ECO-FRIENDLY NATURAL COLORANT FROM WOOD WASTE OF *“DALBERGIA SISSOO”* AND IT’S APPLICATION ON WOOL FABRIC

By

Kriyati Ashish Shah

(21PBX006)

A Thesis submitted to the

Avinashilingam Institute for Home Science and Higher Education for Women

Coimbatore-641043

In Partial Fulfilment of the Requirement for the

Degree of Master of Science in Biotextiles

May, 2023

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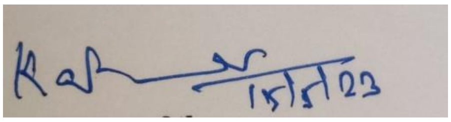

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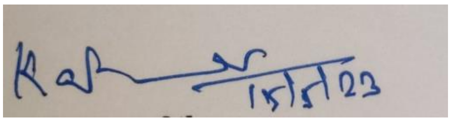


Signature of the
Guide

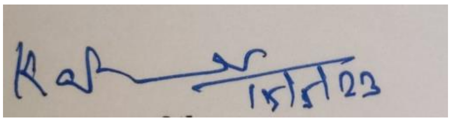
DECLARATION

I declare that the dissertation entitled **"Eco-Friendly Natural Colorant from Wood Waste of *“Dalbergia sissoo”* and Its Application on Wool 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. (Tmt.) K. Kalaiarasi, M.Sc., M.Phil., Ph.D., Associate Professor, Department of Textiles and Clothing, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore-642 043 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 **"Eco-Friendly Natural Colorant from Wood Waste of *"Dalbergia sissoo"* and Its Application on Wool Fabric"** submitted for the degree of Master of Science (M.Sc.) Textiles and Fashion Apparel by **Kriyati Ashish Shah** is the record of project work carried out by her during the academic year 2021 to 2022 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 University or Institution of Higher Learning.



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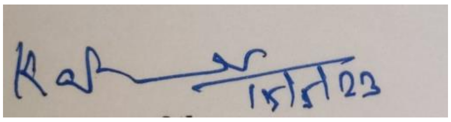

Signature of the Supervisor with Designation

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ACKNOWLEDGEMENT

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INTRODUCTION

INTRODUCTION

Synthetic dyes especially reactive dyes are widely used for the coloration in textile industries [Kumbasar., et al 2009], due to their ability to yield brighter shades at lower costs [Samanta., et al., 2009; Yusuf, et al 2013]. The effluent discharged from textile industries contain several synthetic chemicals, which are disturbing our ecosystem [Meng, et al 2020]. Synthetic dyes are said to be carcinogenic, non-biodegradable and reason for various allergic diseases [Ma, et al 2018]. Many worldwide environmental agencies from U.S.A, Germany, Italy etc., have banned the use of synthetic dyes due to its ill effects on human and environment [Phan, et al 2020].

Consumers have become more and more aware and demanding for eco-safety products, which in turn lead to the use of more environmentally friendly materials. And increase in the use of green technology day by day to avoid or reduce the harm on environment and living-organisms by chemicals released by synthetic dyes [Mia, et al 2019]. Many countries have started promoting researchers to work on natural dyes for textiles coloration [Mittal, 2020].

In olden times, natural dyes were used for many different purposes like, dyeing of food, leather, fibers, fabrics and even plastic as they had full shades, luster and even dyeing. But later in the 19th century, discovery of synthetic dyes recused the consumption of natural dyes [Adeel, et al 2020]. Natural dyes obtained from plants, animals, insects, minerals are sustainable bio-resource products. Idea of extraction of natural dye using the bio-waste sources like rose waste [Karaboyaci, 2014], coconut shell [Teli, & Pandit, 2017], almond shell [İşmal, & Yıldırım, 2012] leaves of different plants [Bechtold, et al 2006], wood waste/sawdust [Kandasamy, et al 2021] or by dye containing waste of food and beverage [Pan, et al 2003].

Raw material used and the process for the synthesis of natural dye is biodegradable and non-polluting to the environment [Kasiri, et al 2015]. Dyeing of textile material depends on various parameters like fiber/fabric structure, temperature, time, pH dye bath and concentration of dye molecules. Protein fibers, show better affinity to natural dyes since they have ionic groups in their structure and form stronger bonds with natural dyes possessing ionic groups in dye structure [Schweppe, 1992; Gupta, 2019].

There are limited studies on dyeing of fabric with dye extracted from sawdust. The main aim of this research is to explore *Dalbergia sissoo* as natural dye source and investigate the dyeing potentiality of the extract on the wool fabric.

Dalbergia sissoo is from the family of Leguminosae plant which is a native to Indian subcontinent [Shukla & Misra, 1979]. It is a state plant of Punjab, a state in India and Punjab province of Pakistan. It is found growing along river banks below 900 meters (3,000 ft) elevation, but can range naturally up to 1,300 m (4,300 ft). It can withstand average annual rainfall up to 2,000 millimeters (79 in) and droughts of 3–4 months. It prefers soils from pure sand and gravel to rich alluvium of river banks. Shisham can grow in slightly saline soils. Seedlings are intolerant of shade [Bhattacharya, 2014]. It is mainly used as timber or furnishing so there is ample amount of sawdust or furnishing waste is created, which we have utilized here as a potential colorant for textile material. *Dalbergia sissoo* is an important herbal, medicinal tree. Various diseases were treated using various parts of this plant in Indian Ayurveda. Wood and bark of this plant has been antipyretic, aphrodisiac, expectorant, and refrigerant treatment in Ayurveda, tree is also used for treating the wounds in Africa [Troup, 1921]. The genus of Dalbergia has in total 300 species out of which 25 species are found in India. Most of the species are important timber and are loved for their decorativeness and are rich in aromatic oil [Vasudeva, et al 2009]. *Dalbergia sissoo* has said to have many organic chemical components like Neo-flavonoids, quinines, coumarins, dalbergichromene, dalbergenone (Figure.1) etc., all these organic components are responsible for all the medical benefits and for the colorant provided by this plant.

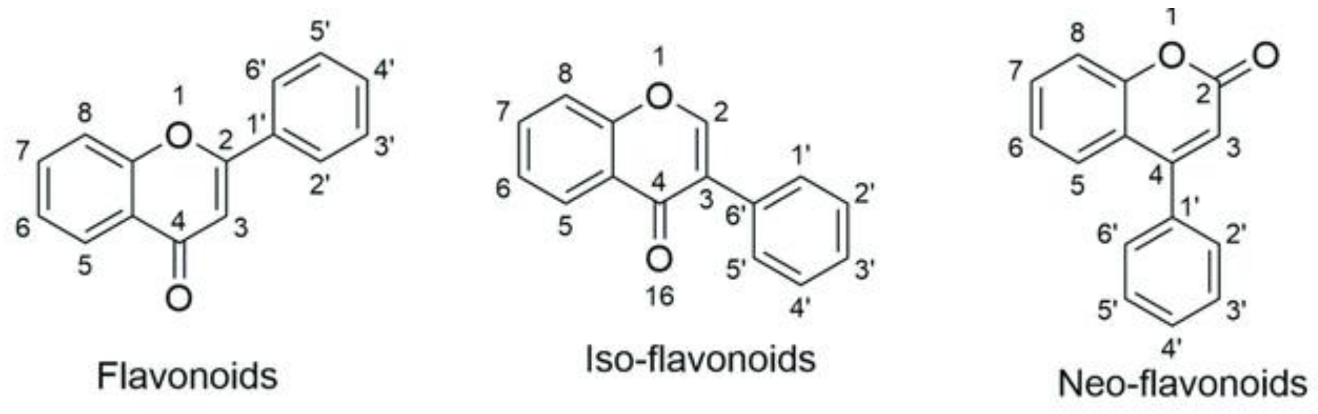

Figure.1 Basic Chemical Structure of '*Dalbergia sissoo*'

Wool is a type of protein fiber obtained from the animal for proactive covering. It is traditionally obtained by shearing fleece from living animals, but sometimes even loosen fibers are used. Though the shearing is done by hand, wool fabric is manufactured by machine. Wool is more suitable for winter clothing as it gives warmth [Allafi, et al 2022]. Wool fiber is mainly consisting of protein called Keratin. Wool's diameters range from 16 to 40 microns. Fine wools are about 1.5 to 3 inches long; extremely coarse fibers are 14 inches in length [https://www.britannica.com/topic/wool]. Almost 75% of wool is used in garment industry with 15-45% in home furnishing, 6-7% in industrial applications and 5% in exports, wool shares 4% of all fibers in textile industry [Shabbir, et al 2017].

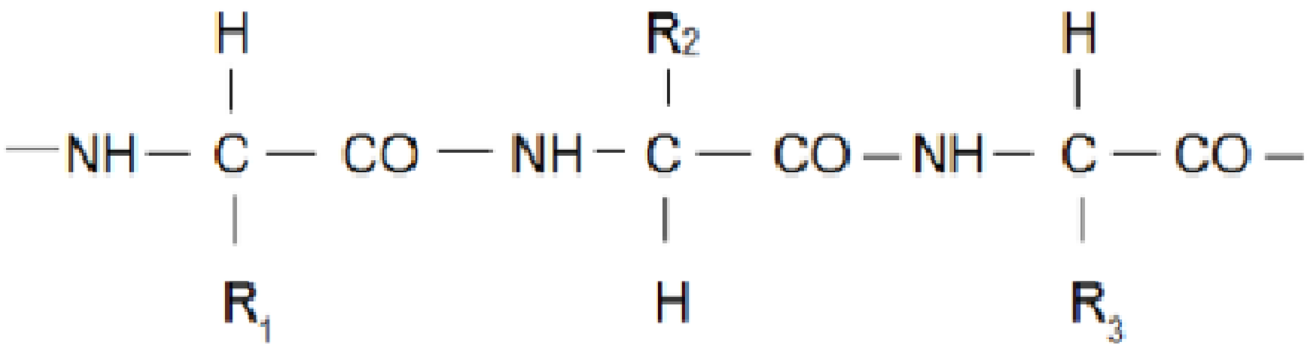

Figure.2 Basic Chemical Structure of Wool

Mordanting is a process where a mordant or dye fixative is used to bine the dye molecules with the fiber structure.
[https://en.wikipedia.org/wiki/Mordant#:~:text=Mordants%20include%20tannic%20acid%2C%20oxalic,in%20fact%20a%20trapping%20agent.]

Mordants are used to increase the quality of fabric and color brightness. Mordants can be natural like tannic acid, citric acid, clay, leaves etc. or synthetic like metallic slats like alum, stannous chloride, copper sulphate, ferrous sulphate etc. [Dutta, et al 2021]. In this study, alum was selected as it is widely used mordant for wool and wool fibers, yarn or fabric and it possess the lowest negative ecological impact among other synthetic mordants [Mitra, 2015]

This research reports on the utilization of the *Dalbergia sissoo* sawdust extract as a source of natural colorant. Different dyeing parameters were optimized using a one-variable-at-a-time technique [Kovačević, et al 2021]. The present study entitled *"Eco-Friendly Natural Colorant From Wood Waste Of "Dalbergia Sissoo" And Its Application On Wool Fabric"* was carried out with the following objectives:

a. To screen and select the natural dye source from wood waste
b. To optimize dye extraction and dyeing parameters
c. To evaluate physical and functional properties of the dyed fabric

REVIEW OF LITERATURE

1. REVIEW OF LITERATURE

The review of literature pertaining to the study entitled *"Eco-Friendly Natural Colorant From Wood Waste Of "**Dalbergia Sissoo**" And Its Application On Wool Fabric"* is discussed under following topics.

1.1 Natural Fiber

1.2 Wool

1.2.1 History of Wool

1.2.2 Wool Characteristics

1.2.3 Properties of Wool

1.2.4 Wool Structure

1.2.5 Global Scope for Wool

1.3 Natural Dye

1.3.1 Introduction

1.3.2 Classification of Natural Dyes

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1.3.4 Advantages of Natural Dyes

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1.5 *Dalbergia sissoo*

1.5.1 Introduction

2.1 Natural Fiber

Natural fiber' is a term used to refer to the fibers that are obtained from (or are produced by) animals and plants. These fibers have a wide range of applications in the manufacture of composite materials. Paper and felt (a type of textile material) can be prepared by matting different layers of natural fibers into sheets.

[https://www.wool.ca/images/uploads/files/care/wool-fact-sheets.pdf]

Natural fibers have traditionally been used in all cultures of the world to meet basic requirements of clothing, storage, building material, and for items of daily use such as ropes and fishing nets. People in olden times used various kinds of natural fibers depending on their local availability.

[https://www.wool.ca/images/uploads/files/care/wool-fact-sheets.pdf]

India is rich in plant resources and the use of a variety of natural fibers such as banana, pineapple, sisal, hemp, coconut, palm, grasses etc. was widely prevalent in olden times. Their use became limited once cotton acquired the prime status of plant fibers. In cotton production, organic cotton accounts for a very small percentage of total cotton production. Silk, linen, and jute are other natural fibers that have continued to enjoy popularity

[https://www.wool.ca/images/uploads/files/care/wool-fact-sheets.pdf]

Most natural fibers are known to be good absorbers of sweat and other liquids. A wide range of textures can be obtained from different natural fibers (either individually or through a combination of two or more natural fibers). For example, cotton fibers (which are natural fibers that are derived from the cotton plant) are used in the production of cotton fabrics that are characterized by their relatively low weight and their soft texture. Another advantage of cotton fiber is that it can be woven into the clothing of various sizes and colors. Clothing which is made up of natural fibers (like cotton) is usually preferred over clothes that are made up of synthetic fibers, especially by the people who live in hot and humid regions

[https://www.wool.ca/images/uploads/files/care/wool-fact-sheets.pdf]

2.2 Wool

2.2.1 History of Wool

Like human civilization, the story of wool begins in Asia Minor during the Stone Age about

10,000 years ago. Primitive man living in the Mesopotamian Plain used sheep for three basic human needs: food, clothing and shelter. Later on, man learned to spin and weave. As primitive as they must have been, woolens became part of the riches of Babylon. The warmth of wool clothing and the mobility of sheep allowed mankind to spread civilization far beyond the warm climate of Mesopotamia.

Between 3000 and 1000 BC the Persians, Greeks and Romans distributed sheep and wool throughout Europe as they continued to improve breeds. The Romans took sheep everywhere as they built their Empire in what is now Spain, North Africa, and on the British Isles. During the twelfth century, weaving in Florence, Genoa and Venice was stimulated by the Norman conquest of Greece. The conquerors sent about a hundred Greek weavers to Palermo as slaves, and their extraordinary work was copied at once by Italian weavers. Back in Spain a thriving wool trade helped finance the voyages of Columbus and the Conquistadores.

Guarding its wealth closely, Spain levied the death penalty on anyone exporting sheep until 1786. That year King Louis XVI imported 386 Merino ewes to cross with sheep on his estate at Rambouillet in Northern France. The resulting Rambouillet breed is highly desirable today because of its fine and long-staple wool. Just like Spain, England froze its borders to raw wool exports. In 1377 England's King Edward III, "the royal wool merchant," stopped woven-goods imports and the domestic weaving of foreign wools and invited Flemish weavers fleeing the Spanish invasion to settle in England where the industry thrived. By 1660 wool textile exports were two-thirds of England's foreign commerce.

New inventions like the spinning jenny, combing machines and water-powered looms, expanded the industry rapidly. Sheep moved West with civilization and beyond; at the turn of the 18th century small flocks in the hands of pioneers started the industry in Australia, New Zealand and South Africa. Sheep are as versatile as the fiber they produce. All parts are used; they provide tender, delicious meat… and wool is a renewable resource. Sheep thrive in all 50 states and most nations of the world, often in rough, barren ranges, or high altitudes where other animals cannot survive because of lack of vegetation. Sheep can survive and flourish on weeds and vegetation other animals will not eat, therefore they convert to protein a group of natural resources which would otherwise be wasted. Sheep fill our food and fiber needs today just as they have for centuries.

[https://www.wool.ca/images/uploads/files/care/wool-fact-sheets.pdf]

2.2.2 Characteristics of Wool

- *Anti-static* — because wool can absorb moisture vapor, it tends not to create static electricity, so it is less likely to cling uncomfortably to your body than other fabrics.
- *Anti-wrinkle* — at a microscopic level, each wool fiber is like a coiled spring that returns to its natural shape after being bent. This gives wool garments natural wrinkle resistance.
- *Biodegradable* — When wool is disposed of, it will naturally decompose in soil in a matter of months to years, releasing valuable nutrients back into the earth.
- *Breathable* — wool fibers can absorb large quantities of moisture vapor then move it away to evaporate into the air. Wool clothing is extremely breathable and less prone to clamminess.
- *Elastic* — natural elasticity helps wool garments stretch with your body, yet return to their original shape. So fine wool clothing is ideal to wear when exercising.
- *Fire-resistant* — wool is flaming retardant, doesn't melt and stick to the skin, and even self-extinguishes when the source of flame is removed.
- *Nature's fiber* — Wool is grown year-round from a simple blend of water, air, sunshine and grass.
- *Odor resistant* — in contrast to synthetics, wool can absorb moisture vapor, which means less sweat on your body. They even absorb and locks away the odors from sweat, which are then released during washing.
- *Renewable* — every year sheep produces a new fleece, making wool a completely renewable fiber source
- *Stain-resistant* — wool fibers have a natural protective outer layer that prevents stains from being absorbed. And because wool tends not to generate static, it attracts less dust and lint.
- *Soft* — Wool fibers are extremely fine, enabling them to bend and feel soft and gentle next to your skin.
- *Sun-safe* — wool is much better at protecting skin against UV radiation than most synthetics and cotton. So, the whole family will be safer wearing wool on sunny days.
- *Warm and cool* — in contrast to synthetics, wool is an active fiber that reacts to changes in body temperature. So, it helps you stay warm when the weather is cold, and cool when the weather is hot.

[https://www.textileschool.com/162/wool-fiber-basics-characteristics-properties/]

2.2.3 Properties of Wool

For processing wool fiber, we should know about properties of wool fiber. Now I have discussed the following properties of wool fiber.

A. Physical properties of wool fiber

B. Chemical properties of wool fiber

A. PHYSICAL PROPERTIES OF WOOL FIBER:

a) *Specific Gravity*: 1.31
b) *Length*: 35 to 250 mm
c) *Color*: The color of wool fiber could be white, near white, brown and black.
d) *Flame reaction*: Odor of burnt horn
e) *Luster*: Luster of course fiber is higher than fine fiber.
f) *Moisture Regain*: 13-16%, very absorbent, decrease strength when wet, seem warmth, will shrink in washing.
g) *Electrostatic reaction*: Highly electrostatic at dry conditions
h) *Strength*: Tenacity dry =1.35 g/d, Wet = dry 0.69 weak (Due to few H-bond)
i) *Elasticity*: Breaking extension – 42.5 %, Recovery % – 69 at 5%
j) *Elongation at break*: Standard elongation is 25 – 35% and 25 – 50% in wet condition.
k) *Feel or Hand*: Soft.
l) *Resiliency*: Excellent (due to crimp)
m) *Abrasion resistance*: Good
n) *Dimensional stability*: Bad (For tendency of felting).
o) *Effect of Heat*: Heat affects the wool fiber greatly.
p) *Effect of Sun Light*: The fibers become discolored and develop a harsh feel. [https://textilelearner.net/physical-and-chemical-properties-of-wool-fiber/]

B. CHEMICAL PROPERTIES OF WOOL FIBER:

a) *Effect of Acids*: Wool is attacked by hot concentrated Sulfuric acid and decomposes completely. It is in general resistant to mineral acids of all strength even at high temperature though nitric acids tend to cause damage by oxidation.
b) *Effects of Alkalis:* The chemical nature of wool keratin is such that it is particularly sensitive to alkaline substances. Wool will dissolve in caustic soda solutions that would have little effects on cotton. Strong alkaline effect on wool fiber but weak

alkaline does not affect wool.

c) *Effect of Resistance to Compression*: Resistance to compression values is useful in assessing the suitability of wool for specific end uses. Resistance to compression (R to C) is the force per unit area required to compress a fixed mass of wool to a fixed volume. Resistance to compression is related to fiber diameter and the form and frequency of crimp.
d) *Effect of Resilience*: Wool fibers can be stretched up to 50 percent of their original length when wet and 30 percent when dry.
e) *Effect of Organic Solvent*: Wool does not affect in organic solvents.
f) *Effects of Insects*: Wool affected by insects.
g) *Effect of bleach*: Chlorine bleach is ordinary harmful to the wool. KMnO4, Na2O2 are utilized for bleaching.
h) *Effect of Micro Organism*: It is affected by mildew if it remains wet for long time.
i) *Dyeing ability*: Wool absorbs many different dyes deeply, uniformly and directly without the use of other chemicals. Because of this ability, wool is known for the beautiful, rich colors that can be achieved.
j) *Effect of Colorfastness*: Like cotton, wool is easy to dye. Acid dyes, chrome and mordant dyes are utilized to dye this. The dye molecules are attracted into the amorphous areas of wool.
[https://textilelearner.net/physical-and-chemical-properties-of-wool-fiber/]

2.2.4 Structure of Wool

A. Chemical Structure of Wool

Wool belongs to a group of proteins known as keratins. It has a heterogenous composition where the protein is made up of amino acids and acidic carboxyl groups. Which is what is responsible for its flexibility, elasticity, resilience, and good wrinkle recovery properties. It also allows it to absorb both moisture and dyes so well.
[https://www.hdwool.com/blog/the-structure-of-wool]

Table.1 Chemical Composition of Wool

Component	Percentage
Keratin	33%
Dirt	26%
Suint	28%
Fat	12%
Mineral Matters	1%
Total	100%

[http://textileaid.blogspot.com/2013/07/wool-fiber-chemical-composition-of-wool.html]

The wool fiber is composed of a particular protein, this protein is known as "keratin". This keratin consists of long polypeptide chains. The polypeptide chains have eighteen different amino acids. The most of these amino acids have the general formula H2N.CHR.COOH. In this formula R is a side chain of varying character. And at intervals bridges derived from the amino acid cystine connect the chains. Some of the side chains end in amino groups and others in carboxyl groups. Internal salts are therefore formed and the Molecules are bound together by electrovalent linkages. The molecules of keratin are very large, with and average molecular weight estimated at about 60,000.
[https://www.textileadvisor.com/2019/07/chemical-composition-of-wool-fibre.html]

B. Physical Structure of Wool

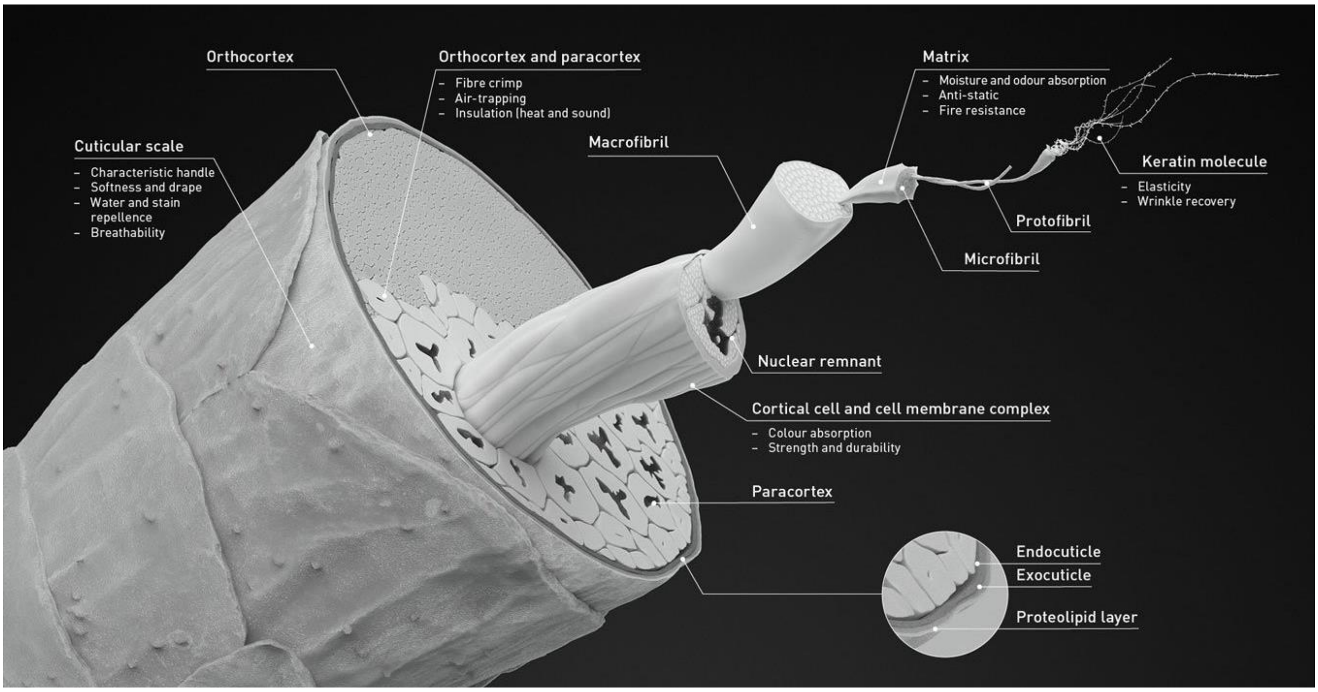

Figure.3 Physical Structure of Wool [43]

a) *Fibre diameter*- Fibre diameter refers to the 'thicknesses of the fibre. Fine fibres bend easily, making them soft. Thick fibres bend less easily, making them resilient. Fine yarns and fabrics are used to make clothes. Thicker yarns can be used to make carpets.

b) *Cuticle scales*- Cuticle scales are tiny overlapping scales, which surround the wool fibre. If untreated during processing the cuticle scales can cause wool to felt and become thicker and hairier during washing. Moisture vapour penetrates beneath the scales, allowing the fibre to 'breathe'.

c) *Ortho-cortex and para-cortex*- The ortho-cortex and para-cortex cells form the core of the wool fibre. The arrangement of the cells causes the 'crimp' (wave) in the wool fibre and traps air (providing insulation), which produces wool fabrics that keep us warm during winter.

d) *Cell membrane complex*- The cell membrane complex surrounds each strand of internal cortex cells (fibrils). It holds fibrils together and absorbs colour, allowing wool products to achieve deep vibrant colours, which don't fade.

e) *Microfibril and Microfibril*- The cortical cells are made up of microfibrils and microfibrils. The material binding these fibrils is often called the 'matrix' material.

f) *Matrix*- The matrix consists of high-sulphur proteins. It absorbs moisture to resist static and burning, delivering cleaner and safer clothing and carpets.

g) *Alpha helix*- The protein chains that form the helical coil are the smallest parts of the wool fibre. They give wool its flexibility, elasticity and resilience, which delivers easy-to-live with, durable and wrinkle-resistant products.

1. *Epicuticle*- The epicuticle is one of the outer cuticle cell layers, on the surface of the wool fibre. It repels liquids and resists abrasion, which gives the fibre its stain and water resistance, making it easier to clean [https://www.woolmark.com/fibre/].

2.2.5 Global Scope of Wool

Pure Wool Market size is expected to be valued at $32.2 billion by the end of the year 2026 and is set to grow at a CAGR of 5.5% during the forecast period from 2021-2026. The growing population across the world coupled with factors like increasing urbanization, constant changes in lifestyle, changing styles and trends is highly driving the pure wool market. Furthermore, the increase in demand for warm clothing and blankets from cold region countries is one of the major factors increasing the demand for pure wool market. Additionally, owing to the many properties of wool such as high thermal resistance, less flame spread, porosity and others, the demand has been increasing from various customers across the globe. Various types of wool being innovated through the years, such as reprocessed wool, synthetic wool, and others is expanding the options for wool which is also further increasing the demand for pure wool market.

Increasing production and export of wool

There has been an increase in the demand and production of woollen fabric from various end-use industry, especially post Covid-19. This is contributing to the demand for pure wool market. According to American Sheep Industry Association, Defence Logistics Agency (DLA), plans to procure 1.5 million linear yards of wool and wool blend fabrics for use in recruit issue uniforms in the year 2021. They are also planning on selling more than 40,000 wool berets during the year 2021. According to Korea Customs Services, the export of textile yarns increased by 4% to US$130 thousands in June 2021 from US$125 thousands from May 2021.
[https://www.industryarc.com/Research/Pure-Wool-Market-Research-501413]

2.3 Natural Dyes

2.3.1 Introduction

Natural dyes are colorants obtained from plants, invertebrates, insects, fungi or minerals. Most natural dyes are vegetable dyes, the main sources of which are various parts of plants such as roots, stems, seeds, barks, leaves and wood. There are also other biological sources such as fungi, snails, insects, etc. Natural sources were the main source of textile dyes before chemically dyeing [Shanmathi, & Soundri, 2016]. Since prehistoric time natural dyes is used for coloring of food substrate, leather as well as fibers like wool, silk and cotton. The use of non-allergic, non-toxic and eco-friendly natural dyes on textiles have become a matter of significant importance due to the increased environmental awareness in order to avoid some hazardous synthetic dyes [Agarwal, 2009].

Color fastness of natural dyes to washing and light is in general inferior to well-selected and applied synthetic dyes, and normally does not meet consumer demands.
The term 'natural' and 'safe' are not synonymous; there are many naturally occurring substances, e.g., arsenic and asbestos, which are harmful. Natural dyes are derived from plant, animal or mineral sources, and while some dyes are quite safe to use, some are hazardous. For example, indigo and logwood are skin and respiratory irritants, and plants such as lily of the valley and bloodroot are toxic.

Handling of natural dye and its dyeing process needs scientific interventions at four main steps:

1. Extraction
2. Isolation of dye molecule
3. Dyeing
4. Dye fixing

Applications of natural dyed textile can be extended to a diverse field such as sportswear and medicinal field due to its various functional properties such as antimicrobial as well as UV protection.

2.3.2 Classification of Natural Dyes

Natural dyes were classified in many ways at different time periods by researchers on the basis of source, chemical constitution and method of application.

2.3.2.1 Classification Based on Source

a) *Plants*: Roots, leaves, fruits, flowers and barks can be used as a source of natural dyes. Different colors can be obtained from each part such as Sapon-wood tree pods give red, barks give brown and root gives yellow color. Many by-products of plants can also be used to form dyes.

b) *Animals*: Dyes can be obtained from dried body of insects for example, Lac, Cochineal and Kermes. Cochineal is a brilliant red dye produced from insects living on Cactus plants. Carmine and Tyrian purple dye derived from cochineal, shellfish (Murex spp.) respectively.

c) *Minerals*: Mineral dyes include iron buff, iron black, manganese bistre, chrome yellow, and Prussian blue.

d) *Microorganisms*: Natural colorant can be extracted from fungi, bacteria and algae that are fast growing and have the potential of being standardized commercially. Chitosan, Serratia spp., Trichoderma virens and Alternaria alternata were used to obtained dyes. Natural Red color is produced by Monascus anka and also from fungus Echinodontium tinctorium. Phycocyanin is blue pigment extracted from Spirulina plarensis algae.

[https://textilelearner.net/natural-dyes-properties-types-production/]

2.3.2.2 Classification Based on Their Chemical Constitution

a) *Indigoid dyes*: This group includes Indigo and Tyrian purple dye. Indigo is extracted from Indigofera tinctoria and considered the most primitive dye. Woad plant (Isatis tinctoria) also has indigo as the chief blue dyeing component.
b) *Anthraquinone dyes*: Most of the red natural dyes from both plant and mineral origin are based on the anthraquinoid structure. Madder, Lacs, Cochineal are some examples of this group. Alizarin and purpurin are the main chromophores in Rubia tinctorum.
c) *Alpha naphthoquinones*: Lawsone (henna) is a most important member of this class. Another dye is juglone, isolated from the shells of unripe walnuts.
d) *Flavonoids*: Yellow dyes obtained from this group and can be classified under flavones, isoflavones, aurones and chalcones. These yellows are found in a variety of plants, including Persian berries (Rhamnus spp.), young fustic (Cotinus coggygria), old fustic (Chlorophora tinctoria) and yellow wood (Solidago virgaurea).
e) *Di-hydropyrans*: In chemical structure, di-hydropyrans are similar to the flavones. These natural dyes give dark shades on cotton, wool and silk. Logwood and Sappan-wood are the most common examples.
f) *Anthocyanidins*: Orange dye carajurin obtained from leaves of Bignonia chica. Carajurin is a chemical member of this class.

g) *Carotenoids*: The class name carotene is derived from the orange pigment found in carrots. In these, the color is due to the presence of long conjugated double bonds. Usually, red, orange and yellow colors come in this category and can be obtained from different plants, e.g., yellow, orange color in sunflower. [https://textilelearner.net/natural-dyes-properties-types-production/]

2.3.2.3 Classification Based on Method of Application

a) *Direct Dyes*: Direct dye soluble in water can be taken up directly by the material. Direct dye also called substantive dyes because of their excellent substantivity for cellulosic material like cotton and viscose rayon. Turmeric, Chebulic myrobalan and Annatto used in direct dyes.

b) *Vat Dyes*: As the name suggests that the dye is prepared in a large container for storing and mixing liquids or wooden vessels commonly known as ‘Vat’. This is a primitive method of dye preparation.

c) *Mordant Dyes*: Mordant dyes are attached to textile fibers by a fixing agent “mordant” which can be organic or inorganic substance. Since chromium is used extensively hence, mordant dyes are sometimes called chrome dyes.

d) *Acid Dyes*: These dyes performed in acidic medium. Sulfonic or Carboxylic groups of dye molecules can form electrovalent bonds with amino groups of wool and silk.

e) *Basic Dyes*: These dyes form an electrovalent bond with the carboxylic group of wool and silk. Berberine has been classified as basic dye.

f) *Disperse Dyes*: Disperse dye have low aqueous solubility and low molecular weight. These dyes require post mordanting treatment with chromium, copper or tin salt. [https://textilelearner.net/natural-dyes-properties-types-production/]

2.3.2.4 Classification Based on Color

a) *Natural Yellow Dye*: Yellow symbolizes growth and happiness and is perhaps the most abundant hue in nature. The number of plants that yield yellow dyes is much higher than the number that yieldother colors, and the Color Index lists a total of 28 natural yellow dyes. Yellow is of particular significance in India, where it is still considered an auspicious color with great religious significance [Patel, 2011]

b) *Natural Red Dye*: The Color Index lists 32 red natural dyes. Most of the red colorants are found in thebarks or in roots of the plant or camouflaged in the bodies of the dull grey insects. Few prominent members are madder (Rubiatinctorum), manjistha (Rubiacordifolia), Brazil wood/sappanwood (Caesalpineasappan), Al or morinda (Morindacitrifolia), cochineal (Coccuscacti) and lac dye (Coccuslacca) [Vankar, 2000 & Yusuf, et al 2017].

c) *Natural Blue Dye*: The Color Index lists only four blue natural dyes, viz. natural indigo, sulphonated natural indigo, Kumbh (Manipur) and the flowers of Japanese ‘Tsuykusa’ used mainly for making awobana paper [Sinha, et al 2012]. The most brilliant and the fastest blue shades are obtained from indigo on all fibers. The principal coloring matter is indigotin, whose main sources are Indigo (Indigofera tinctoria) and woad (Isatis tinctoria) [Patel, 2011]. These dyes exhibit excellent fastness to wash on cotton Photo-stabilization of gardenia blue may be induced using functional UV absorbers [Oda, 2012].

d) *Natural Black Dye*: One important black natural dye is Logwood Haematoxylum campechianum) which isalso known as Cam peachy wood because it was discovered by the Spaniards on the bay of Campeche in Mexico. It is still used today for dyeing silk in deep shades on an iron tannate mordant. It also gives excellent depth and fastness on most natural and synthetic fibers. Tanninsare further important sources of black dyes. Pomegranate rind contains the hydrolysable tannicflavogallol, which combines with iron salts to give deep blacks.

e) *Natural Brown Dye*: The majority of natural brown dyes are obtained from quinone-based dyes, naphthoquinones and anthraquinones. Generally, copper and iron salts are used as mordants and they tend to turn the color to dull and deep shades, particularly browns. There is one othernatural dye, cutch, which produces rich brown shades with copper and chromium salts. This dye is a tannin-based flavonoid, and is derived from Acacia catechu and wild Acacia arabica.

f) *Green Dye*: Plants that yield green dyes are rare. Both woad (Isatistinctoria) and indigo have been used since ancient times in combination with yellow dyes to produce green shades. Woolen cloth mordanted with alum and dyed yellow with dyer's green weed was over dyed with woadand, later with indigo, to produce the once-famous Kendal green. Soft olive greens are also obtained when textiles dyed yellow are treated with iron mordant [Mansour, 2018].

g) *Orange Dye*: Orange Dyes that create reds and yellows can also yield oranges. The sources for a natural orange dye are barberry, annatto, sweet pepper blood roots etc. [Yusuf, 2017, Tayade, & Adivarekar, 2013].

2.3.3 Production of Natural Dyes

Natural dyes are obtained from vegetable, animal and mineral sources. Production flow chart of natural dyes are described below.

Flow chart for the production of natural dyes:

Raw Material
↓
Size Reduction
↓
Batch Extraction
↓
Phase Separation
↓
Fine Filtration
↓
Evaporation
↓
Spray Drying
↓
Finishing
↓
Packing

1. Raw materials:

The raw material for the production of natural dye is mostly vegetable matter such as seeds, leaves, roots, bark, heart wood, etc., of the plants. The most important part of the production of natural dyes is the sourcing of the raw material. The raw material selected for the extraction of the colouring matter should be easily available at reasonable price and in large quantity throughout the year. For the procurement of the raw materials, proper specifications in terms of moisture content, ash content, water or alkali, extractable matter, and the absorption spectra must be specified so as to ensure reproducible results.

2. Size reduction:

The raw materials are required to be ground to powder form so as to facilitate the extraction. The powder should have a fine and uniform particle size distribution. If the particle size becomes very fine then there are chances of swelling and lump formation. Hence for the proper extraction, optimum size between 50 and 100 mesh is required to be adjusted for each raw material depending on its swelling characteristics. Excess heating of the raw material during grinding should be avoided since these raw materials are sensitive to heat.

3. Bach extraction:

The batch extraction of the coloring component must be carried out in noncorrosive stainless steel (SS) vessel. The coloring component can form metal complexes with the material of construction of the extractor. Depending on the batch size and the material to liquor ratio, suitable steam jacketed vessel with low-speed stutter is recommended to be used for extraction of the coloring matter. It is important that the water used for extraction should be free from metallic impurities. Hence, soft water with less the 50-ppm hardness is recommended for the extraction of the coloring matter. Other important factors for the proper and reproducible results are the time, temperature, and pH of the water used for extraction. This varies from color to color.

4. Phase separation:

   After extraction, the solids and the liquor are required to be separated. This can be done in various ways such as, by continuous decanting, continuous centrifugation, etc. During this process, the solid waste generated after extraction is separated and disposed of.

5. Fine filtration:

   For removing the fine particle, >5 microns, a sparker filter with a now-woven filter cloth is recommended. One also uses the reverse osmosis system for eliminating the fine suspended particles.

6. Precipitation / concentration / drying:

   The precipitation of the dye from the extract is brought about with change in pH from alkaline to acidic pH. The precipitated dye is filtered through the filter press or separated from the liquor by centrifugation. The precipitated dye is dried under vacuum at the low temperature. In some cases, the dye liquor is concentrated under vacuum to a solid content of approximately 30%, and spray dried. The dye powder thus obtained is ground to 200 mesh particle size and formulated to get the standardized natural dye.

   [https://textilelearner.net/natural-dyes-properties-types-production/]

2.3.4 Advantages of Natural Dyes

Natural dyes are recommended to be applied on textile materials. The natural dyes have several advantages such as: these dyes need no special care, wonderful and rich in tones, act as health cure, have no disposal problems, have no carcinogenic effect, easily biodegradable, require simple dye house to apply on matrix and mild reactions conditions are involved in their extraction and application. Following points support the use of natural dyes on a large scale.

- ✓ *Eco-friendly*: Natural dyes are extracted from natural sources therefore they are environment safe.

- ✓ *Biodegradable*: These dyes are capable of being decomposed by microorganisms.
- ✓ *Renewable*: Replaced by the new material obtained from nature.
- ✓ *No health hazard/Non-toxic*: Natural origin of these dyes makes them harmless.
- ✓ *Variety of shades*: Varieties of color, shades and hues present in nature itself.
- ✓ *Soothing, soft and lustrous color*: Natural dyes are soft and relaxing.
- ✓ *Utilization of waste material*: Many agriculture waste products can be used in the dyeing process.
- ✓ *Antibacterial/UV Protective*: Naturally dyed fabrics get special properties like antibacterial and UV protection.

[https://textilelearner.net/natural-dyes-properties-types-production/]

2.3.5 Disadvantages of Natural Dyes

There are some limitations of natural dyes which includes, lesser availability of colors, poor color yield, complex dyeing processing, poor fastness properties and difficulty in blending dyes. As there are many advantages in using natural dye but they also have some drawbacks:

- ✓ *Expensive*: Natural dyes are expensive due to being limited in source.
- ✓ *Faded easily*: Sometimes their poor attachment on fabric makes them fade easily.
- ✓ *Difficult to produce/collect*: Collection is somewhat difficult in large amounts.
- ✓ *Time consuming*: The complete process like collection of dye takes long time.
- ✓ *Reproducibility of shades is difficult to control*: These dyes produced by secondary metabolic activities of plants or by very special processes in other animals, which depend on climate conditions, age and seasonal variations. Thus, one particular shade cannot be achieved again and again by a single dye.

[https://textilelearner.net/natural-dyes-properties-types-production/]

2.4 Extraction Methods of Natural Dye

Natural dyes have plant and animal constituents such as water-insoluble fibers, carbohydrates, protein, chlorophyll, and tannins, among others, extraction is an essential step for preparing purified natural dyes. Extraction of natural dyes is a complex process. There are different methods for extraction of coloring materials are:

- ✓ Aqueous extraction
- ✓ Alkali or acid extraction
- ✓ Microwave and ultrasonic assisted extraction
- ✓ Fermentation
- ✓ Enzymatic extraction
- ✓ Solvent extraction
- ✓ Super critical fluid extraction.

2.4.1 Aqueous Extraction

Aqueous extraction was traditionally used to extract dyes from plants and other materials. In this method, the dye-containing material is first broken into small pieces or powdered and sieved to improve extraction efficiency. It is then soaked with water in earthen, wooden, or metal vessels (preferably copper or stainless steel) for a long time usually overnight to loosen the cell structure and then boiled to get the dye solution. For getting effective dye solution in water requires different temperatures and time changes. As most of the dyeing operations are carried out in aqueous media, the extract obtained by this method can be easily applied to the textile materials [Chungkrang, et al 2021].

2.4.2 Alkali or Acid extraction

Extraction of dye is done under acidic or alkaline medium. For this dilute acidic or alkaline can also be used which helps in hydrolysis of glycosides resulting in better extraction. Acidic method is used in extraction of natural dye from flower. Alkaline medium is used for those color extraction which contain phenolic groups. Extraction of color from lac insect, annatto seeds, safflower petals are extracted by this method [Prabhu, et al 2012].

2.4.3 Microwave and Ultrasonic Assisted Extraction

Actually microwave- and ultrasound-assisted extraction processes where extraction efficiency is increased by the use of ultrasound or microwaves, thus reducing the quantity of required solvent, time, and temperature of extraction. When the natural dye containing plant materials is treated with water or any other solvent in the presence of ultrasound, very small bubbles or cavitations are formed in the liquid. These increase in size but upon reaching a certain size, they cannot retain their shape. When this happens, the cavity collapses or the bubbles burst creating high temperature and pressure. Millions of these bubbles form and collapse every second. The creation of very high temperature and pressure during extraction increases the extraction efficiency within a short time. Also, the process can be performed at lower temperature and therefore extraction of heat-sensitive dye molecules is better. As exploration of new dye sources and attempts to optimize the dye extraction process is continuing, use of this extraction technique has been recently reported by many researchers [Mansour, 2018]

In microwave extraction, the natural sources are treated with a minimum amount of solvent in the presence of microwave energy sources. Microwave increases the rate of the processes so the extraction can be completed in a shorter time with better yield. Sinha et al. have reported extraction of annatto colorant with microwave energy. Earlier their group had reported microwave-assisted extraction of blue pigment from the butterfly pea. Microwave and ultrasound extractions can be considered as green processes due to reduction of extraction temperature, solvent usage, and time which results in lower consumption of energy [Mansour, 2018].

2.4.4 Enzymatic and Fermentation Extraction

Recent developments in biotechnology for the extraction of effective components from natural plants are becoming popular. There is a selection of appropriate enzymes that can decompose plant tissues mildly, accelerate the release of effective components, and improve the extraction rate. For example, cellulase can degrade cellulose, hemicellulose, and other substances, and can cause localized loose and swelling changes of the cell wall and cytoplasmic structure, thus increasing the diffusion of effective components in the cell to the extraction medium and promoting the efficiency of pigment extraction. Temperature and pH are the main factors affecting the effect of the enzyme. The enzyme extraction method has the advantages of milder extraction conditions and stable physical and chemical properties of active components. The structure of Geniposide in natural gardenia yellow pigment can be changed by an enzymatic reaction to produce gardenia red and blue pigment. The extraction of anthocyanins by the enzymatic method is about 72% higher than that by the solvent method. This method is suitable for the dyes extracted from hard plant materials like the bark and roots.

2.4.5 Solvent Extraction

Natural coloring matters depending upon their nature can also be extracted by using organic solvents such as acetone, petroleum ether, chloroform, ethanol, methanol, or a mixture of solvents such as mixture of ethanol and methanol, mixture of water with alcohol, and so on. The water/alcohol extraction method is able to extract both water-soluble and water-insoluble substances from the plant resources. The extraction yield is thus higher as compared to the aqueous method as larger number of chemicals and coloring materials can be extracted. Acid or alkali can also be added to alcoholic solvents to facilitate hydrolysis of glycosides and release of coloring matter. Purification of extracted color is easier as solvents can be easily removed by distillation and reused. Extraction is performed at a lower temperature thus chances of degradation are fewer. The disadvantages of the method are the presence of toxic residual solvents and their greenhouse effect. Another disadvantage of this method is that the extracted material is not readily soluble in water and the subsequent dyeing process has to be carried out in an aqueous medium [Mansour, 2018].

2.4.6 Super Critical Extraction

Supercritical fluid is the most complex process but has the advantages of both liquids and gasses, high density and viscosity, lower surface tension and higher solubility, which enhance rapidly with the increase in pressure. It can penetrate the matrix of extraction materials and be a very effective extraction mechanism. Extraction separation and solvent removal are combined into one unit that identifies the process flow and improves the production efficiency. In addition, it also has a few advantages, such as fast extraction speed, good selectivity, extraction and segregation can be carried out at room temperature or a low temperature. There is no residual solvent pollution, no environmental pollution, e.g., some natural products are sensitive to heat emitted during the process, or the chemically unstable components are easily destroyed, which can preserve the original flavor and nutritional components of natural products.

2.5 Dalbergia sissoo

2.5.1 Introduction

Herbs are plants which having healing properties and can treat a number of health-related problems. Herbal medicine (Herbalism) is the study of pharmacognosy and the use of medicinal plants, which are a basis of traditional medicine. The World Health Organization (WHO) estimates that 80 % of the population of some Asian and African countries nowadays use herbal medicine for some aspect of primary health care. Some prescription drugs have a basis as herbal remedies, including artemisinin, aspirin, digitalis, and quinine [Su, et al 2015].

Herbal remedies are most popular in people having chronic diseases, such as cancer, diabetes, asthma, and end-stage kidney disease. Multiple factors such as age, ethnicity, gender, education, and social class are also shown to have an association with the prevalence of herbal remedies use [Bishop et al 2010].

Dalbergia sissoo is an important medicinal plant which belongs to legume family (Fabaceae). *Dalbergia sissoo*, commonly known as Indian Rosewood and also known as sisu, Sheesham, tahli, and Tali. It is native to Himalayan foothills in Northern India and is distributed in many countries such as India, Pakistan, Burma, Sri Lanka and Mauritius. It is introduced in many other countries of tropics and subtropics and now naturalized in Africa and America. It occurs at river banks below up to 900 meters (3,000 ft) elevation but can range naturally up to 1,300 m (4,300 ft).

It can withstand in average rainfall up to 2,000 millimeters and it can grow in droughts of 3-4 months. It prefers soils from pure sand and gravel to rich alluvium of river banks, and it grows in slightly saline soils. Sissoo is an important timber tree of India. It has nut-brown heartwood, which is very hard, heavy, strong, and elastic. The wood is used to making doors, window frames, flooring, furniture, boats, cabinets, etc. The pulp of wood is also used in papermaking. It enriches soil due to the presence of nitrogen-fixing bacteria in roots. The leaves falling from the tree are help to improves soil quality.

[https://www.bimbima.com/ayurveda/medicinal-treeshishamsissoo-dalbergiasissoo/31 6]

Dalbergia sissoo is also an herbal medicinal tree. In Ayurveda, it is used for the treatment of various diseases. The wood and bark of D. Sissoo used abortifacient, anthelmintic, antipyretic, aphrodisiac, expectorant, and refrigerant treatment. In Africa, this tree is used to treat wounds and gonorrhea.

The genus consists of 300 species, among which 25 species occur in India. Many species of Dalbergia are important timber trees, valued for their decorative and often fragrant wood, rich in aromatic oils. The most famous of these are the rosewoods, so-named because of the smell, but several other valuable woods are yielded by the genus [Nikum, et al 2021].

The isolation of several compounds of confirmed biological activity such as flavones, isoflavones, quinines and coumarins from *Dalbergia sissoo* . It also contains tectoridin, caviunin-7-O- glucoside, iso-caviunin, tectorigenin, dalbergin, bio-chaninA, and 7-hydroxy -4-methylcoumarin. The heartwood gave 3,5-dihydroxy-trans-stibene, biochanin A, dalbergichromene, dalbergenone and iso-dalbergin [Khare, 2004]

Dalbergia sissoo is also effective against blood diseases, syphilis, stomach problems, dysentery, nausea, eye and nose disorders, ulcers, skin diseases; it has been used as an aphrodisiac and expectorant; also, for its nitric oxide production inhibition activity, anti-inflammatory, analgesic, antipyretic, larvicidal activities.

- **Synonyms:**

Amermnon Sissoo (Roxb.) Kuntze, Amerimnon P. Browne, Ecastaphyllum P. Browne, Coroyo Pierre, Triptolemea Mart [Bharath, et al 2013].

- **Vernacular Names:**

Sanskrit - Shinshapa, Aguru

English- Indian Rosewood Bombay Blackwood

Hindi - Shisham, sissu, sissai, sisam

Tamil - Sisso, gette

Kannada - Betti, shista baage agaru, bindi

Bengali - Shishu, Sissoo

French - Ebenier Juane

Arabic - Arabic

Indonesia - du Khaek Pradu Khack

Javanese - Sonowaseso

Spanish - Sisu

Thai - du-Khaek Pradu Khaek

Persian - Jag

Trade Name – Sisso

[Asif, M et al 2011]

- **Scientific Classification:**

Kingdom – Plantae

Unranked - Angiospermae

Unraked - Ecidicots

Unranked - Rosids

Order - Fabales

Family – Fabaceae (Leguminoseae)

Sub Family – Faboideae

Tribe – Dalbergia

Genus - Dalbergia

Species – Sissoo

[Pooja, et al 2010]

- **Taxonomical Classification:**

Domain: Eukaryota

Kingdom: Plantae

Division: Magnoliophyta

Phylum: Tracheophyta

Class: Magnoliopsida

Order: Fabales

Family: Fabaceae

Tribe: Dalbergieae

Genus: Dalbergia

Species: D. sissoo

Binomial Name: *Dalbergia sissoo*

[http://zipcodezoo.com/Plants/D/Dalbergiasissoo/]

2.5.2 Botanical Description

Dalbergia sissoo is a medium to large tree of about 25 meters high with grey yellow trunk, 2-3 meters in diameter [Sheikh, 1989].

Figure.4 *Dalbergia sissoo* Tree

2.5.3 Traditional Uses of *Dalbergia sissoo*

Dalbergia sissoo is a medicinal plant that has different biological activities. It is used in conditions such as emesis, ulcers, leukoderma, dysentery, stomach troubles, and skin diseases. Plant parts of *Dalbergia sissoo* are traditionally used in treating many diseases and are mentioned below:

2.5.3.1 Bark

Active extracts of bark possess carbohydrates, phenolic compounds, flavonoids, and tannins. In the Ayurvedic medicinal system, the bark of *Dalbergia sissoo* is used for the treatment of abortifacient, anthelmintic, antipyretic, aperitif, aphrodisiac, expectorant, and refrigerant and also used for controlling anal disorders, dysentery, dyspepsia, leukoderma, and skin ailments. The bark is used to treat Vata-related disorders such as sciatica, hemiplegia [Niranjan, et al 2010].

2.5.3.2 Seed

Seed oil *Dalbergia sissoo* is used in treatment of blue itching, burning on the skin and scabies [Lal, et al 2012].

2.5.3.3 Leaves

Rural people in India and Nepal use *Dalbergia sissoo* leaves in the treatment of animals suffering from non-specific diarrhea. Leaf extract has been used to treat sore throats, heart problems, dysentery, syphilis, and gonorrhea. The juice of the leaves is used for anthelmintic, good for diseases of the eye and the nose. It is used to treat scabies, burning sensations of the body, scalding urine, syphilis, and digestive disorders [Al-Quran, 2008].

Decoction of leaves is used for the treatment of gonorrhea. Ayurvedics has also prescribed leaf juice for eye ailments.

2.5.3.4 Wood

The wood was used for anthelmintic, antileprotic, and cooling. Arial parts were used for spasmolytic, aphrodisiac, and expectorant. Wood is used in the treatment of leprosy, boils, vomiting. Yunana use the wood of D. sissoo for blood disorders, burning sensations, eye and nose disorders, scabies, scalding urine, stomach problems, and syphilis [Kirtikar, 1933].

2.5.3.5 Heartwood

The heartwood is used to treat herpes, vitiligo, and fever. Shimshapa Sara ksheerapaka is indicated in treating fever (Sushruta).

2.5.3.6 Root

Roots is used in the treatment of diarrhea and dysentery.

2.5.4 Medicinal Uses of *Dalbergia sissoo*

2.5.4.1 Anti-Inflammatory Activity

Anti-inflammatory activity of ethanolic extract of *Dalbergia sissoo* bark was evaluated. It can be concluded that the ethanolic extract at 1000 mg/kg showed the most potent anti-inflammatory activity compared to the other groups (300 and 500 mg/kg) throughout the observation period [Asif, et al 2009].

2.5.4.2 Anti-Termite Activity

The anti-termite activity of the heartwood of *Dalbergia sissoo* was evaluated. It was concluded that the plant extracts could be used as an alternative for synthetic pesticides for the control of termites in buildings [Kharkwal, et al 2014].

2.5.4.3 Anti-Diabetic Potential

Pankaj Singh Niranjan et al., conducted a study in 2010 to evaluate the antidiabetic activity of ethanolic extract of *Dalbergia sissoo* leaves in alloxan-induced diabetic rats. They concluded that the ethanolic extract of the leaves is 12% more effective in reducing the blood glucose level than standard Glibenclamide [Niranjan, et al 2010].

2.5.4.4 Antioxidant *Potential*

The stem bark of *Dalbergia sissoo* was evaluated for its antioxidant potential. Finally results shown, among the different extracts of stem bark of the plant, chloroform extract exhibited marked antioxidant activity, whereas methanolic extract showed moderate activity in different in-vitro anti-oxidant assays [Kaur, et al 2011].

2.5.4.5 Antimicrobial Property

In this study, an herbal preparation of *Dalbergia sissoo* and Datura stramonium was evaluated for its antibacterial efficacy against gram-positive (Staphylococcus aureus and Streptococcus pneumoniae) and gram negative (Escherichia coli, Pseudomonas aeruginosa, and Klebsiella pneumonia) bacteria. The results of the study show that the extract of *Dalbergia sissoo* and Datura stramonium may be used as a potent antiseptic preparation for the prevention and treatment of chronic bacterial infections [Adenusi, et al 2008].

2.5.4.6 Antibacterial Activity

Antibacterial activity of ethanolic, distilled water and methanol extract of the leaves of Dalbergia Sisso Roxb. was studied against Escherichia coli and Bacillus licheniformis by agar well diffusion method. The growth of both E. coli and B. licheniformis was inhibited by all three extracts of dried leaf extracts of Dalbergia sisso Roxb. The root extracts of *Dalbergia sissoo* Roxb. have potent antibacterial activity when compared with conventionally used drugs and is almost equipotent to the standard (gentamycin) antibacterial drug [Chhabra, et al 2016].

2.5.4.7 Anti-spermatogenic Activity

A study was undertaken to evaluate the anti-spermatogenic efficacy of ethanol extract of stem bark of *Dalbergia sissoo* Roxb. For the in vitro study, semen samples were obtained from 15 healthy fertile men aged 25–35 years. Sperm motility was examined by the Sander-Cramer method. Ethanol extract at a concentration of 20 mg/mL caused complete immobilization within 3 minutes. The in vivo studies ethanol extract at a dose of 200 mg/kg body weight resulted in a significant decrease ($p< 00.01$) in weight of the testis and epididymis. A significant decrease ($p <0.01$) in sperm motility and sperm count in the epididymis were observed. Histological changes in the epididymis and testis were also investigated [Vasudeva, 2011].

2.5.4.8 Neuroprotective Action

This research was performed in 3- Nitro propionic acid-induced neurotoxic rats to characterize the neuroprotective effect of ethanolic extract of *Dalbergia sissoo* leaves. The ethanolic extract of *Dalbergia sissoo* leaves was administered 300 and 600mg/kg orally to neurotoxic rats. These results suggest that ethanolic extract of *Dalbergia sissoo* leaves may have potential therapeutic value in various neurological disorders, probably by its antioxidant, anti-inflammatory and estrogenic properties [Suddhasatwa, et al 2014].

2.5.4.9 Immunomodulatory Activity

The Immunomodulatory effect of *Dalbergia sissoo* bark by using four methods named as Humoral immune response, WBC count, cellular immune response, and Carbon clearance test. Administration of *Dalbergia sissoo* produced a significant stimulation of the immune system. The Metabolic extract of *Dalbergia sissoo* bark dose of 250 and 500 mg/kg body weight was used. Control saline (0.9% w/v NaCl) was used as a general vehicle. Administration of *Dalbergia sissoo* produced a significant stimulation of the immune system, and also, it can be concluded that the immunostimulatory property of extract was dose dependent [Govindula, 2017].

2.5.4.10 Antiulcer Activity

This study evaluates the Antiulcer activity of crude ethanolic bark extract of *Dalbergia sissoo* using pylorus ligation and Indomethacin induced ulcer model in Wistar albino rats. The antiulcer effect of EBED may be due to any of the probable mechanisms viz. reduction in gastric acid secretion, antioxidant action, much protection, or gastric cytoprotection attributed by the presence of various secondary metabolites [Baral, et al 2016].

2.6 Mordant

2.6.1 Introduction

Mordant comes from the Latin word “mordere”, meaning “to bite”. Mordant is a chemical which can itself be fixed on the fiber and also forms a chemical bond with the naturalcolorants. It helps in absorption and fixation of natural dyes and also prevents bleeding and fading of colors i.e., improves the fastness properties of the dyed fabrics. Mordants are metal salts which produce an affinity between the fabric and the dye [Vankar, 2000].

2.6.2 Types of Mordants

Mordants are basically three types -metallic mordants such as metal salts of aluminum,copper, tin etc., (ii) tannic mordant such as tannic acid, e.g., myrobalan and sumach and (iii) oil mordant which forms complex with main metal mordant. Myrobalan and sumach are mostimportant mordants of tannins and Oils or oil-mordants.

Generally, on the basis of origin mordants are two types- Synthetic and Natural mordants. Synthetic mordants are obtained from acid dyes, they are called as acid chrome dyes.Natural mordants obtained from natural sources plants and fruits. Cow dung, aloe vera, lemonpeel, pomegranate rind used as natural mordants [Vankar, 2000].

2.6.3 Application of Mordants

The three methods used for mordanting are:

- **Pre-mordanting:** The substrate is treated with the mordant and then the dye. Thecomplex between the mordant and dye is formed on the fiber.
- **Meta-mordanting:** The mordant is added in the dye bath itself. The process issimpler than pre- or post-mordanting, but is applicable to only a few dyes.
- **Post-mordanting:** The dyed material is treated with a mordant. The complexbetween the mordant and dye is formed on the fiber.
  [https://sciencenotes.org/what-is-a-mordant-definition-and-examples/]

Alum

Alum mordant for use to color protein fibers (wool, hair and silks) with natural dyes, and in combination with tannin for cellulose fibers. Synonyms: Potash Alum.

Alum mordant links chemically with the fiber and creates attachment points which bond with the colorant from natural dyes creating light and wash fast colors. It anchors the color obtained from dye plants (depending on the plant used) and can be used for yellows, lovat, orange, red, and purple.

Alum mordant has also become popular for use in Botanical Printing, also known as ECO printing. This experimental technique is effective on cotton and linen fabrics, as well as wool fabrics including felt, silk fabric and cotton paper. [https://www.georgeweil.com/printing-tools-screens-inks/botanical printing/mordants-for-botanical-printing/500gm-alum/].

2.6.4 Properties of Mordant

- Mordant dyes have no affinity for textile fibers.
- They are attached to the fibers with the help of mordants.
- Mordant have affinity both for the dye and fiber.
- Mordant dyes may be natural or synthetic.
- Mordant dyes are mostly applied on natural protein fibers, nylon and acrylic fibers.
- Good light fastness rating about 4-5.
- Most mordant dye are soluble in cold water.
- Wide range of hues can be produced from mordant dyes

[http://textileengg.blogspot.com/2015]

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METHODOLOGY

3. METHODOLOGY

The following sections outline the experimental technique for the study on *"Eco-Friendly Natural Colorant From Wood Waste Of "**Dalbergia Sissoo**" And Its Application On Wool Fabric"*

3.1 Schematic Chart for the Study

3.2 Selection of the Fabric

3.3 Selection of Dye Source

3.4 Extraction of Dye

3.5 Optimization of Dye Extraction Conditions

- 3.5.1 Dye Source Concentration
- 3.5.2 Time
- 3.5.3 Temperature
- 3.5.4 pH

3.6 Characterization of Dye Extraction

- 3.6.1 UV Analysis
- 3.6.2 Phytochemical Analysis
- 3.6.3 Crude Dye Yield
- 3.6.4 FT-IR
- 3.6.5 TGA

3.7 Optimization of Dyeing Conditions

- 3.7.1 Material to Liquor Ratio (MLR)
- 3.7.2 Time
- 3.7.3 Temperature
- 3.7.4 pH

3.8 Selection of Mordant

3.9 Optimization of Mordant

- 3.9.1 Mordant Percentage
- 3.9.2 Mordanting Methods

3.10 Dyeing Under Optimized Conditions

3.11 Performance Properties of Dyed Fabric

3.11.1 Color Strength

3.11.2 UV Protection Analysis

3.11.3 Anti-Bacterial Activity

3.12 Physical Properties

3.12.1 Fabric Weight

3.12.2 Fabric Stiffness

3.12.3 Fabric Thickness

3.12.4 Absorbency Test

3.12.4.1 Sinking

3.12.4.2 Wicking

3.13 Color Fastness Test

3.13.1 Fastness to Washing

3.13.2 Fastness to Rubbing (Dry & Wet)

3.13.3 Fastness to Light

3.13.4 Fastness to Perspiration

3.14 Product Development

3.1 Schematic Chart for the Study

The flowchart breaks down the methods used in this study into the following sections:

3.2 Selection of Fabric

It was important to choose a natural cloth because the study's goal is to dye natural fabric using natural dye. As a result, the fabric used for this investigation was 100% Wool. It is important in textiles since it supplies 75% of total wool to the garment industry alone. As a result, it is important to introduce new commercial dyeing solutions for wool that are cost-effective. Wool's helical structure, in which the keratin is grouped in scales, makes dyeing wool simple since it absorbs numerous colors uniformly and directly. The color penetrates the structure, causing chemical processes that cause the dye to bond to the fiber permanently.

A certified pre-treated or Ready-for-dyeing (RFD) wool fabric was used in the current study with the specification of 1/2 twill weave with weight density of 65 g/m2, thickness 0.25cm and with the yarn density of 55 ends / inch and 45 picks / inch which was purchased from SHUBHAM & CO., Amritsar, Punjab, India.

Since the fabric was RFD, no pre-treatment was required before carrying out further dyeing process for the study.

3.3 Selection of Dye Source

The dye source selected for the study was sawdust of Dalbergia Sissoo, which was commonly known as Indian Rosewood, Sisam belonging to plant species family of Fabaceae. The sawdust was collected from the local carpenter near Oshiwara, Mumbai, Maharashtra. This tree has wide range of properties including 'medicinal' and each part of the tree has used to cure health issues. Heartwood of Dalbergia Sissoo ranges from golden brown to a darker reddish brown. For this study sawdust powder of DS was used as natural dye source.

For the extraction of dye from the collected sawdust of DS, known quantity of dried flowers (5%) were taken and added to water and heated in water bath for 30min at 100°C. After cooling the extract was filtered and used for dyeing.

3.4 Extraction of Dye

For the extraction of dye from the collected sawdust of DS, known quantity of dried flowers (5%) were taken and added to water and heated in water bath for 30min at 100°C. After cooling the extract was filtered and used for dyeing [Suhaimi, S., et al., 2020].

3.5 Optimization of Dye Extract

3.5.1 Dye Source Concentration

To determine the optimum dye source concentration, different dye source concentrations was used for dye extraction such as 2.5% to 12.5%. The concentration at which the color yield was maximum was selected as optimum concentration for dye extraction from *DS* based on the color strength.

3.5.2 Time

To find out the optimum dye extraction time, the extraction of dye was done at different time intervals 15min to 75min. The extracted dye was assessed by UV-analysis. Based on the UV Analysis, extraction time was fixed for subsequent studies.

3.5.3 Temperature

To analyze the optimum temperature for dye extraction, dye extraction was carried out at different temperature ranging from 30°C to 100°C. The extracted dye was used for UV-Analysis based on that the extraction temperature was fixed for subsequent studies.

3.5.4 pH

To analyze the optimum pH for dye extraction, dye extraction was carried out at different pH ranging from pH5 to pH13. The extracted dye was used for UV-Analysis based on that pH of the extraction was fixed for subsequent studies.

3.6 Characterization of Dye Extract

3.6.1 UV_Analysis

UV Analysis or UV absorption spectra is to detect the pigment type and interference of pigment concentration through absorption peak and intensity. The UV spectra of Dalbergia Sissoo was recorded at the wavelength of 220 to 800 nm. The spectra were taken with the reference of aqueous dye extract [Allafi, et al 2022].

3.6.2 Phytochemical Analysis

Phytochemicals are naturally occurring compounds in plants that contain defensive mechanisms and are utilized to defend against a variety of illnesses. The main phytochemical groups found in plant extracts, such as alkaloids, steroids, flavonoids, phenolic compounds, anthraquinones, and tannins, are responsible for their intrinsic therapeutic effects [Chandrashekar, 2012 & Kalaiarasan, 2010]. Phytochemical analysis is a method of analyzing the chemical compositions of plant-based dyes by precipitation and coloration reactions and classifying them into distinct chemical groups [Tiwari, 2019]. To determine the components included in Dalbergia Sissoo extract, the extracted dye was analyzed using conventional techniques.

3.6.3 Crude Dye Yield

The crude dye yield was determined by evaporation method. To do so, 100mL of extracted and filtered aqueous dye solution was taken in a vessel and was boiled on gas till all the liquid was evaporated and a solid mass was obtained. This solid mass was then dried and weight, and the percentage was calculated using the below formula (F1) in relation to the original weight of the sawdust.

$$\text{Wcd} = \frac{\text{Wae}}{\text{Wbe}} \times 100$$

F1

Where, Wcd is the % of the dye yield, Wae is the weight after evaporation (g) and wbe is the weight before evaporations (g). [Kovačević, 2021]

The solutions of the dye baths remaining after dyeing were analyzed using a UV-Vis spectrophotometer at an appropriate scanning wavelength for the determination of the exhaustion rate (Rex), that was calculated from the following equation (F2) [Lachguer, et al 2021].

$$\text{Rex} = [(C0 - Ct)/C0] \times 100$$

F2

where C0 and Ct are concentrations of the initial dye bath and the residual dye bath, respectively.

3.6.4 FT-IR

Fourier Transfer Infrared (FT-IR) Spectroscopy was used to record the chemical nature and functional group present in the DS dye extract. Dye from sawdust of DS was extracted in the optimized conditions. FT-IR of the dye extract solution was recorded from 4000 cm-1 to 400 cm-1 with the resolution of 16 cm-1. [Kovačević, Z., 2021]

3.6.5 *TGA*

Thermalgravimetric analysis (TGA) was performed on the dye yield powder by TG/DTA - EXSTAR/6300 (Thermo Gravimetric Analyzer) at a flow rate of 2.3 mg/min with the temperature range from 34°C to 1000°C where the behavior of sample was recorded [Ibrahim, 2011].

3.7 Optimization of Dyeing Conditions

3.7.1 *Material to Liquor Ratio (MLR)*

To analyze the material liquor ratio for dyeing. Dye extractions ratios was taken at different intervals like 1:10 to 1:50. With the help of color lab spectrophotometer the color strength of the dyed fabrics was analyzed. The M:L which showed maximum color strength was selected as optimum dyeing material liquor ratio.

3.7.2 *Time*

To obtain optimum dyeing time, the dyeing was carried out at different intervals of time such as 30 min to 90 min. With the help of Color lab Spectrophotometer, the color strength of the dyed fabric was analyzed. The time which showed maximum color strength was selected as optimum dyeing time.

3.7.3 *Temperature*

To analyze the optimum temperature, at different temperatures the dyeing was done such as 30°C to 85°C. With the help of color lab spectrophotometer, the color strength of the dyed fabrics was analyzed. The temperature which showed maximum color strength was selected as optimum dyeing temperature.

3.7.4 *pH*

To analyze the optimum pH for dyeing, dyeing was done using different pH of the extraction ranging from pH5 to pH9. With the help of color lab spectrophotometer, the color strength of the dyed fabrics was analyzed. The pH which showed maximum color strength was selected as optimum pH for dyeing.

3.8 Selection of Mordant

To improve the dye value of the fabric different bio and metallic mordant was used for the study. With the help of color lab spectrophotometer, the color strength of the dyed fabrics was analyzed. The mordant which showed maximum evenness was selected as exact mordant for mordanting.

3.9 Optimization of Mordant

3.9.1 Mordant Percentage

To analyze the optimum mordant percentage for mordanting, mordanting was done using different percentage ranging from 2% to 15%. With the help of color lab spectrophotometer, the color strength of the mordanted fabrics was analyzed. The mordant percentage which showed maximum color strength was selected as optimum mordant percentage for mordanting.

3.9.2 Mordanting Methods

Mordanting process was done in three ways pre, post and simultaneous mordanting. To analyze the mordanting method, mordanting was done using all three methods with optimum mordant percentage. With the help of color lab spectrophotometer, the color strength of the mordanted fabrics was analyzed. The mordant method which showed maximum color strength was selected as précised mordant method for mordanting.

3.10 Dyeing Under Optimized Conditions

Dyeing was done using optimized extraction and dyeing conditions such as dye concentration, time, temperature and M.L.R. The dyed sample was assessed for color strength and color coordinates using color spectrophotometer.

3.11 Performance Properties of Dyed Fabric

3.11.1 Color Strength

The color coordinates of all the dyed samples of fabric were recorded on Spectrophotometer by illuminant D65 and 10°C standard observer in the equilibrated under standard conditions and time. The coordinate used to measure color values are “L*” which determines lightness, “a*” which shows redness as positive value and greenness as negative value, “b*” demonstrates yellowness as positive value and blueness for negative value. Next, the color strength (K/S) was computed using Kubelka-Munk formula (F3) [Jiang, et al 2019].

$$K/S = (1-R)2 / 2R$$

F3

3.11.2 UV Protection Analysis

Ultraviolet Protection Factor testing was performed by using UV-2000F Ultraviolet Transmittance Analyzer under AATCC-183:2010 standard. The readings were taken under the wavelength of 250 nm to 450 nm.

3.11.3 *Anti-Bacterial*

The control fabric, mordanted fabric, and dyed fabric are individually tested for antibacterial activity against Staphylococcus aureus and E. coli strains. The samples were placed in culture medium and compared with standard antibiotics. The plate was aerobically incubated at 37°C for 24 h. The diameters of the inhibition zones against the tested bacteria measured [Muthukumar, et al 2014 and Ya-Dong Li, et al 2019].

3.12Physical Properties

3.12.1 *Fabric Weight (ASTM D 2646/D3776, IS0 3801)*

Weight of fabric was expressed as weight of particular specimen in piece of gram/ square meter/ ounces / square yards.

GSM cutter is used to cut the sample. The sample cutter cuts out quick and exactly circular sample of 100cm² which is exactly one hundredth of a square meter. Cut sample should be weighed and noted. The weight of the fabric is measured using electronic balance. The value in grams is multiplied by 100, gives the GSM directly. For lock position: The blades are held inside the knobs. For unlock position: The blades are allowed for cutting and knobs are opened to cut the fabric. The same procedure was followed for all the UDF, DF and MDF samples. Three samples were weighed three times and the mean value was calculated and recorded.

$$\text{Grams per Square Meter} = \text{Specimen weight in grams} * 100$$

3.12.2 *Fabric Stiffness (IS 6490:1971)*

Stiffness is nothing but the ability to resist the bending of fabric and used to measure the resistance of bending property by external forces on fabric [textileadvisor.com 2020]. The bending rigidity and fabric handling parameters are mostly judge by using stiffness test. Stiffness of a fabric is determined by using Shirley stiffness tester. The tester consists of flat surface platform supported with two side pieces engraved with index lines. The operator can view both index lines from convenient position with the help of mirror which is associated with instrument. With the help of scale, the bending length was measured in cm. The specimen was placed on the platform with template on it, so that the edges are coincide at zero on leading edge of specimen. The specimen was slowly pushed and the horizontal scale was moved slowly until the leading edged of specimen and template project beyond edge of platform. The sliding of specimen was stopped when it cuts both index lines. The readings of warp and weft specimen were recorded. The same procedure was followed for UDF, DF and MDF samples of warp and weft bending readings was noted. Three readings from weft and warp were taken and the average was calculated and recorded.

3.12.3 Fabric Thickness (ASTM D1777, ISO 1765)

Thickness of a fabric is defined as perpendicular distance through the fabric, which determines the dimension between the upper and lower side of the fabric. Three loads of different weights are given by the ASTM standards to use on fabric. It is given in kappa. In practice thickness measurement are rarely used as they are very sensitive to the pressure used in the measurement. Fabric thickness gauze is used to measure the thickness of the sample [textileall.blogspot.com, 2016]. The specimen should be free from wrinkles, creases and folds and it is placed between anvil and pressure foot by uplifting pressure foot and leaving down the pressure foot slowly on the specimen. The dial indicates the thickness of the sample and the readings were noted from dial gauze. Five readings were taken from different places of sample and the same procedure was followed for all the UDF, DF and MDF samples. Three readings were taken from different places of the fabric sample and the mean was calculated. It is expressed in mm.

3.12.4 Absorbency Test

3.12.4.1 Sinking

Sinking is nothing but something is falling down into liquid or on the surface of liquid. Sinking test is done to find the wet ability of fabric. If samples took more than 1 min for sinking then those are marked as floated behavior textiles [Saville, 1999] A 50 ml of distilled water is taken in transparent beaker. 25mmX25mm size samples were dropped on the surface of the water from certain standard height. Sinking time of sample is measured using stopwatch. Stopwatch was started when the fabric struck the surface of water and it was stopped when the fabric corners sank below the water surface. The sample sink time was recorded.

The UFD, DF and MDF specimen were taken as 2.5cm*2.5cm. The sample were dropped at certain height into 50ml of distilled water in glass beaker and the sinking time of sample were recorded using stopwatch. The same procedure was repeated for all the samples three times. The results were noted and mean value was calculated.

3.12.4.2 Wicking

Wicking is spreading of liquid into fibre or fabric due to external forces or by capillary forces [Kissa,1996] or the spreading of liquid through the pores of free spaces of fabric is called capillary action or wicking [Morent et al 2006]. The sample was cut into dimension of 2.5cmX15cm long. Required amount of distilled water is taken in transparent beaker then the samples were marked with ink discharged pen at 1cm from bottom edge of sample. The samples were hanged on a clamp and submerged in water. Stopwatch is used to record the readings. On the sample how far the water has moved upward with capillary action of fabric and crossed or reached marked line time was considered as wicking ability of fabric. The higher the wicking distance at the same interval the better the fabric in wicking AATCC197,2012 [Geyter et al 2006].

The UDF, DF and MDF are tested to wicking. The 2.5cm*10cm long specimen was taken and at the bottom of specimen 1cm height was marked and the sample was submerged in water. With the help of stopwatch readings were taken. The same procedure is followed for DF and MDF samples. The testing is done for three times and the mean value of all the samples were calculated and the results are noted.

3.13 Color Fastness

3.13.1 Fastness to Washing

Color fastness to washing is defined as the degree of change in color and staining after performing process. Following standards were used for washing fastness test (ISO 105 C06:2010, ISO 105 C08: 2010 and ISO 105 C09: 200). The specimen is stitched four sides of edges with reference fabrics. The specimen was washed using suitable detergent solution at 40°C for 30 min. Then the specimen was rinsed and dried properly [Gersak et al 2013].

Color change is assessed using grey scale. The DF and MDF were tested for washing using three specimens five times. The level of color change in dyed and mordant fabrics was compared and assed by using grey scale.

3.13.2 Fastness to Rubbing (Dry & Wet)

Fastness to crocking is nothing but the transfer of color from dyed textile material to undyed textile material by means of rubbing. Crock meter equipment is used to test the fastness property of dyed fabrics (ISO 105X12:2001). The test is performed in two ways – using dry specimen and wet specimen against dyed fabric. A white fabric used to place on the top of dyed fabric and rubbed against on it in back and forth as straight line for about 10 cycles with downward movement with the help of handler. After testing the tested rubbing specimens were assessed using grey scale according to AATCC. Color fastness to crocking is assessed in between 1- 5 level. The higher the number indicates the good color fastness [Gersak et al, 2013., orinetbag.net 2016]. The same procedure was performed for DF and MDF specimen and the amount of colour transferred to the white fabric is assessed using AATCC grey scale.

3.13.3 Fastness to Light

Color fastness to light was performed under ISO B02:2013 by direct method of color fastness to sunlight by placing dyed sample in a glass chamber from 9 am to 3pm in the sun then the sample was graded using blue scale.

3.13.4 Fastness to Perspiration

Color fastness to perspiration was carried out using ISO 105-E04:2013 as standard for test, dyed sample with undyed multifiber was immersed in acidic and alkaline solution for 30 mins and dried at 37°C for 4 hours and evaluated.

3.14 Product Development

Based on the results of the study, 3 products were developed. Aesthetic and functional properties were considered while selecting the product which was develop.

All the three products were dyed using optimum dyeing and mordanting conditions.

❖ Nomenclature of the Samples

The nomenclature of the samples is presented in Table 2

Table.2 Nomenclature of the samples

S.no	Description of sample	Nomenclature used
1	Undyed Fabric	UDF
2	Dyed Fabric	DF
3	Mordant dyed Fabric	MDF

RESULTS AND DISCUSSION

4. Results & Discussions

The results of the study “Extraction and Application of Natural Dye from **Wood Waste of *“Dalbergia sissoo ”*** on **Wool Fabric**” are discussed under the following headings.

4.1 Optimization of Dye Extract Conditions

4.1.1 Optimization of Dye Source Concentration

4.1.2 Optimization of pH

4.1.3 Optimization of Time

4.1.4 Optimization of Temperature

4.1.5 Optimized Conditions for Extraction of Natural Dye from *Dalbergia Sissoo*

4.2 Characterization of Dye Extract

4.2.1 UV Analysis

4.2.2 Phytochemical

4.2.3 Crude Dye Yield

4.2.4 FT-IR

4.2.5 TGA

4.3 Optimization of Dyeing

4.3.1 Optimization of MLR

4.3.2 Optimization of pH

4.3.3 Optimization of Time

4.3.4 Optimization of Temperature

4.3.5 Optimized Conditions for dyeing Wool Fabric with *Dalbergia Sissoo*

4.4 Selection of Mordant

4.5 Optimization of Mordant

4.5.1 Mordant Percentage

4.5.2 Mordant Technique

4.6 UV Protection Analysis

4.7 Anti-Bacterial

4.8 **Physical Properties**

4.8.1 Fabric Weight

4.1 Optimization of Dye Extract Conditions

4.1.1 Optimization of Dye Source Concentration

In order to optimize dye source concentration dye was extracted using different concentrations (2.5% to 12.5%) keeping extraction time (30 mins) and extraction temperature (100°C) constant.

The optical density of the dye extract was analyzed using UV-Vis spectrophotometer (Figure 5). It is clearly observed from Figure 5 that increase in dye source concentration increases dye yield up to 5% whereas further increase in the dye source concentration, didn't show much increase in optical density. Hence the liquid-to-solid ratio 20:1 is taken as optimum. (5% in 100ml of water) [Jiang, H., et al 2019].

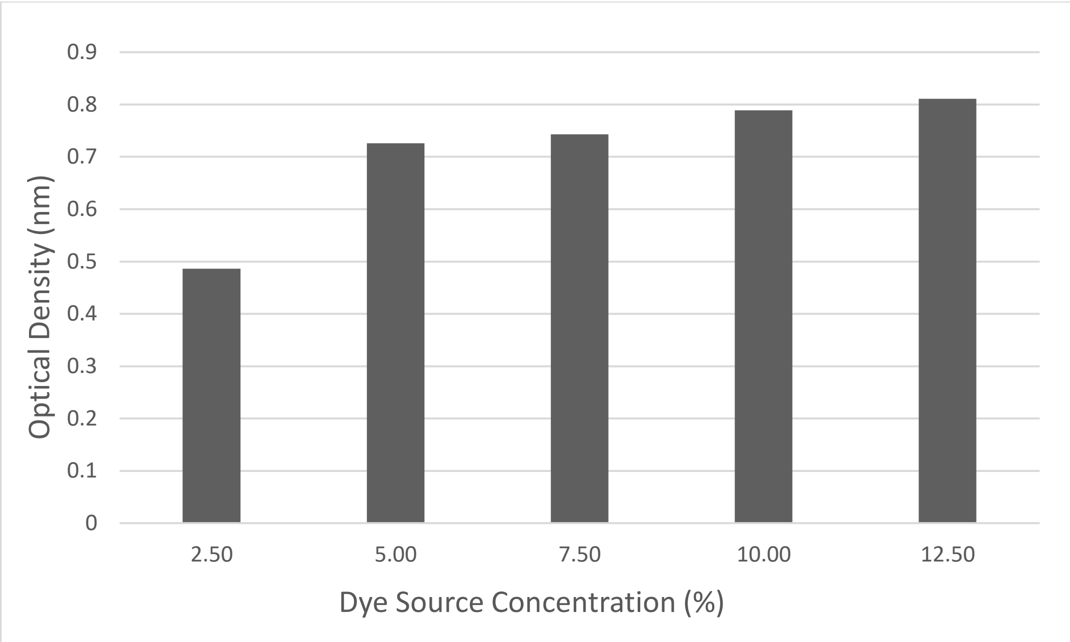


Figure.5 Effect of dye source concentration on color yield

4.1.2 Optimization of pH

pH is an important factor for dye extraction. In order to optimize pH for dye extraction from DS, 5 different pH ranging from 5 to 13 with the interval of 2 was studied keeping extraction time (30 mins), temperature (100°C) and dye source concentration (5%) constant.

It is observed from Figure 6 that increase in pH from 5 increases the color yield up to pH 7, which might be due to increased solubility of colorant at slightly acidic to neutral range, whereas further increase in pH decreases the optical density. This might be due to increase in pH above 7 would destroy the structure of the colorant; and results in lower color yield. Hence the optimum pH is taken as 7 for further experiments.

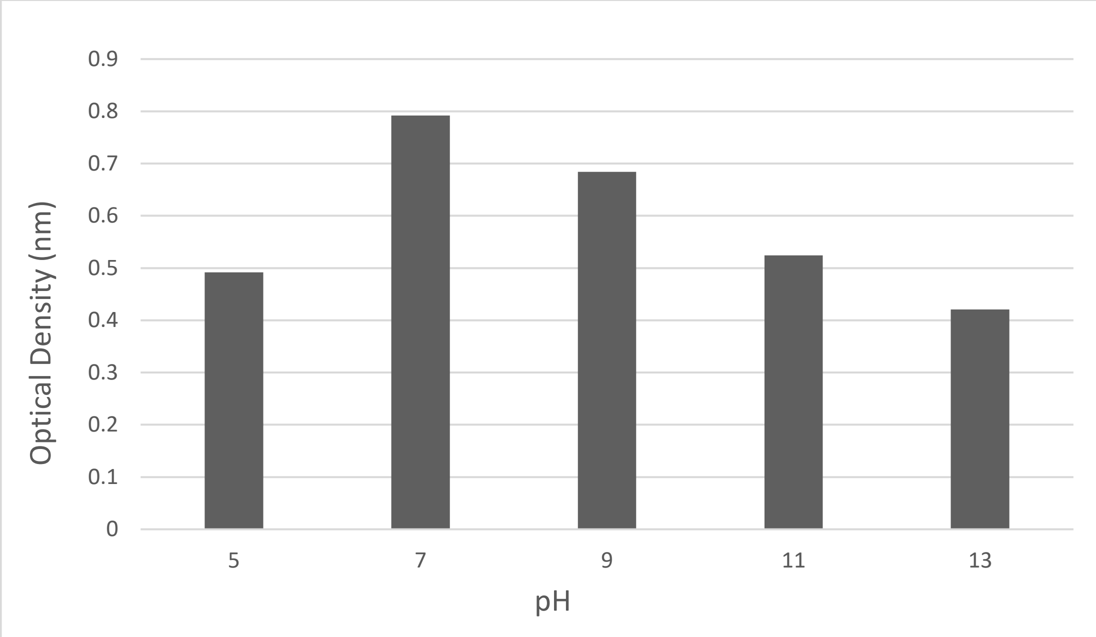


Figure.6 Effect of pH on color yield

4.1.3 Optimization of Time

To optimize the extraction time, extraction was carried out from 15 to 75 minutes while maintaining the pH (7), temperature (100°C), and dye source concentration (5%) constant.

From Figure 7 it is clear that the optical density of the dye extract increased with the increase in extraction time and reached maximum at 30 min. Beyond 30 min there was a slight decrease in color yield. Hence extraction time of 30 minutes was chosen as the optimum time.

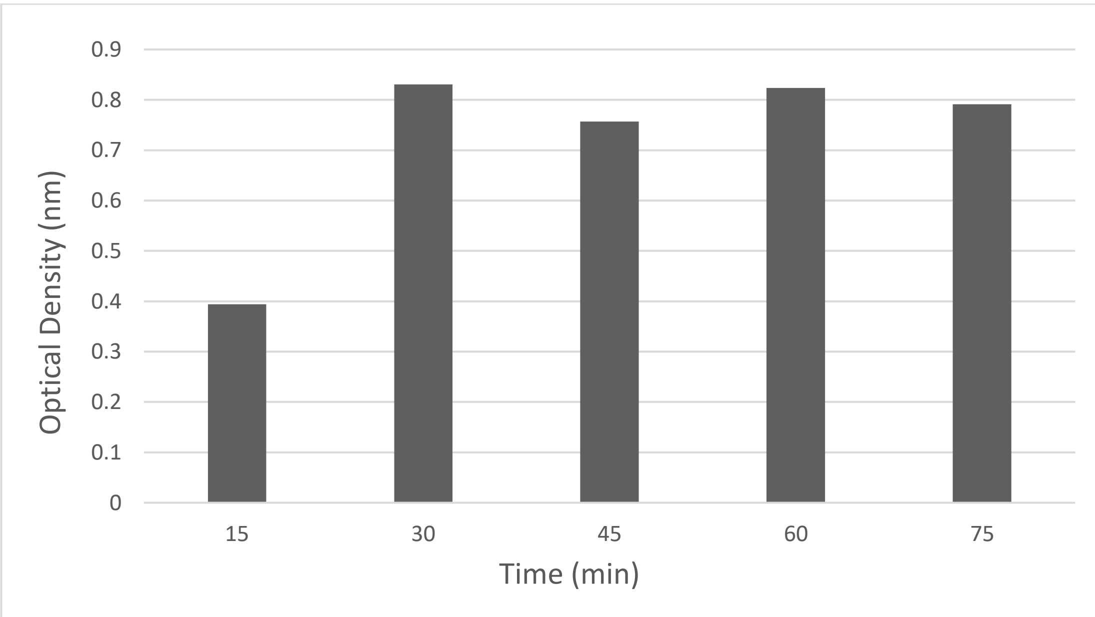


Figure.7 Effect of time on color yield

4.1.4 Optimization of Temperature

Dye was extracted at different temperatures (30°C to 100°C) while maintaining the pH (7), duration (30 min), and dye source concentration (5%) as constant.

Figure 8 clearly show that increase in the extraction temperature enhance the optical density of the extract. Color yield increased with increase in the extraction temperature and reach at maximum at 100°C. Therefore, 100°C was chosen as the optimal extraction temperature.

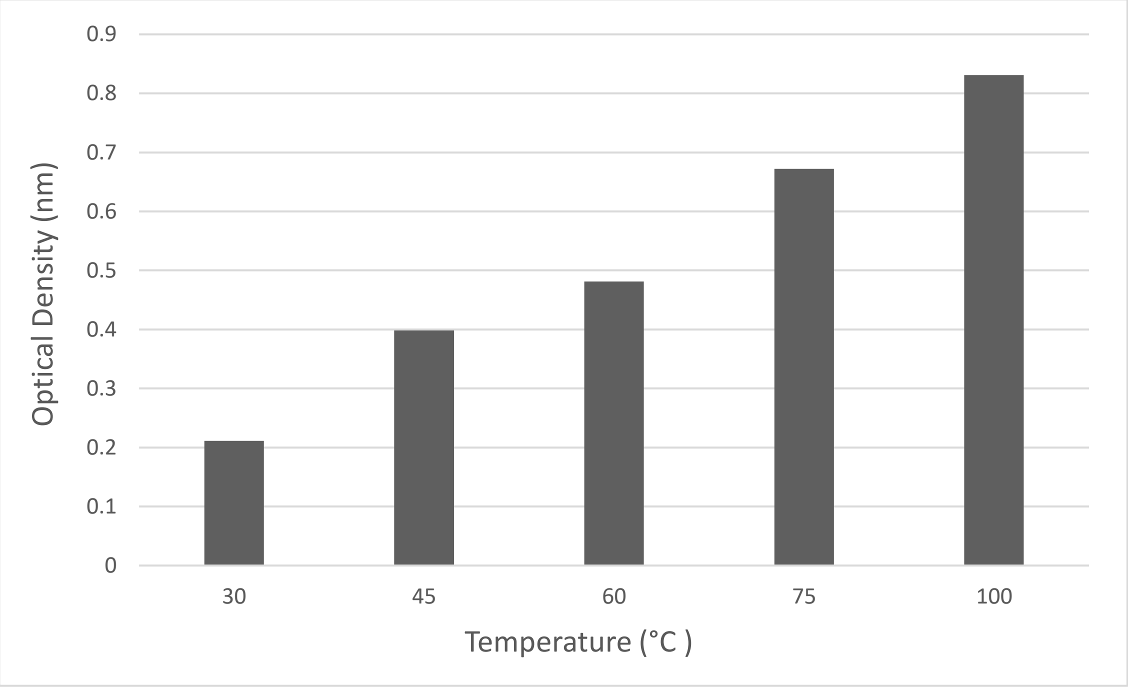


Figure.8 Effect of temperature on color yield

4.1.5 Optimized Conditions for Extraction of Natural Dye from Dalbergia Sissoo

Optimized conditions for extraction of natural dye from Sawdust of *Dalbergia Sissoo* are presented in Table 3

Table.3 Optimized conditions for extraction

S.No	Parameters	Optimized conditions
1	Solvent	Water
2	Dye source concentration	5%
3.	Time	30 min
4.	Temperature	100°C
5	pH	7

4.2 Characterization of Dye Extract

4.2.1 UV Analysis

UV-VIS analysis of sawdust from *Dalbergia Sissoo* extract results are presented in Table 4.

Table.4 UV-Vis Analysis

Wavelength (nm)	Absorbance
220	2.927
300	0.996
350	0.844
400	0.446
500	1.014
600	0.271
700	0.156
800	0.111

From Table 12, it reveals that the wavelength of sawdust from *Dalbergia Sisso*o extract was peak at 220nm and the absorbance level of dye extract absorbed at 0.111 wavelength of 800 (Fig 9)

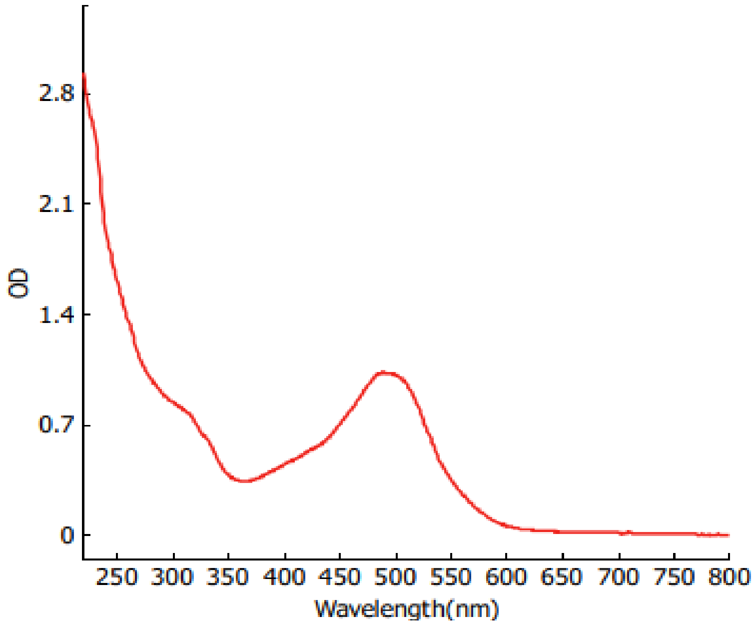


Figure.9 UV-VIS spectrum of sawdust from *Dalbergia Sissoo* Extract

4.2.2 Phytochemical Analysis

Phytochemical analysis of natural dye extracted form sawdust of DS is showed in the Table 5.

Table.5 Results of Phytochemical Screening of sample

Sr.No.	Metabolite	Test performed	Observation	Results	Figure No.
1	Flavonoids	$+H_2SO_4$	Presence of reddish Orange colour	+	**1**
2	Anthraquinone (Borntrager's test)	+ $FeCl_3$ + Conc.HCl+diethyl ether +Ammonia	Presence of reddish orange colour	+	**2**
3	Proteins	+conc. HNO_3	Presence of Yellow Colouration	+	**3**
4	Carbohydrates	Molisch's test	Presence of Violet ring	+	**4**
5		Fehling's test	Presence of Red precipitate	+	**5**
6	Saponins	Shaken with water	Presence of foam	+	**6**
7	Cardiac glycosides	+Baljet reagent	Presence of yellow orange colour	+	**7**
8		Keller-killani test	Presence of brown ring	+	**8**

Table 5, reveals the composition of phytochemicals presented in extracted dye. Dye extract from sawdust of DS shows presences of flavonoids, anthraquinone, proteins, carbohydrates, saponins and cardiac glycosides.

This conclude that the reddish orange color is due to presences of Anthraquinone and the presences of Cardiac glycosides gives it a high medicinal value for cardiac diseases.

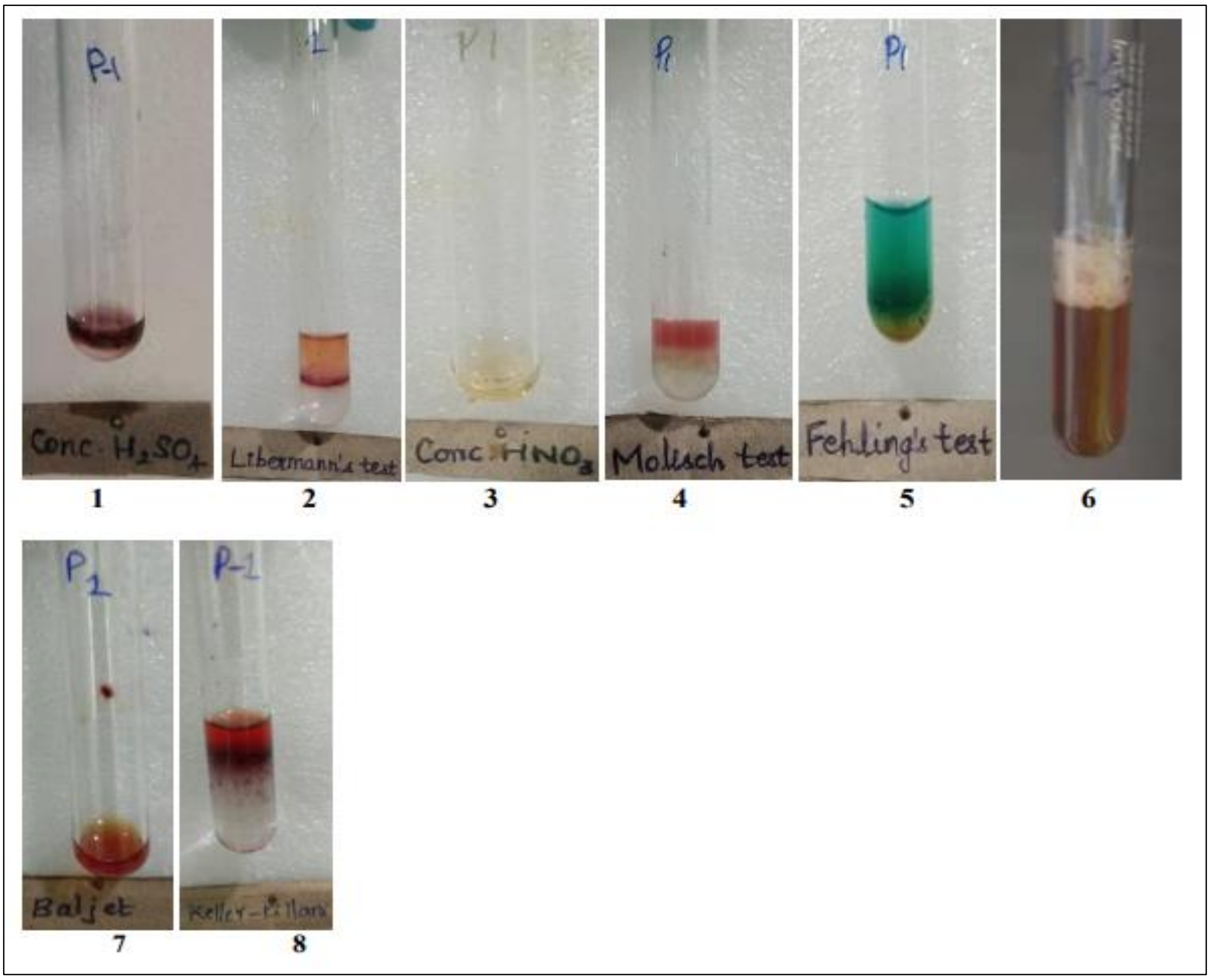


Figure.10 Phytochemical Screening Tests

4.2.3 Crude Dye Yield

The crude dye yield indicates the total amount of pigment recovered from the plant source. It is heavily influenced by plant features (climate, harvesting period, etc.) as well as extraction process parameters (pH, temperature, time). The quantity of extracted pigment may be determined objectively by using the Crude dye yield formula (F1). After extraction, a reasonably high amount of crude dye yield (44%) was achieved in this study. The above-mentioned dye yield obtained, is termed crude, because no attempt was made to isolate the colorants present in the filtrate to obtain pure dye. Nonetheless, it can be expected that the actual amount of pure dye after isolation of the dye would be lower.

- *Dye Exhaustion*

The exhaustion rate was analyzed by dyeing wool fabric at optimum condition i.e., 5% dye concentration, 5% for mordant dyeing, pH 5, 85°C temperature, and 30 min dyeing time are obtained for better dyeing performance of wool with a dye bath exhaustion rate of around 54%.

4.2.4 FT-IR

Functional groups of DS were determined by FT-IR spectroscopy, (Figure 11). From Figure 11 it is evident that there are three distinct peaks at 3310, 1636 and 671.

A peak at 3310 cm-1 is due to stretching vibration of strong intermolecular bond of -OH. The absorption peak at 1636 cm-1 are characteristics of C=C stretching and a peak at 671 is due to C-Br stretching vibration. Therefore, the results of FT-IR help to conclude that the chemical nature of the dye extracted from the sawdust of DS has polyphenolic and flavonoid components. These -OH and C=C groups helps in fixation of natural dye molecules with the fabric during dyeing [Lachguer, et al 2021].

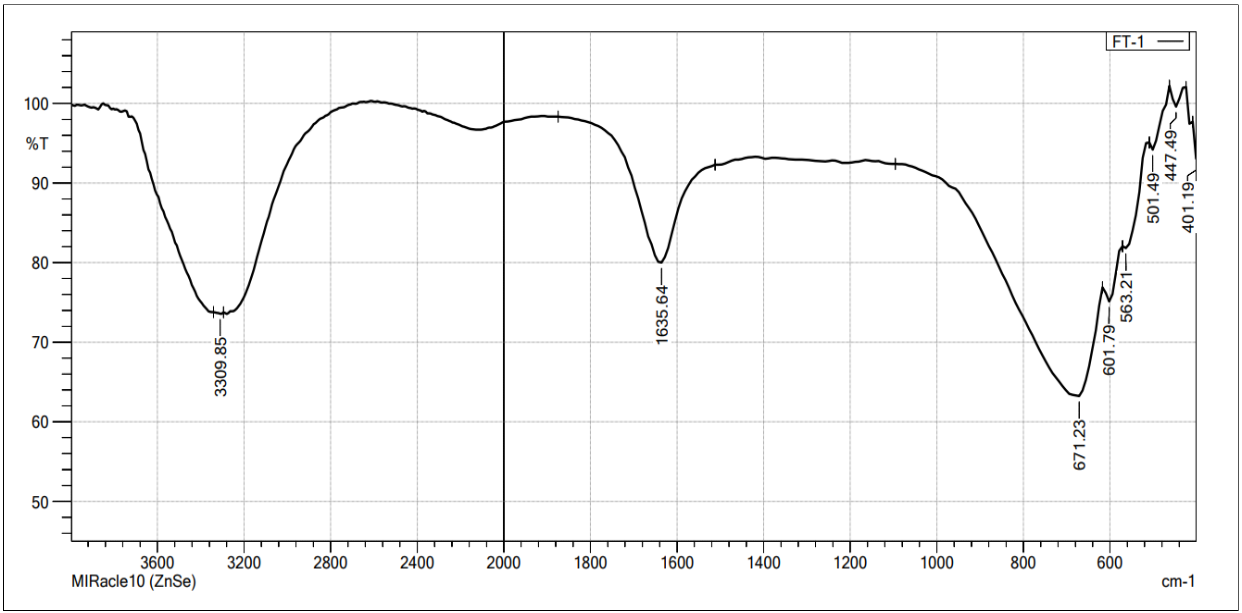


Figure.11 Fourier Transform Infrared Spectra Of Dalbergia Sissoo Natural Dye

4.2.5 TGA

Thermogravimetric (TG) measurement of DS dye powder revealed two mass loss events. Graphical analysis for the same has been shown in Figure 12.

The graph clearly shows that the mass loss is stable at 95°C which indicates start of decomposition. The first mass loss was seen as the temperature rises to 305°C with the weight loss of 25.2% which is linked to the water evaporation. The mass loss shown in second peak was observed from 320°C till 625°C with the weight loss of 31.9%. which is linked to the evaporation of organic components present in the extract[Lachguer, et al 2021]. This shows that DS extract has higher thermal stability compared some other natural extract. This can be due to presences for phenolic components. The DTG curve shows a decomposition peak at 330°C.

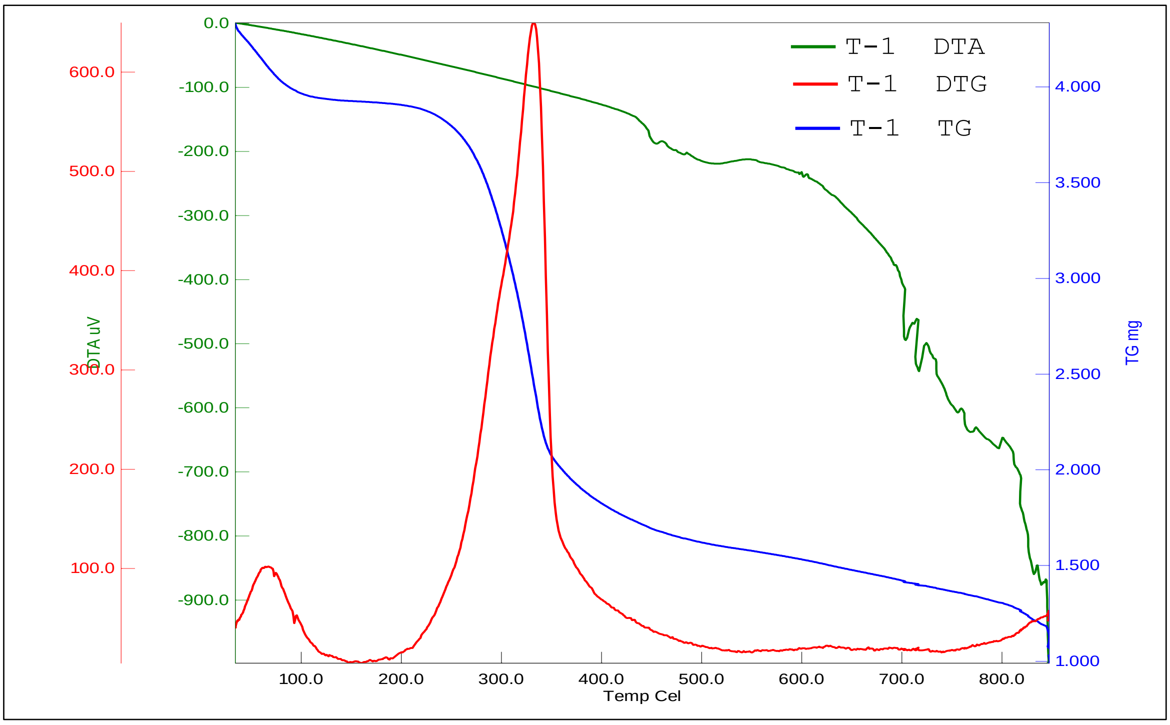


Figure.12 Thermogravimetric (TG) and differential thermogravimetric (DTG) curves of DS

4.3 Optimization of Dyeing

The extract obtained from the above method was filtered and used for the optimizationof dyeing at various effects of dyeing parameters such as temperature, dyeing time, liquor ratioand mordanting were noted for process optimization. Fabrics were dyed using extracted dye solution at 30° to 85°C for temperature optimization and for optimized M:L ratio dyeing was done using 1:10, 1:20, 1:30, 1:40 and 1:50 material to liquid ratios. In order to observe the effect ofdyeing time dyeing was carried out for 30, 45, 60, 75 and 90 min.

4.3.1 Optimization of MLR

Dye solution was extracted using optimum conditions and the extract was then used to dye wool fabric with various MLR ratios ranging from 1:10 to 1:50 under dyeing conditions of 80°C for 30 minutes at pH 7. The dyed fabric was examined for color strength and the results are shown in the below Table 6. From Figure 13 it is clear that K/S value increased with the increase in MLR 1:30. At lower MLR, the extracted particles from natural dye are distributed in less amount which causes in low dye up-take and uneven dyeing. Whereas higher MLR dilutes the colorant molecules resulting in lower K/S value. Hence MLR 1:30 was fixed as optimum for subsequent experiments [Jiang, et al 2019].

Table.6 Color strength measurement of M:L ratio on wool

MLR	L*	a*	b*	K/S	Shade Produced
1:10	94.463	4.972	1.980	258.507	
1:20	94.488	4.704	2.024	305.848	
1:30	94.241	3.641	1.210	439.940	
1:40	94.324	4.050	1.466	362.597	
1:50	94.269	3.763	1.284	372.789	

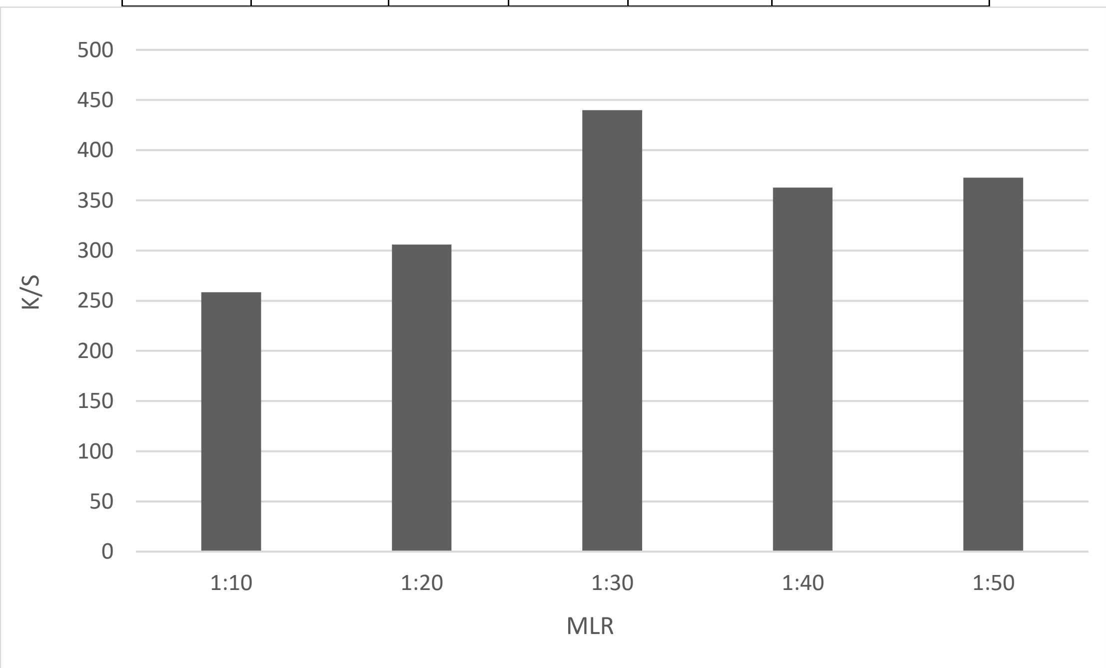


Figure.13 Effect of M:L ratio on color strength

4.3.2 Optimization of pH

The pH of dye bath is a key element that influences dye stability in solution as well as dye affinity for fiber [Mehrparvar, et al 2016]. The presence of numerous hydroxyl groups in flavonoid compounds allows them to ionize or oxidize at different pH levels. Hence to determine optimum dye bath pH, dyeing of wool was done at different pHs. It is clear from Figure 14 that pH5 showed color strength of dyed wool decreased with the increase in dye bath pH. The color strength was found to be maximum at pH 5. Primary mechanism regulating dye absorption might be due to ionic interactions between dye molecules and wool chains. Flavonoids process no. of hydroxyl groups. Wool fibers have carboxyl groups (-COOH) and amino groups (-NH_2), which forms bond with functional hydroxyl groups (-OH) of dye. In acidic condition, COO^- becomes COOH, whereas NH_3^+ stays positively charged, and the extract's phenolic component converts into anionic forms. Wool dyeing increases ay an acidic condition of dye bath and pH 5 was fixed as optimum dye bath pH.

Table.7 Color strength measurement of pH on wool

pH	L*	a*	b*	K/S	Shade Produced
5 pH	94.297	3.813	1.374	388.074	
7 pH	94.403	4.619	1.734	359.475	
9 pH	94.384	4.372	1.664	358.898	

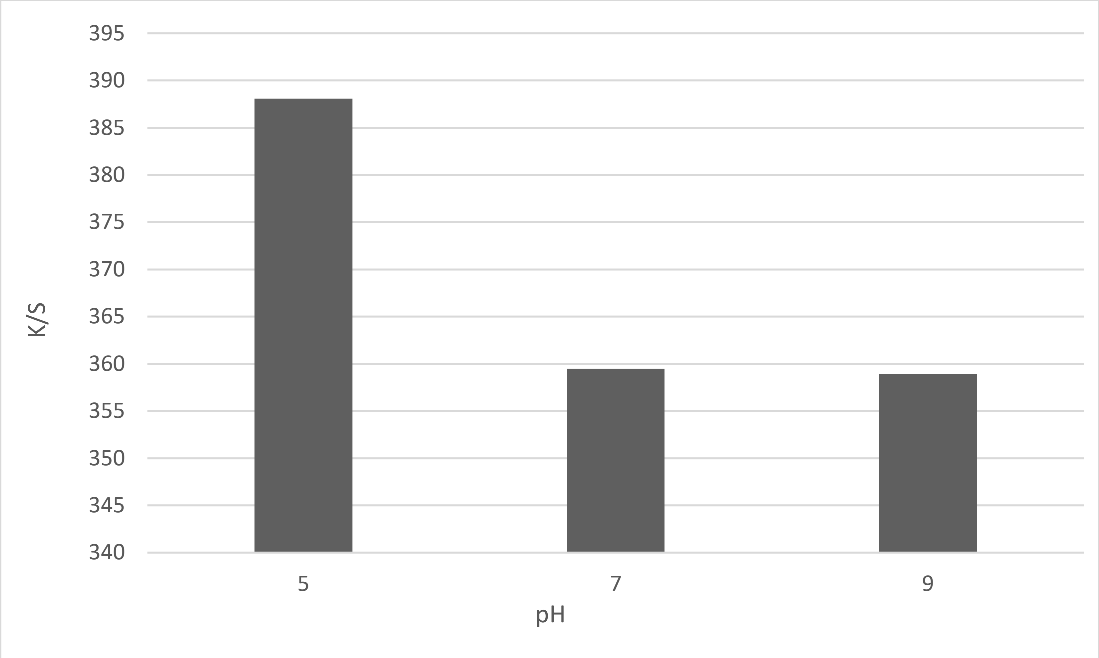


Figure.14 Effect of pH on color strength

4.3.3 Optimization of Time

The contact time between the colorant and the functional site of proteinic fabrics is important in obtaining the desired effects. Wool was dyed at various time intervals ranging from 30 to 90 min. Figure 15 clearly shows with increasing dyeing time fabric color strength decreases. Heating for a short period of time will not increase the kinetic energy of the colorant to travel towards the woolen molecules, however heating for a lengthy period of time will promote breakdown of the colorant particles into byproducts, resulting in low tint strength (K/S). Hence dyeing time of 30 min was chosen as optimum.

Table.8 Color strength measurement of time on wool

Time (min)	L*	a*	b*	K/S	Shaded Produced
30	94.2199	3.445	1.128	451.229	
45	94.296	4.296	1.480	390.264	
60	94.345	4.440	1.558	365.739	
75	94.403	4.948	1.827	268.516	
90	94.529	5.217	2.137	196.920	

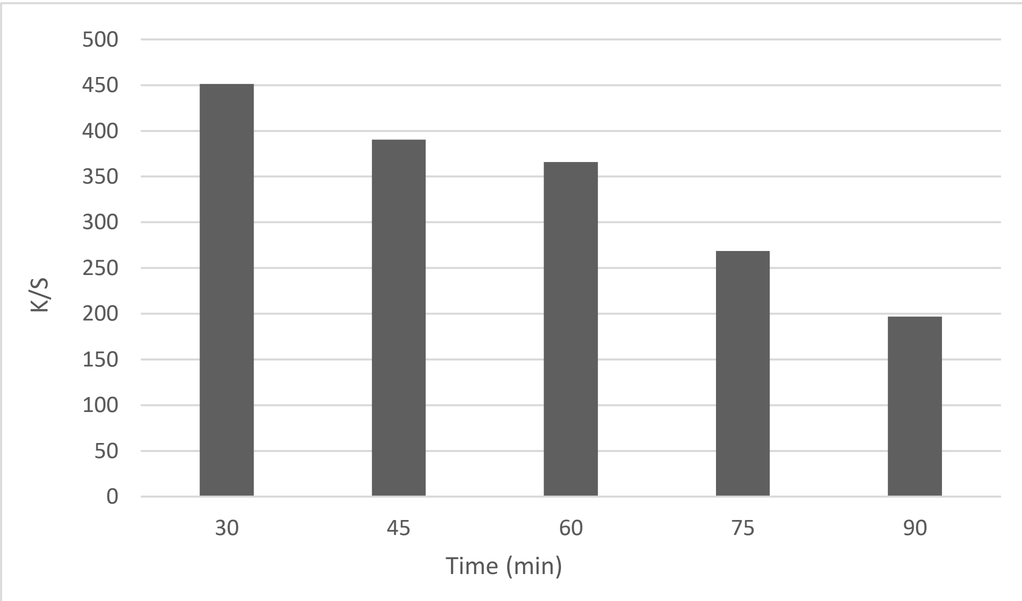


Figure.15 Effect of time on color strength

4.3.4 Optimization of Temperature

The optimal temperature level constantly adds value in the fixing of colorant into woolen fibers to produce the desired outcome [Jiang, et al 2019]. To determine the optimum dyeing temperature, dyeing was carried out at different temperature ranging from 30°C to 85°C for which results are shown in Table 9. Low temperatures cannot increase the kinetic energy of colorant molecules to rush towards wool molecules for fixation [Mehrparvar, et al 2016], while high temperatures may alter the equilibrium between the colorant and the woolen fabric, resulting in weaker colorant binding to the fabric [Nasirizadeh, et al 2012]. Hence, 85°C was fixed as optimum temperature for dye of wool.

Table.9 Color strength measurement of temperature on wool

Temperature (°C)	L*	a*	b*	K/S	Shade Produced
30	94.700	4.446	2.632	78.119	
45	94.786	4.696	2.812	113.440	
60	94.679	4.986	2.537	212.970	
75	94.390	4.802	1.760	302.839	
85	94.359	4.750	1.626	323.526	

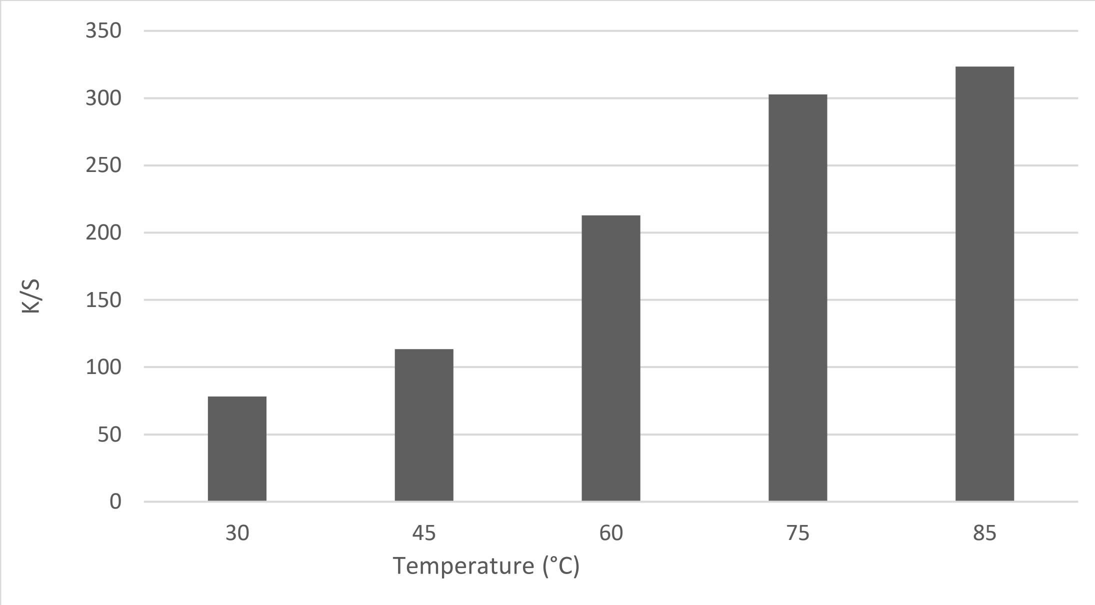


Figure.16 Effect of temperature on color strength

4.3.5 *Optimized conditions for dyeing of wool fabric with Sawdust of Dalbergia Sissoo extract*

The optimized dyeing conditions for dyeing wool fabric using Sawdust of Dalbergia Sissoo extract are presented in Table 10.

Table.10 Optimized dyeing conditions

S.no	Parameters	Optimized conditions
1.	MLR	1:30
2.	pH	5
3.	Time	30 min
4.	Temperature	85°C

4.4 Selection of Mordant

In natural dyeing of the fabric, tint development is very essential process. One of the drawbacks of natural dyeing is their poor retention of dye on the fabric. Mordants like Fe^{+2}, Al^{+3}, tannic acid, and others can help to overcome these constraints by assisting in the appropriate fixing of colorant molecules onto fabric.

In this study, initially, two bio-mordants, Guava leaf powder and myrobalan powder, were used, but the results were unsatisfactory since the dyeing was visibly uneven. As a result, two metallic mordants were used: citric acid and alum. Using citric acid as a mordant resulted in somewhat uneven dyeing, whereas alum resulted in rather even coloring. As a result, alum was utilized as a mordant in dyeing.

Table.11 Evenness of different mordant

Mordant	Evenness
Guava Leaf Powder	Uneven
Myrobalan Powder	Uneven
Citric Acid	Uneven
Alum	Even

4.5 Selection of Mordant

4.5.1 Effect of Mordant Concentration

To find the optimum mordant concentration, alum with concentrations of 2%, 5%, 10%, and 15% (owf) were employed for mordanting and wool was dyed under optimized conditions, and color strength for all four dyed samples was assessed, as indicated in Figure 17. Table 12 clearly showed that lower % of mordant results in lower K/S value. Increase in mordant concentration shows lower K/S. value. This might be due to aggregation of the extract molecules caused by the addition of excess metal salts, resulting in a reduction in the solubility of the extract, which leads to difficulty in penetration of dye during dyeing [Ali, 2011]. Hence, 5% of mordant concentration was taken as optimum mordant concentration.

Table.12 Optimization of mordant concentration on wool

Mordant Concentration (%)	L*	a*	b*	K/S	Shade Produced
2	94.269	4.073	1.374	409.014	
5	94.252	3.618	1.195	442.965	
10	94.261	3.661	1.239	340.733	
15	94.247	3.472	1.155	307.930	

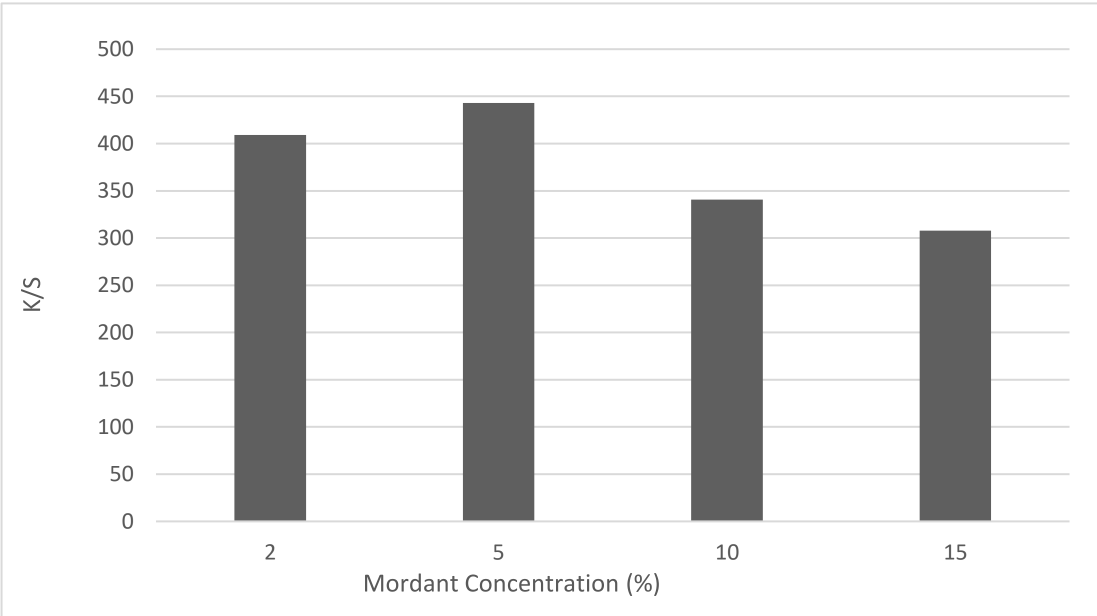


Figure.17 Effect of mordant concentration on color strength

4.5.2 Effect of Mordanting Technique

Wool fabric was dyed and mordanted using several mordanting techniques, including Pre-Mordanting, Simultaneous Mordanting, and Post-Mordanting; the color characteristics of the dyed fabrics are shown in Table 13. The results demonstrate that mordant-dyed fabric have higher K/S values. When different mordanting methods were compared, pre-mordanted samples had higher K/S values than post-mordanted and simultaneous-mordanted samples. This might be due to the presences of metal ions in mordant which may form coordination complexes with fabric during pre-mordanting and coordination bonds with dye molecules during dyeing. Hence, pre-mordanting technique was selected for the study.

Table.13 Effect of mordanting technique on color strength

Mordant Technique	L*	a*	b*	K/S	Image
Pre-Mordanting	94.252	3.618	1.195	442.965	
Simultaneous Mordanting	94.535	5.544	2.187	206.412	
Post-Mordanting	94.356	4.466	1.718	343.515	

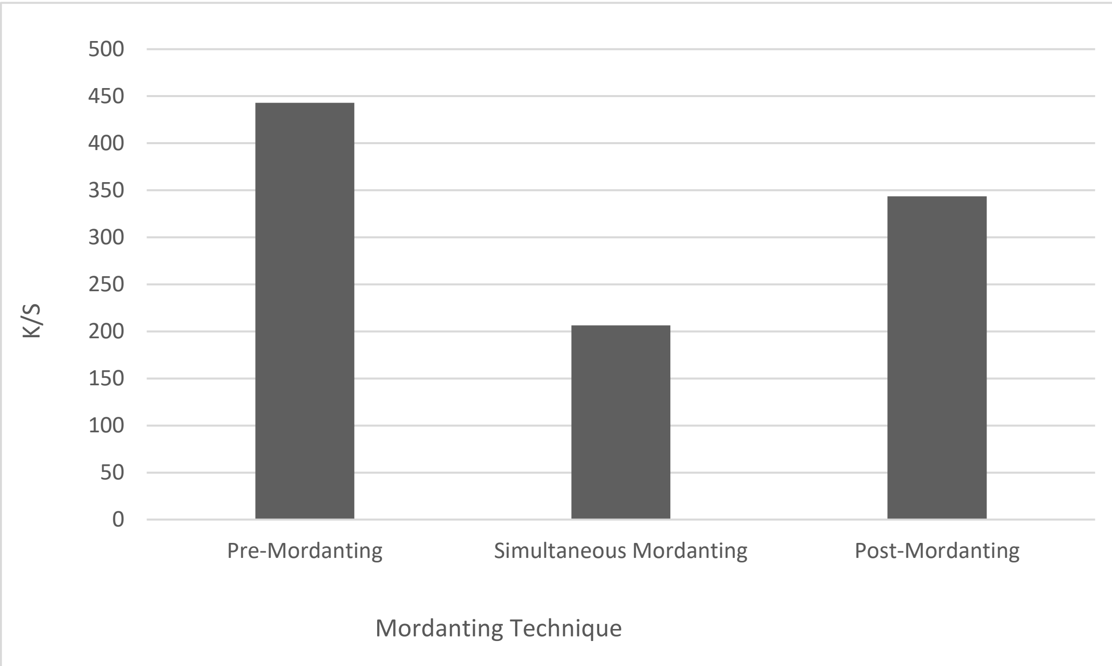


Figure.18 Effect of mordanting technique on color strength

4.6 UV Protection Analysis

UV protection property of the dyed fabric were analyzed and the results are presented in the Table 14.

Results indicate that, dyed wool didn’t exhibit UV protection. Though there was increase in the UV factor of dyed wool compare to control fabric but yet it doesn’t have any UV protection. This might be due to the chemical components of dye and fabric. Hence, it is clear that the wool dyed with DS extract does not exhibits UV protection property.

Table.14 UV protection property of Dalbergia sissoo dyed fabric

Sample	Mean			UV protection category
	UV-A Blocking (%)	UV-A Blocking (%)	UPF Rating	
Control	62.16%	73.76%	3	No Protection
Without Mordant	78.72%	79.27%	5	No Protection
With Mordant	79.05%	79.50%	5	No Protection

Note: UPF value less than 15- No protection, UPF value between 15 to 24- good, UPF value between 24 to 40- very good, UPF more than 40- Excellent.

4.7 Anti-Bacterial

Table.15 Effect of Anti-Bacterial Analysis on Wool

Samples	Zone of inhibition (mm)	
	Staphylococcus aureus Gram-positive	Escherichia coli Gram- negative
UDF	-	-
OM	12	-
DF	15	17
MDF	15	20

Table 15 reveals that no zone of inhibition was recorded in UDF for both gram-positive and gram-negative bacteria, and no zone of inhibition was recorded in only mordant for gram-negative bacteria. Wool has no zone of inhibition because its molecular structure contains many more amino acids with polar side residues. It influences the fabric's dye and heavy metal adsorption capacity, resulting in improved antimicrobial properties (Ki, 2006). MDF had the largest clear zone against both S. aureus and E. coli, with inhibition zones of 15 and 17 cm. The suppression activity was also observed on DF with inhibition zone 15 & 17. This result reveals that mordant types especially alum enhanced the antibacterial property of the dyed wool on both positive and negative strains.

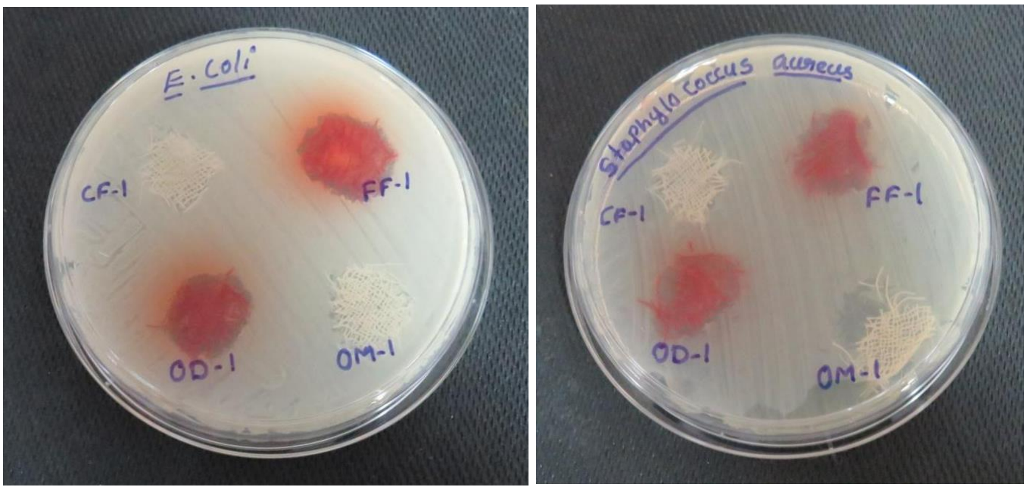


Figure.19 Wool treated with staphylococcus aureus and E. coli

4.8 Fabric Physical Properties

4.8.1 Fabric Weight

The weight of fabric (GSM) of undyed fabric, dyed fabric and mordant dyed fabric samples were analyzed and the values are presented in Table 15. From Table 16, it is observed that the weight of undyed fabric is lower 0.65(GSM) when compared to dyed and mordant dyed fabrics. There is increase in weight of dyed and mordant dyed fabrics with 23% and 30% respectively. But mordant dyed fabric shows highest increase in weight than undyed and dyed fabrics (Fig, 20).

Table.16 Fabric Weight

S.no	Sample	Mean fabric weight (GSM)	Gain or loss over original	%gain or loss over original
1	UDF	0.65	-	-
2	DF	0.80	0.15	23
3	MDF	0.85	0.20	30

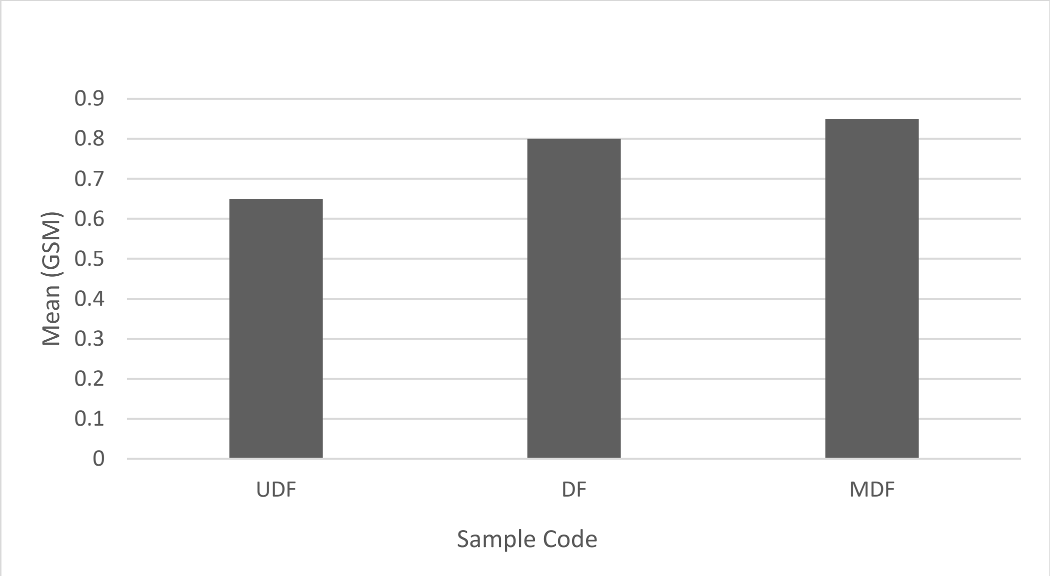


Figure.20 Fabric Weight

4.8.2 Fabric Thickness

The thickness of undyed, dyed and mordant dyed samples is analyzed and presented in Table 17. From Table 17, it is clear that the thickness of dyed and mordant dyed fabrics gain thickness than undyed fabric with gain of 20% and 32% respectively. Hence the mordant dyed fabric gains 0.33 mm in thickness. The increase in thickness over dyed fabric due to treatment of fabricwith mordant before dyeing (Fig 21).

Table. 17 Fabric Thickness

S.no	Sample	Mean fabric thickness(mm)	Gain or loss over original	%gain or loss over original
1	UDF	0.25	-	-
2	DF	0.30	0.05	20
3	MDF	0.33	0.08	32

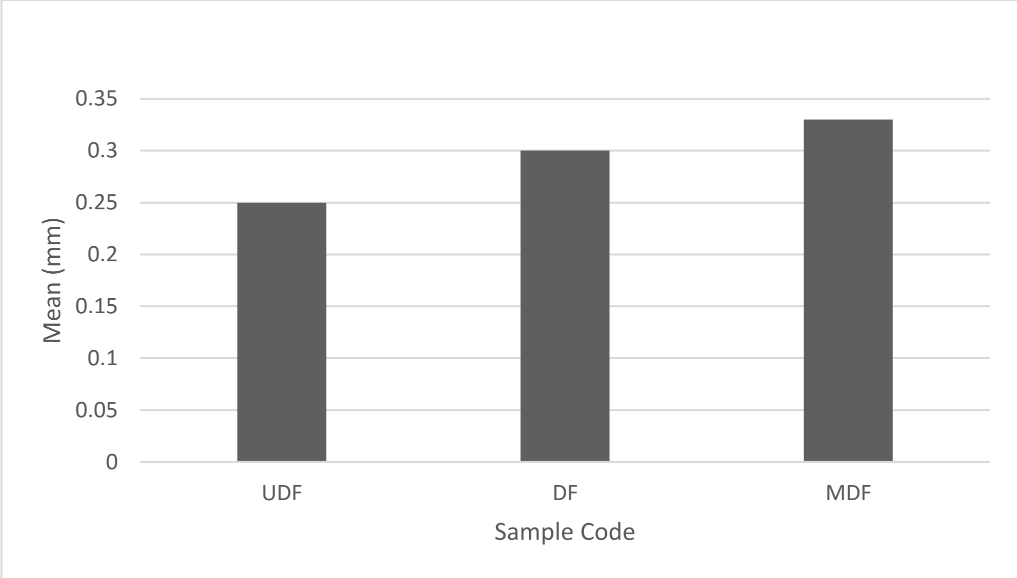


Figure.21 Fabric Thickness

4.8.3 Fabric Stiffness

- Warp Direction

The stiffness of samples in warp direction are analyzed and values are presented in Table 18. From Table 18, it shows that the undyed fabric has high stiffness value in warp direction compared to both dyed and mordant dyed fabric. Dyed fabric shows reduction of stiffness in warp direction than dyed fabric and higher than mordant dyed fabric (Fig 22).

Table. 18 Fabric Stiffness (Warp Direction)

S.no	Sample	Mean fabric stiffness (cm)	Gain or loss over original	%gain or loss over original
1	UDF	1.6	-	-
2	DF	1.9	0.03	1.9
3	MDF	2.0	0.04	2.5

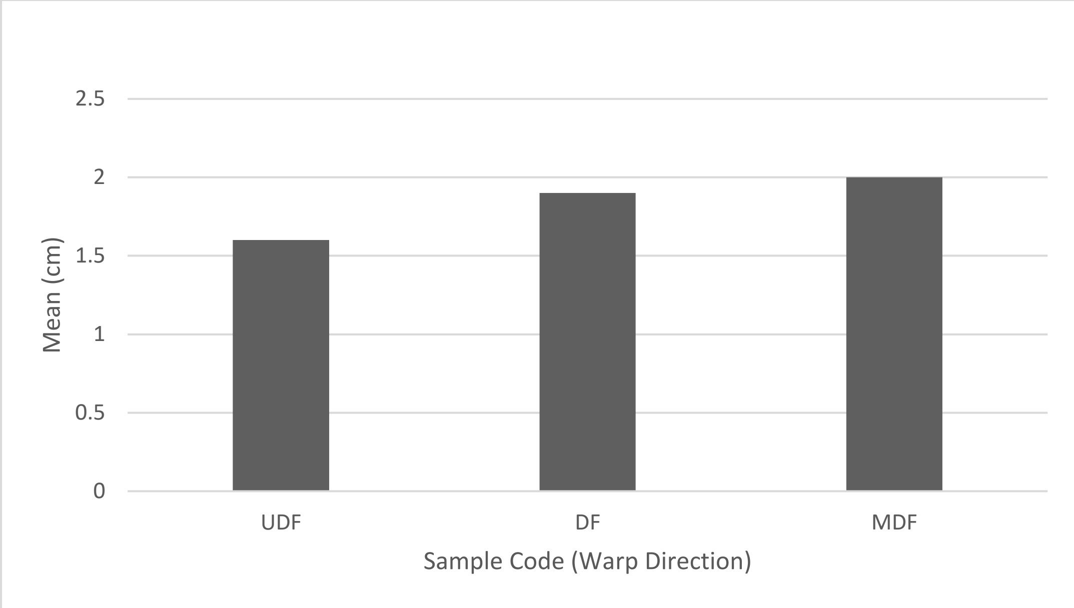


Figure.22 Fabric Stiffness (Warp Direction)

- Weft Direction

The stiffness of the samples along weft direction are analyzed and values are presented in Table 19. From Table 19, it is clear that the undyed fabric shows highest stiffness value in weft directionand dyed fabric shows reduction in stiffness compared to dyed fabric. Also, mordant dyed fabricshows reduction in weft direction compared to both undyed and dyed samples (Fig 23).

Table. 19 Fabric Stiffness (Weft Direction)

S.no	Sample	Mean fabric stiffness (cm)	Gain or loss over original	%gain or loss over original
1	UDF	1.9	-	-
2	DF	2.0	0.01	0.5
3	MDF	2.1	0.02	1

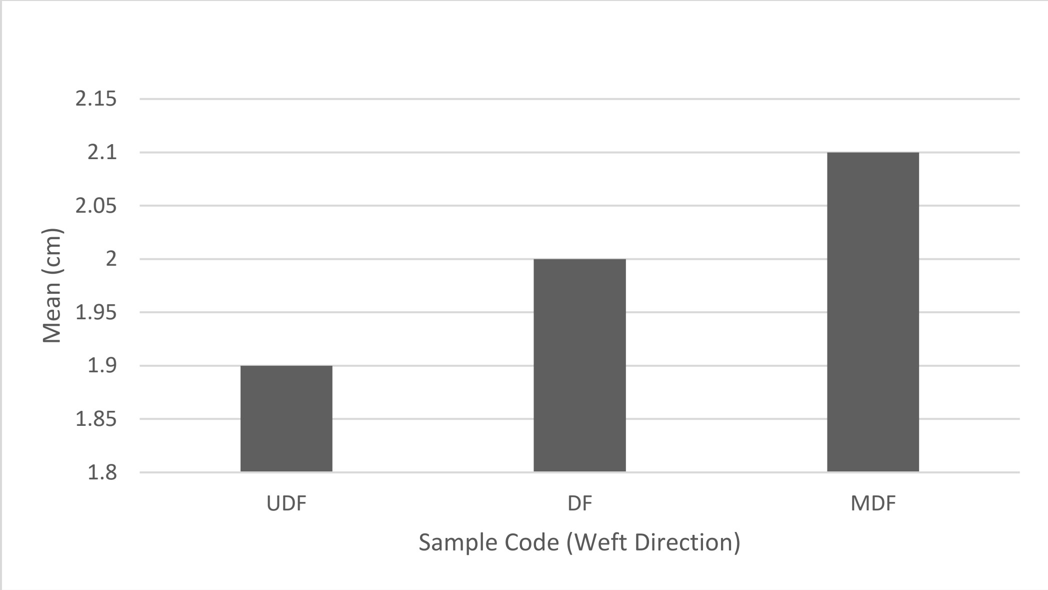


Figure.23 Fabric Stiffness (Weft Direction)

4.8.4 Fabric Absorbency

4.8.4.1 Sinking

The results of fabric sinking time of undyed, dyed and mordant dyed fabrics are presented in Table 20. From Table 20, it is clear that the time taken for sinking of wool fabric for more than standard 1min. Hence, undyed, dyed and mordant was floating on the water.

Table. 20 Sinking Time

S.no	Sample	Mean sinking time (seconds)
1	UDF	Floating (0.0)
2	DF	Floating (0.0)
3	MDF	Floating (0.0)

4.8.4.2 Wicking

The results of wicking ability of undyed, dyed and mordant fabric are presented in the Table 21 & Fig 24. From Table 21, it is evident that the dyed samples increased when compared to undyed fabric. Mordant dyed fabric exhibits higher absorbency when compared to dyed and undyed fabric (Fig 24).

Table. 21 Wickability of fabric

S.no	Sample	Mean absorbency in 1 Minute (cm)			
		Time constant	Extended absorbability	Gain or lossover original	%gain or loss over original
1	UDF	1min	0.5	-	-
2	DF	1min	1.0	0.50	50
3	MDF	1min	1.5	0.50	50

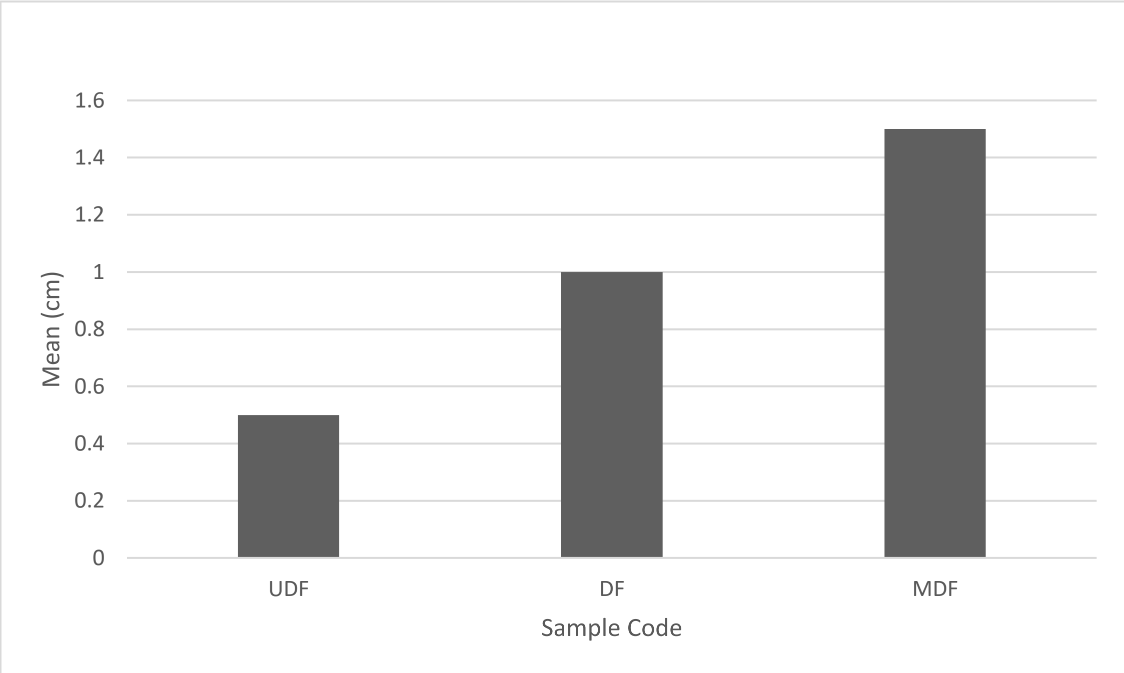


Figure.27 Wickability of fabric

4.9 Color Fastness to

4.9.1 Washing
4.9.2 Crocking
4.9.3 Light
4.9.4 Perspiration

Natural dyed wool fabric color fastness properties are assessed to washing, crocking, sunlight and perspiration and results are presented in Table 21.

Table. 22 Color Fastness

S.no	Sample	Washing	Sunlight	Crocking		Perspiration	
				Dry	Wet	Acidic	Alkaline
1	DF	3/4	4	4/5	4	3/5	2/5
2	MDF	4/5	4/5	5	4/5	4/5	4/5

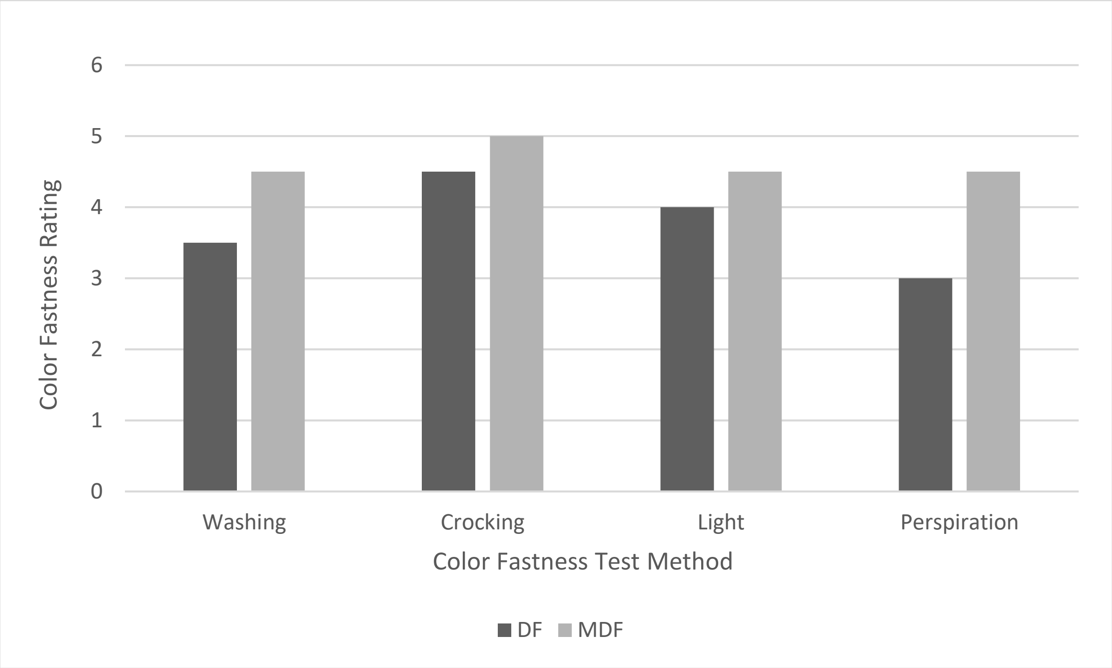


Figure.25 Color Fastness

The results confirm that wool fabrics dyed with DS have good to excellent colorfastness to washing, dry and wet rubbing, light and acidic perspiration. It can be seen that the rating is always above 3. Only in alkaline perspiration, colorfastness was fair to good. This might be due to the proteinic nature of the fabric. After washing, color fastness is also improved by using mordants.

4.10 Product Development

4.10.1 Pocket Square

1a. Pocket Square

1b. Pocket Square

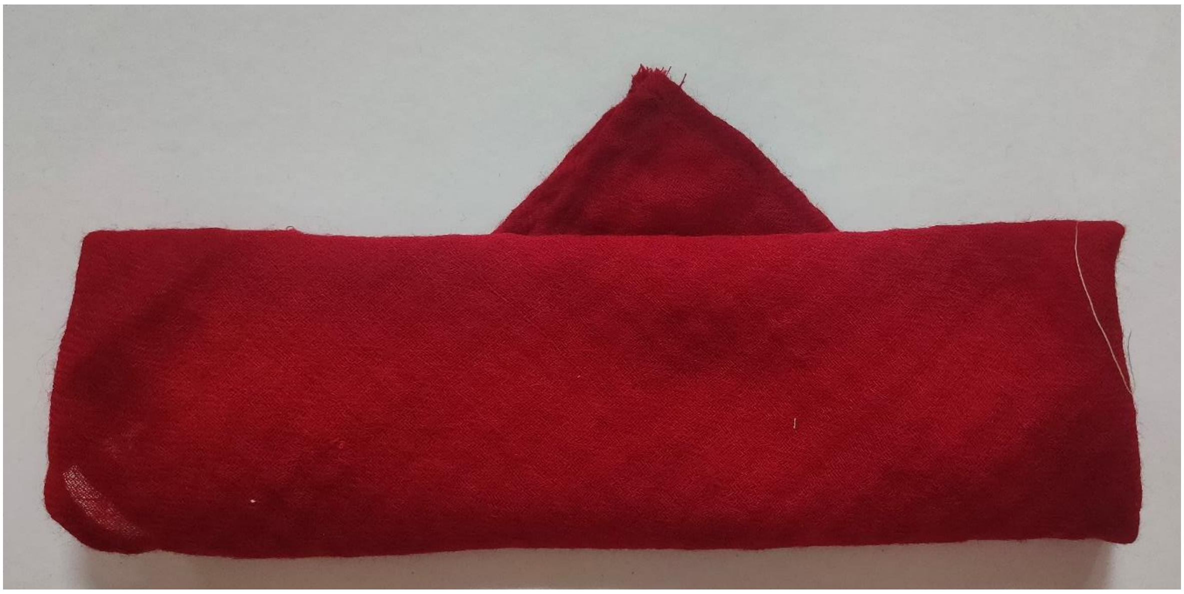
4.10.2 Hair Band

2a. Hair Band

2b. Hair Band

4.10.3 Head Scarf

3a. Head Scarf



3b. Head Scarf

SUMMARY AND CONCLUSION

5. SUMMARY AND CONCLUSION

Colors have always played an important part in human life. It beautifies the world. Coloring textiles is an interesting art form. Dyes come in two varieties: natural and synthetic, and both are used to color fibers, yarns, and textiles. Because of the problems connected with synthetic dyes, it is becoming more common to color fabrics with natural dyes. Because of the harmful effluent produced by the dyeing process of these dyes, the usage of synthetic dyes has been greatly reduced. Natural dyes are becoming increasingly popular as people become more conscious of environmental issues and sustainability. Natural colors were derived from animal, vegetable, and plant elements such as leaves, fruits, roots, barks, and flowers. Natural dyes are categorized depending on their chemical structure, origin, application technique, and color. The two primary benefits of natural colors over synthetic dyes are: natural synthesis methods accomplished without environmental pollution and biodegradability of natural materials, which does not affect toxic effluent upon degradation in the environment.

These dyes give incredibly unusual, relaxing, and gentle colors. These colours are biodegradable, environmentally benign, renewable, and less allergenic. It encourages everyone to use natural sources for textile coloring. These items are pleasant to wear because to their relaxing color and non-allergic qualities. The usage of natural dyes will also create additional jobs in rural areas. Because the technique is eco-friendly, naturally coloured products provide a fantastic potential for value-added manufacturing. Using plant dyes to their full potential for textile dyeing requires a competent and scientific process for dye extraction and application to textile materials without sacrificing fabric quality, and some dyes have therapeutic characteristics. The use of natural dyes on textiles felt the need to reinvestigate and rebuild the old procedure of natural dyeing in order to manage each treatment and pre-dyeing process and produce unusual hues with balanced fastness qualities and eco-performance on textiles.

Mordant is an ingredient that aids in the binding of dyes to fabric by building a chemical bridge from dye to fiber, so boosting a dye's staining capacity and increasing its fastness attributes. It is primarily used on fabric in three ways: pre-mordanting, meta mordanting, and post mordanting. The use of different mordants with the same dye can change the colors of a wide range or generate whole new colors. Natural dyes are used to create high-value textiles by artisan/craftspeople, small-scale/cottage level dyers and printers, and small-scale exporters across the world. Most commercial dyers are interested in the possibility of employing natural dyes on a regular basis. To fulfill the increased demand for natural colorants, new pigment crops and contemporary dyeing procedures are being researched.

Natural dyes have non-reproducible and non-uniform hues, as well as weak to moderate color fastness due to a lack of scientific information on the chemistry of extraction and dyeing. Color component extraction from natural sources is a key stage in dyeing any textile substrate. A systematic dyeing procedure produces good results for evaluating their dying qualities and maximizing the color output on textile materials. Standardization procedures such as pH, time, temperature, and dye concentration for dye extraction and dying are ideal conditions in standardized dyeing methods. Standardization of the extraction process and optimization of the extraction variables have both technical and commercial implications for color yield, extraction cost, and dyeing cost. Standardised recipes and dyeing techniques aid in the preservation of natural dyes as reproducible colors, the creation of newer colours, the improvement of the fatness process, and the affinity of dyes on all natural fibres.

Hence, the present study entitled **"Eco-Friendly Natural Colorant From Wood Waste Of "*Dalbergia Sissoo*" And Its Application On Wool Fabric"** was carried out with the following objectives

a. To screen and select the natural dye source from wood waste
b. To optimize dye extraction and dyeing parameters
c. To evaluate physical and functional properties of the dyed fabric

Experimental Approach

The study's methodology is detailed in the following steps:

- ✐ The study's base was made entirely of natural fibers - wool cloth.
- ✐ Dalbergia Sissoo sawdust, more commonly known as Indian Rosewood, was the dye source used for the study. The dye was isolated from sawdust of Dalbergia Sissoo using aqueous extraction.
- ✐ Alum powder was chosen as the mordant for the investigation.
- ✐ For dye extraction, several parameters such as dye source concentration (2.5%-12.5%), duration (30 - 90 min), temperature (30°C - 100°C), and pH were

optimized.

- The dyeing conditions were optimized using different parameters such as time (30min-90min), temperature (30°C-85°C), and material liquor ratio (1:10-1:50).
- Fabric was treated with selected mordant with various mordanting techniques. Dyeing was done at optimized conditions.
- The color strength of the optimum dyed cloth was assessed with a premier color scam spectrophotometer.
- The Anti-Bacterial and UPF of the dyed cloth was assessed using the appropriate standards.
- Physical properties such as fabric count, thickness, weight, stiffness, and absorbency through wicking and sinking were evaluated for the dyed fabric.
- The color fastness qualities of cloth to washing, crocking, light, and perspiration were investigated.

Research findings

- Concentration of 5% (*Dalbergia Sissoo*) was found to be optimum concentration for dye extraction.
- Optimum dye extraction time was found to be 30 min.
- Dey extraction was found to be maximum at 100°C
- The optimum material liquor ratio selected for the dyeing cotton fabric was 1:30
- Optimum dyeing time and temperature was found to be 30 min & 85°C respectively.
- Optimum pH was found to be 5.
- The dye uptake was found to be increased after using mordant (alum powder).
- The maximum uptake of dye was found in pre-mordanting technique.
- In pre-mordanting technique, the dye uptake was found to be good at 85°C
- Weight of the fabric was found to be increased in mordant dyed fabric (MDF).

- The thickness of the mordant dyed fabric (MDF) was found to be increased when compared to dyed fabric.
- The stiffness of dyed fabrics was found to be lower when compared to undyed fabric in both warp and weft direction.
- With regard to color fastness tests to washing, sunlight and crocking, the mordant dyed fabrics showed excellent fastness properties whereas the fabric dyed without mordant showed good fastness properties.
- In absorbency test, the wicking ability of mordant dyed fabric (MDF) was found to be increased. The sinking time was found to be increased in dyed fabric (DF).

Conclusion

According to the findings of this study, Dalbergia Sissoo sawdust extract is a possible natural dye source for textile dyeing. The dye extraction technique is ecologically benign and creates less contamination to the environment. The dye has excellent fastness qualities. The extraction and dyeing parameters have a considerable impact on the color qualities and fabric quality. The optimal circumstances were as follows: solvent as water, dye source concentration-5%, extraction time 30min, temperature 100°C, and pH 7, whereas the best dyeing parameters were M.L.R 1:50, dyeing duration 30min, temperature 85°C and pH 5. The introduction of a pre-mordant method resulted in excellent fastness qualities. This study clearly shows that the extract from Dalbergia Sissoo sawdust might be utilized as a source for natural dyes and for coloring wool fabric. The standardized dyeing procedure for natural dye yields unusual hues with high fastness features. At the same time, this has the potential to minimize the need of synthetic colors.

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