Faculty of Engineering
Department of Textile Engineering

Dyeing of Cotton Fabric with Mahogony saw dust Using Milk as Mordant

Course Code: TH-519 Course Title: Project (M. Engg.)

Submitted by:
Yasmin Nahar Shila
191-32-389

Supervised by:
Tanvir Ahmed Chowdhury
Head & Assistant Professor
Department of Textile Engineering
Daffodil International University

A project submitted in partial fulfillment of the requirements for the degree of **Master of Science in Textile Engineering**

DECLARATION

I hereby declare that this project has been done by me under the supervision of **Tanvir Ahmed Chowdhury, Head & Assistant Professor**, Department of Textile Engineering, Faculty of Engineering, Daffodil International University. I also declare that neither this project nor any part of this project has been submitted elsewhere for the award of any degree or diploma.

Yasmin Nahar Shila

ID: 191-32-389

Department of Textile Engineering

Daffodil International University

LETTER OF APPROVAL

This project report, prepared by Yasmin Nahar Shila (ID: 191-32-389), is approved as partial fulfillment of the requirements for the degree of Master of Science in Textile Engineering. I have supervised the student throughout his project work, and during the research period, I found Yasmin to be sincere, hardworking, and enthusiastic.

Tanvir Ahmed Chowdhury

Assistant Professor

Department Of Textile Engineering

Faculty Of Engineering

Daffodil International University

ACKNOWLEDGEMENT

Firstly, I express my gratitude to Almighty Allah for His divine blessings that have made it possible for me to successfully complete this project.

I am grateful to my supervisor, **Tanvir Ahmed Chowdhury, Head & Assistant Professor**, Department of Textile Engineering, Faculty of Engineering, Daffodil International University. His deep knowledge and keen interest in the field of textile finishing have influenced and inspired me throughout this project. I am thankful for his endless patience, scholarly guidance, continual encouragement, energetic supervision, constructive criticism, valuable advice, and his dedication to reading and correcting multiple drafts at every stage, which have played a significant role in the completion of this project.

I would like to express my gratitude to **, Tanvir Ahmed Chowdhury, Head & Assistant Professor,** Department of Textile Engineering, Faculty of Engineering, Daffodil International University, for his kind assistance in the finalization of my project report. I am also thankful to **All Faculty Members** for providing me with the necessary information to complete the report on time.

I would like to extend my thanks to all my course mates at Daffodil International University who participated in discussions and provided valuable insights during the completion of the coursework.

Finally, I would like to express my heartfelt gratitude to my beloved parents and friends for their unwavering support, strength, and assistance throughout the process of writing this project report.

DEDICATION

This project report is dedicated to my beloved parents and teachers

ABSTRACT

According to evidence, the usage of natural dye Mahogony(saw dust)on cotton fabric through a bio-based mordant, such as milk, has been incorporated in the study. Major objective of this research is to assess whether milk enhances uptake and fastness properties of dye on biocompatibility and antimicrobial potential of dyed samples. There are six samples of which three are mordanted with milk and three are unmordanted. Then, three pH levels were assigned for the dyeing-part: 4.5 or acidic, 7 or neutral, and 11 or alkaline-with the intention of viewing the influence of varying pH levels on dye absorption and fixation.

It was noted in results that colour fastness from alkaline dyeing at pH 11 was better than acid and neutral dyeing in terms of wash and rub tests. Most of the mordanted samples had intense color and more stable than those that were not mordanted, thus showing effectiveness of milk as a co-mordant when natural dyeing. Allergy screening tests were performed on all samples with no reactions and skin irritations thus confirming that the procedure is dermatologically safe. Antimicrobial activity tests further proved that those fabrics are not just penciling out lipids but possess inhibitory effects on selected bacteria strains, thus implying even more hygienic value.

Its study indicates that a transition from synthetic to natural dyeing is feasible in promoting Mahogony(saw dust)t and milk in sustainable textile dyeing as the environental friendly alternatives to synthetic colors and chemical mordants with promising functional properties required for skin contact textiles.

TABLE OF CONTENTS

Contents

CHAPTER-1

INTRODUCTION

1.1 Introduction:

Dyeing is a major process in the textile and garment value chains which involves application of dyes to textile materials. Dyeing is the most chemical intensive process in textiles and requires most synthetic dyes; often, high temperatures, adjunct chemicals, and mordants are required for effective dye-fiber interaction. Industrially, more than 10,000 types of dyes and pigments are recorded to be in use. More than 7 million tons of dye effluents are discharged into various water bodies every year (Yusuf et al. 2017). The environmental consequences of discharges of these effluents include aquatic toxicity, soil contamination, and disruption of microbial ecosystems. Most synthetic dyes also come from non-renewable fossil fuels which contribute to carbon emissions and resource loss.

To tap into this entire movement, new sources are being developed to replace the older synthetic ones; these include pulling in natural dyes into the fold of green chemistry and sustainable textile production in all forms. Such biomaterials are ones that are biodegradable, reuseable,renewable, and mostly non-toxic. They also tie into traditional knowledge systems that have utilized plant-based dyes for generations before the advent of industrial chemistry to be specific standards algebraic. Natural dyes do not easily maintain their color permanence over and above. Additionally, they do not show good reproducibility when they have been applied on cellulose fibers like cotton without the presence of mordants (Siva, 2007).

Since synthetic dyes have health and environmental risks, the textile industry has pursued environmentally friendly and durable coloring methods in recent years. Natural dyes developed from plant content are drawing as much attention as an alternative. I, i, mahogany sawdust, one of the products from the woodworking industry, has shown capacity as a natural source of dye. In addition, it is proposed as a more environmentally friendly alternative than regular metal -based mature that uses milk as a model.

Using Mahogony waste wood powder is also aligned with the principles of the circular economy and zero-waste design. This has all sorts of advantages by converting a waste into a resource for dyeing. Not only does it save waste but it also reduces the costs involved while presenting another sustainable input for dyeing. The other aspect to consider, which ultimately bridges the gap of extraction, is the ability of the dye to hold on to the fiber during wash or environmental stress and keep saving its color. This is where the role of a mordant becomes central. Traditional mordants used for fixing dyes to fabrics are alum ($KAl(SO_4)_2 \cdot 12H_2O$), iron sulfate ($FeSO_4$), copper sulfate ($CuSO_4$), and chromium salts ($K_2Cr_2O_7$). Toxicity, heavy metal build-up, and destruction of aquatic ecosystems are associated with these substances, considering that they render themselves completely impractical for dyeing towards sustainability. In contrast, there has emerged the innovation in bio-mordanting using a natural biodegradable and non-toxicity milk. It contains about 3-4% of proteins, mostly casein, having phosphate, carboxyl, and amino groups that create binding sites for both dye molecule and cellulose fiber (Gupta & Gulrajani, 1992). These chemical interactions will enhance the absorption and fastness of the dye but will not be affected by the term eco-friendliness in the process. They treat the fibers with whole milk or milk-soaked pre-treatments. Hence, it proteins the fabric very well in favoring dye-fiber affinity. Additionally, this commodity can be said to be available free, costless, and consumable; it is good for cottage industries, sustainable brands, or low-resource areas. Cotton is the predominant fiber worldwide, about 25% of the total consumption of textile fiber in the world. It is preferred due to its comfort, breathability, biodegradability, and renewable nature. However, its cellulose structure does not naturally have good bonding with most plant-based dyes unless they are submitted to chemical modification or mordantation. This renders such study of natural mordants like milk along with natural dyes such as tea relevant to the sustainable modern trendy textile research.

It is the cuddle and the breathability, the biodegradability, and also the perspective between the renewables that makes cotton the most consumed fiber the worldover accounting close to 25% of the total consumption of textile fiber in the world. On the contrary, this structure of cellulose does not naturally bond well with most dyes coming from plants unless they are chemically modified or mordanted. This makes the study of natural mordants like milk, in combination with natural dyes such as tea, quite relevant in terms of potential sustainable textile research in the present time. The chemistry involved in dye-fiber interaction includes a combination of chemical affinity, physical adsorption, and hydrogen bond formation. In the case of cellulose fibers that are cotton, dyeing with natural dyes becomes very difficult due to absence of amino groups normally found in protein fibers, such as wool and silk, which could facilitate better uptake of the dye. Thus, when dyeing cotton, mordanting is made important as it introduced intermediate bonding agents between the dye and the fiber. Casein proteins act as a natural adhesive layer for milk-treated cotton. The starches of casein can chelate the phenolic hydroxyl groups present in tannins (from tea dye) developing very stable complexes. Further, casein's potential for hydrogen bonding helps in absorption and retention of dye molecules on cotton cloth. The coating of protein practically changes the surface of cotton to that resembling a proteinaceous fiber, hence making it much more reactive towards tea-based polyphenols. Further, similar relevant research has analytical justification with studies on FTIR (Fourier-transform infrared spectroscopy) that involved proteinaceous mordants to enhance dye fixation (Sarkar, 2004).

Using milk as a mordant is not a new idea. In fact, both ancient Indian textiles and Egyptian textiles used such organic mordants as cow's milk or buffalo curds or even egg whites along with natural dyes. In Rajasthan and Gujarat, some of India's artisans still use pre-treatments with milk to facilitate block printing with natural vegetable dyes. While still being empirical in nature, these practices are now being revisited by means of modern analytical techniques to quantify their effect and validate that they are useful within commercial applications.

These traditional practices are scientifically studied and optimized in the content of this thesis, hence contributing to preserving culture while bringing in sustainable innovation.

1.2 Objectives

1. To extract natural dye from Mahogony (saw dust) for the dyeing of cotton fabric.
2. To investigate milk on its effect as a natural mordant for increasing the uptake and fixation of dyes in the cotton fibers.
3. To evaluate the color strength Shade of dyed cotton samples combined with milk mordant.
4. To determine the fastness properties for faded dyed fabrics such as wash fastness, light fastness, and rub fastness.
5. To compare color intensity and durability of milk-mordanting samples with that of non-mordanted samples.
6. To study the validity of using mahogony waste wood powder and milk for dyeing and mordanting as sustainable biodegradable alternatives to conventional approaches.

CHAPTER-2

LITERATURE REVIEW

2. Introduction:

2.1 Evolution of Textile Dyeing: A Thousand-Year Glorious Routes An ancient art practiced thousands of years ago, where plants, insects, and minerals were used for dyeing fabrics. Cotton is the most popularly used natural fiber throughout this world. Earlier, dyeing was done using different natural sources until synthetic dyeing started in the mid-19th century after the industrial revolution. Natural dyes are obtained from renewable sources like plant leaves, roots, barks, flowers, fruits, and even some insects and minerals. They are biodegradable and generally non-toxic, thus being a valuable alternative to synthetic dyes, which are mainly polluted and hazardous (Bechtold & Mussak, 2009).

2.2 Importance of Natural Dyes: In fact, in recent years, environmental issues, including liquid effluents that are toxic, bioaccumulating, and possibly carcinogenic, from certain synthetic dyes, have made people pay more attention to natural dyes. Advantages of natural dyes include eco-friendliness, sustainability, and health safety (Saxena & Raja, 2014). Gradually, natural dyeing is coming into the limelight in academic, industrial, and consumer sectors due to the increasing demand for sustainable fashion, organic textiles, and green processing technologies.

2.3 Objectives of Review: The review set out the following objectives: Explore natural dye historical developments. Classify and describe the different types of natural dyes applicable to cotton. Study the methods of dye extraction and applications. Explain the techniques of mordanting and their effects on dye uptake and fastness. Analyze the environmental, economic, and technical implications. Identify research gaps and recommend future directions. Historical Perspective Natural Dyeing Practices

2.3.1. History: Natural dyeing proved during the sites of ancient civilization: as early as 2600 BCE have crystalline artifacts. Evidence of textiles dyed with Indigo and madder have come from excavation sites, showing the high sophistication of the earliest techniques in dyeing (Cardon, 2007).

Dyeing techniques used by ancient Egyptians were plant-based, such as woad and safflower for dyeing linens, while mulberry leaves and indigo plants were heavily exploited in China for traditional textile levels. In Peru and Central America, vibrant shades of red were obtained from cochineal insects on cotton fabrics, which should be considered as socially and culturally identity markers and status symbols (Balfour-Paul, 1998).

2.3.2 Traditional Uses:

India: Famed for its crafts in dyeing with natural dyes, particularly indigo, turmeric, and madder. The cotton dyeing and printing "chintz" methods were in great demand in Europe during the late 17th and 18th centuries (Gulrajani, 2010).

China: Made use of all various types of plant dyes along with resist dyeing techniques like tie-dye and batik.

Middle East: Kermes, saffron, and several others that are endemic to the area were utilized for dyeing cotton and wool textiles.

Europe: In Europe, madder and woad were the main dyes before indigo from Asia came into the picture.

2.4 Move from Natural Dyes to Synthetic

: The most significant transition in dye history: 1856, when William Henry Perkin discovered mauveine, the first man-made dye derived through chemical processes. The discovery of man-made dyes was a real chemical revolution because it permitted, for the first time, the mass production of brilliant, fast, and reproducible shades at lower prices (Perkin, 1901).

In due course, artificial dyes slowly replaced natural ones because they lasted longer, were easily available, and easier to apply. Yet, in the late 20th century, awareness began to dawn over the environmental and health hazards stemming from synthetic dyeing, thus understanding sustainable textile production that began showing interest in natural dyes again.

2.5. Cotton as a Medium for Natural Dyeing

2.5.1 Organization and Features of Cotton Fibers

Cotton is a natural fiber albeit a cellulose fiber; composed of primarily cellulose, a polysaccharide of glucose units. Its features include high crystallinity, hydroxyls that can hydrogen bond, and, thus, are fairly hydrophilic, which is important in the uptake of dyes, making them very good for natural dyeing procedures (Kadolph & Casselman, 2004).

The primary hydroxyl groups in cellulose are the most active reactive sites for the natural dyes especially when a mordant is present. Cotton also has given an advantage for such penetration by its high water affinity making it tender for dye molecules, although there are no protein-based functional groups like those in wool or silk for fixation without proper pretreatment or mordanting.

2.6 Preparing Cotton for Dyeing

To dye cotton, it must first be cleaned and prepared to ensure good dye uptake. These procedures are:

A- Desizing: This includes taking off for sizing agents, which usually include starch added during weaving.

B- Scouring: Removal of natural waxes, oils, and a few impurities using an alkaline treatment, usually by sodium carbonate or caustic soda.

C-Bleaching (optional): hydrogen peroxide is sometimes employed to increase whiteness and brighten a color.

The proper pretreatments open up the chances of hydroxyl groups making them more receptive to the dye and more even in distribution.

2.7 Demand and Constraints of Dyes

While cotton provides an excellent substrate for many natural dyes, there are, however, some constraints. Most importantly, it does not bond well with many plant-based colorants compared to protein fibers. Hence, this means that mordanting in itself becomes a critical process for ensuring proper fixation, fastness, and yield of color. Dyeing conditions such as the pH level, temperature, and time must be optimized carefully (Samanta & Konar, 2011).

2.8. Sources of Natural Dyes

2.8.1 Plant-Based Dyes:

Plant-based sources represent the most common sources of natural dyes, such as leaves, roots, bark, flowers, fruits, and seeds. Notable examples include: Indigo (Indigofera tinctoria): Extracted from leaves; provides blue shades.

Madder (Rubia tinctorum): Root-based dye; giving red to pink shades due to alizarin content.

Turmeric (Curcuma longa): Rhizome-based; impart yellow hues.

Pomegranate (Punica granatum): Rind extract used for yellow to greenish tones.

Henna (Lawsonia inermis): Leaves produce reddish-brown.

These plant-based dyes are sustainable and extensively researched regarding their bioactivity and dyeing properties (Gulrajani, 2010).

2.8.2 Insect-based dyes

Insects that have historically been used in producing rich colors include:

Cochineal (Dactylopius coccus): This little insect that lives in cacti produces carmine acid, from which crimson and scarlet colors result. Lac (Kerria lacca): The lac dye is produced biologically and has been mainly employed in the production of purple to red shades.

Insect-derived dyes therefore show very good tinctorial strength, general resistance to light and washing by mordanting them (Cardon, 2007).

2.8.3 Mineral and Other Sources

Though rarer, some minerals were also found to be useful in natural dyeing:

Ochre: A naturally occurring earth pigment containing iron oxide, used for earthy yellow to red colors.

Charcoal and ash for gray and black tones at times.

Other natural sources include fungi and lichens, though their use is limited due to availability and sustainability concerns.

2.8.4 Synthetic Vs Natural Dyes:

Comparative Aspects Natural dyes, unlike synthetic dyes, are:

- Biodegradable and eco-friendly.
- Very often require mordants for achieving fastness.
- Variations in shades depending on the source of the plant and methods of extraction.
- Offer functional benefits, such as antimicrobial, UV-protective, and antioxidant properties (Saxena & Raja, 2014).
- But then, synthetic dyes completely dominate the market on uniformity, factor of cost, and simplicity of application.

2.9. Extraction Procedures and Application Techniques

2.9.1 Extraction Techniques for Natural Dyes

The methods of extracting natural dyes depend on the source of dye and its application. The most widely adopted and common methods are:

Aqueous: Plant materials boiled in water extract soluble dye components. This is the most traditional and widely practiced method.

Acid/alkali: By modulating pH, particular classes of compounds may be extracted from the plant tissues. For instance, anthocyanins can be extracted in acidic conditions.

Solvent extraction: Organic solvents like ethanol, methanol, or acetone are used for isolating dyes from plant materials, particularly flavonoids and carotenoids.

Enzymatic extraction: Enzymes like cellulases or pectinases can deconstruct plant cell walls and enhance additional dye yield.

Ultrasonication/Microwaves-Assisted Extraction: Modern techniques fasten dye extraction, increase yield while conserving energy (Saxena & Raja, 2014).

2.9.2 Preparation of Dye Baths

Once extracted, the dye solution must be filtered and concentrated to provide the dye bath. Concentration, pH, and temperature of dye baths are critical parameters that determine dye uptake. Some dyes need fermentation (indigo) or reduction prior to application.

2.9.3 Mordanting Techniques:

Mordants are substances that affix dyes to fibers and enhance their fastness properties. Mordanting techniques include:

Pre-mordanting: Mordanting cotton (alum, iron, tannin) before dyeing.

Simultaneous mordanting: Mordant and dye are introduced together to the fabric in dyeing.

Post-mordanting: The dye is then mordanted after dyeing.

Common mordants include alum (potassium aluminum sulfate), iron (ferrous sulfate), copper sulfate, and tannic acid. Natural mordants such as myrobalan, harda, and pomegranate peel have been gaining interest for their eco-friendly properties (Gulrajani, 2010).

2.9.4 Dyeing Procedures:

Temperature: Generally set between 60-90 degrees Celsius.

Duration: A duration of 30 minutes to 1 hour is dependent on the type of dye and fiber.

Agitation: To assist in uniform dye uptake.

Post-dyeing, rinsing, and drying are necessary to remove unfixed dye and thus stabilize the shade. Further dyeing (layering) might be carried out to enhance the depth of the color.

2.10 Relevance of Mahogony saw dust in Dyeing

Mahogany sawdust, as a natural byproduct of woodworking, has been investigated for its potential use in various applications, including dyeing, due to its chemical composition. especially for tannins content and for its rich color . it is also an ecofriendly dyeing process.

Using sawdust in dyeing processes supports sustainable practices, as it repurposes waste material from the timber industry. This is important in reducing environmental waste and offering a more eco-friendly alternative to synthetic dyes, which are often toxic and contribute to pollution.

2.10.1 Purpose of the Literature Survey

This literature review, therefore, is aimed at examining Mahogony saw dust extract in relation to four aspects: the chemical composition and extraction methods, dyeing processes, and application in using it as dye source in textiles. This review would also seek to assess the barriers and limitations of mahogany saw dust dyeing in its fastness properties and the prospective ecological dye substitute in the textile industry.

2.11. Chemical Composition of mahogany wood waste powder:

2.11.1 Tannins :Mahogany wood, like many other hardwoods, contains tannins (a type of polyphenol compound). Tannins are known to act as mordants in natural dyeing processes. Mordants help fix the dye onto fibers, making the color more vibrant and longer-lasting.

2.11.2 Rich Color : Mahogany sawdust may impart a reddish-brown color when used in the dyeing process, which can be desirable for textile or leather materials. The color comes from the natural pigments in the wood, which are released during the dyeing process.

2.12. Method of Mahogony saw dust Preparation for Dyeing

2.12.1 Mahogony saw dust Dye Extraction Process

Extraction of the tea dye may be performed by several means which include boiling, steaming and cold infusion.

- **Powdered Sawdust**: The sawdust can be boiled or soaked to release its natural colorants. It can then be used as a dye for textiles, leather, or paper products.

- **Extracting Dye**: By boiling mahogany sawdust in water and then straining it, you can create a natural dye bath. The pH of the solution can be adjusted (with acidic or alkaline substances) to affect the final color.

- **Natural Mordants**: You can use natural mordants like milk, alum, iron, or vinegar to enhance or alter the color of the dye.

2.12.2 Temperature, Time and Concentration Effects:

Temperature and time play an important role in dyeing. Higher temperature may favorably bring increases in the extraction of those polyphenolic compounds which bring color and increases the time to extraction for more dye to be leached from the tea leaves. The concentration of dye extract is also responsible for the shade of color produced on fabric.

2.12.3 Comparison of Different Extraction Methods

Indeed, boiling remains the commonest method for extracting the Mahogony saw dust dye. Some researchers have also compared its efficacy with other methods such as microwave-assisted extraction, ultrasound-assisted extraction, and enzymatic methods. Such processes may be more advantageous in extraction times, amounts of dye yielded per sample, and reliability of results (Gulrajani et, al., 2011).

2.13 Technique and processes for dyeing

2.13.1 Preparing Cotton for Mahogony saw dust Dyeing

Proper pre-treatment removes impurities or residues that preclude dye absorption, usually, this is done pre-washing with water or a mild detergent. For better dye uptake, cotton can also be pre-treated with a mordant like alum; both increase intensity and fastness.

2.13.2 Mahogony saw dust Dyeing Process

The procedure includes pre-treated cotton being placed in the dye bath. Temperature and time of dyeing are vital for the final color. The dyeing temperature is usually in the range of 60°C-90°C, and the dyeing time is about 30 minutes to 2 hours, depending on the requirement for color intensity.

2.14 The Effect of Mordants on Mahogony saw dust Dyeing

A mordant is a chemical substance that serves for fastening the dye to the fabric. Among the most commonly used kinds for mahogony saw dust dyeing are alum, iron, and tannins. Although mordants may help cast colors into more depth or improve permanence characteristics of the dyed fabric, for instance, it often shows using a pale or partial color with alum.

2.15 Dyeing Parameters: Temperature, pH, and Time

Many different kinds of parameters are involved in tea dyeing; for example, the temperature of the dye bath, the pH, and time. Darker shades are obtained when temperatures and dyeing times are high, while lighter shades are obtained when there are low temperatures and short times. The pH of the dye bath can also make an alteration to the final color as some compounds of tea are also pH-sensitive.

2.16 Color Outcomes of mahogany saw dust Dyeing :

When dyeing with mahogan ywaste wood powder, the color variation primarily depends on factors like the type of wood, the concentration of dye, the method of application, and the wood's natural grain structure. Mahogany wood, known for its rich reddish-brown tones, can yield a range of hues when used in dyeing processes. Here are a few key aspects that influence color variation in mahogany wood powder dyeing:

1. Wood Type and Quality

- **Different Mahogany Species**: There are several types of mahogany (e.g., Honduran, African, and Cuban mahogany), and each can have a slightly different base color. Some may have a more pronounced reddish hue, while others lean more toward brown or golden tones.

- **Wood Aging**: The age of the wood can affect its color. Older wood often has deeper, richer tones compared to newer, fresher wood that may appear lighter.

2. Concentration of Dye

- **High Dye Concentration**: A higher concentration of mahogany powder will create deeper, more intense colors (usually darker reds and browns).

- **Low Dye Concentration**: When diluted, the powder will produce lighter, subtler shades—ranging from pale reddish tones to light brown.

3. Application Method

- **Brush Application**: Brushing on the dye may produce a streaky or gradient effect, with darker colors where more dye is applied and lighter tones where less dye is used.

- **Dip Dyeing**: Submerging the wood in a dye bath tends to produce a more uniform color, but the time the wood is left in the dye can influence how deep or light the color turns out.

- **Spray Application**: Spraying the dye on wood can create a more even and subtle color distribution, but may not bring out as much depth as other methods.

4. Wood's Natural Grain

- **Grain and Texture**: The unique grain patterns of mahogany can influence how the dye absorbs into the wood. Harder or denser sections may absorb less dye, resulting in a lighter color, while softer or more porous sections may take the dye more readily, creating a darker hue.

- **Wood Moisture Content**: The moisture content of the wood can also affect how it accepts the dye. Drier wood may absorb more dye, leading to deeper hues, while fresh or green wood might not take the color as well.

5. Environmental Factors

- **Temperature and Humidity**: These can affect how quickly the dye sets and how deep the color becomes. Warm, dry conditions may cause the dye to dry faster and potentially result in a more uneven tone.

- **Sunlight**: Prolonged exposure to sunlight can cause the color of the dye to fade over time, especially with natural, plant-based dyes like mahogany wood powder.

6. Finishing Products

- **Varnish or Oil**: After the dyeing process, applying a varnish or oil finish can enhance or slightly alter the final color. Some finishes can deepen the color, while others may bring out the natural wood tones more, depending on whether they are matte, gloss, or satin finishes.

7. Layering or Blending

- **Layering**: Some people like to apply multiple layers of dye to build up color depth. The number of layers applied, as well as the drying time between layers, will influence the final tone of the wood.

- **Blending with Other Dyes**: To achieve a more unique color, mahogany wood powder can be blended with other types of wood powders or dyes. For instance, mixing mahogany with walnut or cherry wood powder can create a more complex color palette with varied undertones.

2.16.1 Possible Color Results:

- **Deep Red-Brown**: A typical mahogany dye will often have a deep reddish-brown appearance, similar to the natural wood's color but more intense.

- **Light Reddish Hue**: Lighter applications can give you a more pastel or muted reddish color.

- **Golden-Red Tone**: Sometimes, mahogany can produce a goldish undertone, especially when applied lightly and allowed to absorb unevenly.

- **Warm Brown**: Depending on the wood's natural characteristics, some mahogany powder dyes may turn out with more brownish hues instead of reddish.

2.17. The Different Fastness Properties of Dyeing

2.17.1 Color Fastness to Light

One of the problems in natural dyeing, including mahogany wood waste, has to do with how far the color lasts, especially under light. Most of the natural compounds in mahogany wood, especially tannins and flavonoids, have a property of fading away with time due to the exposure of the dye to UV radiation from sunlight. So, in case of using tea as a dye for textile, light fastness becomes a major issue.

Factors Affecting Light Fastness: The type of wood used and the concentration of dye extract in the dyeing bath can influence light fastness. The use of mordants, particularly those very rich in iron, can also improve light fastness by strengthening the dye bonds.

Improving the Light Fastness of Dyed Fabrics: Improvement of light fastness of mahogany wood waste dyed fabrics has been proposed by researchers in form of post dyeing treatments like UV protective agents or fixatives. Alum, for instance, is one of the mordants that prevent the fading of such dyes by making them much more resistant to UV degradation.

2.17.2. Wash Fastness

Wash fastness is an equally vital property for considering the permanence of the mahogany dyeing. Being a natural dye, generally does not retain wash fastness like synthetic dyes. After washing multiple times, such fabrics might fade or lose color. This is remedial to some extent through proper mordanting and treatment after dyeing.

The Influence of Mordants on Wash Fastness: With mordants, particularly alum and iron, wash fastness is improved as these metal ions help in attaching the dye better to cotton fibers. Iron enhances fixation of the dye much more, making the color remain stable in passing through many wash cycles. Even the wash fastness with mordants would generally be lesser than synthetic dyes.

Improving Wash Fastness: Washing techniques such as hand washing with cold water and avoiding strong detergents can help protect the color to some extent. Further application of a fixative after dyeing enhances the wash fastness of mahogany saw dust-dyed fabric. Natural mordants that are known to afford the wash fastness are some tannin extracts from pomegranate .

2.17.3. Factors Affecting Dye Stability

Dye stability, in the case of mahogany, is influenced by various factors such as temperature, humidity, pH, and airborne pollution. Stability of mahogany wood waste dyes may surely be better than some other plant-derived dyes; they are susceptible to environmental factors. Thus, proper care and handling with regard to storage of tdyed textiles are required for extended retention of their colors.

2.18. Mahogany saw dust Extract as an Eco-Friendly Alternative

2.18.1. Environmental Impact Comparison with Synthetic Dyes

1.Environmental Impact

- **Mahogany Sawdust Dye (Eco-Friendly)**
    - **Sustainable Source:** Mahogany sawdust is a byproduct of woodworking, which means it's essentially waste that can be reused. If sourced responsibly from sustainable forests or plantations, the impact

is minimal.

  - **Biodegradable:** Natural dyes, including those from mahogany sawdust, tend to be biodegradable and don't pollute the environment in the same way synthetic dyes do.
  - **Less Chemical Waste:** Creating a natural dye from sawdust requires fewer chemicals and energy compared to the industrial processes used for synthetic dyes.

- **Synthetic Dyes**
  - **High Environmental Footprint:** Synthetic dyes are often derived from petroleum or coal, which are non-renewable resources. The production process can release harmful chemicals into water systems and soil.
  - **Toxic Waste:** Many synthetic dyes contain heavy metals (like cadmium, chromium, and lead) or other toxic substances. Their production can lead to significant environmental pollution, especially in developing countries with lax environmental regulations.
  - **Non-biodegradable:** Synthetic dyes do not biodegrade easily, which means they can persist in the environment, especially in wastewater, where they pose long-term risks to aquatic life.

2. Health and Safety

- **Mahogany Sawdust Dye (Eco-Friendly)**
  - **Non-Toxic (if properly processed):** Natural dyes made from plant and wood sources tend to be much safer for human health. There's minimal risk of chemical exposure if the dyeing process is done with care and proper ventilation.
  - **Allergy Considerations:** Some people may be sensitive to certain natural dyes, although this is relatively rare.
  - **No Harmful Additives:** Typically, natural dyes don't require the addition of harmful chemicals or fixatives unless you're using certain

mordants (e.g., alum, which is usually safe).

- **Synthetic Dyes**
    - **Toxic Ingredients:** Many synthetic dyes contain chemicals that can be harmful to human health, such as azo dyes or other carcinogenic compounds. Workers in dye factories or those handling synthetic dyes without protective equipment can be at risk.
    - **Skin Irritation:** Some synthetic dyes can cause skin irritation or allergic reactions, especially for people with sensitive skin.
    - **Residue:** Some clothing dyed with synthetic dyes may release residual chemicals into the skin or the environment, even after washing.

3. Colorfastness and Durability

- **Mahogany Sawdust Dye (Eco-Friendly)**
    - **Colorfastness:** While natural dyes, including those from wood like mahogany, can produce rich and beautiful colors, they often don't have the same level of colorfastness (resistance to fading from washing, light, or exposure to chemicals) as synthetic dyes. However, using mordants can help improve this.
    - **Fading:** Mahogany-based dyes may fade over time, especially if exposed to direct sunlight or frequent washing. The natural hues they produce (typically shades of brown, red, and amber) can still look beautiful, but the longevity may be shorter than synthetic dyes.
- **Synthetic Dyes**
    - **Superior Colorfastness:** Synthetic dyes, especially modern ones, are engineered to be more durable. They generally provide brighter and more vibrant colors that don't fade as quickly, even after multiple washes or exposure to sunlight.
    - **Consistency:** Synthetic dyes are consistent in terms of shade and quality. They can be controlled to produce uniform colors in large batches, which is crucial for commercial use.

2.18.2. Sustainability of Mahogony saw dust Dyeing

Minimal Resource Use: The dye is essentially a "waste product" from woodworking, meaning it's a form of recycling. As long as the mahogany comes from sustainably managed forests, the environmental impact is relatively low.

Local Sourcing: You can often obtain mahogany sawdust from local woodworking shops, which reduces the carbon footprint associated with transportation

Low Cost (if DIY): If you're collecting and processing the sawdust yourself, it could be a very affordable option, especially if you already have access to the raw material.

2.19. Applications of mahogany saw dust Dyeing in the Textile Industry

Increasingly, this is being employed in diverse sectors of the textile industry from the aspect of fashion to interior design. The very basis that it is eco-friendliness, simplicity of the process, and availability of materials make it popular in making today's sustainable textiles.

2.19.1. Fashion and Apparel

With the increasing demand for eco fashion, consumers now switch to other substitutes for mass-produced textiles, mostly preferring the sustainable and natural sources. This is one of those methods popular among designers specializing in eco and organic and responsible fashion. The shades that mahogany wood produces, combined with the sustainable dyeing process, are perfectly aligned with the principles of such eco-friendly clothing. It is ideal for creating vintage-influenced garments like dresses, scarves, and accessories, most of which are created in a bohemian style by using mahogany saw dust dyed fabrics.

2.20. Mahogany saw dust Dyeing in Home Textiles and Crafts

2.20.1. Home Textiles: Bedding, Curtains, and Towels

This dyeing has attracted much attention in the home textile sector due to its sustainability and unique shades that come out as highly aesthetic. Bed linens, towels, tablecloths, and many other home textile products are being dyed with mahogany saw dust to impart a natural vintage look to them.

Curtains and Drapes: Mahogany saw dust dyeing is also used to create soft muted colors for curtains and drapes that help achieve the warm natural feel, so that tea-dyed curtains have that vintage feel or rustic touch, which melds perfectly into a natural design theme at home. With the increasing popularity of minimalistic, eco-friendly home designs,Mahogony saw dust dyed fabrics now appeal most to those who want an organic interior aesthetic.

2.20.2. Craftsmanship and Textile arts

This is an old technique that has served textile arts since time immemorial, especially in handicrafts and DIY projects. Crafters use it to impart some character to fabrics, aging them for use in quilts, embroidery, and other crafted items. So much so, it is simple, inexpensive, and the mahogany saw dust makes for an easily available, harmless dyeing medium.

2.21. Challenges Associated with mahogany saw dust Dyeing

While this dyeing comes with many advantages, there are also challenges and limitations attached when adopting this method for large-scale production or commercial applications.

2.21.1. Color Consistency

Natural Variation: Color output depends on factors such as the **age**, **species**, and **origin** of the mahogany wood.

Batch-to-Batch Differences: Even sawdust from the same tree can yield slightly different shades, making standardization difficult.

2.21.2. Mordant Dependence

Requires the use of **chemical or natural mordants** (e.g., alum, iron, copper) for: Better color fixation andImproved fastness properties.
Some mordants, especially **metal salts**, may reduce the eco-friendly appeal and require proper handling and disposal.

2.21.3. Limited Color Range:

Typically produces browns and reddish-browns.Lack of vibrant or diverse shades can limit its use in fashion and textile industries that seek bright, varied palettes.

2.21.4. Labor-Intensive Process

Requires multiple steps:Extraction,Mordanting,Prolonged dyeing and post-dyeing treatments andNot ideal for fast or high-volume industrial applications.

2.21.5. Resource Intensity

Large quantities of sawdust may be needed for deep shades.High water and energy usage (especially during boiling and dyeing stages) can be a concern in **scaling up** the process.

2.21.6. Wood Processing Contaminants

Sawdust may contain:Glue, varnish, or chemical residues if sourced from treated wood.These can interfere with dye quality or pose environmental/health risks.

2.22 Sensitivity to Environmental Factors:

Being a natural dye, it is very sensitive to its surroundings. Light, moisture, and pollution have all been known to affect the durability and overall appearance of mahony saw dust dyed fabrics. When exposed to sunlight or aggressive cleaning practices, dyed fabrics may, therefore, be substantially more susceptible to fading than their synthetic-dyed counterparts

2.23. Innovations and Future Directions in mahogany saw dust Dyeing:

2.23.1. Improving Stability and Fastness of the Dye

Recent work has aimed toward stabilizing the dye in the most fast way, focusing on the use of mordants and post-dyeing treatment of fabrics with tea extract. Progress of this kind in modern innovation intends to stabilize saw dust dyed fabric against light, washing, and abrasion from machinery so they can be fashioned into textiles that could be in use long-term.

Cutting-edge mordanting: New mordanting procedures are being considered in order to enhance penetrability into the fabric and fastness of the dyes. One instance may include a blend of the traditional mordant alum and some innovative fixatives, which would bolster against fading and washing.

Natural Fixatives: The making of natural fixatives from other plant-based sources, such as pomegranate or sumac, is another promising area. These fixatives could be used next to this dye as a more durable dye combination.

2.23.2. Scaling Mahogony saw dust Dyeing for Commercial Use

A growth of interest in the eco-friendly products today is likely to spell a bright future for the this dyeing technique in the production of textiles for commercial use. The challenge would be finding cost-effective modes of dyeing that are practical for bulk fabric runs without compromising consistency and quality. Use of the batch dyeing machine specifically for natural dyes could be one such answer to the limitations posed by traditional dyeing methods.

Green Extraction Technologies

Ultrasound-assisted extraction (UAE):
Enhances dye yield by breaking down cell walls using sound waves.Reduces extraction time and energy consumption.
Microwave-assisted extraction (MAE):
Speeds up dye extraction and improves color strength.Uses less water and solvent compared to traditional boiling.

Hybrid Dyeing Techniques: Combine natural dyeing with digital textile printing as Use mahogany dye as a pigment base in ink formulations.Opens the door to precision patterns and scalability.

2.24. Mahogany saw dust Dyeing in Eco-Fashion and Sustainable Apparel

2.24.1 The Greener the Demand for Fashion

This dyeing has recently gained quite a reputation in the emerging eco-fashion industry-especially regarding sustainable and low-impact garments. This section sets the scene for the rise of this dyeing in light of environmentally friendly fashion and industry advantages.

Dyes based on wood waste, which would otherwise end up in landfills as they are biodegradable, help fashion designers to limitedly rely on harmful, non-renewable chemicals.

Energy-Saving: This dyeing procedure typically requires relatively low temperatures and less time than other conventional dyeing processes using synthetic dyes. Therefore, this dyeing saves energy, making it more eco-friendly.

Limited Waste: The biodegradable ingredients used in mahogany saw dust dyeing, sometimes considered waste products themselves , generate very little waste in comparison to traditional dyeing processes.

2.24.2. Garment and Accessories with mahogany saw dust Dyeing

Garments and accessories that are fully eco-friendly are made from saw dust-dyed fabrics. The types of eco-friendly garments made include dresses, scarves, handbags, and hats. The soft earthy tones of tea-dyed hues are well-suited to adorn such fashion items as could incorporate the natural beauty and sustainable materials' aspects.

Organic Clothing Lines: mahogany wood waste-dyed fabrics render a natural and rustic appearance, which corresponds well with the growing consumer interest in slow fashion-a movement supporting high-quality sustainable wear against fast fashion.

Upcycled Fashion: The dyeing procedure also finds a place in some upcycling projects aimed at giving a new life to discarded or unwanted garments via dyeing. This behavior falls under zero-waste philosophies, where the focus is on minimizing textile waste through reuse and repurposing. This dyeing is an environmentally friendly and cost-effective way to enhance second-hand clothing.

2.24.3 Challenges Associated with Eco-fashion

While mahogany saw dust dyeing has a lot to offer in sustainable fashion, challenges must also be addressed. Some of these challenges relate to the technical issues of dyeing, while others result from market requirements and consumer preferences.

Market Demand and Color Preferences: The earthy, subdued tones resulting from this dyeing are beautiful. However, they may not appeal to all consumers nor correspond to the major fashion trends today, which are bold, bright colors. Designers and manufacturers should therefore figure out ways by which such colors can be used in popularity in mainstream fashion.

Color Fastness: Another major consideration regarding the application of saw dust dyeing in fashion is that the dye fades with time - especially after repeated washing. This concern poses problems, particularly for articles such as garments, which undergo frequent laundering. Improvements in the wash fastness and light fastness of dyed fabrics through more effective mordanting or by application of natural fixatives (pomegranate, sumac, etc.) are being studied by researchers.

2.25. Cultural Significance of Mahogany Sawdust Dyeing

2.25.1. Connection to Traditional Craft and Natural Dyeing

In many cultures, especially in Africa, Asia, and Latin America, plant-based dyeing is part of an ancient heritage.
Although mahogany sawdust itself is not among the most widely used traditional dyes (like indigo or madder), it can be a modern extension of traditional natural dye practices.also Seen as a continuation of cultural stewardship of forests and nature-based craftsmanship.

2.25.2. Symbolism of Mahogany Wood

Mahogany (from the *Swietenia* genus) is a symbol of strength, wealth, and status in many cultures due to Its deep reddish-brown color. and Use in high-quality furniture, carvings, and ceremonial objects.
Using its sawdust for dyeing connects textiles to the symbolic and spiritual value of the tree, elevating cloth from a functional item to a storytelling medium.

2.25.3 Local Identity and Textile Storytelling

Communities involved in handloom weaving and natural dyeing (e.g., in Ghana, Indonesia, or the Amazon) may begin to incorporate mahogany sawdust into: Region-specific patterns or motifs.Natural dyeing narratives that preserve local identity and folklore.This fosters place-based aesthetics, where the source of the dye becomes a key part of the cloth's cultural story.

2.25.4. Ritualistic and Ceremonial Potential

Mahogany-dyed cloth could be used in: Weddings, funerals, or ancestral rituals, where earthy tones carry symbolism of grounding, lineage, and continuity.Traditional garments or ceremonial wraps in regions where mahogany trees are native and revered.

2.25.5. Contemporary Cultural Movements

In modern slow fashion and eco-art circles, mahogany dyeing reflects:
The blending of ancient and modern craft practices.A philosophical shift toward "material consciousness"—knowing the origin and lifecycle of what we wear.

2.26. Mahogany saw dust Dyeing Process and Techniques: An In-Depth Traversal

2.26.1.Preparation of Mahogany Sawdust for Dyeing

Step 1: Source the Right Type of Sawdust

After collecting sawdust from untreated mahogany wood — preferably *Swietenia mahagoni* or *Swietenia macrophylla*. and Avoiding Varnished, painted, or chemically treated wood
Sawdust from plywood or MDF boards (may contain glue and toxins)

Step 2: Sieve and Sort

Then we have to use a fine mesh or sieve to remove Larger wood chips Nails, debris, or plastic contamination

Step 3: Wash

Rinsing the sawdust with cold water to remove Dust,Soil particles, Surface sap or resin and
drain and spread on a mesh or cloth to air dry in a shaded, ventilated area.

Step 4: Drying

Ensuring the sawdust is completely dry before storage or use to prevent mold and decomposition and Avoid sun-drying as UV light may degrade natural pigment compounds.

Step 5: Storage

Storing the clean, dry sawdust in airtight containers or bags in a cool, dry, and dark place

2.26.2. Process and Techniques of Dyeing

Dyeing will start only once the tea extract is prepared. The practical dyeing process involves several factors Temperature, immersion time, and agitation.

Prewashing and Preparing the Fiber: Prewash before mahogany saw dust dyeing for any oils or dirt or chemicals to wash out, which would inhibit dye absorption. The preparation allows the fabric to absorb dye evenly. For this dye and other natural dyes, it is also appropriate to remove any synthetic finishes from the fabric to maximize uptake.

Temperature and Dye Bath: For saw dust dyeing, it is usually advisable to set it up between 60°C to 90°C. The temperature must be well monitored, because either too hot can destroy the fabric, or too cool may not make the dye uptake process possible. It is lowered in the dye bath in amounts into the dye bath for a time of 30 minutes to several hours, depending on the strength of color desired.

Aggitation and Uniform Dyeing: Continuous gentle agitation or stirring of the fabric ensures an even distribution of the dye solution. This step helps prevent uneven staining or blotches, resulting in a more uniform appearance. Care must be taken not to over-agitate the fabric, as this could lead to unnecessary stretching or distortions in the fiber structure.

Rinsing and Drying; The fabric is taken from the dye bath once it has acquired the desired shade and then thoroughly rinsed in cold water so that any excess dye is washed away. The fabric must be rinsed until the water runs clear so it can be ascertained that loose dye particles have all been washed away. This must then be air dried in the shade, not in the sun, to avoid fading.

2.26.3. Variation in Color

There are different reason of variation in color in mahogany saw dust dyeing.

Species and Source of Mahogany:There are different types of mahogany (e.g., Honduran, African, Philippine).Each species has different levels of tannins, natural oils, and pigments, leading to different dye hues — from reddish-brown to golden-brown.
Age and Part of the Wood:Heartwood vs. sapwood: Heartwood is usually darker and richer in colorants.Older wood tends to be more resinous and can yield deeper shades.
Particle Size of the Sawdust:Fine sawdust leaches color more efficiently and evenly than coarse chips.Uneven particle sizes can result in patchy dye extraction and inconsistent results**.**
Water Quality and pH:The pH of water used in the dye bath affects color.Acidicwater may yield brighter tones.Alkaline water can dull or deepen the color.Iron content in water can also affect the dye tone (iron acts as a mordant, darkening the dye).
Soaking/Boiling Time and Temperature:Longer extraction times generally yield deeper, richer colors.Over-boiling can degrade some pigments, leading to muted or inconsistent tones.
Mordanting:Adding mordants (alum, iron, copper, vinegar) affects the final shade and fastness.AlumEnhances brightness,Iron Darkens the tone,CopperCan add greenish or gray undertones
Fabric or Material Type:Natural fibers (cotton, silk, wool) absorb dye differently.Pre-treatments (scouring, mordanting) can enhance uniform uptake.

.

2.26.4. Mahogany saw dust Dyed Fabrics Post-Treatment

Post-treatment of mahogany sawdust–dyed fabric is crucial to enhance colorfastness, longevity, and vibrancyof the natural dye. Since natural dyes like those from mahogany contain tannins and phenolic compounds, they benefit greatly from proper post-dye care.

Rinsing**:**After dyeing irnsing the fabric in cold water until the water runs clear.This removes excess dye particles that didn't bond and prevents crocking (color rubbing off).Avoidind harsh wringing; be gentle to avoid fabric stress.
Post-Mordanting (Optional, but Recommended):If not mordanted before dyeing, or to enhance fastness. Dipping the dyed fabric briefly (1–5 min) in a diluted iron bath (0.5–1% w/v).It darkens color (reddish-browns become deeper browns/greys).
Alum Can be used if you want to brighten the color or improve wash fastness.
Copper sulfate can be used to give greyish/olive tones.
Fixatives (Natural Alternatives):Soy milk soak (before dyeing or after as a post-treatment) — especially effective with cotton and cellulose fibers.
Salt and vinegar are traditional but have limited effectiveness on their own — better for synthetic dyes than natural ones.

2.27. Challenges of mahogany saw dust Dyeing

Dyeing with mahogany sawdust presents a number of technical, environmental, and practical challenges. Below are the primary ones:

Low dye yield**:** Mahogany (Swietenia spp.) sawdust may contain lower concentrations of color-yielding tannins or flavonoids compared to other natural dyes like turmeric or indigo.
Inconsistent composition: The amount and type of dye compounds can vary with the species, age of wood, and part of the tree.
Complex extraction**:** Efficient extraction may require long boiling times or use of solvents, which can degrade the dye or make the process less eco-friendly.

Color Fastness :Natural dyes, including those from mahogany sawdust, often have poor light and wash fastness unless properly mordanted.Variability in how fibers absorb the dye can lead to patchy or uneven coloring, especially on synthetic or tightly woven fabrics.
Mordanting Requirements: Mahogany dyes usually require metal salts (like alum, iron, or copper) to fix the color to fabrics. Some mordants (e.g., chrome, copper) are toxic and not sustainable.Different mordants can drastically alter the final color, which may be a challenge for achieving consistent results.

Difficult to standardize**:** The natural origin of the dye makes it hard to replicate colors consistently across batches. The dye solution or sawdust may lose potency over time, especially if not stored properly.
Limited availability**:** Not always available in commercial quantities, especially sustainably sourced.
Health and Safety**:** Mahogany sawdust can be an irritant or allergen; prolonged exposure is harmful.Some tropical hardwoods (including certain mahoganies) may contain naturally occurring toxins.

2.28. Milk as a Mordant in Natural Dyeing

Natural dyeing without the use of mordants will leave the colors poor in fastness and brightness. The bond that the dye and textile fiber forms is built up by the mordant during natural dyeing, which enhances the ability of the fiber to uptake the color and also the fastness of the color. While alum, iron, and copper salts exhibited their effectiveness as traditional mordants, they are, however, harmful to the environment and human health. Thus, interests in environment-friendly, biodegradable, and non-toxic alternatives have increased. It is found mostly in milk bio-dye mordant which has satisfactory casein protein content.

Natural dyeing has gained a renewed interest in view of apathy to the problems associated with synthetic dyes and mordants. In the meantime, the search for alternative, non-toxic mordants has led researchers to look at biologically sourced materials such as tannins, extracts from plants, and animal-derived products. Because of its organic composition and availability, it has come out to be a very attractive option called "milk".

2.29. Composition and Properties of Milk

Milk is a very complex biological fluid that encompasses water, fat, lactose, mineral, and protein. Among the proteins, casein is most welded as it contributes about 80% of the total protein. Amphiphilic activity is possessed by casein and has many functional groups such as carboxyl, phosphate, and amino groups, which both interact with textile fibers and dye molecules.

Due to this amphiphilic nature, casein forms micelles which are very important for retaining its interaction with fibers. These micelles can trap dye molecules or make binding sites at the surface of the fabric.

Major Chemical Components:

Water (87-88%):Acts as a solvent for other milk components.

Proteins (3.3-3.5%):Mainly casein (80%), whey proteins (20%), and minor proteins. Casein forms micelles, which help bind dyes when used as a mordant.

Fats (3.5-4.5%):Exist as emulsified globules, stabilized by protein and phospholipids. Provides energy and contributes to the creamy texture.

Carbohydrates (4.5-5%):Mostly lactose, which affects the taste and fermentation properties.Can influence milk's role as a mordant by interacting with tannins in dyes. Minerals (0.7-0.9%): Calcium, phosphorus, potassium, and magnesium are the major minerals.

Vitamins: Rich in Vitamin A, D, B2 (riboflavin), and B12, important for nutrition.

pH and Acidity: Fresh milk has a pH of 6.6 - 6.8 (slightly acidic).

Acidic conditions (like the addition of vinegar or lemon juice) cause casein to coagulate, which is key for fabric mordanting.

2.30. Mechanism of Milk as a Mordant

The action of milk as a mordant takes place in its casein protein. In general, the fabric can be dipped in the whole milk or diluted and dried. In this preparation, casein proteins get stuck on the fiber surface, forming a layer of proteinaceous substance that is much better at binding with natural dyes. Bonding between casein and dye is mostly by hydrogen bonding, van der Waals forces, and ionic interactions, which although much weaker than the metal-dye-fiber bonds, suffice for many natural dyeing applications.

The fibers mordanted by milk show a surface modification which makes them absorb dye molecules to a greater extent, particularly those having functional groups capable of creating a bond with proteins. Consequently, milk is especially well suited to anthraquinones and flavonoid dyes obtained from plants such as madder, turmeric, and henna.

In the effectiveness and applications of milk as a mordant, studies have shown its ability to goggle with other things. Shabbir et al. (2016) researched on eco-friendly methodologies in dyeing, focusing on natural dyes and bio-mordanting agents-of which one was milk. The results showed that fabrics treated with milk had quite good color strength and an acceptable level of fastness, especially with plant-based dyes such as Punica granatum.

Ali et al. (2020) used milk as a mordant in dyeing wool and silk with Lawsonia inermis (henna). It points out that milk contributed to the vibrant hues and better environmental profiles in comparison to metal mordants.

Bhattacharya and Shah (2000) indirectly favor the feasibility of casein as a mordanting agent by demonstrating the potential of protein-based mordants.

It works especially well on protein-based fibers like wool and silk, where casein forms strong bonds. It is less effective but still perceptible for cellulose-based fibers like cotton. Some improvement in cotton results can be achieved by repeated application or combination with other bio-mordants, such as tannins or alum.

Traditionally dyeing artisans would also use milk or milk derivatives such as curd or yogurt to treat the fabrics before they are dyed. The above empirical observations are now going through scientific inquiry that would lead to their wider adoption.

Advantage of Using Milk as Mordant:

Eco-Friendly: Non-toxic and bio-degradable, it reduces the amount of chemical waste.

Sustainable: Available for anyone and renewable resources.

Cost-Effective: Most suitable in the rural areas or those regions that are rich in livestock.

Safe: Non-hazardous to health unlike metal salts.

Enhance Texture: Generally treatment of fabric with milk leaves it much softer and richer compared to the untreated fabric.

Restrictions:

Reduced Fastness: Compared to traditional metallic mordants, the milk treatment fabrics are usually less walk and light fastness; Dependence fiber: Most effective on protein fibers than the cellulosic ones; Storage-and-spoilage: The fresh milk can spoil and require cautious treatment or use of dried/powdered alternatives; Allergen Advisories: Possible development of allergic reactions by some sensitive individuals when using derived products from animals.

CHAPTER-3

METHODOLOGY

3.1 Materials And Methods:

3.1.1 Materials:

Now to perform natural dyeing of cotton fabric with Mahogony saw dust using milk as a mordant, a couple of the very basic materials are required. Most importantly, you need to have 100 percent cotton fabric, which is neat and completely free from any finishes or coatings. For the mordanting step, whole milk is used as the proteins of the milk assist the dye to bind better with the fabric. The main source of dye is mahogany saw dust extract, which are full of tannins that produce a heat-inducing brown color. Need water to wash boil and rinse the fabric. A non-reactive pot such as stainless steel or enamel would be used for boiling the saw dust; a large bowl or bucket to soak fabric in milk. A strainer or cheesecloth helps in separating the saw dust from the liquid dye bath. A hot fabric handling tool like tongs or a stick might be needed, stirring spoon and just a hand glove and an apron for protection against staining for the above mentioned processes. Lastly, measuring tools can also be helpful to repeat the processes reliably against variable conditions.

3.2 Methods:

3.2.1 Dye Extraction Process:

To Prepare the Sawdust have to Weigh the sawdust .Then soak in water overnight to soften and start breaking down lignins and tannins.After that transfer soaked sawdust and water into a stainless steel pot.Simmer gently (do not boil vigorously) for 1–2 hours, stirring occasionally.Keep the lid partially covered to reduce evaporation.Then the mixture cool to room temperature and strain the liquid through cheesecloth or a fine mesh strainer to remove solids.Usually a reddish-brown to golden brown liquid is found

3.3 Dyeing procedure:

1. Scouring (Cleaning the Fabric)

Purpose: To remove sizing, oils, and chemicals.

• Boil the fabric in water with 1–2 tsp of soda ash per liter.

• Keep at 90-95°C (194-203°F) for 1 hour.

• Rinsed well in warm water.

• Air dry before mordanting.

3.3. Mordanting With Milk

The purpose is to bind protein on the cotton for helping to fix dye.

1. Soak clean dry cotton in cold full-fat milk (straight from the fridge is fine) for soaking.

2. Let it soak at room temperature (approx. 25°C/77°F) for 12 to 24 hours.

3. Squeeze out surplus milk gently (don't rinse).

4. Hang to dry in a shady, ventilated place.

5. (Optional) Repeat the soak and dry for more dye uptake.

3.4 Preparing the Mahogony saw dust Dye Extract

Purpose: Tannins extraction from Mahogony saw dust.

1.10-50g of mahogany sawdust per liter of water.

2. Simmer around 90°C (194°F) for 30 minutes.

3. Strain off the solids.

4. Cool dye bath until just below hot, around 70°C (158°F), before adding fabric.

3.5. Dyeing the Fabric

1. Wet the milk erstwhile fabric using lukewarm water.

2. Place into the warm Mahogony saw dust dye bath (60° C /158°F).

3. Simmer gently (don't boil) for about 1 hours.

4. Stir occasionally for color all around.

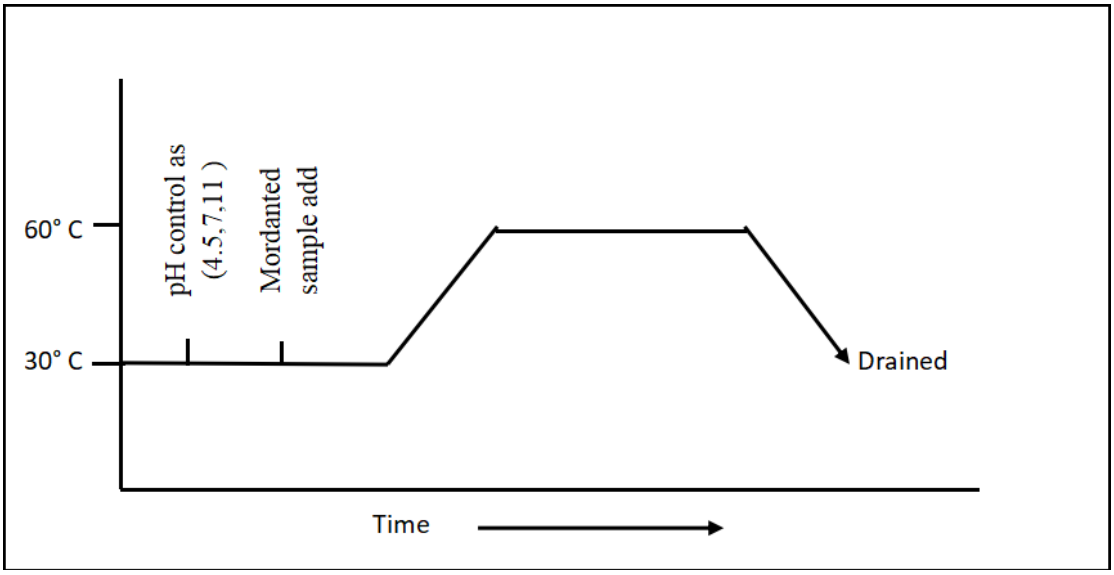
5. For darker tones, it may be left to soak while the bath cools overnight (room temperature).

3.6. Rinsing & Drying

1. Remove fabric and rinse in cool water (around 20-25°C/68-77°F).

2. Rinse until the water runs most clear.

3. Air dry in the shade to prevent fading.



3.7.Wash Fastness procedure:

3.7.1 Materials Needed

- Dyed fabric sample (about 10 cm x 4 cm)
- Undyed white cotton fabric (the same dimensions) – as adjacent fabric
- Mild detergent (non-bleach, neutral pH detergent)
- Beaker
- Stirring rod
- Water bath
- Distilled
- Sewing machine & thread
- Gray scale for color change (optional, for evaluation)

Figure3.1: Wash fastness test machine

3.7.2 Test Conditions

• Temperature: 40 degrees Celsius

(depending on intensity of test)

• Concentration of detergent: 1 g/L

• Duration: 30 minutes

• Liquor ratio: 50:1 (e.g.: 250 mL water for 5 grams of fabric)

• Mechanical action: Mild stirring

• Rinsing: 3x with clean water

• Drying: Air dry at room temperature, away from sunlight

3.7.3 Steps

1. Sample Preparation

• Stitch your dyed fabric to an undyed white cotton fabric (face to face).

• This will help you check for color bleeding or transfer.

2. Prepare Wash Solution

• Dissolve 1 g of mild detergent in 250 mL of water.

• Heat the solution to the desired wash temperature (40°C).

3.7.3. Washing

• Place the fabric pair into the solution.

• Stir gently for thirty minutes.

• Maintain consistent temperature throughout.

3.7.4. Rinse

• The sample will be rinsed thrice with cool clean water to get rid of the detergent.

3.7.5. Drying

• Separate fabric pieces and air dry flat in the shade.

3.7.6 Evaluation

A. Gray Scale for Color Change

• Compare the dyed sample pre- and post-wash through gray scale (1 = poor, 5 = excellent).

B. Staining on Adjacent Fabric

• Check whether any color has transferred to the undyed white fabric.

• Use gray scale for staining if available.

3.8 Method of Rubbing (Crocking) Fastness Test

3.8.1 Materials Needed

· Dyed fabric sample (minimum size: 5 cm x 5 cm)

· White undyed cotton fabric (for rubbing test)

· Crockmeter

· Gray scale for staining

· Water (for wet rubbing)

· Level surface

· Rubber gloves

Figure3.2: Crockmeter machine

3.8.2 Types of Test

• Dry Rubbing Fastness

• Wet Rubbing Fastness

Both tests will typically be performed in fully assessing crocking behavior.

3.8.3 Procedure

1. Sample Preparation

   · The sample would be dyed cotton (clean and dry).

· Cut a piece of white cotton cloth (usually 5 cm × 5 cm) as the rubbing fabric.

3.8.4 Dry Rubbing Test

1. Spread the dyed fabric over a flat surface.

2. Now take the white cotton fabric and rub it over the dyed fabric front and back for a total of 10 strokes (i.e. 10 double strokes).

· Keep the pressure and speed as constant as possible.

· Use a Crockmeter

3. Look and compare the rubbed area on the white fabric for any stains.

3.8.4 Wet Rubbing Test

1. Wet a new piece of white cotton fabric using distilled water and squeeze to remove the excess moisture (make it damp, not soaking wet).

2. Repeat the same rubbing strokes with the dampened rubbing fabric along a new section of the dyed fabric--10 back-and-forth stroking motions.

3. Air dry the rubbed white fabric at room temperature and evaluate for staining.

3.8.5 Evaluation

A. Gray Scale for Staining

· Stained rubbing cloth is compared against gray scale.

• Ratings:

o 5 = No Staining

o 4 = Light Staining

o 3 = Observable Staining

o 2 = Heavy Staining

o 1= Very Heavy Staining

3.9 The Saliva Fastness Test Procedure for Dyed Fabric

` Figure3.3: Saliva test machine

3.9.1 Materials Used

o Dyed cotton fabric sample

o Artificial saliva solution (recipe given below)

o White undyed cotton (for contact testing)

o Glass containers

o pH meter

o Shaker

o Gray scale for staining

o Gloves and metallic tongs

3.9.2 Saliva Solution (Standard Recipe)

Ingredient Amount (Per 1 L)

Sodium chloride (NaCl) 0.4 g

Potassium chloride (KCl) 0.4 g

Calcium chloride dihydrate ($CaCl_2 \cdot 2H_2O$) 0.795 g

Sodium bicarbonate ($NaHCO_3$) 1.0 g

Distilled water To make 1 liter

pH Adjustment Adjust to pH 6.8–7.0 with dilute HCl or NaOH

3.9.3 Procedure

1. Sample Preparation

- Cut a sample of the dyed fabric (~5 cm x 5 cm).
- Prepare a corresponding piece of white undyed cotton for testing any dye transfer.

2. Soaking Procedure

- Soak the dyed fabric in an artificial saliva solution.
- Place white undyed cotton in contact with it (sandwich them together or lay them side-by-side touching).
- Keep soaked for up to 2 hours at 37°C (body temperature) to mimic real conditions.
- Room temperature can be used.

3. Post-Soaking

- After soaking, remove both fabrics and rinse gently with distilled water.
- Let them dry completely in the air (not in direct sunlight).

3.9.4 Evaluation

A. Change in Color/Test

- Look at the dyed fabric and check for fading or tone change.

B. Staining of Adjacent White Cotton

· Assess any color transfer onto the white cotton using:

· Gray scale for staining (1 = heavy transfer, 5 = no transfer)

· Or a visual 1–5 rating if gray scale is unavailable

3.10 Light Fastness Test Procedure for Dyed Fabric

Figure3.4: Light Fastness machine

3.10.1 Materials Used

· Dyed cotton fabric sample (at least 5 cm × 5 cm)

· Standard light source:

· Sunlight (natural-light exposure for DIY-or-field test)

· Gray scale for color change (optional)

· Black paper or opaque cover

· Scissors, pen and tape

3.10.2 Test Method

1. Sample Preparation

· Cut a dyed fabric swatch (~5 cm x 10 cm).

· Fold it in half lengthwise.

· Light-blocking is provided for half the sample (one side of the fold) with black paper or foil-this will become the reference area.

· Unfold, tape, or pin it flat on a board; half exposed and half covered.

2. Light Exposure

Option A: Xenon Arc Lamp (Lab)

- Place the sample in the test chamber under a xenon arc lamp.
- Follow standard exposure time: 20, 40, or 80 hours, depending on desired intensity.

Option B: Natural Sunlight (DIY or Field Method)

- Place the sample in direct sunlight (ideally under glass to simulate window exposure).
- Exposure must be for at least 3-5 sunny days; more if cloudy.
- Ensure uniform orientation to light, e.g., facing south in the northern hemisphere.

3.10.3 Post-Treatment

- The sample is removed and unfolded.
- Compare the exposed half with the covered half for obvious fading or color change.

3.10.4 Evaluation

A. Gray Scale for Color Change

- Rate for difference between exposed and unexposed sides using gray scale method:

5 = No fading

4 = Slight fading

3 = Moderate fading

2 = Considerable fading

1= Severe

3.11 Perspiration Fastness Testing Method:

Figure 3.5: Perspiration machine

3.11.1 Materials Required

- Dyed cotton fabric sample (minimum 5 cm x 5 cm)
- Undyed white cotton fabric (of an equal size - for contact test)
- Acidic perspiration solution
- Alkaline perspiration solution
- pH strips or a pH meter
- glass or plastic containers

- weights or clamping press (e.g., glass plates + books)
- Incubator or oven (or warm place at ~37°C)
- Gray scale for color change and staining (optional)

3.11.2 Perspiration Solutions

A. Acidic Sweat Solution (pH ~5.5)

Ingredient Amount (per 1L)

Sodium chloride (NaCl) 5 g

Lactic acid 1 g

Bring the pH up to 5.5 by using sodium hydroxide (NaOH).

B. Alkaline Sweat Solution (pH ~8.0)

Ingredient Amount (per 1L)

Sodium chloride (NaCl) 5 g

Disodium hydrogen phosphate (Na_2HPO_4) 0.5 g

Adjust pH to 8.0 with sodium hydroxide (NaOH)

3.11.3 To carry out the test

1. Preparation of Sample

- Stitched or pinned up with an undyed piece of white cotton is the dyed fabric face-to-face.
- Two identical samples-one for acid sweat, another for alkaline sweat.

2. Soaking

- One set in acidic solution and the other in alkaline solution for 30 mins.
- Remove and gently squeeze to remove excess liquid (don't wring out).

In Contact & Pressure Setup

- Place the soaked, stitched fabric between glass plates or flat boards.
- Apply weight (approx. 5 kg or press with books) to simulate body pressure.
- Maintain 37 °C (body temperature) for 4 hours (or overnight at room temperature if no incubator is available).

4. Drying

- Removed from those fabrics.
- Air dry both pieces (dyed and adjacent white) away from sunlight.

3.11.4 Evaluation

A. Change of color in the dyed fabric

• Color change before using gray scale for color change/visual rating:

· 5 = No change

· 1 = Severe fading

B. Staining on Adjacent Fabric

Use a gray scale for staining to assess dye transfer to white cotton:

· 5 = No staining

· 1 = Heavy staining.

CHAPTER-4

RESULTS AND DISCUSSION

4.1 Shade Analysis:

Figure: 4.1

A: Undyed Fabric

Figure: 4.2

B: Unmordanted Dyed

Figure: 4.3

C: Mordanted Dyed

Analysis: This research work is on dyeing cotton fabric with mahogany saw dust extract using milk as a mordant. Since mahogany wood waste is a natural dye and not those synthetic chemicals, it is also environment friendlier, as the whole process is bio-degradable. This is a process that bestows a soft, warm, vintage or antique look to cotton fabric which is usually ranging anywhere from beige, tan, or light brown shades; and helps tone well bright white cotton or make an entirely new fabric appear aged or rustic. It is cheap and easily accessible; thus, a good option for budget dyeing. Very straightforward, no special equipment required, just hot water and mahogany saw dust; and also used milk as mordant because it increases dye affinity and strong bonding to fabric and also very fastness property by mordant.

We found that mordanting dyeing is better than such dyeing without mordanting, given that figure 4.1 A shows an undyed sample, figure 4.2 B shows dyed sample this dyed completed without mordanting, and figure 4.3 C is a dyed with mordanting. Hence, after careful visualization, it can be said that a mordanting-dyed sample is good. This sample's percentage and depth shade of color and color fastness are better than that of the dyeing process without mordanting.

4.2 Wash Fastness Test Result:

Table: 4.2 Wash Fastness Test Result

Sample No.	Sample Type	pH	Wash Fastness(1-5)
1	Unmordanted	4.5	2
2	Mordanted	4.5	3
3	Unmordanted	7.0	2
4	Mordanted	7.0	3
5	Unmordanted	11.0	3
6	Mordanted	11.0	4

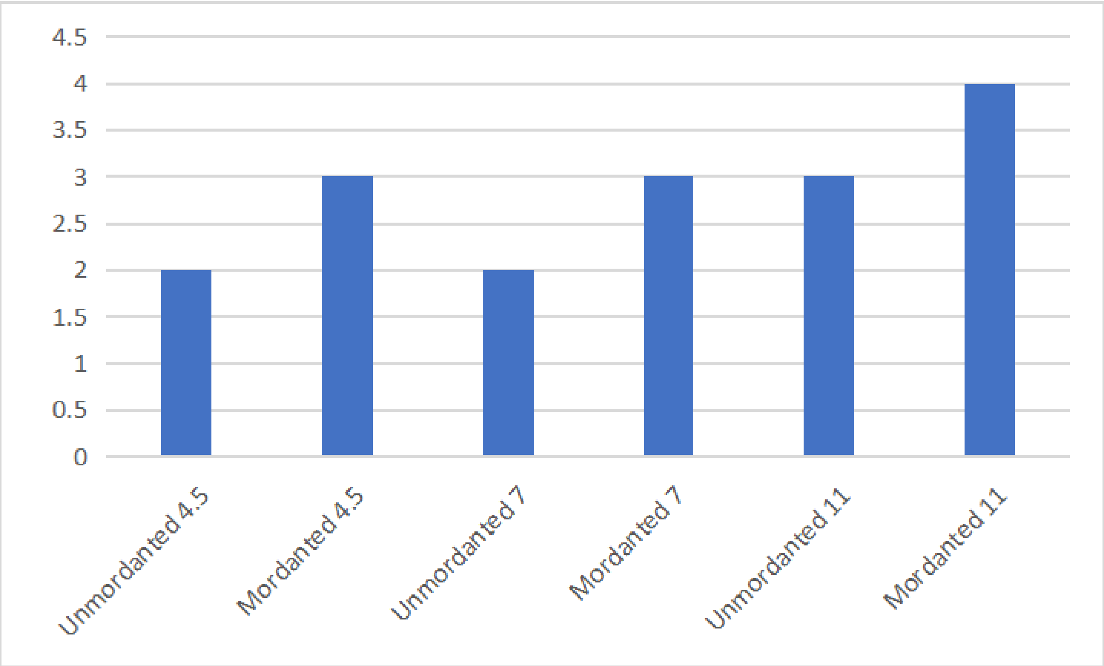


Table 4.2. Analysis: The table shows the wash fastness ratings of cotton fabric dyed with mahogany saw dust extract at various pH and mordanting conditions. Six samples were tested, including both mordanted and unmordanted fabric at three different acidic, neutral, and alkaline pH levels: acidic (4.5), neutral (7.0), and alkaline (11.0). From the study, it has been shown that the mordanted samples exhibit better wash fastness than unmordanted counterparts. At pH 4.5, unmordanted fabric recorded wash fastness at 2, while the mordanted sample showed an improvement in the ratings to 3. At neutral pH 7.0, recorded similar patterns as above, where the unmordanted fabric again scored 2 while the mordanted had a score of 3. At the highest pH level of 11.0, both sample types increased in wash fastness, whereby unmordanted sample reached a rating of 3 and the mordanted fabric achieved the highest rating of 4. These results indicate that both mordanting and alkaline pH conditions favor dye fixation and, therefore, improve the wash durability of the dyed fabric.

4.3 Saliva Fastness Test Result:

Table: 4.3 Saliva Fastness Test Result

Sample No.	Sample Type	pH	Saliva Fastness (1-5)
1	**Unmordanted**	**4.5**	**2**
2	**Mordanted**	**4.5**	**3**
3	**Unmordanted**	**7.0**	**2**
4	**Mordanted**	**7.0**	**3**
5	**Unmordanted**	**11.0**	**3**
6	**Mordanted**	**11.0**	**4**

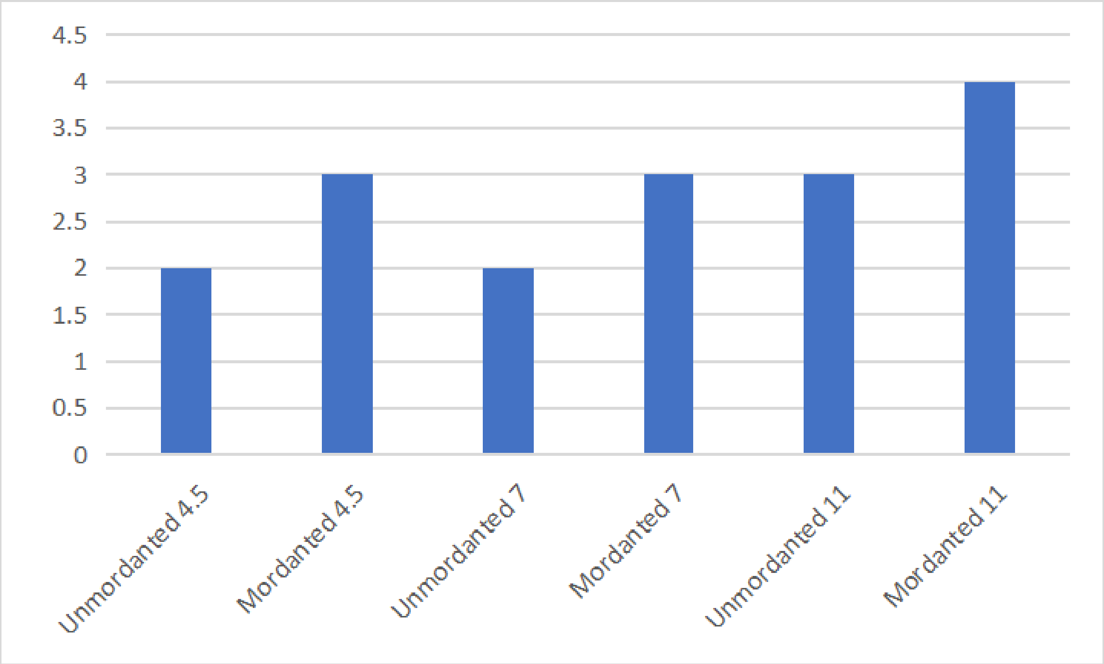


Table 4.3. Analysis: This table displays the saliva fastness ratings of cotton fabric treated with mahogany saw dust extracts dyed at different pH levels with treatment conditions (mordanted and unmordanted). Six samples were examined under different pH conditions of acidic (pH 4.5), neutral (pH 7.0), and alkaline (pH 11.0). The data indicate robustly improving saliva fastness for the mordanted samples. At pH 4.5, the unmordanted sample received a rating of 2 for saliva fastness, but the mordanted one improved slightly, with the score of 3. Similar findings were observed at pH 7.0, with the unmordanted fabric continuing to maintain a score of 2 and the same holding true for the mordanted version attaining a score of 3. At pH 11.0, there was an upturn for both sample types whereby, for the unmordanted, a score of 3 was accrued and the maximum of 4 achieved by the mordanted sample. Which shows that there are two conditions under which the dye becomes more resistant to saliva, specifically being mordanted and making it alkaline while also increasing overall longivity and color retention in dyed cotton fabric.

4.4 Light Fastness Test Result:

Table: 4.4 Light Fastness Test Result

Sample No.	Sample Type	pH	Light Fastness(1-8)
1	Unmordanted	4.5	3
2	Mordanted	4.5	4
3	Unmordanted	7.0	3
4	Mordanted	7.0	5
5	Unmordanted	11.0	4
6	Mordanted	11.0	6

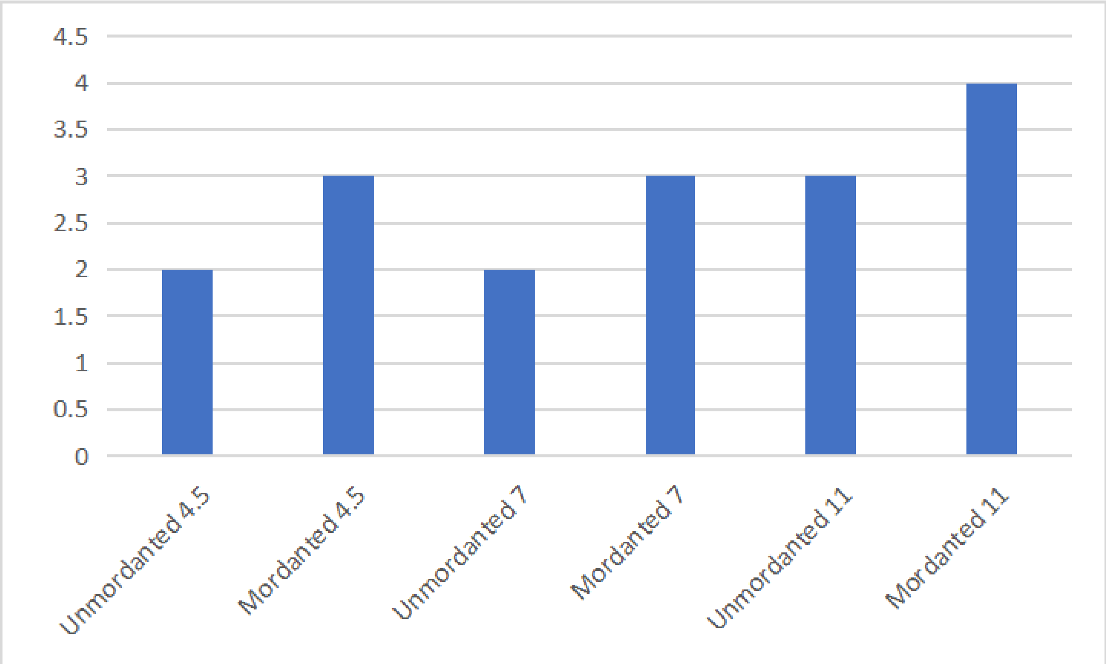


Table 4.4. Analysis: The table provides light fastness ratings of cotton fabric dyed with mahogany saw dust extract according to the different pH levels and treatment

conditions. The fabrics were tested in acidic (pH 4.5), neutral (pH 7.0), and alkaline (pH 11.0) environments for mordanted and unmordanted fabrics. Under pH 4.5, the unmordanted fabric showed a rating of 3 on light fastness, while the mordanted had it at 4. Most differences were seen at pH 7.0 where the unmordanted kept its rating at 3, while the mordanted increased to 5. At pH 11.0, both showed further improvement unmordanted scored 4 while mordanted scored the highest rating of 6. Such results showed that mordanting is an effective treatment for enhancing light fastness of the dyed fabric, especially under neutral and alkaline conditions. This would also mean improvement in performance at high pH levels; clearly, treatment with high pH also improves the performance of light fastness because of better dye fixation and light resistance with leaving it exposed.

4.5 Perspiration Fastness Tesr Result:

Table: 4.5 Perspiration Fastness Test Result

Sample No.	Sample Type	pH	Perspiration Fastness(1-5)
1	**Unmordanted**	**4.5**	**2**
2	**Mordanted**	**4.5**	**3**
3	**Unmordanted**	**7.0**	**2**
4	**Mordanted**	**7.0**	**3**
5	**Unmordanted**	**11.0**	**3**
6	**Mordanted**	**11.0**	**4**

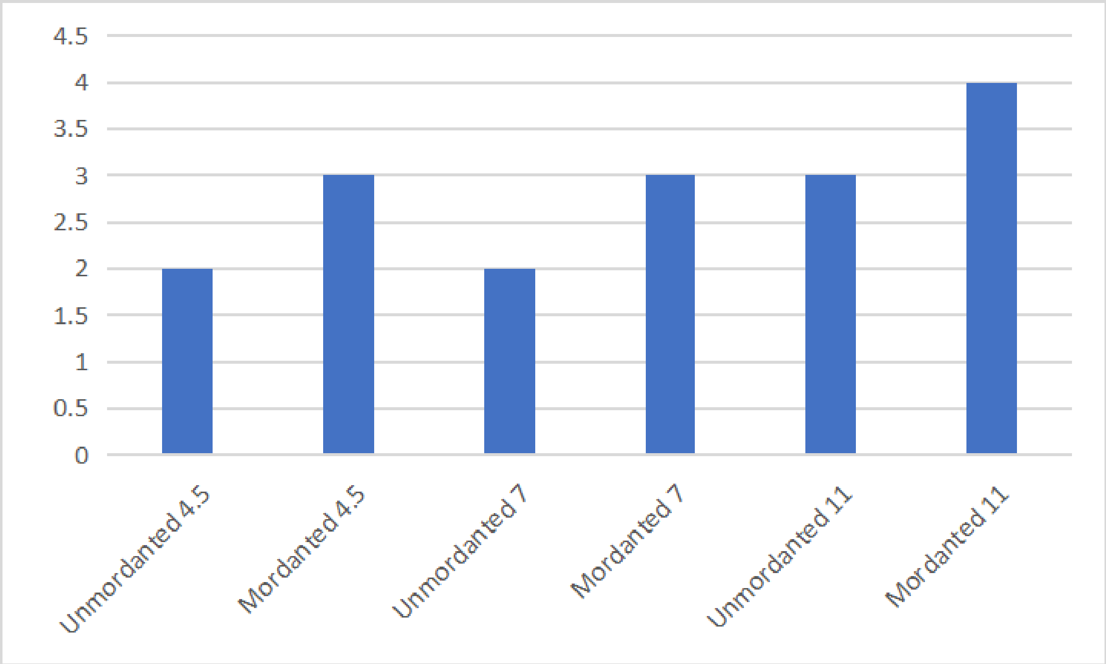
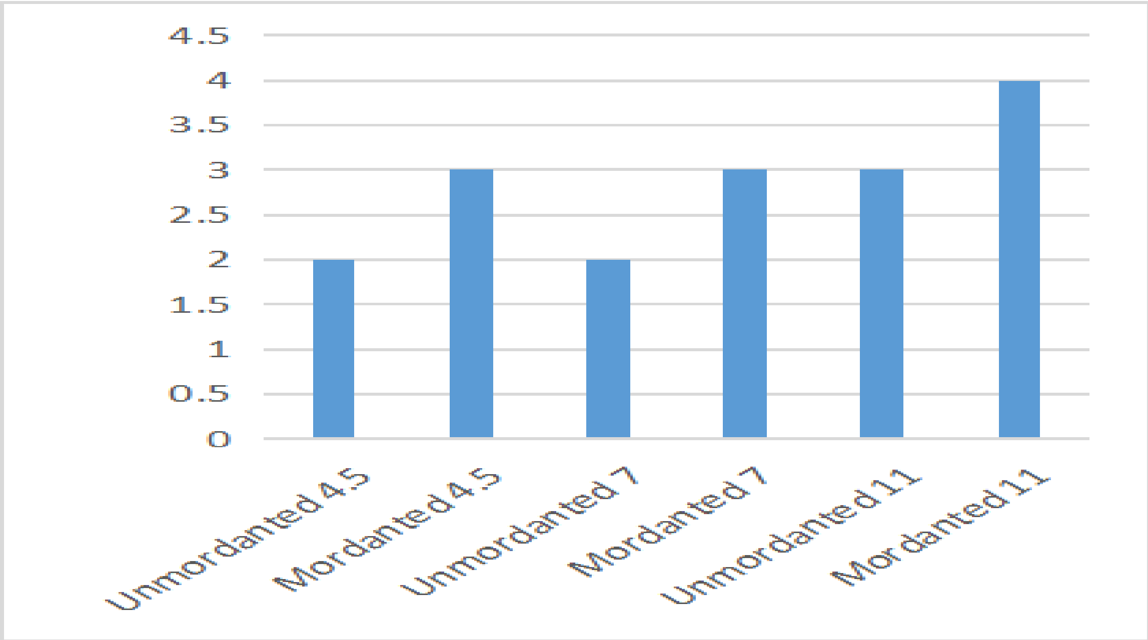


Table 4.4. Analysis: The table illustrates the ratings of perspiration fastness of cotton fabrics dyed with a mahogany saw dust extract at different pH conditions and kinds of mordanting treatments. All the samples were subjected to acidic (pH 4.5), neutral (pH 7.0), and alkaline (pH 11.0) testing conditions. Results reveal that all the characteristics of excessive perspiration resistance are found in the mordanted samples as compared to that of the unmordanted samples. For instance, with pH 4.5, an unmordanted sample had a perspiration fastness rating of 2 while the mordanted sample improved to level 3. The trend goes the same for pH 7.0, where ratings were 2 for the unmordanted and 3 for the mordanted fabric. At the extreme alkaline level, pH 11.0, results were quite excellent for both samples, recording 3 for the unmordanted fabric and the highest 4 for the mordanted fabric. This indicates that the property of both mordanting and pH level being higher enhances the resistance of the fabric to perspiration, leading further to color fastness and durability.

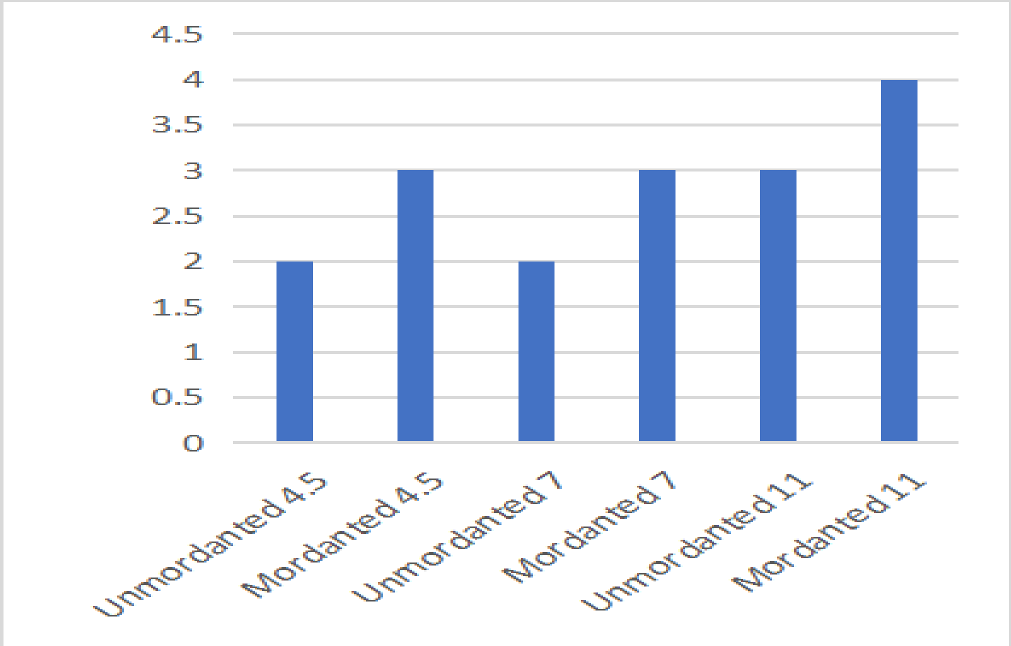
4.6.Rubbing Fastness Test Result:

Table: 4.6 Rubbing Fastness Test Result

Sample No.	Sample Type	pH	Dry Rub	Wet Rub Fastness(1-5)
1	Unmordanted	4.5	2	2
2	Mordanted	4.5	3	3
3	Unmordanted	7.0	2	2
4	Mordanted	7.0	3	3
5	Unmordanted	11.0	3	3
6	Mordanted	11.0	4	4



Dry rub fastness



wet rub fastness

The fastness to rubbing of the dye-soaked cotton fabric using mahogany saw dust lea extract was tested under different pH levels (4.5, 7.0, and 11.0) both for unmordanted and mordanted samples. At pH 4.5, the unmordanted sample revealed a very poor dry and wet rub fastness with a rating of 2 for both attributes, whereas the mordanted sample exhibited slight improvement, scoring 3 for both dry and wet rub fastness. A similar pattern emerged at neutral pH (7.0), with the unmordanted sample having a rating of 2 for both dry and wet rub, but the mordanted fabric scored 3 for both. Rubbing fastness improved remarkably at alkaline pH (11.0). The unmordanted sample attained 3 ratings for both dry and wet rub fastness, while the mordanted showed the highest performance with a score of 4 for both dry and wet rub tests. This shows that mordanting increases fastness to rubbing at all levels of pH with the best improvements under alkaline conditions.

CHAPTER-5

CONCLUSION

5.1 Conclusion:

The use of mahogany sawdust as a natural dye in combination with a milk mordant presents a sustainable and eco-friendly method for textile dyeing. The experiment demonstrates that milk, acting as a protein-based mordant, effectively binds the natural tannins and pigments present in mahogany sawdust to the fabric, enhancing color uptake and fixation.

Key conclusions include:

1. **Effective Coloration**: Mahogany sawdust produces warm, earthy hues ranging from soft browns to reddish tones, depending on fabric type and dye concentration.

2. **Milk as a Natural Mordant**: Casein in milk facilitates strong dye adherence, resulting in moderate to good color fastness without the need for chemical mordants.

3. **Eco-Friendly Process**: Both mahogany sawdust (a wood industry byproduct) and milk are biodegradable, making the process environmentally sustainable.

4. **Limitations**: The color may vary based on the type and pre-treatment of fabric, and lightfastness might be lower than synthetic dyes, necessitating further post-treatment for enhanced durability.

Overall, mahogany sawdust dyeing with milk mordant is a promising alternative for natural textile coloring, especially suited for small-scale, artisanal, or sustainable fashion production.

6.References:

- **R. Mia et al. (2023), Results in Engineering, 17, 101032** – Investigates the dyeing performance of organic nonwoven cotton fabric using mahogany wood waste and its fastness properties.
- **M.S. Sk et al. (2022), Surface Innovations** – (Reference should be verified for relevance).
- **M.R. Repon et al. (2017), Fashion Textiles** – Discusses natural dyeing of cotton fabrics and their color fastness properties enhancement.
- **Bhuyan, R., & Saikia, C. N. (2005)**. *Isolation of colour components from native dye-bearing plants in northeastern India.* Bioresource Technology, 96(3), 363–372. https://doi.org/10.1016/j.biortech.2004.04.004
- **Yusuf, M., Shabbir, M., & Mohammad, F. (2017).***Natural colorants: Historical, processing and sustainable prospects.* Natural Products and Bioprospecting, 7, 123–145. https://doi.org/10.1007/s13659-017-0119-9
- **Siva, R. (2007).***Status of natural dyes and dye-yielding plants in India.* Current Science, 92(7), 916–925.
- **Gupta, D., & Gulrajani, M. L. (1992).** *Casein as a natural mordant: Dyeing and fastness characteristics on wool.* Indian Journal of Fibre & Textile Research, 17, 274–277.