease resisting, softening, flame retarding and Antimicrobial Finishing. It improves the outward appearance and the quality of the fabric and imparts its specific properties.

2.7.2 Importance of Finishing

- Finishing help to clean the fibres and improve appearance, hand, performance and to produce a variety of finish.
- Finishing helps to enhance the distinctive characteristics of fibres.
- Tentering, stiffening of fabrics introduce luster, heatness and drape ability to the fabric.

- Fabrics are finished for a specific end use such as fire proofing, moth proofing, water proofing and antimicrobial finishes.
- The finishes help to increase the suitability and utility.
- It also helps to produce imitation.
- Finishes makes fabrics more saleable, as there is market enhancement in their appearance (Ramkumar, 2017).

2.7.3 Types of Finishing

On the basis of performance, finishes are classified into three types such as temporary, semi-permanent, and permanent.

- A. Temporary:** They are nondurable finished and run off after the first wash or dry cleaning. Many of these are renewable and can be reapplied at home, e.g. starching and blueing of white fabrics.
- B. Semi-permanent:** Semi-permanent finishes stay on the fabric surface for several washings, e.g. bleaching.
- C. Permanent:** Permanent finishes are usually given to the fabric by a chemical treatment. It changes the fibre structure and remains stable on the fabric for its lifetime, For example, Fire proofing, water proofing and so on (Rekha and Poornima, 2010).

2.7.4 Methods of Application

The whole cycle of finishing consists of mechanical and chemical processes, which are used depending on the kinds and end use of the fabric. Mechanical processes include drying, calendaring, schreiner, embossing, raising, etc. Chemical processes refer to the application of some special substances to the fabrics by impregnation with size, starch, dextrin and other polymeric substances. For instance, plain fabrics (bleached, dyed and printed) are subjected to finishing and other kinds of treatment to impart specific properties to the fabric (Gupta, 2017).

- A. Mechanical finishes:** Applying steam, heat or pressure using a mechanical device is called mechanical finishes, and these are also known as dry finishes. These finishes include drying, raising, calendaring, sanforising, etc, which does not last long and are called temporary or semi durable finish.
- B. Chemical finishes:** These are also known as wet finishes. In these, chemical treatment is given to fabric, either to change its appearance or basic properties. These finishes are

usually durable and permanent or wet finishes. Examples are: fireproof, crease resistance, etc (Jhon et al., 2018).

2.8 Antimicrobial Finishes

2.8.1 Introduction of Antimicrobial Finishes

Over the last few years there has been increased interest in antimicrobial finishes. The main reason for this increased interest includes: the promotion of healthier and physically active lifestyle; an increased awareness of the harmful effects of organisms on textiles as well as on human hygiene and freshness (Holm, 2022).

These natural antimicrobial substances are not only eco-friendly, but also from renewable sources. Bacteria and fungi are microbes that can grow on textiles. Antimicrobial finish on fabrics can minimize the transfer of micro-organisms onto the wearer by creating a physical barrier. It prevents the skin diseases caused by the micro-organisms. The various medicinal plants found in nature exhibit excellent anti – microbial properties. Microbial growth, especially bacteria, in textile materials can result in the deterioration of fabric properties, development of foul smells, skins irritation, and cross infections (Bhoomika et al., 2017). Following are the functions of antimicrobial finishes:

- To avoid cross infection by pathogenic microorganisms.
- To control the infestation by microbes.
- To arrest metabolism in microbes to reduce the odour formation.
- To safeguard the textile products from staining, discolorations, and quality deterioration.

Germs grow very rapidly by cell division, doubling their population every 20 minutes. They require humidity and an organic medium for growth. Antimicrobial finishing of textile fabrics can prevent the growth of various microorganisms and therefore, contribute to deodorizing. Antimicrobial finishing products are divided into bactericides (causing destruction of bacteria) and bacteriostats (inhibiting bacterial growth). Yarns, fabrics, and finished products can all be treated with antimicrobials. Microbes bacteria, virus, fungi and yeast are present almost everywhere. Whereas human beings have an immune system to protect against accumulation of microorganisms, materials such as textiles can easily be colonized by high number of microbes or even decomposed by them (Dorugade and Bhagyashri, 2021).

2.8.2 History of Antimicrobial Finishes

The first antimicrobial textile material, in modern history, was developed by Lister in 1867 (Worley and Sun, 2018).

2.8.3 Origin of Antimicrobial Textiles

During World War II, when cotton fabrics were used extensively for tent, tarpaulins and truck covers, these fabrics needed to be protected from rotting caused by microbial attack. This was particularly a problem in the South Pacific campaigns, where most of the fighting took place under jungle- like conditions. During the early 1940s, cotton duck, webbing and other military fabrics were treated with mixtures of chlorinated waxes, copper and antimony salts that stiffened the fabrics and gave them a peculiar odor. After World War II, fungicides used on cotton fabrics were compounds such as a hydroxyquinoline salts, copper ammonium fluoride and chlorinated phenols (Vishnu et al., 2015).

2.8.4 Requirement of Antimicrobial Finishing

However, there is an increase in public concern about the possible effects of antibacterial finishing related to environmental and biological systems. An ideal textile antibacterial finishing should not only kill undesirable microorganisms and stop the spread of diseases but also full fill three other basic requirements. Researchers are now focusing on safe, durable, and environment friendly natural substitutes. An ideal antimicrobial finishing must satisfy several requirements, of which the most important are a broad spectrum of activity and low toxicity to the consumer (Silva et al., 2021).

2.8.5 Characteristics of Antimicrobial Application

This type of finishing inhibits the growth of microbes on the surface of the fabric.

- Maintains hygiene and freshness, stops bad odour
- Controls or eliminates microbial staining.
- Improves life of the articles wherever applied.
- Improves strength.
- Eliminates the chances of transmission of diseases.
- Effective on any substances like cellulose, synthetics as well as their blends and any surface other than textiles (Tomsic et al., 2018).

2.8.6 The different methods of Antimicrobial application

The Antimicrobial agents can be applied to the textile substance by Exhaust, Pad – dry – cure, Coating and Spray (Srikanth, 2020).

2.8.7 Evaluation of the activity of treated textile material

Two types of Antimicrobial testing methods are mostly used. The first method is based on agar zone inhibition and consists of the immersion of treated material in an agar culture medium containing inoculated microorganisms (bacteria or fungi). It is standardized by standard EN ISO 20645/2004, which set up a method for determining the effect of applied antimicrobial treatments on woven and knitted textiles and relatively new ISO/DIS 20645. The ISO 11721 is a burial test. The antibacterial effect can be defined as an inhibition of bacterial growth under favourable conditions. The second method is based on bacteria number testing and is based on the determination of bacteriostatic /fungi static activity of the treated material which has been sterilized and inoculated with micro-organisms, by numbering the bacteria/fungi colonies (Comana et al., 2020).

For the assessment of diffusible anti–microbial activity, inhibition of multiplication is calculated by a qualitative procedure AATCC Test method (100–1999); this method is adequately sensitive, but time consuming for routine quality control and screening. The quantitative evaluation of activity can also be performed which gives clear picture of possible percentage kill by such treated materials. When the intent is to demonstrate bacteriostatic activity of diffusible agent, then the Parallel Streak method is used. This qualitative method is relatively quick and easy. It has been proved to be effective over a number of years, in providing evidence of anti – bacterial activity against both Gram positive and Gram-negative bacteria. A number of test methods have been developed to determine the efficacy of antimicrobial textiles (Hipler et al., 2016).

These methods generally fall into two categories: the agar diffusion test and suspension test. The bacterial species *Staphylococcus aureus* (Gram positive) and *Escherichia coli* (Gram negative) are recommended in most test methods. These two species are potentially pathogenic and therefore require proper physical containment facilities for handling (e.g. a biosafety cabinet). Many studies have used the innocuous *Escherichia coli* (Gram negative) as a test micro-organism which can be cultured and handled in a standard laboratory with minimal

health risk. There are several standard methods to assess antimicrobial activity on textile materials because there is no unique test that is suitable for all the sorts of the antibacterial fibers and micro-organisms. These standards are classified on the basis of the kind of evaluation of microorganism inhibition: qualitative and quantitative. Qualitative methods include AATCC 147:2004, ISO 20645:2004, SN 195920:1992, and JIS L 1902:2002 – Halo method) for antibacterial assessment, and AATCC 30:2004, SN 195921:1992 and JIS Z 2911-1992 for antifungal assessment. Quantitative methods include AATCC 100:1999, JIS L 1902:2002– Absorption method and ISO 20743:2007 (Gao and Cranston, 2018).

2.9 Microorganisms

2.9.1 Introduction of Microorganism

Bacteria and fungi are microbes that can grow on textiles. Microbes are named in accordance with the binominal system of nomenclature established by Carol Linnaeus in 1735. This system is not restricted to microbes but applies to all organisms. The names are latinized, and each organism carries two names(binominal),the first designating the genus and the second designating the species. Bacteria are cosmopolitan in distribution and are ubiquitous in natural habitats such as soil (Rao and Prakruthi, 2009).

Antibiotics are substances produce by micro-organisms like bacteria, fungi and actinomycetes that kill or inhibit, through growth of other micro-organisms. A microbe or micro-organism is an organism that is so small that it is microscopic (invisible to the naked eye). Microorganisms i.e. bacteria, fungi, mildew, mold and yeasts, are found everywhere in nature, even in hostile environments (Mustafa and Mangat, 2020).

There are both good and bad types of micro-organisms. Thousands of species of microorganisms that exist are found everywhere in the environment and on our bodies. Although microbes can be useful in many ways, for example in brewing, baking and biotechnology, they can also be harmful to both textiles and humans. Biocide properties are desired for textile substrates to protect both the wearer and the textile substrate itself (Toshniwal et al., 2019).

2.9.2 Bacteria

Gram -negative bacteria- bacteria that is not dyed purple when treated with Gram's stain. Gram-positive bacteria – bacteria that remain purple when treated with Gram's stain.

Bacteria play an important role as part of the body's micro flora, and along with the skin, are shed continuously. Under acceptable growth conditions, they can multiply from one organism to more than one billion in just 18 hours (White et al., 2020).

2.9.3 Types of Bacteria

2.9.1 *Staphylococcus aureus*

Taxonomy-Class : Bacilli
Order : Bacilli's
Family : Staphylococcaceae
Genus : Staphylococcus
Species : Staph, aureus, staph.epidermidis (or) albus, staph, saprophyticus.

Staphylococcus belongs to a group of pathogenic bacteria parasitic to humans. These spherical bacterial cells usually occur in grape like clusters and hence the name bunch of grapes kokkosseed. First observed by Von Reckling Hausen in 1871, these are gram positive bacteria. Genus staphylococcus contains three medically important species: staph aureus, staph epidermises and staph saprophyticus. Staph aureus-the main pathogen responsible for phylogenic infections is more (Chen et al., 2018).

2.9.2 *Escherichia coli*

Taxonomy-Class : Proteobacteria
Order : Enterobacteriales
Family : Enterobacteriaceae
Genus : Escherichia
Species : Escherichia

In 1885, Escherich, a German pediatrician, first discovered this species in the feces of healthy individuals and called it Bacterium coli commune due to the fact it is found in the colon; early classifications of Prokaryotes placed these in a handful of genera based on their shape and motility (Kumari, 2017).

2.9.4 Anti-Fungal

Antifungal works by exploiting differences between mammalian and fungal cells to kill the fungal organism without dangerous effects on the host. Unlike bacteria, both fungi and humans are eukaryotes. Thus fungal and human cells are similar at the molecular level, making

it more difficult to find a target for an antifungal drug to attack, that does not also exist in the infected organism. Consequently, there are often side effects to some of these drugs. Some of these side effects can be life-threatening if the drug is not administered properly, explains Wikipedia, the free encyclopedia. Fungi are eukaryotes. Morphologically, they can be divided into two groups - the yeasts and the molds. The yeasts are unicellular and are larger than bacteria and may reproduce by budding. Molds are the most typical fungi and are multicellular, consisting of long, branched, and intertwined filaments. Fungi are ubiquitous, found in air, water, soil, on plant or animal bodies (Rao et al., 2016).

The term fungi describe a taxonomic classification of organisms but no longer include organisms such as slime molds and water molds that had traditionally been considered to be fungi. Fungi require organic compounds for energy and carbon source, often from dead organisms. Most fungi are aerobic (or) facultative anaerobic. Only a few fungi are anaerobic (Veena, 2012).

2.9.5 Effect of microbes on Textiles and Human

The ideal growth conditions for microorganisms exist in the human being and for this reason clothing, textiles are very prone to infestation by microbes. Rapid increase in allergies is often provoked by microorganisms such as mold fungi. In addition to provoking allergies such as microorganisms can also directly cause diseases. One of the most susceptible garments to microbial attack is next to the skin garments which remain close to skin secretions such as perspiration and secretions from axillary and pelvic regions. The contaminated next to the skin garments can cause infections like furuncles and boils. This problem cannot be eliminated by even most frequent washings with the exception of washing at boiling temperature. Microorganisms are most dangerous creating harm to our lifestyle in different ways. So to take environment healthy, hygienic and fresh it becomes very important to have the control over the growth of the microorganism and for these the garments should be treated with some specialty chemicals which can restrict the growth of microorganisms (Tarafder, 2013).

2.11 Finishing Test Methods

Four test methods are commonly used within the textile industry to measure the activity of Antimicrobial fabrics. They are AATCC 100, AATCC 147, ASTM E2149, and JIS L 1902. Quantitative methods involve actual microbe enumeration, with results reported as a

percentage or log reduction in the contamination level. Qualitative methods are subjective, using ratings and measured zones of inhibition (Thiry, 2016).

2.10.1 AATCC 30 – Antimicrobial Textile

Antifungal Activity - Antimicrobial assessment on textile materials -The two purposes of this antimicrobial test method (AATCC 30) are to determine the susceptibility of the textile materials to mildew and rot; and to evaluate the antimicrobial efficacy of fungicides on textile materials. The AATCC 30 antimicrobial test method provides two purposes: determining the susceptibility of textile materials to mildew and rot; evaluating the antimicrobial efficacy of fungicides on textile materials, The AATCC 30 Antimicrobial Test standard (Antifungal Activity, Assessment on Textile Materials: Mildew and Rot Resistance of Textiles) contains several tests: Soil-Burial Method - AATCC 30 Antimicrobial Test, AgarPlate / Pure culture / Sterile Specimen Method - AATCC 30. Antimicrobial Test for cellulose materials only employs the use of *Chaetomium globosum*: (common name -Yeast), *Aspergillus Niger* on glucose mineral-salt agar - AATCC 30. This test method is used to determine the susceptibility of textile materials to mildew and rot, and to evaluate the efficacy of fungicides on textile materials.

2.10.2 Durability of Antimicrobial Textiles

Temporary antimicrobial properties in textiles are easy to achieve in finishing but readily lost in laundering. Temporary antimicrobial textiles are useful only for disposable materials. Durable antimicrobial function is quite challenging to achieve and can last more than 50 machine washes (Tanner, 2019).

METHODOLOGY



3. METHODOLOGY

The Methodology adopted for the study on “Comparative study on Antimicrobial activity of *Solanum trilobatum* extract on Tencel cotton woven fabric” consists of a series of processes, techniques and instruments subdivided into three phases.

- The First Phase includes analyzing the literature review, selection of fabric and herbs for the study and collecting the source for the study, Pre-treatment of the fabric, Authentication of herbs and Processing of herbs.
- The second phase includes Herbal extraction by Rotary Shaker, Qualitative phytochemical analysis of herbal extract, Fourier Transform Infrared (FTIR) Spectroscopic Analysis and Antimicrobial assay of the herbal extract.
- The Third phase includes the application of herbal extraction on Tencel cotton by exhaust method and Spray drying method, evaluation of fabrics by their physical properties, mechanical properties, comfort properties, absorbency properties, antimicrobial, washability, spectrophotometric and colorfastness.

PHASE I

3.1 Literature Review

3.2 Selection of Fabric and Herb

3.2.1 Tencel cotton as the fabric

3.2.2 Herbs as *solanum trilobatum*

3.3 Collection of Fabric and Herb

3.4 Pre-treatment of fabric

3.4.1 Desizing

3.4.2 Scouring

3.4.3 Bleaching

3.5 Authentication of Herb

3.5.1 Plant Authentication

3.5.2 Taxonomy of Plants

3.6 Processing of Herb

3.6.1 Surface Sterilization

3.6.2 Drying

3.6.3 Grinding

PHASE II

3.7 Herbal Extraction by Rotary Shaker

3.8 Testing of Herbal Extraction

- 3.8.1 Qualitative phytochemical analysis of herbal extracts
 - 3.8.1.1.1 Test for Alkaloids
 - 3.8.1.1.2 Test for Carbohydrates and Glycoside
 - 3.8.1.1.3 Test for Phyto Steroids
 - 3.8.1.1.4 Test for Saponins
 - 3.8.1.1.5 Test for Phenolic Compounds
 - 3.8.1.1.6 Test for Flavonoids
- 3.8.2 Fourier Transform Infrared (FTIR) Spectroscopic Analysis
- 3.8.3 Anti-microbial Testing

PHASE III

3.9 Application of Herbal Extract on Tencel Cotton Fabric

- 3.9.1 Exhaust method
- 3.9.2 Spray drying Method

3.10 Evaluation of Finished Fabric

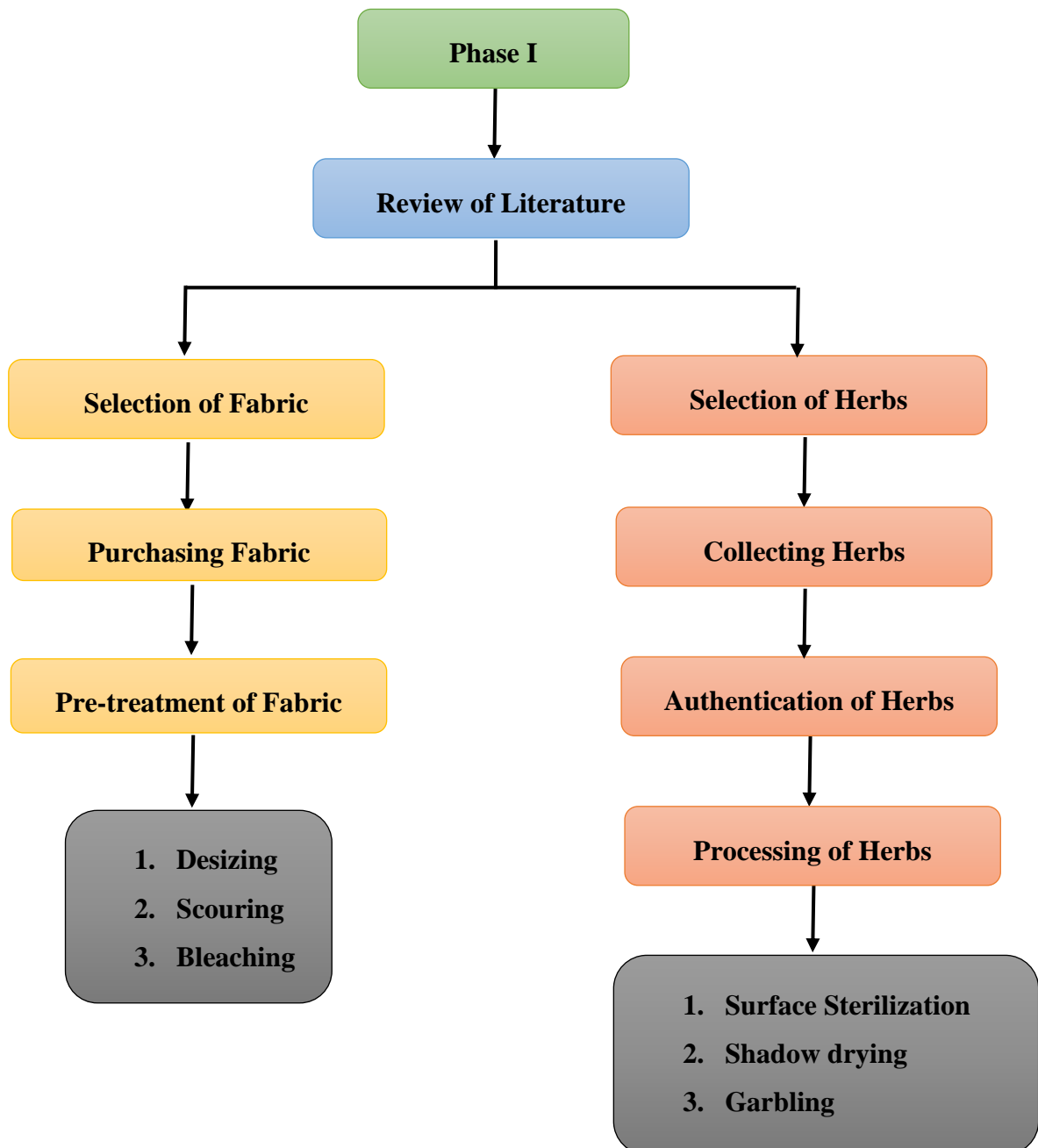
- 3.10.1 Physical Test
 - 3.10.1.1 Fabric Weight
 - 3.10.1.2 Fabric Thickness
 - 3.10.1.3 Fabric count
 - 3.10.1.4 Fabric Stiffness
- 3.10.2 Mechanical Test
 - 3.10.2.1 Fabric Tensile Strength
 - 3.10.2.2 Fabric Elongation
 - 3.10.2.3 Fabric Abrasion Resistance
- 3.10.3 Absorbency Test
 - 3.10.3.1 Drop Test
 - 3.10.3.2 Sinking Test
 - 3.10.3.3 Wicking Test
- 3.10.4 Antimicrobial Activity
- 3.10.5 Colour Measurement with Spectrophotometer
- 3.10.6 Colourfastness test
 - 3.10.6.1 Colourfastness to Crocking
 - 3.10.6.2 Colourfastness to Washing
- 3.10.7 Wash Durability Test
 - 3.10.7.1 Anti-microbial Property Before Washing and after washing

3.11 Statistical Analysis

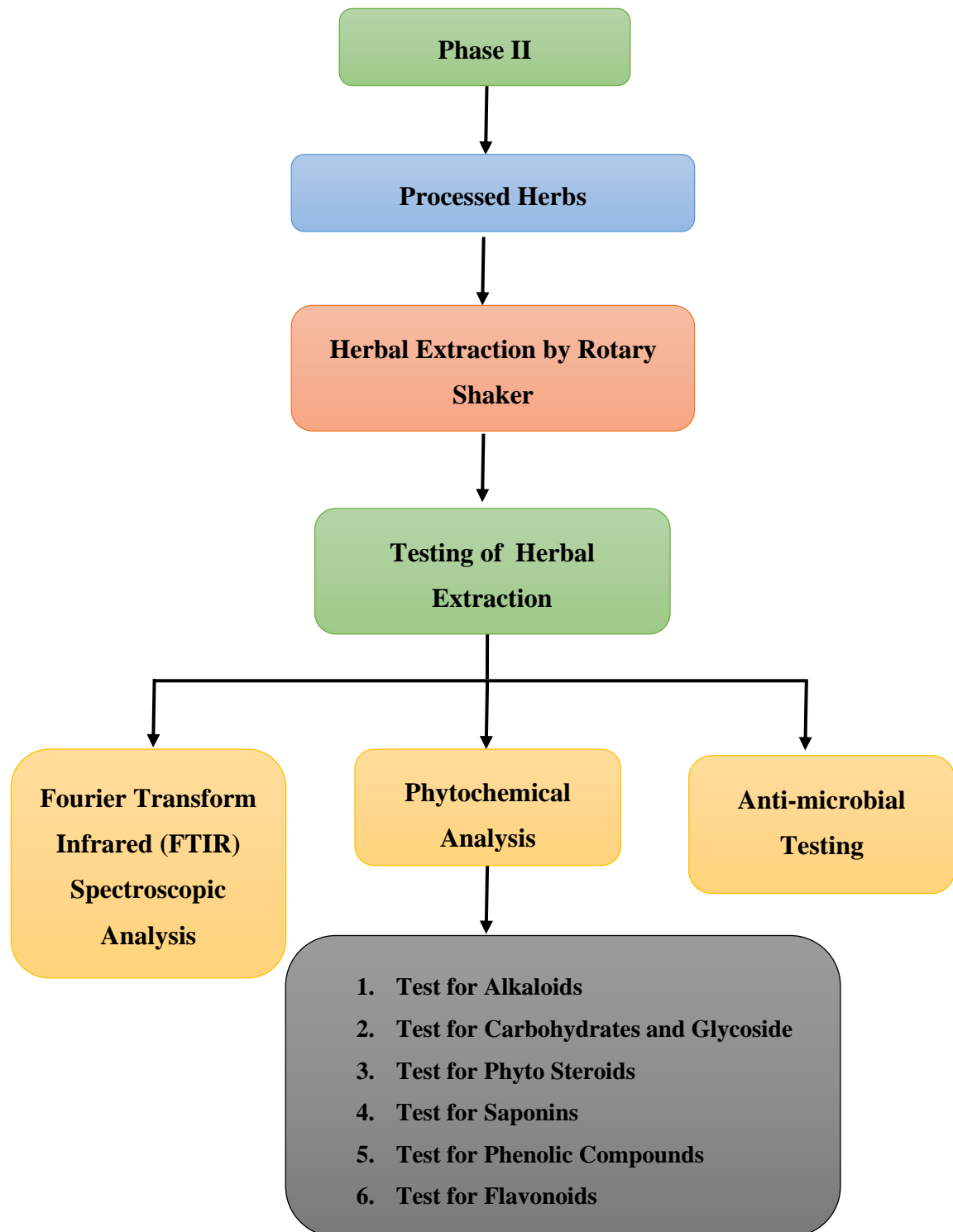
3.12 Nomenclature

The schema chart for the different phases of the study is presented as follows.

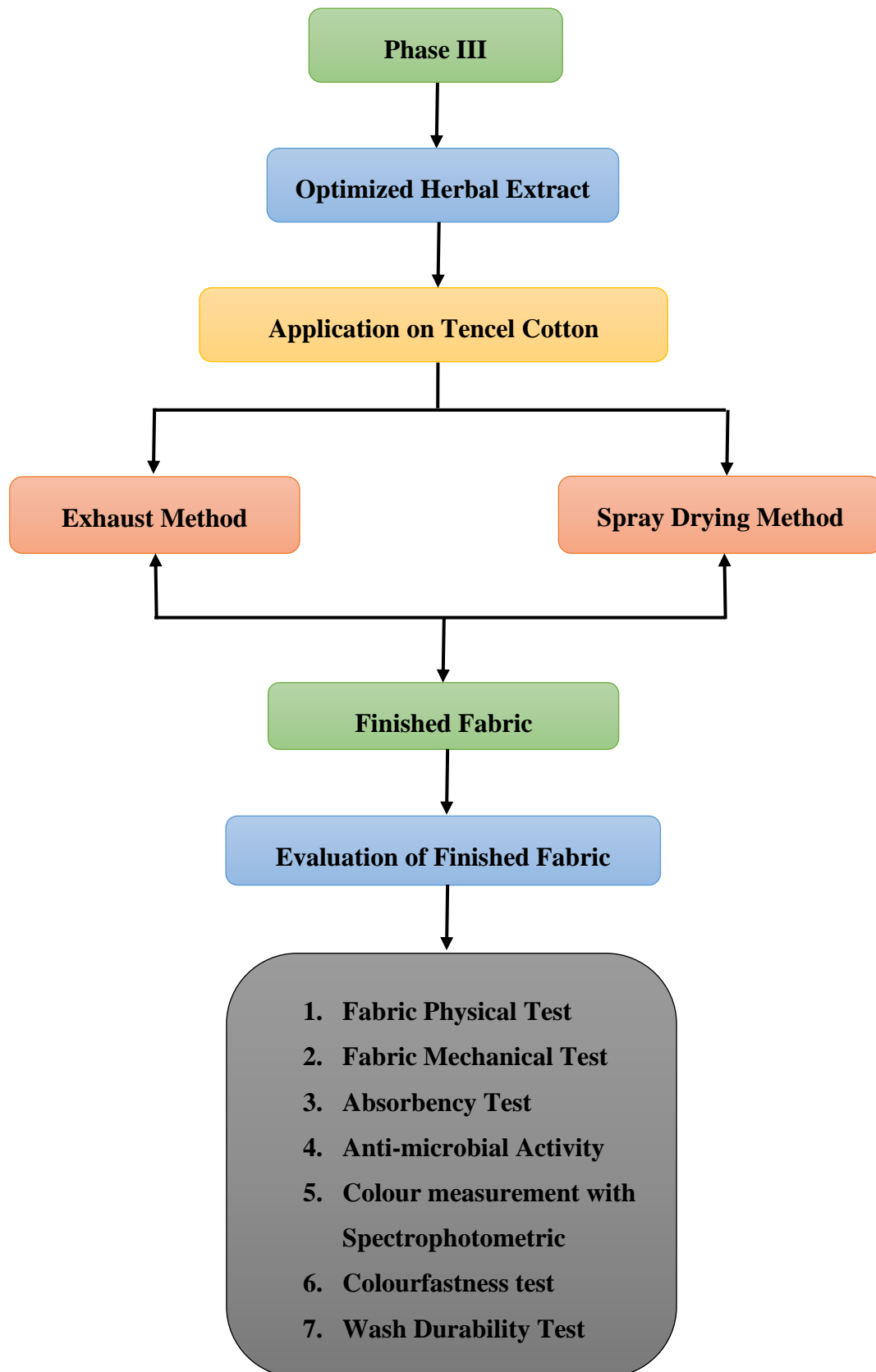
PHASE I



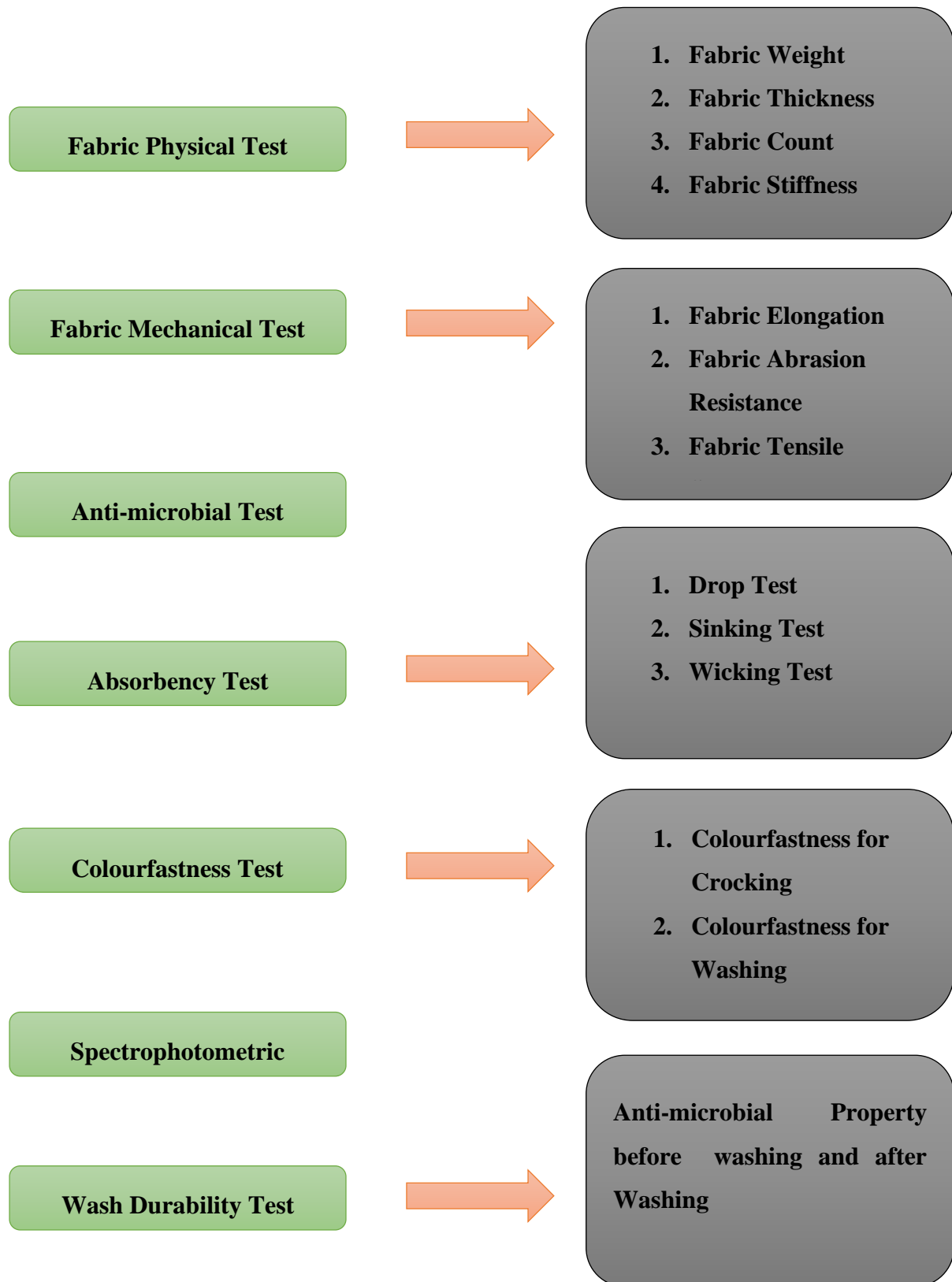
PHASE II



PHASE III



Evaluation of Finished Fabric



3.1 Literature Review

The literature Review for the study was carried out in the library of Avianashilingam Institution of Home Science and Higher Education for Women, Coimbatore, Google Scholar and a few online journals.

3.2 Selection of Fabric and Herbs

Based on the review collected from various sources the fabric and herbs are selected and used for the study.

3.2.1 Tencel Cotton as the Fabric

Cotton has excellent properties such as absorbency, biodegradable, breathable, drape, easily sterilized, high wet strength, insulating properties, non-allergic, renewable resource, softness and water retaining capacity (Gopalakrishnan and Aravindan, 2005). The cotton fabric has good properties withstanding severe treatment, especially during dyeing and finishing (Barker and Midgley, 2007).

Tencel is produced from wood pulp using a solvent-spinning process. More than 99% of the solvent is recycled within the process, making fiber production environmentally accountable. The standard fiber produced is 1.4 dtex, 38 mm, but it can be produced in a range of linear densities and staple lengths. The fiber has a smooth surface and a round cross-section, giving high luster in the raw state. The use of blended fabric has tremendously increased even in India. The government's price structure multi-fiber policy has increased the use of cellulosic mixed fabrics. Hence due to the above properties tencel cotton was selected and used for the study (Hassanin et al.,2016).

3.2.2 Herbs as *solanum trilobatum*

Solanum trilobatum is used in treatment to relieve respiratory disorders, bronchial asthma, chronic febrile infection, tuberculosis and other commonly occurring conditions like cough, diabetes and gastric problems. It possesses antioxidant, anti-bacterial, anti-ulcerogenic, hepatoprotective, anti-inflammatory and anti-cancer properties. Additionally, it is used as an antidote for snake venom. It is composed of saponins, phenols, flavonoids, tannins, cardiac glycosides, sobatum, solaine, solasodine and diosogenin (Muniyan et al.,2022).

A review of the literature on the anti-microbial activity of plant-derivatives products revealed that many significant contributions have been to the bioactivities of medicinal plants. Herbal spices are important sources of anti-bacterial. Therefore, based on the literature review *solanum trilobatum* herb was selected for the study.

3.3 Collection of Fabric and Herb

Tencel cotton fabric was procured from the local merchants and the fabric was in the composition of 50% Tencel and 50% cotton. It is a blended cellulosic fabric. The fresh *solanum trilobatum* was brought from Ponmalai sandhai, Tiruchirapalli, and R.S. Puramam uzhar sandhai, Coimbatore.

3.4 Pre-treatment of fabric

Pre-treatments are essential for successful finishing. It is applied before the final finishes are given because it contains impurities. Pre-treatment improves the usability of fabrics and therefore improves the quality. It is very essential before the application of special finishes.

The term 'pre-treatment' summarizes all types of basic finishes such as desizing, scouring, mercerizing and bleaching on fabric. The preparation process aims to improve functionality by removing impurities and foreign matter thoroughly and uniformly from the fabric. For this study scouring and bleaching process was done on 50:50 Tencel cotton. Two meters of Tencel cotton fabrics were subjected to desizing, scouring and bleaching process (Plate 1).

Following are the Pre-treatment processes which were carried out in the wet processing laboratory of Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore.

3.4.1 Desizing

Desizing is the process employed to remove the sizing material from the fabric. It is the first wet-processing textile finishing technology used to remove the sizing material from the fabric applied for specific production benefits. The desizing processes for the woven fabric were carried out with the recipes was given in Table I.

Table I
Recipe for Desizing

Parameters	Values
Material: Liquor Ratio	1:10
Time Duration	1 Hour
Temperature	30°c
Hydrochloric acid	Few drops
Fabric weight before Desizing	94.544 grams
Fabric weight after Desizing	92.544 grams

The woven fabric was dipped in two liters of soft water in which a few drops of hydrochloric acid were added and boiled for 60 minutes at 30°c and stirred continuously. The processes were carried out for two meters of woven fabric. The material was removed from the vessel, washed thoroughly in soft water and dried. The weight of the fabric before and after desizing was noted.

3.4.2 Scouring

Table II
Recipe for Scouring

Parameters	Values
Material: Liquor Ratio	1:10
Sodium hydroxide	3.75 gpl
Sodium bicarbonate	1 gpl
Temperature	80°c
Wetting agent	Few Drops (turkey red oil)
Time	30 min
Fabric weight before Scouring	92..544 grams
Fabric weight after Scouring	92.121 grams

Scouring is an important operation by which natural impurities such as greases, waxes, fats, and acquired impurities from the fabric are removed. The recipe of Scouring is given in Table II.

The woven fabric was scoured with a material: liquor ratio of 1:10. The scouring bath was added with 3.7 gpl and 1 gpl of Sodium Hydroxide and Sodium Bicarbonate, respectively. A few drops of Turkey Red Oil have added as wetting agent and the scouring bath temperature was maintained at 80°c. The fabric was boiled in the scouring bath for 30 minutes with a pH of 10. The weight of the fabric before and after scouring was noted.

3.4.3 Bleaching

Bleaching is to impart perfect whiteness to the fabric by removing the natural coloring matter from the fabric. In one word, to bleach it as well as to eliminate any impurities by which they may increase the fabric affinity towards dye. The recipe adopted for the bleaching process of woven fabric is given in Table III.

Table III
Recipe for Bleaching

Parameters	Values
Material: liquor ratio	1: 10
Hydrogen peroxide (35 %)	1gpl
Sodium hydroxide (NaOH)	3.75 gpl
Wetting agent	1 gpl
Sodium silicate	3 gpl
Magnesium sulfate (Epsom salt)	1 gpl
Temperature	80°C
Time	60min
Water	2 liters

Adopting the above recipe bleaching process was carried out Material: liquor ratio was taken as 1:10. Bleaching bath containing two liters of water, one gram per liter of Hydrogen Peroxide, 3.75 gpl of Sodium Hydroxide, one gram per liter of wetting agent, three grams per liter of sodium silicate, one gram per liter of Epson salt was used for bleaching processes. The temperature maintained was 80°C and the time taken for the bleaching of woven fabric was 60 minutes. The bleached fabric was then taken out, rinsed thoroughly and dried in the shade.

3.5 Authentication of Herb

3.5.1 Plant Authentication

The authentication of the plant *Solanum trilobatum* was conducted in the Department of Botanical Survey of India (BSI) at The Tamilnadu Agricultural University, Coimbatore. The plants were collected in the Trichy market and the collected plants were pressed together in between two objects and pasted on an A4 sheet that is shown in Plate 2. The plant sample is submitted to the Department of Botanical Survey of India, The Tamilnadu Agricultural University, Coimbatore for the authentication tests.

3.5.2 Taxonomy of Plants

Table IV
Taxonomy of *Solanum trilobatum*

Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Super division	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytes
Order	Solanales
Family	Solanaceae
Subfamily	Solanoideae
Tribe	Solaneae
Genus	<i>Solanum</i>
Species	<i>Solanum trilobatum</i>

Solanum trilobatum Linn has its place in the family Solanaceae, the nightshade plant originates below the order of Solanales, with 102 genera in addition to nearly around 2500 species. It is a thorny creeper with a bluish-white flower and grows as climbing under a shrub. It is a touchy diffuse, bright green recurrent aromatic plant, wooded at the base, 2-3 m in height, found all over the Asian continent, mostly in dry places as a wild plant along waysides and harsh environments. The plant has much branched sharp scandent bushes. The leaves are deltoid, trilateral, or wedge-shaped using irregularly lobed. Flowers are purplish-blue, in cymes. Berry is globose, pink or crimson (Balakrishnan et al., 2015).

3.6 Processing of Herb

3.6.1 Surface Sterilization

The garbling process served as the first step to ensure the purity and cleanness of the medicinal plant materials. After the bulk amount of the selected source, *Solanum Trilobatum* was collected, all extraneous and unwanted matters including dirt like soil, dust, mud, and rubbles, impurities such as insects, rotten tissues and residual non-medicinal parts were separated from the plants. The process also involved the removal of foreign substances, damaged parts and unwanted plant parts besides the sieving and trimming process. Although sorting was done by mechanical means, in some cases, the garbling was performed by hand operation (Plate 3.1).

3.6.2 Drying

The plant *Solanum Trilobatum* was collected, washed and dried at room temperature and shade dried till the moisture was expelled. Proper drying reduced the plant's moisture content and prevents spoiling (Plate 3.2).

3.1.1 Grinding

In the grinding processes, the separated leaves of *Solanum Trilobatum* were mechanically broken down into very small units ranging from larger coarse fragments to fine powder. Powders were prepared to suitable particle size by grinding for further processing. Grinding or mincing of the leaves was carried out in a mixer grinder. Coarsely ground herbs absorb water much more quickly than unground herbs and the ground material was quickly packed in airtight containers. The Coarse powder obtained after grinding was used for extraction (Plate 3.3 and Plate 3.4).

3.7 Herbal Extraction by Rotary Shaker

Extraction was carried out by dissolving 500 grams of the herbal powder of *solanum trilobatum* in 100 ml consisting of 80% methanol and distilled water. The containers were closed and kept overnight under shaking conditions for the proper dissolving of the compounds into the solvent. Then the extract was filtered using Whatman filter paper, and the filtrate was collected and that is a crude extract (Plate 4).

Table V
Recipe for Herbal extraction

Parameters	Values
Powder	100 grams
Ethanol	500 ml consists of 80% methanol and balanced distilled water
Time	24 hours
Temperature	Room temperature

3.8 Testing of Herbal Extraction

After extraction, the herbal extract needs to be optimized to identify the efficiency of bioactive compounds, and optimization was also done to identify the solvent that is suitable for further Process.

3.8.1 Qualitative phytochemical analysis of herbal extracts

The different qualitative chemical tests were performed for establishing the profile of the given extract of its chemical composition. The crude extract was redissolved in methanol and subjected to various phytochemical analyses. The following tests were performed on the extracts to detect various phytoconstituents present in them (Evans, 2009).

3.8.1.1 Test for Alkaloids

Solvent-free extract (50 mg) was stirred with a few mL of dilute hydrochloric acid and filtrate. The filtrate was tested carefully with various alkaloid reagents (Plate 5.1) as follows (Waldi, 2007).

- (a) **Mayer's test:** To a few ml of filtrate, a drop or two of Mayer's reagents was added by the sides of the test tube. A white creamy precipitate indicated the test as positive.
- (b) **Dragendorff's test:** To a few ml of filtrate, 1 or 2 ml of Dragendorff's reagent was added. A prominent yellow precipitate indicated the test as positive.

3.8.1.2 Test for Carbohydrates and Glycosides

The extract (100 mg) was dissolved in 5 ml of water and filtrate. The filtrate was subjected to the following tests (Plate 5.2) .

- (a) **Molisch's test:** To 2 ml of filtrate, two drops of alcoholic solution of α -naphthol were added, the mixture was shaken well and 1mL of concentrated sulphuric acid was added slowly along the sides of the test tube and allowed to stand. A violet ring indicated the presence of carbohydrates.
- (b) **Fehling's test:** One ml of filtrate was boiled in a water bath with 1ml each of Fehling solutions I and II. A red precipitate indicated the presence of sugar.
- (c) **Barfoed's test:** To one mL filtrate, 1 ml of reagent was added and heated in a boiling water bath for 2 min. red precipitate indicated the presence of sugar.

3.8.1.3 Test for Phyto Steroids

- (a) **Spot test:** A small quantity of extract was pressed between two filter papers. The oil stain on the paper indicated the presence of fixed oil.

3.8.1.4 Test for Saponins

(a) **Foam Test:** The extract (50 mg) was diluted with distilled water and made up to 20 ml. The suspension was shaken in a graduated cylinder for 10 min. A two cm layer of foam indicated the presence of saponins (Plate 5.4).

3.8.1.5 Test for Phenolic Compounds

(a) **Ferric Chloride:** The extract (50 mg) was dissolved in 5 ml of distilled water. To this, a ferric chloride solution was added. A dark green color indicated the presence of phenolic compounds (Plate 5.3).

(b) **Lead Acetate Test:** The extract (50 mg) was dissolved in distilled water and to this, 3 ml of 10% lead acetate solution was added. A bulky white precipitate indicated the presence of phenolic compounds (Plate 5.3).

3.8.1.6 Test for Flavonoids

(c) **Alkaline Reagent Test:** An aqueous solution of the extract was treated with a 10% ammonium hydroxide solution. Yellow fluorescence indicated the presence of flavonoids.

Table VI
Phytochemical Analysis of herbal extract

S. No.	Phytochemical Tests	Confirmatory Tests	Indication	Progress	Result
1	Test for Alkaloids	Mayer's Test	Yellow Colour	+	Yes
		Dragendorff's Test	Reddish Colour	+	Yes
2	Test for Carbohydrates and Glycosides	Molisch's Test	Brown Purple Ring Formed	+	Yes
		Fehling's Test	Red Precipitate	+	Yes
		Barfoed's Test	Red Precipitate	-	No
3	Test for Phyto steroids	Spot Test	Oil Stain	+	Yes
4	Test for Saponins	Foam Test	Soap Formation	+	Yes
5	Test for Phenolic Compounds	Ferric Chloride	Deep Blue	+	No
		Lead Acetate Test	Yellow Colour	-	Yes
6	Test for Flavonoids	Alkaline Reagent Test	Bulky white precipitate	+	Yes

+ Present,- Absent

From the Table VI, the presence of Alkaloids, Carbohydrates, Glycosides, Phyto steroids, Saponins, Phenolic, Tannins, and Flavonoids in the methanol extract was observed and confirmed.

3.8.2 Fourier Transform Infrared (FTIR) Spectroscopic Analysis

The FTIR spectral analysis was carried out to identify the functional groups present in *Solanum trilobatum*. Spectra were collected on a bench FTS 3000 MX spectrometer (Varian Instruments, Randolph, MA) equipped with KBr beam splitter. Fourier transform infrared spectroscopy (FTIR) was an analytical tool to identify the nature of chemicals present in the Herbal extract. It also helps to know to what extent the molecules of the finishing chemicals are attached to the fiber molecules of the specimen. The samples were analyzed for their variations in chemical groups using FTIR spectroscopy (Usha et al., 2010). Infrared spectroscopy was used to identify and quantitatively analyze chemical compounds, mixtures, the extent of reaction and molecular structure. Different chemical compounds absorb infrared radiation at frequencies corresponding to their molecular vibration frequencies. Infrared (IR) spectroscopy is a chemical analysis technique that measures the absorption of different IR frequencies by a sample positioned in the path of an IR beam. The main goal of the IR spectroscopic analysis was to determine the chemical functional groups in the sample (Kale and Balaskar, 2010).

3.8.3 Anti-microbial Testing

The Agar well diffusion method was adopted for the study. The microbes such as *Staphylococcus aureus* and *Escherichia coli* were selected for the study. The selected microbes were tested with the herbal extracts and the zone of inhibition was calculated.

The antimicrobial activity of the *Solanum trilobatum* is calculated. Sterile nutrient agar plates were prepared. The plates were allowed to solidify for 5 minutes and wells of 6 mm were punctured using a well borer. 0.1% inoculum suspension of test bacterium *Escherichia coli* and *Staphylococcus aureus* was swabbed uniformly over the surface of the agar. Then, 100 µl of the herbal extract was loaded into the well and the plates were kept for incubation at 37°C for 24 hours. The antimicrobial activity was evaluated in terms of the zone of inhibition, measured and recorded in millimeters.

The extract of *Solanum trilobatum* showed better antimicrobial activity. Levofloxacin was used as positive control and distilled water was used as a negative control.

3.9 Application of Herbal Extract on Tencel Cotton Fabric

Functional finishing has become the most required for textile materials. The herbal extract prepared was finished onto the fabrics by two methods namely Exhaust Method and Spray Drying.

3.9.1 Exhaust method

The Exhaust method involves the gradual transfer of Herbal extract from a dye bath to the textile material. The Recipe for the Exhaust method is given in the Table VII.

Table VII
Recipe for Exhaust method

Parameters	Values
Material: Liquor Ratio	1:10
Time Duration	30 minutes
Temperature(in oven)	40°C
Citric Acid (Binder)	7 %

Two meters of the pre-treated fabric were weighed and wet. The wet fabric was immersed in the solution containing herbal extract with 80% concentrate prepared at the ratio 1:2:1:1 at the material: liquor ratio of (1:10) for 30 minutes at 40°C in the water bath with 7% of citric acid as a binder. After treatment with the herbal finish, the fabric was removed from the bath, squeezed gently and dried at 100°C in the oven for 5 minutes and cured at 120°C for 2 minutes.

3.9.2 Spray drying Method

Spray drying of the herbal extract was done using an ultrasonic atomizer. In a display of “dose it” press the parameter button. Mention the parameters such as name, type, tubing ID, volume, repetitions, pause, flow rate and direction. Dip the aspiration tube connected to the silicone tube into the Herbal Extract. The silicon tube from the aspiration tube should extend to the peristaltic pump of “dose it”, the other end of the silicone tube ends by connecting with the atomizing probe. Press the start button in the “dose it”, it confirms the mentioned parameters and the instruments start dispensing by press again the start button. Simultaneously

press the power button of the atomizer and adjust the amplitude if needed. The liquid travels through the probe and spreads out as a thin film on the atomizing surface. Once the process gets completed switch off the instrument and its plug points. The fabric is finally finished with the tiny droplets.

Table VIII
Recipe for Spray drying method

Parameters	Values
Tencel cotton fabric	1 meter
Herbal Extract	80 ml
Flow rate	0.0009.7 ml/min
Dispensing Time	927.8 sec
Speed	5.8 rpm

3.10 Evaluation of Finished Fabric

Textile testing refers to the vigorous testing done on textile materials which may be inside the laboratory as well as in their natural setting, or day-to-day uses, using various testing equipment. It plays a crucial role in gauging product quality, ensuring regulatory compliance, and assessing the performance of textile materials (Jewel, 2015).

3.10.1 Physical Test

The finished fabrics were evaluated for physical properties namely weight, thickness, count and Stiffness.

3.10.1.1 Fabric Weight – ASTM D 3776-96

Fabric weight is the relative weight of the fabric and is expressed as the weight of a particular size piece, in grams per square meter or ounces per square yard. The investigator cuts the samples from unfinished and two-method finished fabrics by using GSM Die Cutter and weighed the fabric using a digital weighing balance. Five readings were noted for each and the individual mean was calculated (Gulrajani, 2016).

$$\text{Grams per square meter (GSM)} = \frac{\text{Weight of the fabric (g)}}{\text{Area of square}} \times \text{square metre}$$

Square meter = 100 cm x 100 cm = 10000 cm², Area of square = Length x Breadth square units.

The same procedure was followed to find out the fabric weight of unfinished, two-method finished fabrics used in the present study. Fabric weights were carefully recorded using the above formula. The mean difference will be calculated.

3.10.1.2 Fabric Thickness – ASTM D 3883-2004

Thickness is defined as the distance between the upper and lower surface of the material measured under a standard pressure using the thickness gauge. The thickness of a fabric is one of its basic properties, giving information on its warmth, heaviness, or stiffness in use. Thickness measurements are rarely used as they are very sensitive to the pressure used in the measurement. Fabric weight per unit is used commercially as an indicator of a thickness (Basu and Chellamani, 2016).

The Fabric Thickness Tester a handy instrument was used to find out the thickness of the sample. The fabric is kept between two plane parallel plates and a known arbitrary pressure is applied between the plates and maintained. Then the distance between the plates is noted from the dial gauge. Ten readings were taken at random, and the mean was calculated to find out the thickness of the unfinished and two-method finished fabrics. This was repeated 10 times to find out the accurate value.

3.10.1.3 Fabric count – ASTM D 1059-01

The determination of fabric count measures the number of warp yarns per inch and several weft yarns per inch. The fabric count is the number of warp and weft yarns per unit distance. The fabric is kept without tension and is free from folds and wrinkles. The determination of the number of threads per inch may be made by counting glass (pick glass). The counting glass is a small magnifying glass on a stand over a square exactly one inch away. The number of threads in the field directly gives the number of threads per inch. This is the method generally used for fabric count. The number of ends and picks per inch was counted in five different places and recorded for the unfinished, two-method finished samples. This was repeated 10 times to find out the exact value from the average (Angappan and Gopalakrishnan, 2012).

The fabric count is the number of warp yarn per inch and the number of weft yarn per inch. In the woven fabric, the warp yarns are referred to as ends and weft yarns as picks.

Therefore, a fabric is described in terms of “ends and picks”. A pick glass / magnifying glass was used to find out the fabric count of the samples. The glass was placed randomly at different places and the number of repeats was found by analyzing the weave. Five readings were taken and recorded for all the samples to find out whether there was any shrinkage or elongation during the finishing treatment 10 times to find out the accurate answer.

3.10.1.4 Fabric Stiffness – BS 3356-1990

Fabric stiffness is explained as a combined effect of elastic property and mass per unit area. Stiffness is the ability of a textile fabric to resist changes in shape due to bending deformation. The bending properties like stiffness, drape, handle, and crease recovery are the prime parameters of evaluating the fabric. Stiffness is the ability of a material to resist deformation. Bending length is the length of a fabric that will bend on its weight, to a definite extent. It is a measure of the stiffness that determines the draping quality (Chaudhuri, 2001).

The Shirley stiffness tester was used to determine the stiffness of the fabrics. A scale of 15 cm in length and 2.5 cm in width formed the templates. Ten samples were cut at random both in the warp and weft directions from each of the fabrics from 3 groups of fabrics. Each fabric along with the scale was mounted on a horizontal platform. The scale was moved along with the sample slowly until the fabric fell to the edge of the platform and the tip of the fabric coincided with the index line, which was viewed in the mirror. The bending length was recorded from the scale marked opposite to the zero on the side of the platform. Ten readings were taken, and the mean value was calculated (ASTM TM 1388-02-2005).

3.10.2 Mechanical Test

The mechanical properties of the finished fabrics were evaluated by strength, elongation, and abrasion resistance methods.

3.10.2.1 Fabric Tensile Strength – ASTM D 5034

The maximum tensile stress required to rupture a fabric is expressed in kilograms. The Eureka cloth tensile strength tester was used to measure the strength and elongation. The fabric was cut into 30 cm x 7.5 cm using a template and placed in between the clamps. The load was applied to the sample. When the sample was torn, the movement of the lower clamp

was reversed. The strength in kilogram was noted from the dial. Ten readings were taken for concordance (ASTM TM 5035-03, 2005).

3.10.2.2 Fabric Elongation – ASTM D 5034

Elongation is the increase in the length of a specimen during a tension test, expressed in units of length of the fabric when loaded. The Eureka model tensile strength tester was used for the study. The rate of traverse and capacity of the machine was 48 cm per minute and 90 kg respectively. The gauge length was kept at 25 cm. The dial of the machine was calibrated in pounds and kilograms.

Ten samples from each of the fabrics with a minimum length of 33.02 cm and a width of 3.81 cm were cut from the warp and weft directions separately. Each sample was raveled out to 2.54 cm width and 30.48 cm length of yarns on the two sides. Each sample was clamped firmly between the two jaws. Care was taken to ensure that the sample was perpendicular to the load. The load was applied to the sample which was broken. The dial reading of elongation in centimeters was noted. Ten readings were noted for each sample and the mean value was calculated (ASTM TM 5035-03, 2005) for all three groups of fabrics to find out the reaction of finishes.

3.10.2.3 Fabric Abrasion Resistance – ASTM D 4158

Abrasion is one aspect of wear and is rubbing away of the component fibers and yarns of the fabric. Abrasion may be classified as a plane or flat abrasion, edge abrasion, or flex abrasion (Jewel, 2005). Abrasion is the wearing away of any part of a material by rubbing it against another surface.

The Martindale Abrasion Tester is a useful instrument for determining the resistance to abrasion of all clothes. The severity of the abrasion varies with the nature of the radiation. Five samples were cut at random from each of the samples using a template dimension. The initial weight of the sample was taken accurately using an electronic weighing balance. Then the sample was mounted on sample holders with 200 gms weight. The rubs were standardized to 34 revolutions. The samples were made to rub against the abrasive surface. After 34 revolutions the samples were removed, and the final weight of each sample was taken. The weight loss due to abrasion was calculated. The same procedure was repeated for all the

samples. The mean value of the five readings for each sample is calculated. The loss in weight of each material was recorded separately to find out the abrasion resistance of the unfinished and two-method finished fabrics.

Abrasion is measured by a straight line which becomes a gradually widened ellipse until it forms another straight line in the opposite direction and traces the same figure against known conditions of pressure and abrasion (ASTM Standards, 2005). Abrasion is the wearing away of any part of a material by rubbing against another surface (ASTM, 2000). Abrasion is one of the major criteria to assess the durability of the fabric and this was repeated 10 times.

3.10.3 Absorbency Test (AATCC 79: 2007)

The wettability and absorbency tests include drop, sinking, and vertical wicking tests. This test was conducted to find out the absorbency property of three groups of fabrics to know the absorbency quality for the wear.

3.10.3.1 Drop Test

The drop test is a count of the number of drops required to penetrate through to the under-scale of the fabric when all the drops fall on the same spot (AATCC Technical Manual, 2008). A burette filled with distilled water was clamped in a stand. The stand was mounted in an embroidery frame and placed at the base of the stand. The distance between the sample and the burette nozzle was kept constant. The nozzle of the burette was opened just to allow a drop of water to fall on the sample. The stopwatch was started simultaneously, and it was stopped when the drop of water was fully absorbed into the material. The time taken for this was noted. The same procedure was carried out for the unfinished and two-method finished samples. The mean value was calculated to get an accurate value.

3.10.3.2 Sinking Test

The sinking time test is a simple test that helps to measure the wettability of a fabric (AATCC, 2008). In this method, each fabric was cut into several equal-sized squares of 1" x 1" and added to a 1000 ml beaker which was filled with distilled water. The stopwatch started when the fabric struck the surface of the water and stopped when the last corner was sunk below the water's surface. The test was repeated 10 times for all the fabrics and in the meantime, the sinking was calculated and recorded.

3.10.3.3 Vertical Wicking Test

The Vertical Wicking Method measures the rapidity of absorption. Ten samples were cut into sizes 11 inches in length and 1 inch in width from each sample. One end of the sample strip was pasted with a glass rod which was placed on heavy wooden blocks and the other end was allowed to immerse in a tray of distilled water. The rise of the water level in the strip was noted by keeping the length of the fabric at 5 cm constant. The same procedure was repeated for all the samples. The mean values of ten readings were calculated and recorded. The vertical wicking of each material was recorded carefully to find the absorbency of unfinished and two-method finished fabrics. The mean values of ten readings were calculated and recorded.

3.10.4 Antimicrobial Activity

The antibacterial activity of the fabric was assessed using standard AATCC 100 and 147 test methods. The activity was evaluated by qualitative test methods of parallel streak method (AATCC 147-2000).

Muller Huton agar media was prepared and sterilized at 121°C at 15 lbs for 15 minutes. In these sterile media, five parallel streaks of the respective test organisms were streaked. The unfinished, two methods of finished fabric samples were cut to a size of 21 inches and placed perpendicular to the streaked lines. Then the plates were incubated at 37°C for 24 hours. The antibacterial activity was evaluated in terms of the zone of inhibition, measured, and recorded in millimeters. This test followed for three groups of fabrics.

3.10.5 Colour Measurement with Spectrophotometer

A spectrophotometer is an instrument that measures the intensities of light absorbed after it passes through the sample. With the spectrophotometer, samples can also be determined by measuring the intensity of light detected. The two finished fabric was tested for their color depth and evaluated.

3.10.6 Colourfastness test

The samples were subjected to the parameters of the colorfastness test such as color fastness to Crocking and Washing.

3.10.6.1 Colourfastness to Crocking

The test was carried out as per the method by AATCC using a Crock meter (AATCC test method 8-1974). The Finished Tencel cotton fabric was fixed on the flat plate of the crock meter of 2x5 inches in size. It rests flat on the abrasive cloth with its long dimension in the direction of rubbing. With the help of the transparent plate, the test specimen was fixed on the base.

Tencel Cotton fabric was used on the testing cloth. Samples of the test fabric were cut and clamped firmly over the end of the finger with projected documentation from the weighed sliding arm. To hold the sample spiral wire was used. The testing procedure was followed by lowering the covered finger on the test specimen. Further, the covered finger was slid back and forth and for these ten complete revolutions were required. The degree of staining on undyed cotton cloth was evaluated using a geometric grey scale. The criteria for evaluation were the same as followed for the washing fastness test.

3.10.6.2 Colourfastness to Washing

Dissolve 20.0 ± 0.1 g of 1993 AATCC Standard Reference Detergent (Tide) in 7.57 ± 0.06 L (2.00 ± 0.02 gal) of water at 40°C in a 9.5 L and then add the three fabric test specimens. Wash for 2.0 ± 0.1 minutes with no twisting or wringing. Rinse once using 7.57 ± 0.06 L (2.00 ± 0.02 gal) of water at $41 \pm 3^{\circ}\text{C}$ ($105 \pm \text{SF}$). Remove the specimens and drip dry. It is evaluated with unwashed finished fabric.

3.10.7 Wash Durability Test (AATCC 124-1996)

3.10.7.1 Anti-microbial Property Before Washing and after washing

The samples were washed with 5% neutral soap solution for 20 minutes and dried. The washed samples were tested for the retention of anti-bacterial activity after every 5 launderings for 10 washes using standard procedures. The anti-bacterial was assessed by parallel streak test (AATCC test method 100-2004) the results were compared with the unwashed finished fabric sample.

3.11. Statistical Analysis

The result of the subjective and objective evaluation of the values of the untreated and treated fabrics was statistically analyzed. The values were evaluated using the software package known as a statistical package for social science (SPSS). The statistical tool adopted for the study was the Analysis of Variance.

3.12 Nomenclature

The nomenclature used for samples is given in Table IX.

Table IX
Nomenclature

S. No.	Nomenclature	Fabric Sample
1	OS	Original Sample (Tencel Cotton)
2	EM	Fabric Finished Using Exhaust Method
3	SD	Fabric Finished Using Spray Drying Method
4	EM 0	Exhaust method Finished Fabric Before Washing
5	EM 5	Exhaust method Finished Fabric after 5 wash
6	EM 10	Exhaust method Finished Fabric after 10 wash
7	SD 0	Spray-drying Finished fabric Before Washing
8	SD 5	Spray- drying Finished fabric after 5 wash
9	SD 10	Spray-drying Finished fabric after 10 wash

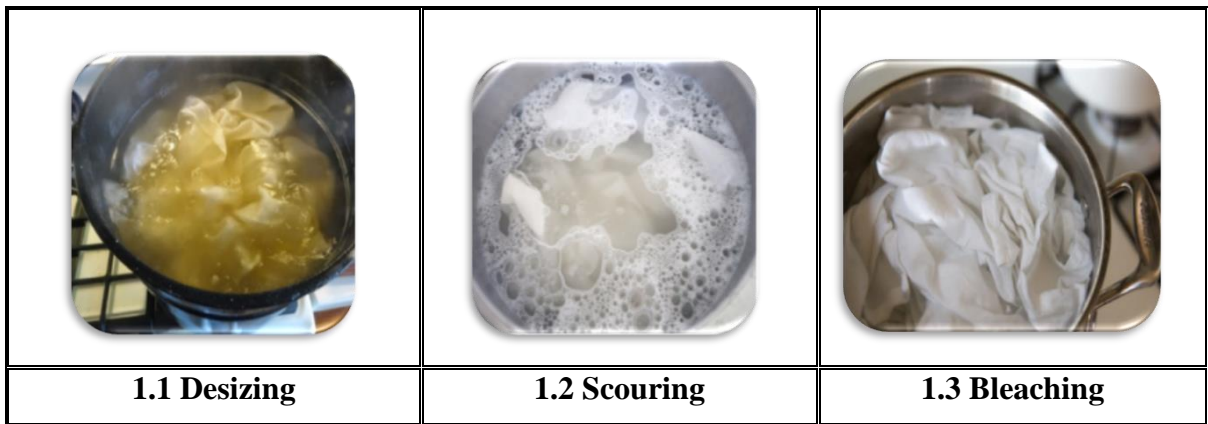


Plate 1
Fabric Pre-treatment



Plate 2
Herbal Plants for Authentication





	
<p>3.1 Surface Sterilization</p>	<p>3.2 Dried Herbs</p>
	
<p>3.3 Grinding</p>	<p>3.4 Herbal Powder</p>

Plate 3
Herb Processing


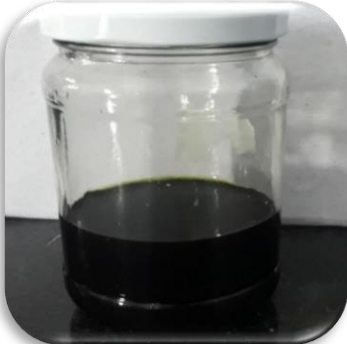
	
<p>4.1 Rotary Shaker</p>	<p>4.2 Herbal Extraction</p>

Plate 4
Herbal Extraction





	
<p>5.1 Test for Alkaloids</p>	<p>5.2 Test for Carbohydrates</p>
	
<p>5.3 Test for Phenols</p>	<p>5.4 Test for Saponins</p>

Plate 5
Phytochemical Screening



	
<p>6.1 Dye bath</p>	<p>6.2 Hot air Oven</p>

Plate 6
Exhaust method of finishing





	
<p>7.1 Ultrasonic Atomizer</p>	<p>7.2 Fabric Finishing</p>

Plate 7
Spray drying method of finishing

	
<p>8.1 GSM Cutter</p>	<p>8.2 Weighing Balance</p>
	
<p>8.3 Thickness Gauge</p>	<p>8.4 Pick Glass</p>

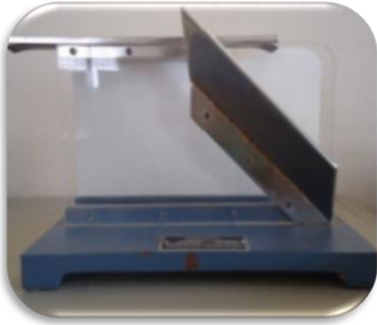




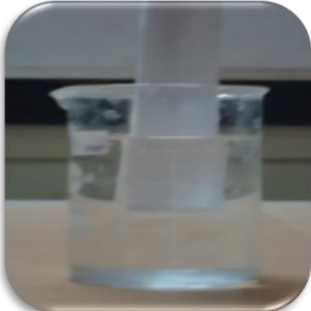
	
<p>8.5 Stiffness Tester</p>	<p>8.6 Drop Test</p>
	
<p>8.7 Tensile Strength and Elongation</p>	<p>8.8 Abrasion Resistance Tester</p>
	
<p>8.9 Sinking Test Method</p>	<p>8.10 Vertical Wicking test</p>

Plate 8
Fabric Evaluation

RESULT AND DISCUSSION



4. RESULT AND DISCUSSION

The results and discussion of the work entitled “Comparative study on Antimicrobial activity of *Solanum trilobatum* extract on Tencel cotton woven fabric” are presented as follows.

4.1 Optimization Test Result of Herbal Extract

- 4.1.1 Phytochemical Test Analysis
- 4.1.2 FT-IR Spectroscopic Test Analysis
- 4.1.3 Anti-microbial Evaluation

4.2 Evaluation of Antimicrobial Finished Fabric

- 4.2.1 Physical Test
 - 4.2.1.1 Fabric weight
 - 4.2.1.2 Fabric Thickness
 - 4.2.1.3 Fabric Count
 - 4.2.1.4 Fabric Stiffness
- 4.2.2 Mechanical Test
 - 4.2.2.1 Fabric Tensile Strength
 - 4.2.2.2 Fabric Elongation
 - 4.2.2.3 Fabric Abrasion Resistance
- 4.2.3 Absorbency Test
 - 4.2.3.1 Drop test
 - 4.2.3.2 Sinking Test
 - 4.2.3.3 Wicking Test
- 4.2.4 Colour Measurement with Spectrophotometer
- 4.2.5 Colourfastness test
 - 4.2.5.1 Colourfastness to Washing
 - 4.2.5.2 Colourfastness to Crocking
- 4.2.6 Anti-microbial Test
- 4.2.7 Wash Durability Test

4.1 Optimization Test Result of Herbal Extract

The *Solanum trilobatum* herb after extraction, the extracted crude solution is given for optimization such as the Phytochemical test, FT-IR Test and Antimicrobial Test. Their result is as follows.

4.1.1 Phytochemical Test Analysis

Using standard procedures to identify the constituents, qualitative phytochemical analysis of plant extracts was carried out. This analysis reveals the presence of phenolic compounds in *Solanum trilobatum*. These plant extracts have anti-microbial efficiency which was also confirmed by various kinds of literature. *Solanum trilobatum* phytochemical screening shows the presence of Alkaloids, Carbohydrates, Glycosides, Phyto steroids, Saponins, Phenolic, Tannins and Flavonoids. So, the extract of *Solanum trilobatum* has anti-microbial activities. These effects are probably due to the presence of phenolic compounds. Hence these extracts were used to incorporate an anti-microbial finish to the fabrics (Balakrishnan et al., 2015).

4.1.2 FT-IR Spectroscopic Test Analysis

The FT-IR spectral analysis was carried out to identify the Functional group present in *Solanum trilobatum*. The Functional groups are found using the graph shown in Figure 4 and presented in Table X.

Table X
FTIR Analysis

Sample	Wavelength(cm ⁻¹)	Appearance	Functional Group	Compound class
<i>Solanum trilobatum</i>	2831.50	Medium	C-H Stretching	Alkane (Flavonoids, Polyphenols, CH ₃ , CH ₂)
	2939.52	Medium	C-H Stretching	Alkane (Flavonoids, Polyphenols, CH ₃ , CH ₂)
	3294.42	Broad	O-H Stretching	Alcohols and Phenols

The Crude sample solution of *Solanum trilobatum* was subjected to Fourier Transform Infra-Red analysis which exhibited in many functional groups based on the wavelength and percentage of transmittance. The peak obtained for *Solanum trilobatum* reveals the presence of functional groups like O-H (alcohol and phenol groups) and C-H (Alkane group). These functional groups confirm the presence of Flavonoids, polyphenols, alcohols,

alkanes and phenols for the selected herbal source. The presence of the functional groups is responsible for the anti-microbial activity (Kanchana et al., 2010).

4.1.3 Anti-microbial Evaluation

The anti-microbial activity of *Solanum trilobatum* herbs were tested against two significant organisms, *Escherichia coli* and *Staphylococcus aureus* using the well diffusion method. The herb showed very good Anti-microbial properties (Plate 9) with a 10 mm zone of inhibition in *Staphylococcus aureus* and a 12 mm zone of inhibition in *Escherichia coli*. The result concludes that *solanum trilobatum* can be used a for Anti-microbial finish on Tencel cotton (Narendhran et al., 2019) .

4.3 Evaluation of Antimicrobial Finished Fabric

4.2.1 Physical Test

4.2.1.1 Fabric weight

The Fabric weight of the original untreated Tencel Cotton is compared with the exhaust method Finished fabric and Spray drying finished fabric. They are presented in Table-X and Figure-5.

Table XI
Fabric weight

S. No.	Samples	Mean Value (gms / sq.mt.)	Gain/loss (%)	Standard Deviation	F-value
1	OC	1.193	-	0.0048	146.44**
2	EM	1.209	1.34	0.0032	
3	SD	1.220	2.26	0.0047	

** Significance at 1% level

It is observed from Table-XI and Figure-5 that the weight of finished samples increased significantly. Both the fabric shows increase in weight after finishing. The weight of Fabric finished with Spray drying is observed comparatively more than the weight of fabric finished with the Exhaust method. The weight gain percentage of Exhaust finished and Spray drying-finished fabric sample is 1.34% and 2.26% more than the original fabric, respectively. Statistically it was proved that there exists a difference at 1% significant level among the samples with the F-value of 146.44.

Hence it could be concluded that the tencel cotton finished with two methods such as Exhaust method and Spray drying Method increases the fabric weight after treatment (Annapoorani and Devi, 2015).

4.2.1.2 Fabric Thickness

The Fabric Thickness of the original untreated Tencel Cotton is compared with the exhaust method Finished fabric and Spray drying finished fabric. They are presented in Table-XII and Figure – 6.

Table XII
Fabric Thickness

S. No.	Samples	Mean Fabric Thickness (mm)	Gain/loss (%)	Standard Deviation	F-value
1	OC	0.26	-	0.0108	258.11**
2	EM	0.26	0	0.0048	
3	SD	0.27	3.84	0.0052	

** Significance at 1% level

It is observed from Table – XII, and Figure - 6 that the thickness of the original fabric has not seen an increase in the Exhaust method but in the spray drying method the thickness of the fabric has seen a slightly increased. In the Spray drying method, a 3.84% Thickness gain is observed whereas there is no percentage gain is observed in the Exhaust method. Statistically it was proved that there exists a difference at 1% significant level among the samples with the F-value of 258.11.

Hence it could be concluded that very slight increase in thickness was absorbed in the samples. This may due to the adherence of the finishing material on the fabric structures (Annapoorani and Devi, 2015).

4.2.1.3 Fabric Count

Fabric count is one of the geometrical properties of textile materials. The fabric count of the original untreated Tencel Cotton is compared with the exhaust method Finished fabric and Spray drying finished Tencel cotton fabric along the warp and weft direction and compared within the Finished sample and its control sample is presented in the Table – XIII and Figure – 7.

Table - XIII
Fabric count (warp and weft)

S. No.	Samples	Warp			Weft		
		Mean Value (Yarn/sq. Inch)	Loss/gain (%)	Standard Deviation	Mean Value (Yarn/sq. Inch)	Loss/gain (%)	Standard Deviation
1	OC	103.30	-	1.1595	68.50	-	1.3540
2	EM	123.10	19.16	1.7919	73.20	6.86	1.75119
3	SD	119.80	15.97	1.6193	75.70	10.51	1.8886
F-value		125.10**			9.39**		

** Significance at 1% level

Table – XIII and Figure – 7, show that the fabric count of all the treated samples created changes in warp and weft direction as follows:

Fabric count Warp Direction:

In the Warp direction, the samples finished with the Exhaust method and Spray drying method had increased in the count along the warp direction by 19.16% and 16.5% respectively. Among the two finished fabrics, the fabric finished with the Exhaust method shows more gain percentage than the spray drying method. So, it is clear that the two anti-microbial treated samples had increased in the count along warp direction when compared with its control sample.

Fabric count Weft Direction:

In weft direction, the samples finished with Exhaust method and Spray drying method had increased in the count along weft direction by 6.86% and 10.51% respectively. Among the two finished fabrics the fabric finished with Spray drying method show more gain percentage than Exhaust method. So, it is clear that the two anti-microbial treated samples had increased in the count along weft direction when compared with its control sample.

Comparison in both warp and weft Direction:

Simultaneously, among warp and weft direction the major gain percentage was observed in warp direction. That shows the warp count was increased after finishing. The samples used in the study such as scoured and bleached Tencel cotton is all hydrophilic in

nature and hence would have liquid pick-up capability. Herbal finishes applied will serve as a binder and enhance the compactness of the yarn structure. As brief above, both herbal finishing treatment make the yarn thinner. This results in more packing of yarns in a unit width resulting in more picks/inches is evident from table. Statistical analysis also proved that there is a significant difference at 1% level with the F-value of warp and weft 125.10 and 9.39 respectively .

Hence it could be concluded that the tencel cotton finished with two methods such as Exhaust method and Spray drying Method increases the fabric count after treatment (Gesese et al., 2022).

4.2.1.4 Fabric Stiffness

The fabric Stiffness of the original untreated Tencel Cotton is compared with the exhaust method Finished fabric and Spray drying finished tencel cotton fabric along the warp and weft direction and compared within the Finished sample and its control sample is presented in the Table – XIV and Figure – 8.

**Table XIV
Fabric Stiffness (Warp and weft)**

S. No.	Samples	Warp			Weft		
		Mean Value (cm)	Loss/gain (%)	Standard Deviation	Mean Value (cm)	Loss/gain (%)	Standard Deviation
1	OC	2.83	-	0.0662	1.70	-	0.0294
2	EM	2.04	- 27.91	0.0246	1.73	1.76	0.02002
3	SD	1.90	-32.86	0.0319	1.92	12.94	0.0395
F-value		7.57**			237.08**		

** Significance at 1% level

From the Table – XIV and Figure – 8, it shows that the fabric Stiffness of all the treated samples created changes in warp and weft direction as follows:

Fabric Stiffness Warp Direction:

In Warp direction, the samples finished with Exhaust method and Spray drying method had decreased in the stiffness along warp direction by 27.91% and 32.86% respectively. Among the two finished fabrics the fabric finished with Exhaust method shows

little gain percentage than Spray drying method. So, it is clear that the two anti-microbial treated samples had decreased in the stiffness along warp direction when compared with its control sample.

Fabric Stiffness Weft Direction:

In weft direction, the samples finished with Exhaust method and Spray drying method had increased in the stiffness along weft direction by 1.76% and 12.94% respectively. Among the two finished fabrics the fabric finished with Spray drying method show little gain percentage than Exhaust method. So, it is clear that the two anti-microbial treated samples had increased in the stiffness along weft direction when compared with its control sample.

Comparison in both warp and weft Direction:

Simultaneously, among warp and weft direction the gain percentage was observed in weft direction. That shows the stiffness in weft was increased after finishing. After herbal treatment, the yarn linear density decreases, which results in more ends/inch or picks/inch. This results in more number of yarns in a unit area the testing specimen due to increase in ends/inch or picks/inch. Such a structure provides more resistance to bending which results in enhancing stiffness as shown in Table - XIV. In this case, based on the experimental results, fabric cover factor has a predominant influence on the stiffness of the fabric. However, in the case of testing along the warp direction based on the results, the smoothness and thinness of yarns increases due to herbal treatments and in turn that influence the bending of fabrics resulting in reduced stiffness value whereas in weft it is wise versa. Statistical analysis also proved that there is a significant difference at 1% level with the F-value of warp and weft 7.57 and 237.08 respectively .

Hence it could be concluded that in weft direction stiffness increased in all the finished samples over the control samples of which it was higher in Spray drying method and in warp direction stiffness decreased in all finished samples over the control samples of which it was higher in exhaust method (Gesese et al., 2022).

4.2.2 Mechanical Test

4.2.2.1 Fabric Tensile Strength

Strength is one of the essential mechanical properties of the textile materials. The fabric Tensile strength of the original untreated Tencel Cotton is compared with the exhaust method Finished fabric and Spray drying finished Tencel cotton fabric along the warp and weft direction and compared within the Finished sample and its control sample is presented in the Table – XV and Figure – 9.

Table XV
Fabric Tensile strength (warp and weft)

S. No.	Samples	Warp			Weft		
		Mean Value (kg)	Loss/gain (%)	Standard Deviation	Mean Value (kg)	Loss/gain (%)	Standard Deviation
1	OC	55.43	-	0.3653	36.61	-	0.2424
2	EM	54.14	- 2.32	0.3204	39.19	6.98	0.3212
3	SD	57.11	3.03	0.3479	40.11	9.56	0.3573
F-value		277.36**			129.68**		

** Significant at 1% level

From the Table – XV and Figure – 9, it shows that the fabric tensile strength of all the treated samples created changes in warp and weft direction as follows:

Fabric Tensile Strength Warp Direction:

In Warp direction, the samples finished with Exhaust method and Spray drying method had decreased and increased in the stiffness along warp direction by 2.32% and 3.03% respectively. Among the two finished fabrics the fabric finished with Spray drying method shows little gain percentage than Exhaust method. So, it is clear that the anti-microbial treated samples of Spray drying had increased, and samples of exhaust method had decreased in the tensile strength along warp direction when compared with its control sample.

Fabric Tensile Strength Weft Direction:

In weft direction, the samples finished with Exhaust method and Spray drying method had increased in the Tensile Strength along weft direction by 7.05% and 9.56% respectively.

Among the two finished fabrics the fabric finished with Spray drying method show little gain percentage than Exhaust method. So, it is clear that the two anti-microbial treated samples had increased in the Tensile strength along weft direction when compared with its control sample.

Comparison in both warp and weft Direction:

Simultaneously, among warp and weft direction the gain percentage was observed more in weft direction. That shows the Tensile Strength in weft was increased after finishing. Statistical analysis also proved that there is a significant difference at 1% level with the F-value of warp and weft 277.36 and 129.68 respectively .

Hence it could be concluded that the Tencel cotton finished with two methods such as Exhaust method and Spray drying Method increases the Fabric Tensile Strength after treatment (Nega, 2019).

4.2.2.2 Fabric Elongation

The Fabric Elongation of the original untreated Tencel Cotton is compared with the exhaust method Finished fabric and Spray drying finished Tencel cotton fabric along the warp and weft direction and compared within the Finished sample and its control sample is presented in the Table – XVI and Figure – 10.

Table XVI
Fabric Elongation (warp and weft)

S. No.	Samples	Warp			Weft		
		Mean Value (Inches)	Loss/gain (%)	Standard Deviation	Mean Value (Inches)	Loss/gain (%)	Standard Deviation
1	OC	1.74	-	0.0226	0.89		0.0216
2	EM	1.80	3.44	0.02002	0.95	6.74	0.0213
3	SD	2.04	17.24	0.0687	2.03	128.08	0.0712
F-value		2.19 ^{NS}			183.23 ^{**}		

** Significant at 1% level NS- Not Significant

From the Table – XVI and Figure – 10, it shows that the Fabric Elongation of all the treated samples had increased in both warp and weft direction.

Fabric Elongation Warp Direction:

In Warp direction, the samples finished with Exhaust method and Spray drying method had increased in the Fabric Elongation along warp direction by 3.45% and 0.3% respectively. Among the two finished fabrics the fabric finished with Spray drying method shows gain percentage than Exhaust method. So, it is clear that the anti-microbial treated samples of Spray drying had increased in the Fabric Elongation along warp direction when compared with its control sample.

Fabric Elongation Weft Direction:

In weft direction, the samples finished with Exhaust method and Spray drying method had increased in the Tensile Strength along weft direction by 6.74% and 128.09% respectively. Among the two finished fabrics the fabric finished with Spray drying method show more gain percentage than Exhaust method. So, it is clear that the two anti-microbial treated samples had increased in the Fabric Elongation along weft direction when compared with its control sample.

Comparison in both warp and weft Direction:

Simultaneously, among warp and weft direction the gain percentage was observed more in warp direction. That shows the Tensile Strength in warp was increased after finishing. The statistical analysis also proved that there was no significant difference between the samples in warp direction but statistically it was proved that there is a significance difference in weft direction at 1% significant level with the F-value of 183.23.

Hence it could be concluded that the Tencel cotton finished with two methods such as Exhaust method and Spray drying Method increases the Fabric Elongation after treatment (Nega, 2019).

4.2.2.3 Fabric Abrasion Resistance

The Fabric Abrasion Resistance of the original untreated Tencel Cotton is compared with the exhaust method Finished fabric and Spray drying finished fabric. They are presented in Table – XVII and Figure – 11.

Table XVII
Fabric Abrasion Resistance

S. No.	Samples	Mean Fabric Abrasion Resistance (gms)	Gain/loss (%)	Standard Deviation	F-value
1	OC	0.137	-	0.0048	167.68**
2	EM	0.173	26.28	0.0082	
3	SD	0.175	27.74	0.0053	

** Significant at 1% level

It is observed from Table – XVII and Figure – 11 that the Abrasion Resistance of the original fabric has been increased after finishing. The Abrasion Resistance of Fabric finished with Spray drying is observed comparatively more than the Abrasion Resistance of fabric finished with the Exhaust method. The gain percentage of Exhaust finished, and Spray drying-finished fabric sample is 26.28% and 27.74% more than the original fabric, respectively. Statistically it was proved that there exists a difference at 1% significant level among the samples with the F-value of 167.68.

Hence it could be concluded that the tencel cotton finished with two methods such as Exhaust method and Spray drying Method increases the fabric abrasion resistance after treatment (Gesese et al., 2022).

4.2.3 Absorbency Test

4.2.3.1 Drop test

The Fabric drop test of the original untreated Tencel Cotton is compared with the exhaust method Finished fabric and Spray drying finished fabric. The absorbency of the material is increased after pre-treatment of the fabric which is indicated by the decrease in time required to absorb a drop of water. The results of the drop test are presented in Table – XVIII and Figure – 12.

It is observed from Table – XVIII and Figure – 12 that the fabric drop test of the original fabric has been increased after finishing. The Drop test of Fabric finished with exhaust method and spray drying method was seen equal. The loss percentage of Exhaust finished, and Spray drying-finished fabric sample is 57.14% more absorbency than the original fabric.

Table XVIII
Drop test

S. No.	Samples	Mean Fabric drop test(seconds)	Gain/loss (%)	Standard Deviation	F-value
1	OC	20.30	-	1.2517	275.32**
2	EM	8.70	-57.14	1.1595	
3	SD	8.70	-57.14	1.1595	

** Significant at 1% level

As it is evident from the fabric drop test results, two methods of finished fabric reduce the time for the water droplets to spread showing that hydrophilicity increases after finishing with herbal extract. As finishes etches the surface, not only it increases the pores, it also endeavours to enhance the surface area of the fabric. The increase in surface area results in increased surface adsorption and this mechanism is responsible for more spreading of water droplets on the surface, which is reflected in reduced time in the drop test. This trend is evident in the two finished samples. Statistically it was proved that there exists a difference at 1% significant level among the samples with the F-value of 275.32.

Hence it could be concluded that both the treated samples expressed an increase in absorbency rate of the finished samples and there is no difference is seen among both the finished fabrics.

4.2.3.2 Sinking Test

The Fabric Sinking Test of the original untreated Tencel Cotton is compared with the exhaust method Finished fabric and Spray drying finished fabric. They are presented in Table – XIX and Figure – 13.

Table XIX
Fabric Sinking Test

S. No.	Samples	Mean Fabric Sinking test(seconds)	Gain/loss (%)	Standard Deviation	F-value
1	OC	13.00	-	0.8165	258.70**
2	EM	3.20	-75.38	0.6324	
3	SD	7.80	-40.00	0.7888	

** Significant at 1% level

It is observed from Table – XIX and Figure – 13 that the Fabric Sinking of the original fabric has been increased after finishing. The Sinking of Fabric finished with Exhaust method is observed comparatively more than the Sinking of fabric finished with the Spray drying method. The loss percentage of Exhaust finished and Spray drying-finished fabric sample is 75.38% and 40% than the original fabric, respectively.

As it is evident from the fabric sinking test results, Exhaust method finishing reduces the time for the fabric to sink into the water, which shows that hydrophilicity increases after Finishing. As the exhaust method etches the surface and affects the porosity, it alters the hydrophilicity enabling quicker sinking of the fabric, which is reflected in reduced time in the sinking test. Statistically it was proved that there exists a difference at 1% significant level among the samples with the F-value of 258.70.

Hence it could be concluded that both the Finished samples took lesser time for sinking when compared with the control samples. Of the Exhaust method and unfinished samples, the Exhaust method sample took lesser time depicting the increase in the rate of absorbency.

4.2.3.3 Wicking Test

The Fabric wicking Test of the original untreated Tencel Cotton is compared with the exhaust method Finished fabric and Spray drying finished fabric. They are presented in Table – XX and Figure – 15.

Table XX
Fabric Wicking test

S. No.	Samples	Mean Fabric Wicking test(seconds)	Gain/loss (%)	Standard Deviation	F-value
1	OC	34.40	-	1.1738	159.38
2	EM	12.70	-63.08	1.1595	
3	SD	26.00	-24.41	1.4907	

** Significant at 1% level

It is observed from Table – XX and Figure – 15 that the Fabric Wicking of the original fabric has been increased after finishing. The Wicking of Fabric finished with Spray drying is observed comparatively more than the Wicking of fabric finished with the Exhaust method.

The loss percentage of Exhaust finished, and Spray drying-finished fabric sample is 63.08% and 24.41% more than the original fabric, respectively.

As it is evident from the fabric vertical wicking test results, the Exhaust method reduces the time for the fabric to wick the water. As the Exhaust method affects the water absorption characteristics, wicking enhances, as reflected in reduced wicking time. Statistically it was proved that there exists a difference at 1% significant level among the samples with the F-value of 159.38.

Hence it could be concluded that both the Finished samples took lesser time for Wicking when compared with the control samples of the Exhaust method and unfinished samples, the Exhaust method sample took less time depicting the increase in the absorbency rate.

Overall from the above test, the absorbency of the untreated got increased after finishing with herbal extract (Annapoorani and Devi, 2015).

4.2.4 Colour Measurement with Spectrophotometer

The dyed cotton fabrics with gambier extract which was processed in this study were subjected to the reflectance of the color measurements by using a visible Spectrophotometer method CIE-Lab with the light reflection technique of "Premiere Color scan" SS 6200. The quantitative value for the color strength was obtained by measuring the percent value of reflectance (% R) at the same wavelength and then converted to K/S value with K/S table assistance by Kubelka-Munk theory. Reflectance value is the reflection of light amount reflected by objects that contain color and the equation is

$$\frac{K}{S} = \frac{(1-R)^2}{2R}$$

Where R = reflectance percentage, K = absorption, and S = scattering of dyes. The values found for all the dyed fabrics are shown in Figures 15 and 16. The figure and the result data got from the test tells that there is not much color difference observed between the sample. When compared to original sample the color depth strength is brighter in both the fabric. Between two samples the fabric finished using spray drying shows little colour depth.

Hence the Spectrophotometer with color lab evident that color difference was observed when compared with original sample. Spray dried sample shows the Color depth when compared to the Exhaust method finished sample. The Brightness index and Whiteness index was also little high in spray dried sample. From the above explanation that tells that spray dried fabric shows good colour depth (Musinguzi et al., 2019).

4.2.5 Colourfastness test

Colorfastness is a fabric's resistance to change in its color characteristics or to transfer its colorant to adjacent materials. A colorfastness test was done on two finished fabrics and the results are discussed below.

4.2.5.1 Colorfastness to Washing

The colorfastness to washing was carried out for the 50:50 Tencel cotton unfinished and finished fabric before and after 5 and 10 washes and the results are given in Table XXI.

Table XXI
Colourfastness to Washing

S. No.	Fabric Samples	Washed Samples	Shade change	Staining
1	EM	EM 0	4.5	4
		EM 5	4.5	4
		EM 10	4.5	4
2	SD	SD 0	4.5	4
		SD 5	4.5	4
		SD 10	4.5	4

The color change for the samples was rated as very good (4.5) and for color staining the samples were rated as good (4) towards color fastness to washing. Hence, it could be concluded that washing did not affect the colorfastness property.

4.2.5.2 Colorfastness to Crocking

The colorfastness to crocking was carried out for the 50:50 Tencel Cotton finished fabric before and after 5 and 10 washes and the results are given in table XXII. The colour fastness to crocking at dry state was rated as excellent (5) to both finished samples and in wet state it was rated good (4) for both the finished samples.

Table XXII
Colorfastness to Crocking

S. No.	Fabric Samples	Crocking	Grade
1	EM	Dry	5
		Wet	4
2	SD	Dry	5
		Wet	4

Hence the fabric after finished by Exhaust method and Spray drying method shows good colourfastness (Yılmaz and Bahtiyari, 2020).

4.2.6 Anti-microbial Test Analysis

The anti-microbial activity of the Exhaust Method and Spray drying are presented in the Table – XXIII, Plate 10 and Figure 17 and 18.

Table XXIII
Antimicrobial Activity in Finished Fabric

S. No.	Samples	Zone of Inhibition (mm)	
		<i>Escherichia coli</i>	<i>Staphylococcus aureus</i>
1	OC	0	0
2	EM	12	12
3	SD	13	12

In Table XXIII, Plate 10 and Figure 17 and 18, the Fabric finished with Spray drying shows more anti- microbial activity than the fabric finished using Exhaust method. This proves that the fabric finished using Spray drying method absorbed the herbal extract and gives its anti-microbial property on the Tencel cotton (Musinguzi et al., 2019)

4.2.7 Wash Durability Test

The anti-microbial activity of the Exhaust Method and Spray drying are tested after 5 and 10 washes, they are presented in the Table – XXIV, Plate 10 and Figure 17 and 18.

The finished fabric samples using exhaust method and spray drying was washed and anti-microbial test was conducted on 5 and 10 wash. The zone of inhibition was reduced after 5 and 10 wash in both the finished samples. Between both the samples, the fabric which is spray dried shows good anti-microbial property.

Table XXIV**Fabric durability test**

S. No.	Samples	Washed samples	Zone of Inhibition (mm)	
			<i>Escherichia coli</i>	<i>Staphylococcus aureus</i>
1	EM	EM 5	10	10
		EM 10	8	8
2	SD	SD 5	12	12
		SD 10	10	10

Hence concluding that the fabric sustains the anti-microbial property even after washing samples for five times and ten times (Riaz and Ashraf, 2020).

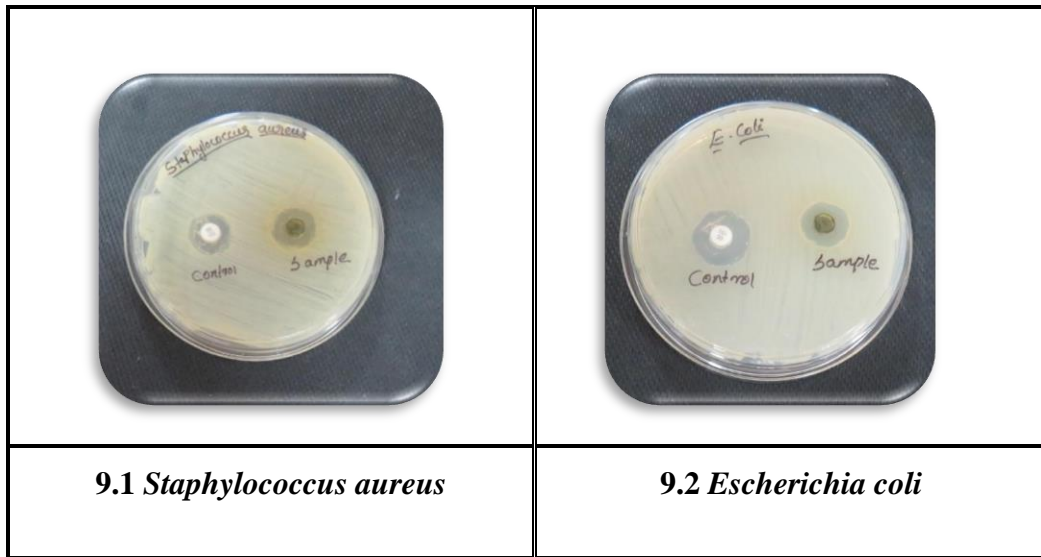


Plate 9
Antimicrobial Test

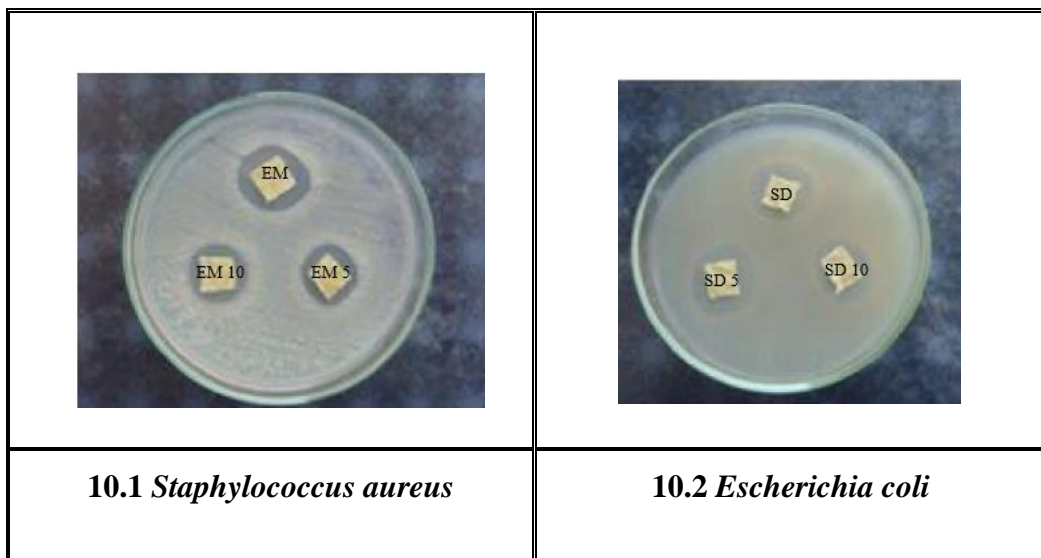
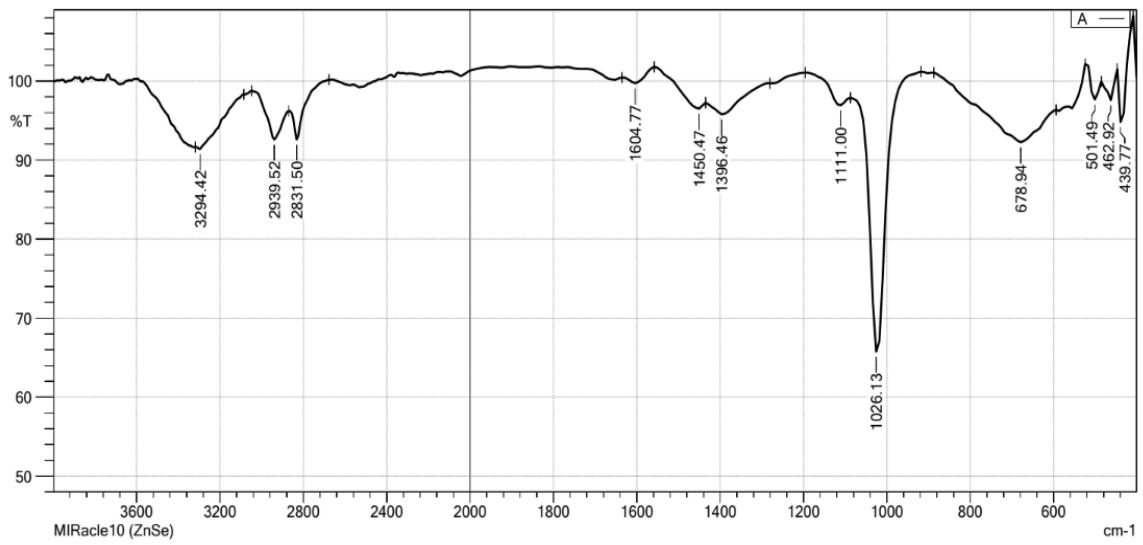


Plate 10
Anti-microbial Activity in finished fabric before and after Washing



D:\FT-IR\2023\MARCH\MAR 17\YASMIN FATHIMA B\A.ispd
MIRacle10 (ZnSe)

Item	Value
2	Sample name
3	Sample ID
4	Option
5	Intensity Mode %Transmittance
6	Apodization Happ-Genzel

Figure 4
FTIR Analysis for solanum trilobatum



Figure 5
Fabric Weight (GSM)

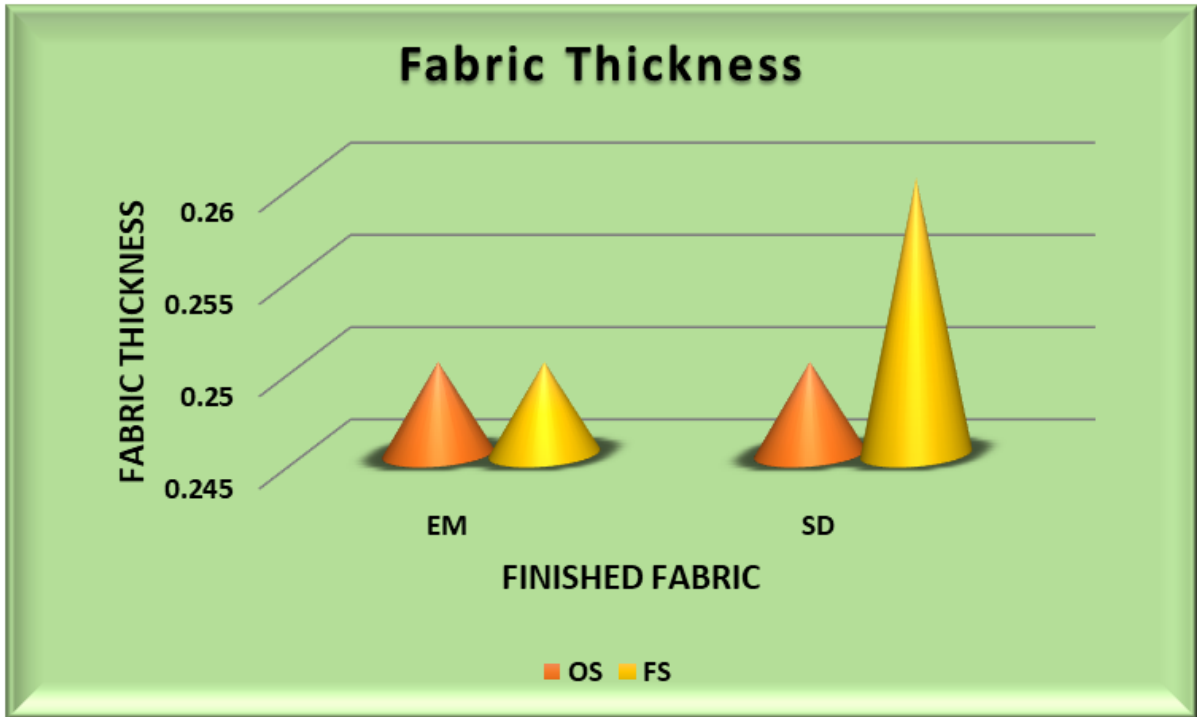


Figure 6
Fabric Thickness



Figure 7
Fabric Count (warp and weft)

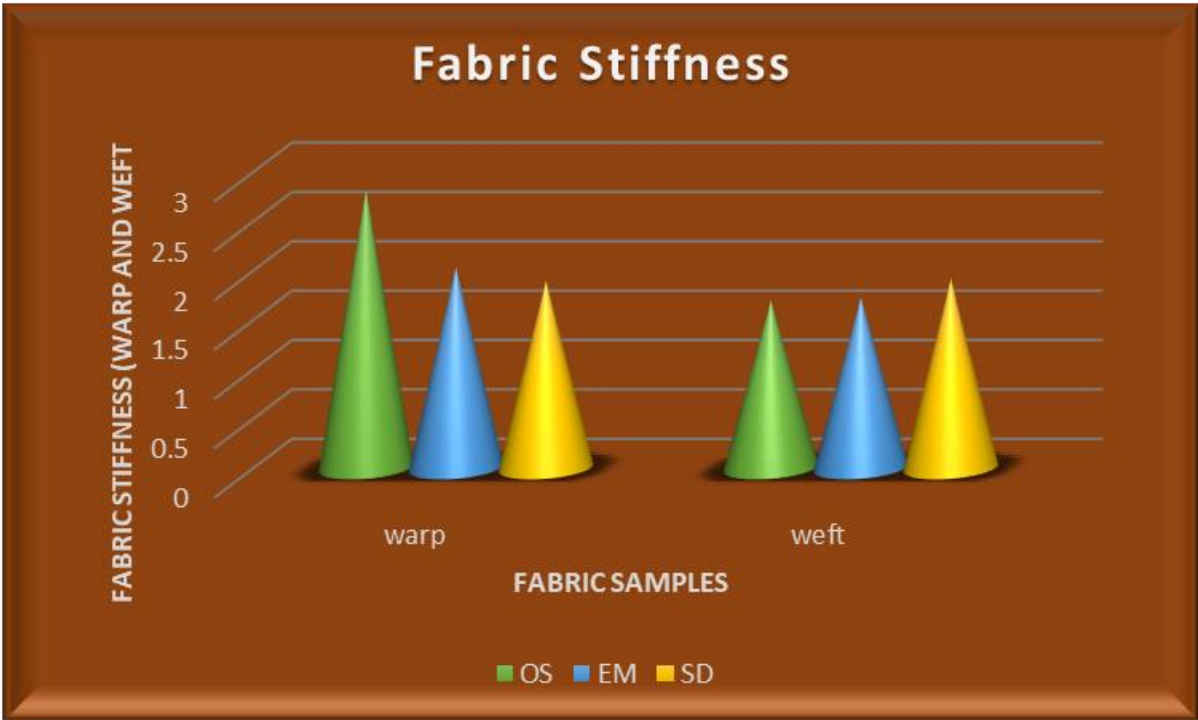


Figure 8
Fabric Stiffness (warp and weft)

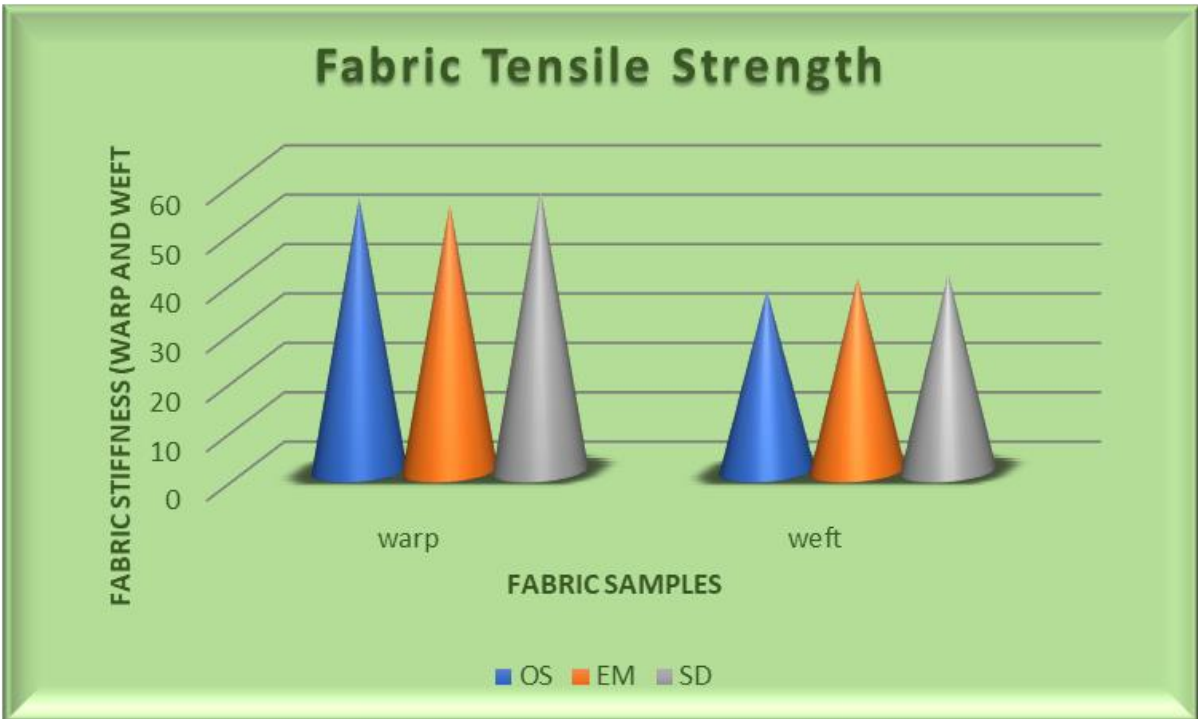


Figure 9
Fabric Tensile Strength (warp and weft)

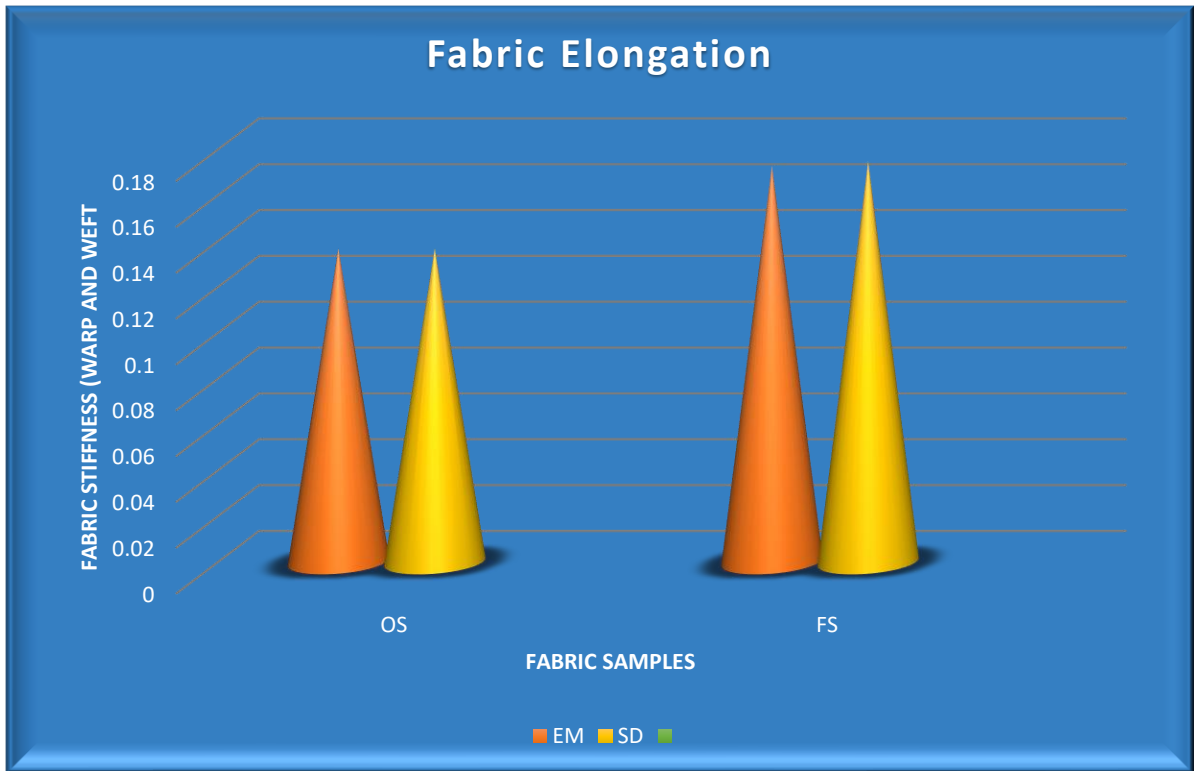


Figure 10
Fabric Elongation (warp and weft)



Figure 11
Fabric Abrasion Resistance

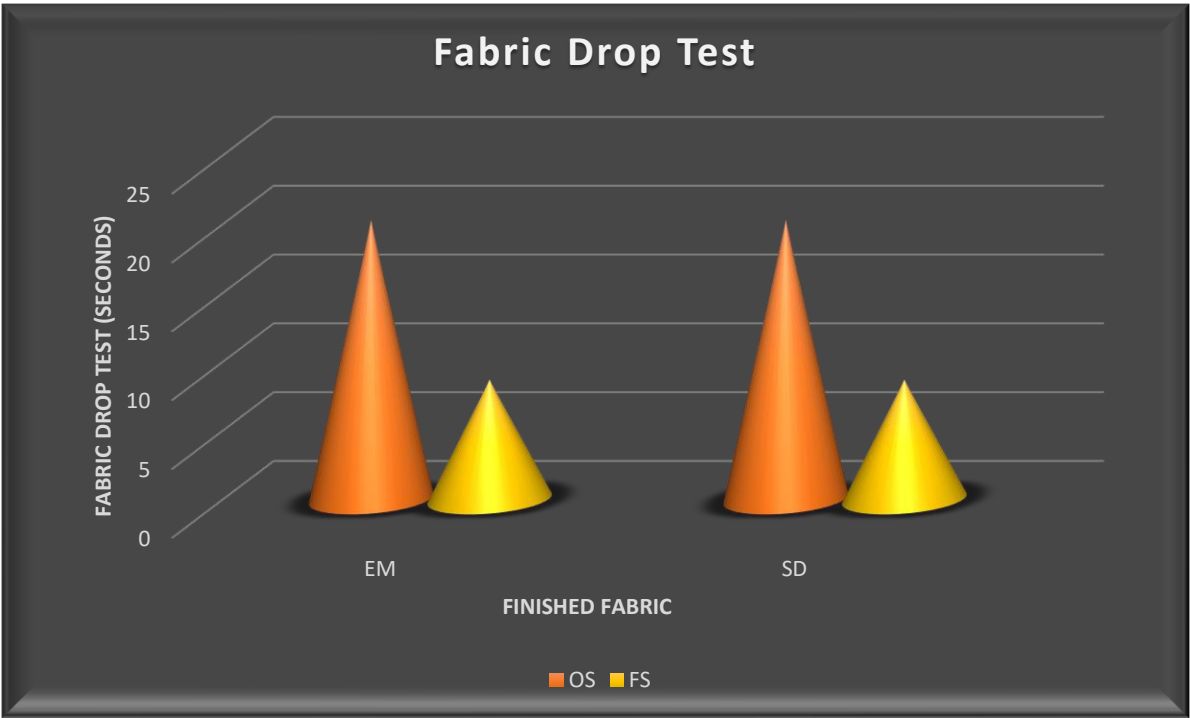


Figure 12
Fabric Drop Test



Figure 13
Fabric Sinking Test

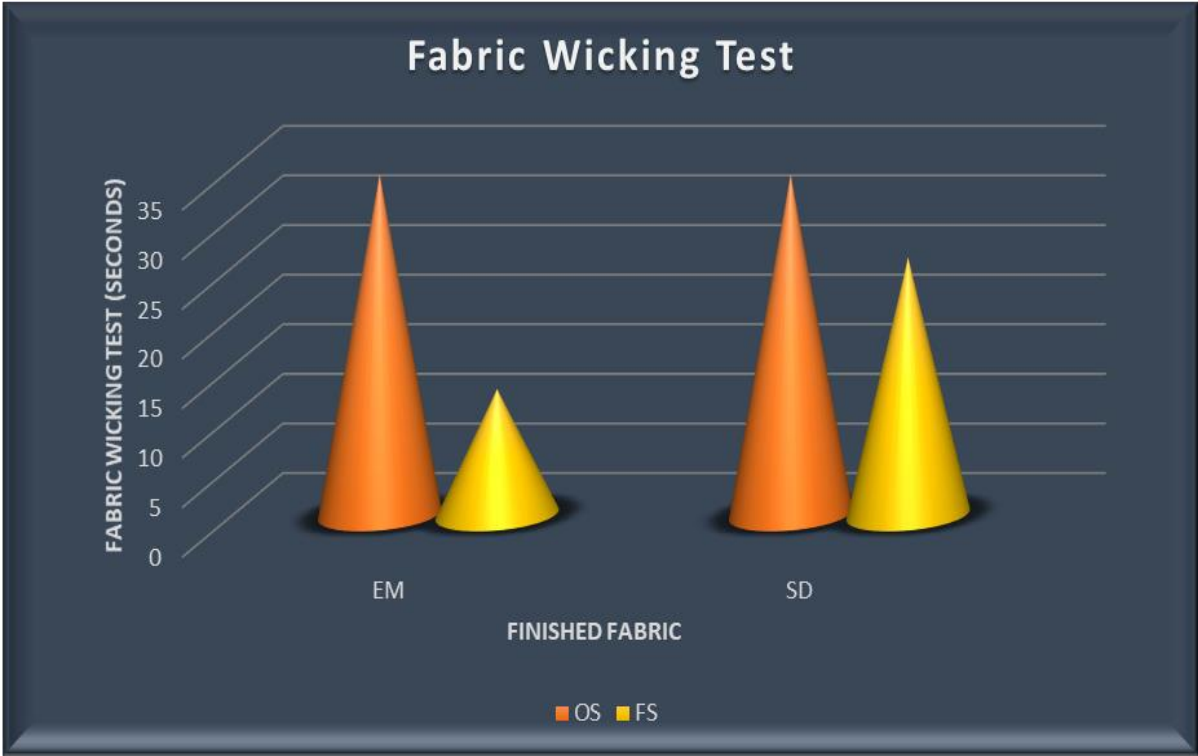


Figure 14
Fabric Wicking Test

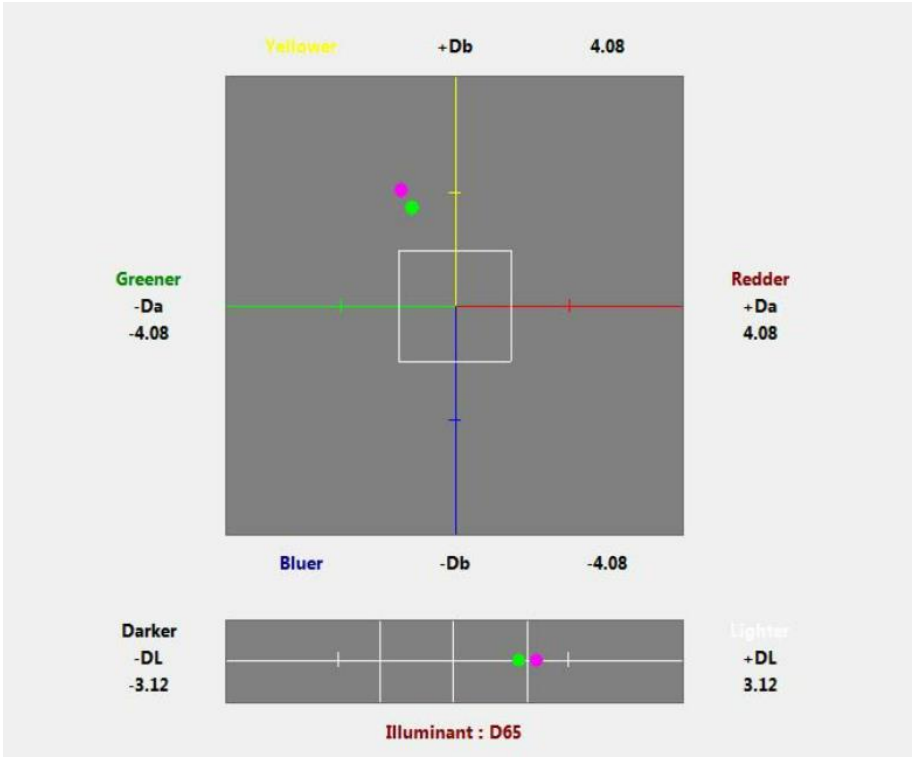


Figure 15
Colour Co-ordinates graph

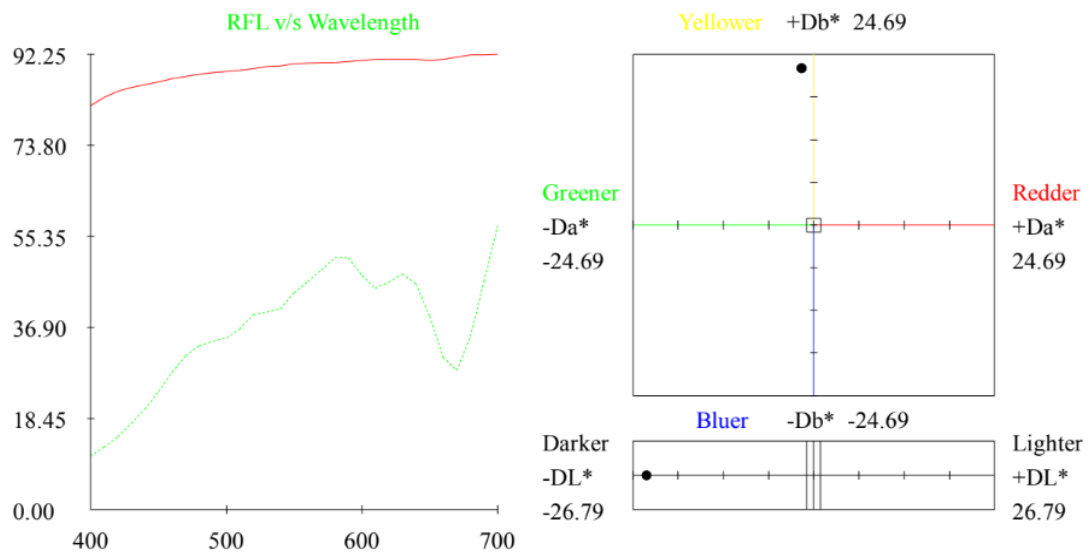


Figure 16
Colour Strength

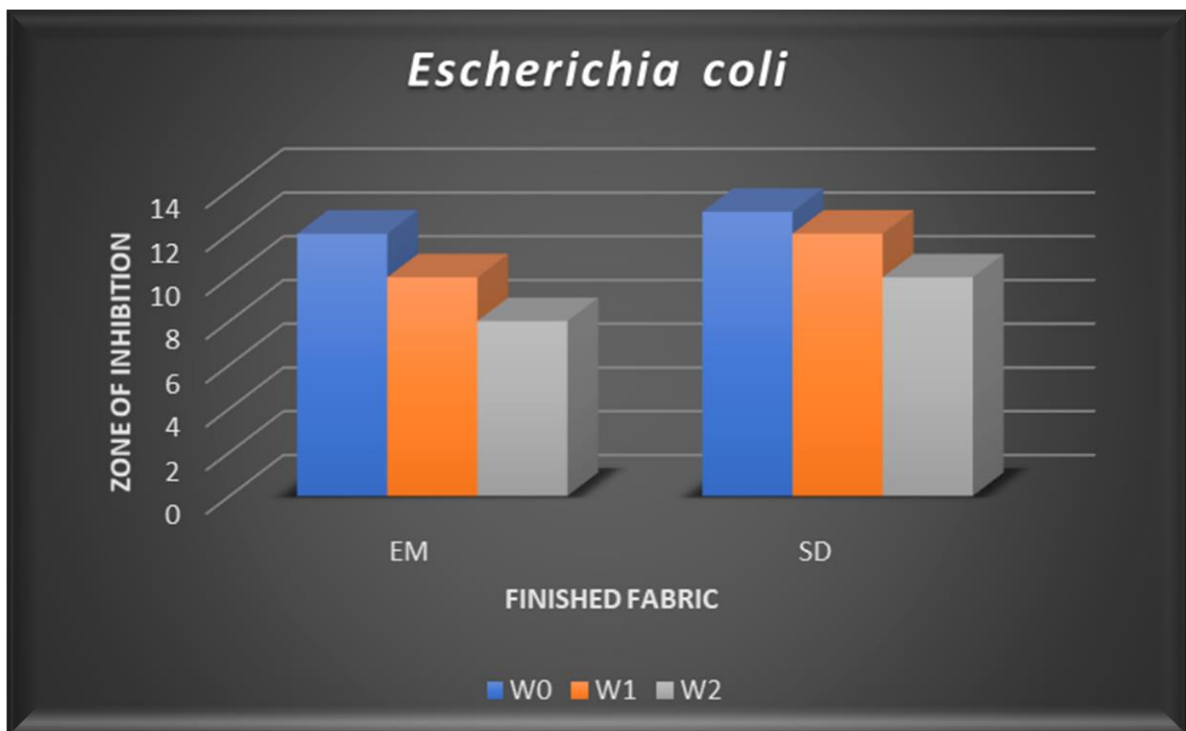


Figure 17
Anti-microbial Activity in finished fabric before and after Washing (*Escherichia coli*)

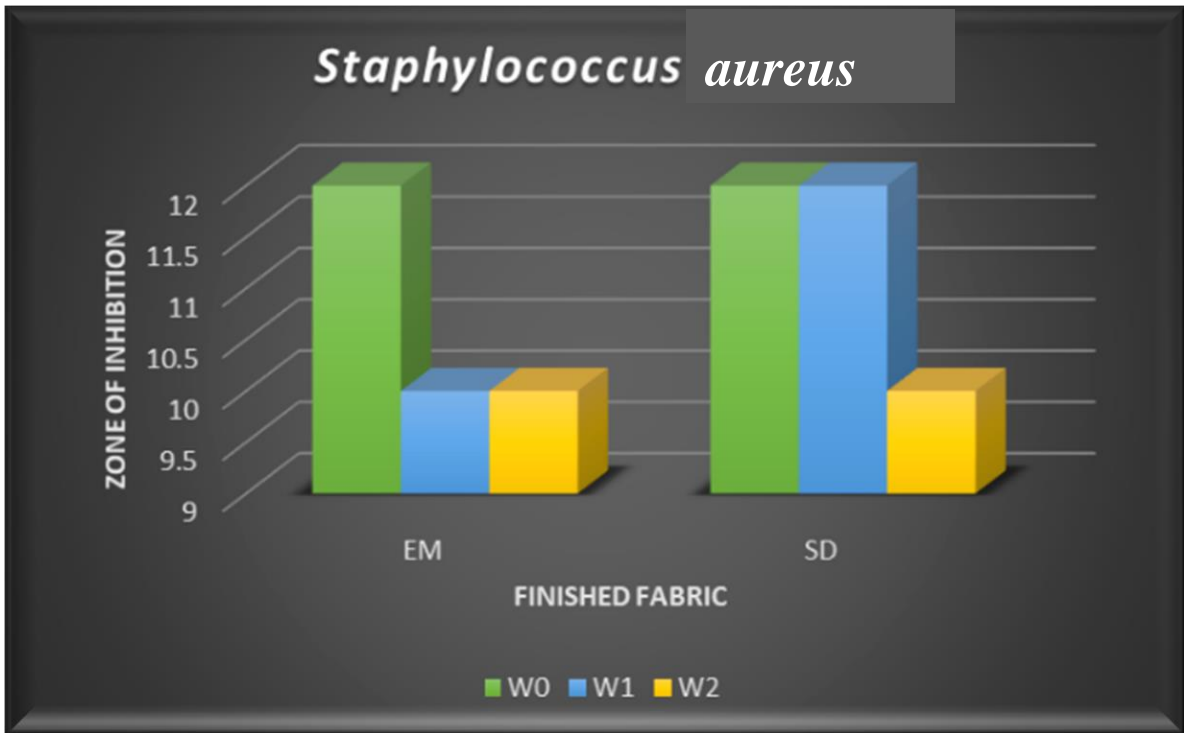


Figure 18

**Anti-microbial Activity in finished fabric before and after Washing
(*Staphylococcus aureus*)**

SUMMARY AND CONCLUSION

5. SUMMARY AND CONCLUSION

The summary and conclusion pertaining to the study entitled “Comparative study on Antimicrobial activity of *Solanum trilobatum* extract on Tencel cotton woven fabric” are summarized.

First Phase

The first phase consisted of a literature survey, selection of herbs and fabric, preparation and processing of herbs and fabric. A literature survey was conducted to select the herbal plants *Solanum trilobatum* which has antimicrobial Property. The plant authentication test was conducted at Tamil Nadu Agricultural University, Coimbatore. The selected herbs were then collected, dried, garbled and ground into dry powder. Tencel cotton fabric was procured from the local merchants and the fabric was in the composition of 50% Tencel and 50% cotton. The Pre-treatment processes for fabric was carried out in the wet processing laboratory of Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore.

Second Phase

The second phase included the extraction process of herbs with Methanol solvent. Qualitative Phytochemical Analysis, Fourier Transform Infrared (FTIR) Spectroscopic Analysis, Anti-microbial testing of Herbal Extracts was also done to test the herbal extraction. The fresh *Solanum trilobatum* was brought from Ponmalai sandhai, Tiruchirapalli, and R.S. Puramam uzhavar sandhai, Coimbatore. Herbal Extraction was done in Rottary shaker and was subjected to Qualitative Phytochemical Analysis to test the presence of Carbohydrates, Saponins, Flavonoids, Alkaloids, Glycosides, Phenols and Steroids. FT-IR test, Anti-microbial test was also conducted in herbal extract.

Third Phase

The fourth phase involved finishing fabric with herbal extraction by Exhaust method and Spray drying method. The finished fabrics were evaluated for its physical test, Mechanical test, Absorbency Test, Anti-microbial test, Spectrophotometric, colourfastness test and wash durability test.

Findings of the Study

The following are the salient findings of unfinished, Exhaust method finished fabric and Spray drying finished method.

- From Phytochemical screening, the test showed the presence of Alkaloids, Carbohydrates, Glycosides, Phyto steroids, Saponins, Phenolic, Tannins and Flavonoid So, the extract of *Solanum trilobatum* has anti-microbial activities. These effects are probably due to the presence of phenolic compounds. Hence these extracts were used to incorporate an anti-microbial finish to the fabrics.
- With reference to the FTIR results the band width spectrum showed the presence of functional groups like O-H (alcohol and phenol groups) and C-H (Alkane group). These functional groups confirm the presence of Flavonoids, polyphenols, alcohols, alkanes and phenols for the selected herbal source. The presence of the functional groups is responsible for the anti-microbial activity.
- Anti-bacterial activity imparted by the herbal powders were assessed by the agar well diffusion method. This was confirmed by the zone of inhibition observed in plant treatment.
- The fabric weight of the anti-bacterial finished fabric samples, Exhaust finished and Spray drying finished fabric sample is 1.34% and 2.26% more than the original fabric, respectively. Increase in fabric weight was significant at 1% level.
- Fabric thickness of the spray drying method sample has increased by 3.84% and exhaust method finished fabric did not show any increase or decrease. This may be due to the adherence of the finishing material on the fabric structures. Statistical analysis also shows a significant difference at one per cent level.
- Fabric count increased in both warp and weft samples. The samples finished with the Exhaust method and Spray drying method had increased in the count along the warp direction by 19.16% and 16.5% respectively. The samples finished with Exhaust method and Spray drying method had increased in the count along weft direction by 6.86% and 10.51% respectively. Statistical analysis also proved that there was a significant difference at one per cent level. This may be due to the shrinkage and expansion during finishing treatment.
- Among the stiffness of unfinished, two method finished samples, the samples finished with Exhaust method and Spray drying method had decreased in the stiffness along

warp direction by 27.91% and 32.86% respectively, the samples finished with Exhaust method and Spray drying method had increased in the stiffness along weft direction by 1.76% and 12.94% respectively. This is because of the reaction of the finishes. Statistical interpretation reveals one per cent of significant difference of all the groups of fabric.

- With regard to the tensile strength, the samples finished with Exhaust method and Spray drying method had decreased and increased in the stiffness along warp direction by 2.32% and 3.03% respectively, the samples finished with Exhaust method and Spray drying method had increased in the Tensile Strength along weft direction by 7.05% and 9.56% respectively. Statistical analysis also proved the level of significance at one per cent.
- With regards to the fabric elongation, the samples finished with Exhaust method and Spray drying method had increased in the Fabric Elongation along warp direction by 3.45% and 0.3% respectively, the samples finished with Exhaust method and Spray drying method had increased in the Tensile Strength along weft direction by 6.74% and 128.09% respectively. The statistical analysis also proved that there was no significant difference between the samples in warp direction but statistically it was proved that there is a significance difference in weft direction at 1% significant level.
- Abrasion resistance value has increased with the gain percentage of Exhaust finished, and Spray drying-finished fabric sample is 26.28% and 27.74% more than the original fabric. The statistical analysis proved that there was a significant difference at one per cent level.
- The Absorbency property of the finished fabrics were increased in water absorbency. The loss percentage of Exhaust finished, and Spray drying-finished fabric sample is 57.14% more absorbency than the original fabric. Statistically also it was confirmed that there exists one per cent level of significant difference.
- With regard to fabric sinking test, Exhaust finished and Spray drying-finished fabric have taken less time to shrink by the sample is 75.38% and 40%. Statistical analysis proved one per cent level of significance.
- As far as the wicking test is concerned the result was found to be improved in finished fabric to great extent. The decrease in time of Exhaust finished, and Spray drying-finished fabric sample is 63.08% and 24.41% more than the original fabric. The statistical data proved that it was significant at one per cent level among all the groups.

- Spectrophotometer with color lab evident that color difference was observed when compared with original sample. Spray dried sample shows the Color depth when compared to the Exhaust method finished sample.
- Colourfastness test for both washing and crocking shows good rating and it is concluded that washing and crocking di not affect the colourfastness property.
- Anti-microbial test for samples proves that fabric finished using Spray drying method absorbed herbal extract more than exhaust method and gives its anti-microbial property on the Tencel cotton. The sample also shows acceptable anti-microbial property even after 5 and 10 wash of the samples. Between both the samples, the fabric which is spray dried shows good anti-microbial property.

Conclusion

Textile finishes has taken over the market over the past years and demand is increasing more day by day. These textiles finishes includes such as eco friendly dyeing. antimicrobial finishes especially using natural plants sources. The antimicrobial finishes fabrics are used in the medical fields as well as everyday wears to protect one from affect microorganism. This microorganism gives bad ordor and discoloration, which leads to rashes on the skin and allergy. The selected plant Solanum trilobatum has antimicrobial activity. This extract can be later treated to tissues and wipes and used it for cleaning of wounds and hands.

Recommendation for future studies

- Animal study can be conducted to find out the effect of antimicrobial finish.
- Other extracts can also be used to test the efficacy of the plant which may give us more results.
- Properties of the plant other than anti-microbial property can be used for further studies.
- Other areas of pharmacological aspects of the different plants can be tested to know its medicinal property.

BIBLIOGRAPHY



BIBLIOGRAPHY

Books:

- Angappan, V. and Gopalakrishnan, R., (2002), "Textile Testing", SSM Institute of Technology, Kumarapalayam, pp. 302-305.
- Anita, Tyagi, (2011), "Textiles for Apparel and Home Furnishings", Sonali Publications, pp. 96.
- Barker, A.F. and Midgley, (2007), "Analysis of Woven Fabrics", Abhishek Publications, Chandigarh, pp. 13, 154,155.
- Basu, A. and Chellamal, P., (2006), "Cotton Fibre Selections and Grading", SITRA, pp. 131, 298-300.
- Diepgen, L., Thomas and Schuster Christian, K., (2006), "Dermatological Examinations on the Skin Compatibility of Textiles Made from Tencel Fibres", Tenzinger Berichte, pp. 61-67.
- Frings, A.G., (2002), "Fashion from Concept to Consumer", Pearson Education Inc. New Delhi, pp. 132.
- Heine, E.,Knops, H.G., Schaefer K., Vangeyte P., Moeller M.,(2007), "Antimicrobial Functionalization of Textile Materials". In: Multifunctional Barriers for Flexible Structure, Textile, Leather, and Paper. Springer-Verlag, Berlin Heidelberg, Volume:32, Issue:1,pp. 36-51.
- Hipler, U.C. and Peter Elsner, (2006), "Biofunctional Textiles and the Skin", Karger Publishers, pp. 44, 45.
- Jewel Raul, (2005), "Textile Testing", APH Publishing Corporation, New Delhi, pp. 41-58
- Kamal Khurana, (2018), "Fabrics for Fashion and Textile Design", Sonali Publication, New Delhi, India, pp. 64-66.
- Kumari, V. R., (2017), Text book of microbiology, B.I. Publications Pvt Ltd, pp. 185-186,80.
- Malik Prem, (2007), "Role of Cotton as Major Textile Raw Material", Textile Magazine, Vol. 48, No. 4, pp. 12.
- Naik S., (2018). Textile Design, APH Publishing Corporation, New Delhi, pp. 34- 35.
- Nayak, R., & Padhye, R., (2014). Antimicrobial finishes for textiles, Woodhead Publishing: Cambridge, UK, pp. 361-385.
- Raghbir, Singh and Lalit, Mohan Kathwia, (2005), Preparedness of Indian apparel exporters after multifibre arrangement, an analysis of selected firms; The ICFAI University Press, pp. 26.
- Rao, J.V., (2016), Denim wash, Chemical Finishing Northern Indian textile research association sector-23. Raj Nagar, Ghaziabad-201002, 5th Edition, pp. 40.
- Roshan, Paul., (2014), Functional Finishes for Textiles-Improving Comfort, Performance, and Protection, United Kingdom: Elsevier Science, pp. 1.
- Sangwan, U., Khambra, K. and Hooda, B.K., (2006), "Analysis of Blend Influences on Parameters of Weft Knitted Fabrics", Textile Trends, Vol. XI, VIX, No. 6, pp. 32.
- Sema Sekhri, (2017), Textbook of Fabric Science Fundamentals to Finishing, PHI Learning Private Limited, New Delhi, 66. Silk Fabrics Dyed with Cassia tora L. Extract. Fibers and Polymers, 5(4), pp. 303-308.
- Thomas, K., (2006), "Know About the Fabric and Their Manufacture", Abishek Publications, Chandigarh, pp. 20, 46-47, 53.
- Veena, (2012), Applied Microbiology, Sonali Publications, pp. 45,255.

- Yilmaz, Demet, Senior, ALAY, (2010), “An Investigation of Knitted Fabric Performances Obtained From Different Natural and Regenerated Fibres”, *Journal of Engineering Science and Design*, Vol. 1, No. 2, pp. 91-95.

Journals:

- Achwal, W.B., (2000), “Lyocell Fibre”, *Colourage*, Vol. XLVII, No. 2, February, pp. 40.
- Aggarwal R., (2018), *Ayurvastra: A Way to Sustainable Living*. *Trends Textile Eng Fashion Technol*, 1(1), pp. 1-3.
- Appidi, S., and AJoy K. Sarkar, (2019), Investigation of ustic acid as an antimicrobial agent on textile substracts, *colourage* ,Issn 0010-1826,Vol 57, pp. 57.
- Badr, A. A., Hassanin, A., & Moursey, M., (2016), Influence of Tencel/cotton blends on knitted fabric performance. *Alexandria Engineering Journal*, 55(3), pp. 2439-2447.
- Bajwa, R.K., Chawla, R., (2015), *Ecofriendly Textiles & Eco Labelling -Essential for Survival*, *Textile Review*, pp. 2.
- Balakrishnan, P., Ansari, T., Gani, M., Subrahmanyam, S., & Shanmugam, K., (2015), A perspective on bioactive compounds from *Solanum trilobatum*. *Journal of chemical and pharmaceutical Research*, 7(8), pp. 507-512.
- Basit, A, Wasif Latif, Munir Ashraf, Abdur Rehman, Kashif Iqbal, Hafiz Shahzad Maqsood, Abdul Jabbar, Sajjad Ahmad Baig, (2018), Comparison of Mechanical and Thermal Comfort Properties of Tencel Blended with Regenerated Fibers and Cotton Woven Fabrics, *AUTEX Research Journal*, 19 (1).
- Bernela, M., Seth, M., Kaur, N., Sharma, S., & Pati, P. K., (2023), Harnessing the potential of nanobiotechnology in medicinal plants. *Industrial Crops and Products*, 194, 116266.
- Beti, R., C., Bogovic Slavica, Katovic Drago, (2015), Tencel with a Microbial Barrier for Medical Bras. *Journal of Fiber Bioengineering and Informatics*, 8 (4) 635-643.
- Bhardwaj, S., and Juneja, S., (2017), Performance of Jute Viscose/Polyester and Cotton Blended: Yarns for Apparel use. *Stud Home Com Sci*, 6(1) 33-38.
- Bhoomika, G.R., Ramesh, G.K., and Anita, M.A., (2017), Phyto-pharmacology of *Achyranthes asera*; A review, *Pharmacognosy Rev*, 1: 143-149.
- Bilir, TB., Şardağ, S., (2019), Investigation of mechanical properties of fabrics woven with lyocell/cotton blend yarns. *Tekstil ve Konfeksiyon*, 29(2), 162-170.
- Borbely, E., (2018), “Lyocell, the new generation of regenerated cellulose,”. *Acta Polytechnica Hungarica* 5(3), 11-18.
- Chaudhuri, A., (2001), “Processing and Labeling of Eco-friendly Textiles”, *Textile Trends*, Vol. 43, No. 4, February, pp. 23.
- Chavan, R., B. and Patra, A., K., (2017), Development and processing of lyocell, *Indian Journal of Fibre & Textile Research*, 29, 483-492.
- Chellamani, K., P., Dedasis Chattopadhyas, and Vittopa, M., K., (2006), “Studies on Spinning Behaviour Antifungal Thermo Properties of Cellulosic Fibres”, *Indian Journal of Fibre and Textile Research*, Vol. 51, No. 6, June, pp. 24
- Chen, C., Zhang, H., Zhang, X., X., and Wang, X, C., (2018), Antibacterial and absorbent acrylonitrile-vinylidese chloride copolymer fibers, *The journal of the textile institute*, ISSN 0040-5000,p-40 Vol. 101(2), pp. 40.
- Chhetri, H., P., Nisha Shrestha Yogol, Jyoti Sherchan, Anupa K.C., Mansoor, S., Panna Thapa., (2013), Formulation and evaluation of antimicrobial herbal ointment, *Journal of Science, Engineering and Technology*, vol. 6(i), pp-102.

- Christopher, D., Delhom, Vikki, B., Martin, and Martin K., Schreiner, (2017), Engineering and Ginning Textile Industry Needs, *The Journal of Cotton Science*, 21, 210–219.
- Coman, D., Oancea, S., Vrînceanu, N., (2010), Biofunctionalization of Textile Materials by Antimicrobial Treatments: A Critical Overview. *Romanian Biotechnology Letters*, pp: 4913-4921.
- Cyriac, M., B., Pai, V., Varghese, I., Shantaram, M., Jose, M., (2017), Antimicrobial properties of Areca catechu (Areca nut) husk extracts against common oral pathogens. *IJRAP* 3, pp: 81-84.
- Dorugade, V., A. and Bhagyashri, K., (2021), Antimicrobial finishing of textiles, *Manmade textiles in India*, pp.89-95.
- Doss, A., Mubarak, H., M., & Dhanabalan, R., (2009), Antibacterial activity of tannins from the leaves of *Solanum trilobatum* Linn. *Indian J Sci Technol*, 2(2), 41-43.
- Elnagar, K., Tarek Abou Elmaaty, and Sally Raouf, (2014), Dyeing of Polyester and Polyamide Synthetic Fabrics with Natural Dyes using Eco-friendly Techniques, *Journal of Textiles*, 1-8.
- Erdem, K., Yurudu, A.S.N.O., (2018), The Evaluation of Antibacterial Activity of Fabrics Impregnated with Dimethyltetradecyl (3-(Trimethoxysilyl) Propyl) Ammonium Chloride, *IUFS, Journal of Biology*, Vol. 67(2), pp.115-122.
- Esra Dirgar, (2017), The Performance Properties of the Fabrics Produced from Cupro and Some Other Regenerated Cellulose Fibers, *Tekstil ve Konfeksiyon* 27(2), 139- 144.
- Firgo, H., Christian Schuster, K., Friedrich Suchome, Johann Männer, Tom Burrow and Mohammad Abu-Rous, (2016), The Functional Properties of Tencel - A Current Update, *Lenzinger Berichte*, 85, 22-30.
- Gao, Y., and Cranston, R., (2008), Recent Advances in Antimicrobial Treatments of Textiles, *Textile Research Journal*, Vol.78, Issue 1, pp.60-72.
- Gautam, S., Mishra, A. and Goel, A., (2017), “Textile Magazine”, Vol. 48, Issue 12, October, pp. 102-103.
- Geissler, S., (2016), Extraction of natural dyes for textile dyeing from coloured plant wastes released from the food and beverage industry, *Journal of the Science of food and Agriculture* 86, 233-242.
- Gettings, R.L., (2020), A New, Durable Antimicrobial Finish for Textiles says by Dow Corning Corporation, Midland, Michigan Benny L. Triplett, Burlington Industries Inc., Greensboro, North Carolina 4 A1 Rev, p.4.
- Gopalakrishnan, D. and Aravindan, (2005), “Nonwovens for Medical Textiles”, *Asian Textile Journal*, Vol. 14, No. 4, April, pp. 36, 39, 41.
- Gopalakrishnan, D., and Aswini, R., K., (2006), Antimicrobial finishes. *Man Made Textiles in India*, 49(10), 372.
- Goyal, R. and Deshpande, R.,V., (2016), “Reactive Softeners”, *Colourage*, Vol. LIII, No. 8, August, pp. 115-117.
- Gupta and Bhaumik, S., (2007), “Antimicrobial Treatments for Textiles”, *Indian Journal fibre and Textile Research*, Vol. 32, June, pp. 253.
- Gupta N., and Bharti P. K., (2019), State of Arton Yarn Manufacturing Process & its defects in Textile Industry, *International Journal of Computational Engineering Research*, 3 (4), 47-60.
- Gupta, D., and Laha, A., (2017), Antimicrobial activity of cotton fabric treated with *Quercus infectoria* extract, *Indian Textile Journal of Fiber*, Vol.32, pp.88-92.
- Gupta, S., (2017), “New Technologies of Value Addition”, *New Cloth Market*, May, pp. 35.

- Hasan, N., B., Begum, A., R., Islam, A., and Parvez, M., (2017), Tencel Process Optimization in Conventional Cotton Processing Machineries and a Quality Comparison with Similar Cotton Yarn Count. *J Textile Sci Eng* 7, 302.
- Hipler, H., D., U., C., and Elsner, P., Karger, Basel., (2016), Antimicrobial Textiles Evaluation of their Effectiveness and Safety, in “Bio functional Textiles and the Skin”, Vol.33, pp. 42–50.
- Holm, (2022), Antimicrobials impart durable freshness, *International Dyer*, Vol.12, pp.9-11.
- Hopenow, (2018), “Spice and Herb Clothing: Indian Weavers Heal with Fashion”. 20.03.2008.
- Jain M., (2018), Ayurvedic Textiles: A Wonderful Approach to Handle Health Disorder, *Colourage*, 57(10), pp. 45-52.
- Jasuja, (2018), Antimicrobial and Anti-insect Finishes, *New cloth market*, Vol.128(12), .13.
- Jayapriya, S. and Bagyalakshmi, G., (2013), Textile Antimicrobial Testing and Standards, *International Journal of Textile and Fashion Technology*, 4(1) 1-10.
- John, M., J., and Anandjiwala, R., D., (2018), Recent developments in chemical modification and characterization of natural fiber-reinforced composites, *Polymer composites*, 29(2), 187-207.
- Joshi, M., Wazed Ali, S., and Purwar, R., and Rajendran, S., (2019), Ecofriendly antimicrobial finishing of textiles using bioactive agents based on natural products ,*Indian journal of fiber and textile research*, Vol.34, pp. 295.
- Jyothirmai, and Sasmita Panda, (2016), *Ayurveda – Herbal Clothing (A New Technology to Heal Naturally)*, *IJARIE*, 2(4), 1166-1171.
- Kale, K., Palaskar, (2010), “Atmospheric Pressure Plasma Treatment of Polyester/ Cotton Blended Fabric with He-O₂ Plasma for Wettability Improvement”, *Asian Textile Journal*, Vol. 41, No. 4, P. 61.
- Kilic, M. and Okur, A. (2019), The properties of cotton- Tencel and cotton-Promodal blended yarns spun in different spinning systems, *Textile Research Journal*, 81(2), 156-172.
- Klaus, S., (2021), All Round Answer to Problem Microbes”, *International Dyer*, Vol.17, Issue-19, pp.1-2.
- Kolte, PP., Shivankar, VS and Ramachandran, M., (2015), Herbal Clothing - An Ayurveda Doctor, *REST Journal on Emerging trends in Modelling and Manufacturing* 1(1):26 –31.
- Korankye, O., (2016), Extraction and Application of plant dyes to serve as colorants for food and textiles, phd thesis.
- Kumar, G., V., N., S., Teli, M., D., (2017), Functional textiles and apparels, *Journal of the Textile Association*, May-June 2007 Issue, pp.21.
- Kumar, S., and Satapathy, M.K., (2012), Medicinal plants in an Urban environment; herbaceous medicinal flora from the campus of Regional Institute of Education, *International journal of pharmacy & life sciences*, Vol.2, Issue-11, ISSN: 0976-7126, pp.1206-1210.
- Lee Y.H., and Kim H.D., (2016), Dyeing Properties and Colour Fastness of Cotton and Silk Fabrics Dyed with Cassia tora L. Extract. *Fibers and Polymers*, 5(4), 303-308.
- Maham, S., Fallah, F., Eslami, G., Shamsafar, S., Radmanesh, R., (2018). The antimycobacterium activity of menthapiperita and menthe spicataethanolic extract against mycobacterium bovis in compassion with isoniazid, *Iran J Clin Infect Dis* 6, 78-81.

- Mamta, and Anita Rani, (2015), Ayurveda: A miracle medicinal cloth, *Medicinal Plants. International Journal of Phytomedicines and Related Industries*, 7(1), 1-8.
- Mendapara, S., Karolia, A., (2015), Application of Antimicrobial and fragrance finish in combinations by microencapsulation on cotton fabric, *Journal of textile association*, Vol.66 (4), pp.158.
- Menezers, E. and Choudhari, M., (2007), “Special Finishes and Effects”, *AATCC Review*, Vol. 7, No. 3, March, pp. 29.
- Mercy Sheeba, J. and Tambidural, S., (2009), “Extraction, Characterization and Application of Seaweed Nano Particles on Cotton Fabrics”, *J. Appl. Polym. Sci.*, 113, 2287-2292, pp. 48.
- Ming, H. and Xiao-Man, R., (2021), Study on the 3-D construction and style design of the adjusting-bra, *TBIS Textile Bioengineering and Informatics Symposium Proceedings*, Beijing.
- Muniyan, R., Sundararajan, S., & Stalin Jochebed, J., (2022), Antimicrobial and Antimycobacterial properties of *Solanum trilobatum* L. - In-vitro. *Research Journal of Pharmacy and Technology*, 5603–5609.
- Murray S., (2016), The overseas textile mills that make our clothes are incredibly wasteful and polluting. Through NRDC's Clean by Design program. *Fixing the Fashion Industry*.
- Mutasim, A., Ahmed., Yassir, A., Eltahir and Haroon, A., M., Saeed, (2018), Eco-Friendly Utilization of Banana Plant Extract for Dyeing of Textile Materials and Related Purposes, *A Review International Journal of Recent Scientific Research* 9(5), 26465-26473.
- Mwnezesa, M., and Choudhari, M., (2017), Special finishes and effects by rossari biotech, Vol.5, pp 34.
- Nair, S. U., (2019), Application and Evaluation of Anti-Microbial Agent: New Trend in Textile, *Journal of the Textile association*, pp. 219-220.
- Naresh, M., Saraf, Dr., Ashok, G., Sabale and Dr., Vaishali Rane, G., (2007), “Antibacterial Agents in Textile Industry”.
- Neella, N., Gaddam, V., Rajanna, K., Nayak, M., M., (2017), “Low cost, disposable and wearable body warmer using RGO sheets coated on cloth substrate as heating element,” *IEEE 12th Int. Conf. Nano/Micro Eng. Mol. Syst. NEMS*, 177–180.
- Pamela Paterson, (2009), “Neem the Wonder Tree : Its Pesticide and Medicinal Application”, *University of Maryland*, August, pp. 27.
- Pandurangan, A., Khosa, R. L., & Hemalatha, S., (2009), Evaluation of anti-inflammatory activity of the leaf extracts of *Solanum trilobatum* Linn. *Journal of Pharmaceutical Sciences and Research*, 1(1), 16.
- Parmer, M.S., (2017), “Colouring, Printing and Finishing of Fabrics”, *Colourage*, Vol. XLIII, No. 7, July, pp. 23.
- Paul, D., Subrata Chandra Das, Tarikul Islam, Md. Abu Bakar Siddiquee, Md. Abdullah Al Mamun, (2017). Effect of Temperature on Dyeing Cotton Knitted Fabrics with Reactive Dyes, *Journal of Scientific and Engineering Research*, 4(12), 388-393.
- Rajkumar, S., & Jebanesan, A., (2015), Scientific Note Oviposition deterrent and skin repellent activities of *Solanum trilobatum* leaf extract against the malarial vector *Anopheles stephensi*, *Journal of Insect Science*, 5(1).
- Ramkumar, S., (2017), Gmsees Huge Potential for Indian Technical Textile Industry, *The Indian Textile Journal*, CXX(9), 80 & 81.
- Rathinamoorthy, R., Udayakumar, S., and Thilagavathi, G., (2017), Antibacterial efficacy analysis of *Punica granatum* L. leaf, rind and *Terminalia chebula* fruit extract

- treated cotton fabric against five most common human pathogenic bacteria, *ijpls*, ISSN: 0976-7126, Vol. 2, Issue 10, pp.1147-1149.
- Rekha, R. and Purnimal, D., (2010), “Functional Finishes on Textiles”, *Man Made Textiles in India*, Vol. LI, No. 52, September, pp. 62-63.
 - Roda, D., (2008), “Biscouring of Cotton Textiles Work – Amyth”, *Colourage*, Vol. LV, No. 1-4, March, pp. 115.
 - Rubia, Aman Bhardwaj, (2016), A Review: Natural Colourants, *International Journal of Engineering Science & Research Technology*, 5(7), 778-781.
 - Sampath, M., R., (2013), “Finishing – An Introduction”, *Colourage*, Vol. 50, No. 1-6, June, pp. 72-74.
 - Sanjay R. Malpani, (2013), *International Journal of Advance Research in Science and Engineering*, IJARSE, Vol. 2, No. 7, July.
 - Saraswathi, R., Krishnan, P., N., & Dilip, C., (2010), Antimicrobial activity of cotton and silk fabric with herbal extract by micro encapsulation. *Asian Pacific Journal of Tropical Medicine*, 3(2), 128-132.
 - Saravanan, P., Chandramohan, G., Mariajancyrani, J. and Shanmugasundaram, P., (2018), Extraction and application of Eco-friendly Natural dye obtained from Leaves of *Acalypha indica* Linn on Cotton Fabric, *International research journal of environment science*. 2 (12), 1 –5.
 - Sathianarayanan, M., P., Bhat, N.,V., Kokate, V., E. and Walunj, (2010), Antimicrobial Finish for Cotton Fabric from Herbal Products. *Indian Journal Fibre and Textile Research*, Volume:35, Issue:1, pp:50-58.
 - Senthil kumar, R., P., Bhuvaneshwari, S., Sathiyavimal, R., Amsaveni, M., Kalaiselvi, Malayaman, V., (2015), Natural Colours from Dyeing Plants for Textiles, *International Journal of Biosciences and Nano sciences*, 2 (7), 160-174.
 - Shaojin Gu, Ling Yang, Wei Huang, Yiming Bu, Dongzhi Chen, Jingjing Huang Yingshan Zhou, Weilin Xu, (2017), Fabrication of hydrophobic cotton fabrics inspired by polyphenol chemistry, *Cellulose*, DOI 10.1007/s10570-017-1274-1.
 - Shilpa, D., N., Kavitha, D. and Niranjali Devaraj, S., (2004), “Antibacterial and AntiDiarrheal Effects of Alkaloids of *Holarrhena Antidysen Trike*”, *Indian Journal of Experimental Biology*, pp. 589.
 - Shilpha, J., Silambarasan, T., Karutha Pandian, S., & Ramesh, M., (2013), Assessment of genetic diversity in *Solanum trilobatum* L., an important medicinal plant from South India using RAPD and ISSR markers, *Genetic resources and crop evolution*, 60, 807-818.
 - Silva, C., Matana, T., Kim, S.Y., Padrao, J., Prasetyo, E.N., Kudanya, T., Gibson, S., Nayanhongo, Guebitz, G.M., Casal, M., Paulo, A.C., Chand Ali, (2021), Antimicrobial and antioxidant linen via laccase-assisted grafting, *Reactive & Functional Polymers*, Vol. 71, pp.713–720.
 - Sinha, K., Aikat, K., Das, P., and Datta, S., (2016), Dyeing of Modified Cotton Fiber with Natural *Terminalia arjuna* Dye: Optimization of Dyeing Parameters Using Response Surface Methodology. *Environmental Progress & Sustainable Energy*, 35(3) 719-728, DOI. 10.1002/ep.12284.
 - Srikanth, S., (2010), “Application of Antimicrobial Finishes in Textiles”, *Apparel views*, Vol. 6, No. 7, July, pp. 96, 60-61.
 - Srivastava, Avernita, and Singh, T., G., (2019), Utilization of aloe vera for dyeing natural fabrics. *Asian J. Home Sci.*, 6 (1), 1-4.
 - Tandon, N., & Reddy, E., E., (1990), A study on emerging trends in the textile industry in India. *Ratio*, 104(108), 212.

- Tanner, B., D., (2019), Antimicrobial fabrics-issues and opportunities in the Era of Antibiotic resistance, AATCC Review, Vol-9(11), pp. 30-33.
- Tanveer Hussian, (2013), “Eco-Friendly Functional Finishes : Antimicrobial Finishing”, Asian Textile Journal, Vol. 19, No. 5, pp 38-41.
- Tarafder, N., (2013), “Functional Finishes for Textiles and Apparels”, Man Made Textiles in India, Vol 9, No. 2, September, pp. 309, 310.
- Thiry, M., C., (2016), Devine Denim, AATCC Review, Vol.10, Pp.40-45.
- Tomoko, N., Takashi, A., Hiromo, T., YukaI, (2012), Antibacterial activity of extracts prepared from tropical and subtropical plants on methicillin-resistant Staphylococcus aureus. J. Health Sci, Vol. 48 (3), pp 273–276.
- Tomsic, B., Simoncic, B., Orel, B., Cerne, L., Tavcer, P. F., Jerman, I., (2018), Sol-gel coating of cellulose fibers with antimicrobial and repellent properties. Journal of Sol, Vol, 47(1), Pp.44-57.
- Toshniwal, L., Target, and Louann, (2019), Evaluating functional properties of performance apparel, AATCC Review, Vol.9, Issue No.12, pp. 29-32.
- Usha, R., Prabu, E., Palaniswamy, M., Venil, C.K. and Rajendran, R., (2010), “Synthesis of Metal Oxide Nanoparticles by Streptomyces SP for Development of Antimicrobial Textiles”, Global Journal of Biotechnology and Biochemistry, ISSN 2078-466X, Vol. 5, No. 3, pp. 153-160.
- Vishnu, A., Dorugade, Bhagyashri, K., (2015), Antimicrobial finishing of textiles, Manmade textile in India, pp. 90.
- Wegier A., Valeria Alavez , and Daniel Piñero, (2016), Cotton: Traditional and Modern Uses, DOI 10.1007/978-1-4614-6669-7_18.
- Wen, H., Y. and Yang, X., J., (2017), The Spinning Process of Tencel Pure and Blended Yarn. Progress in Textile Science and Technology, 1, 44-45.
- White, W., C., Bellfield, R., Ellis, J., Devan, I., P., (2020), Controlling the spread of infections in hospital wards by the use of antimicrobials on medical textiles and surfaces, In Medical and Healthcare textiles, Woodhead Publishing Limited, pp.47.
- Worley, S., D. and Sun, G., (2018), “Chemistry of durable and regenerable biocidal textiles”, Journal of Chemical Education, Vol.82, Issue 1, pp. 60-64.
- Ya Wang, Dudi Gong, Yan Bai, and Yunqi Zhai, (2019), Analysis on the Spinning Process and Properties of Tencel Yarn, Journal of Minerals and Materials Characterization and Engineering, 3, 41-47.
- Yilmaz, Demet, Senior, and Alay, (2015), “An Investigation of Knitted Fabric Performances Obtained from Different Natural and Regenerated Fibres”, Journal of Engineering Science and Design, 1(2), 91-95.
- Yuhuan, M., Longfu, Z. and ZHANG Xianlong, (2019), Down regulation of cotton GbTRP1 leads to accumulation of anthranilates and confers resistance to Verticillium dahlia, Journal of Cotton Research 2(19) 1-12.
- Zhang S., Chunxia Chen, Chao Duan, Huichao Hu, Hailong Li, Jianguo Li, Yishan Liu, Xiaojuan Ma, Jaroslav Stavik, and Yonghao Ni, (2018), Regenerated Cellulose by the Lyocell Process, a Brief Review of the Process and Properties. Bio Resources 13(2), 4577-4592.

Website:

- Evaristo, C.J. "Ayurvastra or herbal couture takes rapid strides". 30.01.2008. <http://www.merineews.com>.
- Baid AM (2014). Method of dyeing textile article from medicinally rich herbs. <http://www.patentgenius.com>. Accessed 10 February, 2014.
- Poonam Sachdev, P (2011), History of Ayurveda in India, 27 www.onlymyhealth.com
- orbisresearch.com.
- Pardeep Kumar Gianchandani, (2010), Socks and its Manufacturing, www.fibre2fashion.com
- Subrata Das, <https://www.fibre2fashion.com/industry-article/1970/properties-of-bamboo-fibre>.
- Textile School, Cotton Fibers and its Properties, 2018, <https://www.textileschool.com/164/cotton-fibers-and-its-properties/>
- William Hilldawn, 2017 <https://medium.com/@SocksManufacturerinChina/whatare-socks-manufacturing-process-562fce84d10c>
- Asif Ahmed Safwan, <https://diutestudents.blogspot.com/2018/04/moistureregain-moisture-regain-is.html>.
- Sharma S (2014) Herbal Textiles: A boon to Textile Industry <http://www.fibre2fashion.com/industry-article/46/4564/herbal-textiles-a-boon-to-textiles-industry-1.asp>. assessed 22 February, 2014.
- Pratima Ati (2018) 8 Different Types Of Socks – Guidelines On How To Wear Them, <https://www.stylecraze.com/articles/different-types-of-socks/#gre>

APPENDIX





भारतसरकार
GOVERNMENT OF INDIA
पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
भारतीय वनस्पति सर्वेक्षण
BOTANICAL SURVEY OF INDIA



दक्षिणी क्षेत्रीय केन्द्र / Southern Regional Centre
टी. एन. ए. यू. कैम्पस / T.N.A.U. Campus
लाउली रोड / Lawley Road
कोयंबटूर / Coimbatore - 641 003

टेलीफोन / Phone: 0422-2432788, 2432123, 2432487
टेलीफक्स / Telefax: 0422- 2432835
ई-मेल / E-mail id: sc@bsi.gov.in
bsisc@rediffmail.com


सं. भा. व. स. द. क्षे. के. / No.: BSI/SRC/5/23/2023-24/Tech - 158

दिनांक / Date: 9th February 2023

पादप प्रमाणीकरण प्रमाणपत्र / PLANT AUTHENTICATION CERTIFICATE

The plant specimen given by you for authentication is identified as
***Solanum trilobatum* L. - SOLANACEAE.**

अभिनिर्धारित प्रतिरूप को संबंधित कॉलेज/विभाग/संस्थान के पादपालय में परिरक्षण हेतु वापस किया जाता है। / The identified specimen is returned herewith for preservation in their College/ Department/ Institution Herbarium.

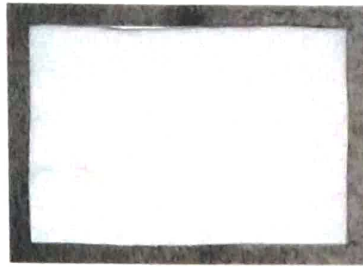

डॉ. एम. यु. शरीफ / DR. M. U. SHARIEF
वैज्ञानिक 'एफ' एवं कार्यालयाध्यक्ष /
SCIENTIST 'F' & HEAD OF OFFICE

सेवा में / To

Ms. YASMIN FATHIMA B
II M.Sc. Student
Department of Textiles & Clothing
Avinashilingam Institute for Home Science &
Higher Education for Women
COIMBATORE - 641 043

APPENDIX – II

FABRIC SAMPLE



Original Fabric - Tencel cotton



Exhaust Method finished fabric



Spray drying finished fabric