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Faculty of Engineering
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Pigment Dyeing Using Natural Binder

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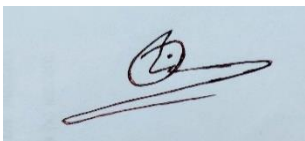
Dept. of TE, DIU

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

Spring-2025

AUTHOR'S DECLARATION

We hereby declare that this project has been done by us under the supervision of **Md. Kamrul Islam**, Lecturer, Department of Textile Engineering, Faculty of Engineering, Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for the award of any degree or diploma.

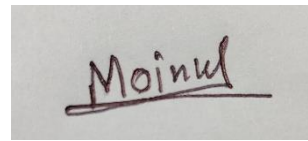


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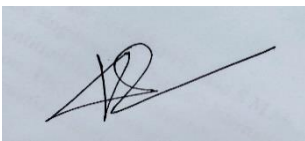
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LETTER OF APPROVAL

This project report is prepared by Md Oliul Ahad Shuvo (213-23-1057) and S M Moinul Hossain Mehedi (213-23-1071), approved as partial fulfillment of the requirements for the degree of Bachelor of Science in Textile Engineering. I have supervised the students throughout their project work, and during the research period, I found them to be sincere, hardworking, and enthusiastic.



Md. Kamrul Islam

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Statement of Contributions

In this project, the author has explored the possibility of using non-chemical binders, i.e., honey and aloe vera, to dye pigment on cotton fabric using the pad-dry process. The researchers have been able to synthesize pigment pastes in these natural substances, and this is a good substitute for the synthetic chemical binders that are used. The coloring procedure had been performed without toxic fixatives that lower the ecological impact of textile treatment. The study involves a detailed overview of pre- and post-dye characteristics of the fabrics, including their thread density (EPI, PPI), GSM, and yarn count, which varied to show that fabric materials kept their structural integrity. Color fastness to light, washing water was carried out, and the outcomes showed very good to excellent responses, which pre-immunized the efficacy of honey and aloe vera as natural fixatives. This research sheds light on the advancement of dyeing processes, in which an inexpensive, low-technological, but feasible dyeing process has been presented, which would be of economic value to small-scale industries or those green-minded industries. It also emphasizes the environmental and health benefits of biodegradable and non-toxic materials in textile utilization.

ACKNOWLEDGEMENTS

Firstly, we express our gratitude to Almighty Allah for His divine blessings that have made it possible for us to successfully complete this project.

We are grateful to our supervisor, **Md. Kamrul Islam**, Lecturer, Department of Textile Engineering, Faculty of Engineering, Daffodil International University. His deep knowledge and keen interest in the field of textile dyeing have influenced and inspired me throughout this project. We are 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.

We would like to express our 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. We are also thankful to All Faculty members for providing me with the necessary information to complete the report on time.

We would like to extend our thanks to all our classmates at Daffodil International University who participated in discussions and provided valuable insights during the completion of the coursework.

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

EXECUTIVE SUMMARY

Pigment dyeing has long been a popular coloration technique in textile manufacturing due to its wide color gamut, ease of application, and suitability for diverse fiber types. However, conventional pigment dyeing processes heavily rely on synthetic binders derived from petrochemicals, which present environmental hazards and potential health risks. In response to the growing demand for sustainable and eco-friendly alternatives, this study explores the application of natural binders—specifically honey and aloe vera—in pigment dyeing of 100% cotton fabrics. The primary objectives of this research were to assess the feasibility of using these bio-based binders, evaluate their impact on dye uptake and fixation, and analyze key performance parameters, including color fastness, handle, and overall aesthetic quality. Experimental work was carried out in a laboratory environment using standardized protocols. Pigment dispersions were prepared with measured concentrations of honey and aloe vera solutions, individually and in combination with commercial binder and using only 100% commercial binder, to determine optimal binder formulations. Samples were applied via pad-dry-cure methods, closely simulating industrial processes. The dyed fabrics were evaluated for wash fastness, rub fastness, light fastness, color strength (K/S values), and physical characteristics such as tensile strength and stiffness. Comparative analysis with conventional acrylic binders was conducted to highlight performance differences.

Results demonstrated that honey and aloe vera binders exhibited promising binding capabilities, achieving acceptable levels of color fastness suitable for light to medium-duty textile applications. Honey-based binders provided superior adhesion, while aloe vera imparted a softer handle to the fabric. Combined formulations yielded balanced performance. Although slight reductions in color depth were observed compared to synthetic binders, the environmental and health benefits are significant. The use of natural binders can potentially reduce harmful emissions and minimize chemical residues in finished textiles.

This project underscores the viability of integrating renewable, biodegradable resources into pigment dyeing systems. Adoption of honey and aloe vera as natural binders aligns with global sustainability goals and offers the textile industry an innovative path toward greener production practices. Further research is recommended to optimize formulations, scale up processes, and evaluate economic feasibility for commercial implementation.

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United Nations Sustainable Development Goals

The steps towards a better and more sustainable life of everybody in the future can be located in the Sustainable Development Goals (SDGs). The global goals deal with such burning problems as environmental degradation, climate change, poverty, inequality, and pollution and encourage sustainable development in all areas. In total there are 17 susceptible goals and this project helps to develop some of the goals.

In this project, the concentration is on the dyeing of natural pigments; we use some friendly natural binders instead of synthetic chemicals, such as honey and aloe vera. Conventional dyeing with pigments may contain hazardous resins and fixatives to the environment and to human beings. Nonetheless, the application of natural binders that are applied in a biodegradable form causes a significant decrease in the negative effects of both chemicals and the toxicity of wastewater. Goal 12, Responsible Consumption and Production at SDGs, is a topic with strong relevance to this research, since it advocates sustainable solutions in the textile manufacturing industry.

Moreover, Clean Water and Sanitation (Goal 6) and Climate Action (Goal 13) are also sustained because of the low use of water or energy in dyeing compared to the traditional dyeing process associated with the pad-dry dyeing method that can be applied in this project. The project makes the environment cleaner and safer as it limits pollution of water and other effects on the environment.

The idea also contributes indirectly towards Good Health and Well-being (Goal 3) by reducing any risk of exposure to workers and consumers of chemicals. Eventually, safer working conditions and safer textile products can be achieved by substituting synthetic chemicals with natural material.

In this way, this project stimulates sound innovation within the textile industries. It shows the way that seemingly minor alterations in materials and procedures such as substituting chemical adhesives with natural ones could contribute a lot to the United Nations global cause of a sustainable future.

CHAPTER-1

INTRODUCTION

1.1 Introduction

Pigment dyeing is an important coloration technique in textile processing, widely used for imparting vibrant, durable colors to cotton, polyester, and blended fabrics. Unlike reactive or direct dyes, pigments are insoluble particles that require a binder to adhere to fiber surfaces. Conventional synthetic binders, typically acrylic or polyurethane emulsions, play a crucial role in the fixation and durability of pigment colors. However, the use of these synthetic chemicals raises environmental and health concerns due to their non-biodegradable nature, toxic monomers, and potential skin sensitization effects. As global textile industries increasingly shift towards sustainable production, there is a growing demand for environmentally benign alternatives that reduce pollution without compromising performance.

Natural binders derived from renewable resources offer a promising pathway to address these issues. Honey, a natural substance composed mainly of sugars, enzymes, and organic acids, has excellent adhesive properties and film-forming ability. Aloe vera, rich in polysaccharides and glycoproteins, is known for its bio adhesive and moisturizing qualities. Although both have been extensively researched for medicinal and cosmetic applications, their use as binders in pigment dyeing has received limited scientific attention. Exploring these materials could open new opportunities for eco-friendly textile processing.

This project is motivated by the urgent need to reduce the environmental footprint of textile dyeing. Conventional pigment dyeing generates wastewater containing hazardous chemicals that contribute to soil and water contamination. By replacing synthetic binders with natural substances like honey and aloe vera, this study aims to develop a process that is safer for workers, end users, and the environment.

Furthermore, adopting natural binders aligns with the United Nations Sustainable Development Goals (SDGs), particularly Responsible Consumption and Production (SDG 12) and Climate Action (SDG 13).

From an industrial perspective, leveraging biodegradable binders can improve the image of textile brands, satisfy increasingly strict regulatory requirements, and meet consumer expectations for

greener products.

1.2 Significant motivation of the study

The motivation for this project stems from the urgent need for environmentally conscious textile processing methods. Traditional dyeing techniques involve the use of a significant amount of water, chemicals, and energy. The use of synthetic binders, in particular, results in effluent discharge containing non-biodegradable substances, which can harm aquatic life and disrupt ecosystems.

the global shift toward green chemistry and sustainable fashion, the textile industry is at a turning point. Consumers and regulatory bodies alike are demanding cleaner production technologies. Bangladesh, being one of the largest textile producers in the world, has both the opportunity and responsibility to lead in sustainable innovations.

This study is significant because:

1. It introduces bio-based binders into pigment dyeing systems.
2. It reduces dependency on petroleum-based synthetics.
3. It promotes cost-effective, eco-conscious production.
4. It aligns with multiple UN Sustainable Development Goals (SDGs), including “Responsible Consumption and Production” and “Clean Water and Sanitation.”

If proven effective, natural binders such as honey and aloe vera can be a game-changer for eco-friendly dyeing, with potential scalability in commercial textile operations.

1.3 Objectives

Aim: To explore and evaluate the effectiveness of natural binders (honey and aloe vera) in pigment dyeing of cotton fabric as sustainable alternatives to conventional synthetic binders.

Objectives:

1. To extract and prepare natural binder solutions from honey and aloe vera.
2. To apply pigment dyes using both natural and synthetic binders on cotton fabric.
3. To analyze and compare the following parameters:
Color strength (K/S value)
Color fastness to wash, rub, and light
Fabric handle and appearance
4. To determine the optimal application methods and concentrations for natural binders.
5. To assess the environmental and health benefits of using natural binders.
6. To provide recommendations for industrial-scale implementation.

1.4 Scope of the Study

This project is primarily focused on pigment dyeing of 100% cotton woven fabrics using the lab Scale equipment:

1. Preparation of Aloe Vera and Honey binders.
2. Dyeing trials using standardized process parameters.
3. Performance evaluation through laboratory testing.
4. Comparative analysis of the results.
5. Industrial-scale process validation, application to blended or synthetic fabrics, and long-term durability studies are beyond the scope of this work but are recommended for future research.

1.5 Methodology

The motivation for this project stems from the urgent need for environmentally conscious textile processing methods. Traditional dyeing techniques involve the use of a significant amount of water, chemicals, and energy. The use of synthetic binders, in particular, results in effluent discharge containing non-biodegradable substances, which can harm aquatic life and disrupt ecosystems.

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5. If proven effective, natural binders such as honey and aloe vera can be a game-changer for eco-friendly dyeing, with potential scalability in commercial textile operations.

1.5 Report Outcome

The outcome of this study demonstrated that both Aloe Vera and Honey can be effectively utilized as natural binders in the pigment dyeing of cotton fabrics, offering an environmentally friendly alternative to conventional synthetic binders. Aloe Vera-based formulations produced moderate color strength with satisfactory rubbing and washing fastness, indicating acceptable film-forming and adhesion properties. Honey binders also exhibited good adhesion and bright coloration, although

Higher viscosity and curing sensitivity posed certain handling challenges. Compared to synthetic binders, the natural binders showed reduced overall fastness ratings but delivered the significant advantage of biodegradability and reduced chemical impact. The findings suggest that while Aloe Vera and Honey require further optimization, they hold considerable promise for sustainable textile dyeing applications. The study highlights the feasibility of integrating natural resources into dyeing processes to support greener production practices in the textile industry.

CHAPTER-2

LITERATURE REVIEW

2.1 Introduction

The demand for eco-friendly textile processing has increased in recent years due to growing concerns over environmental sustainability and worker safety. Among the various stages of textile processing, dyeing is one of the most chemically intensive, particularly pigment dyeing, which requires binders to fix colors on fabrics. Conventionally, synthetic binders such as acrylates and polyurethanes are used; however, these are often non-biodegradable and may release volatile organic compounds (VOCs) during processing.

This chapter presents an in-depth review of:

1. The basics and principles of pigment dyeing,
2. The role and chemistry of binders in pigment dyeing,
3. Environmental concerns of synthetic binders,
4. Potential and properties of natural binders,
5. Past research efforts using honey, aloe vera, and other biopolymers,
6. Knowledge gaps and the need for this current research.

2.2 Overview of Pigment Dyeing

Pigment dyeing is a surface coloration technique widely used for cellulosic and blended fabrics. Unlike reactive or vat dyes, pigments are insoluble colorants that do not form a chemical bond with fiber. Therefore, binders are required to affix the pigment particles to the fabric.

Key characteristics of pigment dyeing:

1. Applicable to a wide range of substrates (cotton, polyester blends).
2. Economical for large-scale production.
3. Requires curing (heat treatment) to fix the binder film.
4. Pigment dyeing process typically includes:

5. Padding with pigment, binder, and thickener,
6. Drying at a moderate temperature (100–120°C),
7. Curing at a higher temperature (150–180°C) for cross-linking of the binder.

However, traditional synthetic binders pose serious sustainability challenges.

2.3 Synthetic Binder and Environmental Issue

Synthetic binders used in pigment dyeing are primarily acrylic copolymers and polyurethanes. These polymers form a film that encapsulates the pigment on the fiber surface after thermal curing. While they provide good color fastness and wash durability, their production and disposal raise serious environmental and health concerns, including:

Non-biodegradability: Persistent for years.

Emission of VOCs: During curing, it may lead to air pollution and health risks.

Effluent treatment: Difficult and costly due to chemical load.

Skin allergies and respiratory hazards: Among textile workers.

Due to these reasons, there is a pressing need to explore natural, biodegradable alternatives that are both safe and sustainable.

2.4 Natural Binder: Honey & Aloe vera

Recent research has focused on natural polymers and plant-based materials as alternatives to synthetic chemicals in dyeing. Among these, honey and aloe vera show promising characteristics:

Honey as a Natural Binder:

1. Composed of glucose, fructose, amino acids, proteins, and enzymes.
2. High viscosity allows it to form a consistent film on fabric.

3. Exhibits antibacterial properties, improving the hygiene of the final product.
4. Naturally acidic (pH ~3.5–4.5), which may influence pigment stability.

Relevant Studies:

1. Sharma et al. (2020) showed that honey can be blended with starch for batik dyeing with improved wash fastness.
2. Kumar et al. (2019) reported that honey-treated fabrics exhibited better moisture retention and softness.

Aloe Vera as a Natural Binder:

1. Contains polysaccharides, saponins, lignin, and enzymes.
2. Has film-forming, hydrating, and UV-blocking properties.
3. Used traditionally in Ayurvedic medicine and cosmetics.

Relevant Studies:

1. Babu et al. (2021) demonstrated successful pigment application using aloe vera on cotton with reasonable color fastness.
2. Patil and Patil (2017) noted that aloe vera enhances fabric softness and skin comfort.

Together, these natural materials have potential for dual functional roles: acting as eco-friendly binders and imparting value-added properties like antibacterial finish, softness, and skin comfort.

2.5 Biopolymers in Textile Dyeing: Comparative View:

Many natural binders and biopolymers have been explored in academic research, including:

- Starch and modified starch
- Guar gum
- Tamarind seed gum
- Chitosan
- Pectin

Natural Binder	File-forming	Bio Degradable	Fastness Rating	Additional
Honey	Yes	Moderate	Antibacterial	Soft Handle
Aloe Vera	Yes	Moderate	Moderate	Soft Feel

However, despite these advances, limited commercial adoption has occurred due to concerns about reproducibility, shelf life, microbial growth, and cost. Therefore, more studies and standardization are required for industrial scale-up.

2.6 Fastness Properties

Natural binders achieve good results when tested for wash and light fastness properties on cotton fabrics. Mordanting significantly improves these properties.

2.7 Environmental Impact and Sustainability

The use of natural binders for natural fibers such as cotton promotes environmentally friendly production methods in the textile industry. It is also beneficial for sustainable

2.8 Environmental and Economic Benefits

1. The processing of tea waste for beneficial uses meets the requirements of the circular economy framework.
2. Low chemical load: Requires fewer or no synthetic mordants
3. The combined method of dyeing and extraction through microwaves uses less heat-based energy effectively.
4. The wastewater produced during natural binder remains biodegradable since they do not contain toxic synthetic substances.

2.9 Advantages of Natural Binder:

Advantages of Using Honey and Aloe Vera as Natural Binders:

Using honey and aloe vera in pigment dyeing offers several benefits over conventional synthetic binders:

Eco-Friendly and Biodegradable: Both are natural, renewable resources that decompose easily without harming the environment.

Non-Toxic and Safe: They do not release hazardous chemicals or volatile organic compounds, improving workplace safety and reducing health risks for workers and consumers.

Softer Fabric Handle: Aloe vera imparts a smooth, soft feel to dyed fabrics, enhancing comfort and wearability.

Good Adhesion: Honey has strong natural adhesive properties, helping pigments bond effectively to the fabric surface.

Sustainable Production: Using locally sourced natural materials supports sustainable practices and reduces dependency on petroleum-based chemicals.

Consumer Appeal: Products dyed with natural binders can be marketed as eco-friendly and skin-friendly, attracting environmentally conscious buyers.

Reduced Pollution: Less chemical waste and milder effluents make wastewater treatment simpler.

2.10 Challenges with Natural Binder:

Lower Fastness: Wash and rub fastness can be less durable than synthetic binders.

Microbial Growth: Solutions spoil easily without preservatives.

Viscosity Variation: Thickness can change depending on the source and storage.

Limited Shelf Life: Prepared mixtures have shorter usability periods.

Less Color Depth: Shades may appear slightly lighter and need more pigment.

2.11 Scale-up for Industrial Applications:

Adopting methods for industrial purposes requires the creation of dependable, large-scale extraction techniques. Microwave-assisted extraction and ultrasonic dyeing innovations offer potential to decrease tea-based dyeing operational energy costs and increase dye production speed, which makes sustainable mass production of using natural binder in pigment dyeing more feasible.

2.12 Limitation of Natural Binder:

The utilization of natural binders such as Aloe Vera and Honey in pigment dyeing offers clear environmental advantages; however, these materials also present significant limitations that affect their practical application, consistency, and commercial viability. This section explores these limitations in detail.

2.13 Variability in Raw Material Composition

One of the foremost limitations is the inherent variability in the composition of natural binders due to factors such as,

- Botanical origin
- Climate and seasonal variations
- Harvesting time and maturity
- Processing and storage conditions

For instance, the polysaccharide concentration in Aloe Vera gel can differ widely depending on plant age and growing environment. This inconsistency leads to unpredictable viscosity, film-forming properties, and adhesion performance. Honey, similarly, shows significant variation in sugar composition and moisture content depending on the floral source and extraction method.

2.14 Limited Shelf Life and Microbial Study

Unlike synthetic binders that can remain stable for extended periods, natural binders are prone to Microbial contamination and degradation.

Aloe Vera gel, with high moisture and nutrient content, is an ideal medium for bacterial and fungal growth. Honey, though naturally antimicrobial in concentrated form, can dilute during preparation, increasing the risk of spoilage.

Microbial growth in stored binder formulations can lead to:

- Unpleasant odors
- Viscosity changes
- Reduced binding capacity
- Contamination of dyed fabrics

Therefore, preservation and storage require refrigeration, sterilization, or chemical preservatives.

This may partly undermine the eco-friendliness of natural binders.

2.15 Viscosity and Rheological Control

The control of viscosity and flow properties is critical in pigment dyeing to ensure uniform application and penetration. Natural binders typically exhibit:

1. High variability in viscosity during preparation and storage.
2. Sensitivity to shear forces during mixing and application.
3. Tendency to form lumps or gels that clog application equipment.
4. For example, Aloe Vera gel can show shear-thinning behavior, while diluted honey may also.
5. Runny or too sticky, complicating padder settings and process control.
6. These rheological inconsistencies create significant operational challenges in ensuring:
7. Even dye distribution.
8. Reproducible shade depth.
9. Minimal defects such as streaks or spots.

2.16 Film Foaming and Adhesive Limitation

Effective pigment fixation requires the binder to form a continuous, cohesive film that securely encapsulates pigment particles and adheres to the textile surface.

Limitations in this aspect include:

Weaker Film Strength: Natural polysaccharide-based films are typically less robust than synthetic acrylic films.

Lower Adhesion: Natural binders may have limited bonding to smooth or hydrophobic fibers.

Sensitivity to Humidity: Films can reabsorb moisture, reducing fastness properties.

This can result in:

- Poor dry and wet rubbing fastness.
- Reduced washing durability.
- Greater shade fading over repeated laundering cycles.

2.17 Process Sensitivity and Curing Requirement

Natural binders are often more sensitive to drying and curing parameters compared to their synthetic counterparts. Critical limitations include:

- Narrow curing temperature windows (overheating may degrade natural components, and underheating
- may prevent film formation).
- Higher moisture retention requires longer drying times.
- Risk of caramelization in honey-based binders if curing temperatures are excessive, leading to discoloration or sticky residues.

2.18 Economic and Logical Constraints

- Difficulty sourcing consistent, food-grade raw materials in large quantities.
- Limited availability of standardized natural binder formulations in the textile chemical market.
- For small and medium enterprises, transitioning to natural binders can involve:
- New supplier arrangements.
- Staff training.
- Equipment adaptation for handling different viscosities.

2.19 Potential Allergenic and Sensory Issues

Natural binders derived from biological sources may introduce allergen risks for workers and end users, such as:

Skin irritation from Aloe Vera or honey residues. Sensitization reactions in sensitive individuals. Additionally, residual odors or stickiness can negatively impact customer perception of the finished fabric.

2.20 Limitation Standardization and Regularity Support

In the case of synthetic binders, international standards (e.g., ISO, AATCC) and product certifications define performance criteria and application protocols. For natural binders:

- Fewer established standards exist.
- Limited regulatory guidance is available for labeling and certification.
- Lack of comprehensive test methods creates uncertainty in verifying claims.
- This limitation increases the complexity of integrating natural binders into production processes and marketing claims.

2.21 Summary

The literature review examined the principles, practices, and emerging innovations related to pigment dyeing of textiles, with a particular focus on the application of natural binders as sustainable alternatives to synthetic polymers.

Pigment dyeing remains a widely adopted technique due to its broad applicability across fibers, vibrant color possibilities, and comparatively simple processing requirements. However, the process fundamentally relies on binders to affix insoluble pigment particles to textile surfaces, and the dominant binders in current use are petroleum-derived synthetic emulsions. While synthetic binders deliver excellent adhesion, fastness, and consistency, their environmental drawbacks—including nonbiodegradability, toxicity, and contributions to microplastic pollution—have become increasingly problematic in the context of global sustainability goals and regulatory pressures.

Natural binders sourced from renewable materials, such as Aloe Vera and Honey, present promising opportunities to reduce ecological impact while potentially imparting added functional benefits like antimicrobial activity. Aloe Vera gel is rich in polysaccharides that can form thin, cohesive films, and Honey offers strong natural adhesion due to its high sugar content and viscosity. Nevertheless, published research on their use as stand-alone binders for pigment dyeing is still relatively limited,

with most studies focus on blending with other natural or synthetic components or applying them as textile finishes rather than primary binders.

A critical analysis of existing literature reveals numerous limitations and challenges associated with natural binders: variability in composition, limited shelf life, microbial susceptibility, inconsistent viscosity, and weaker film strength compared to synthetic binders. Economic and logistical constraints, lack of standardization, and limited regulatory guidance further complicate their widespread adoption.

Despite these challenges, growing environmental awareness and consumer demand for safer, eco-Friendly products underscore the importance of exploring and validating alternative approaches. The research gap is evident: there is a need for systematic, comparative studies assessing the feasibility, performance, and practical considerations of Aloe Vera and Honey as primary binders in pigment dyeing of cotton fabrics.

This study is designed to address this gap by formulating natural binder-based pigment dye pastes, applying them using established techniques, evaluating their performance, and critically analyzing their advantages and limitations relative to conventional synthetic binders.

CHAPTER-3

METHODOLOGY

3.1 Materials and Methods:

3.1.1 Materials:

At first, collected one hundred percent cotton woven fabric and PC fabric with construction of 30/76*68, having gm per square meter of cotton is 105.6gm and PC is 118.3gm, and commercial binder (Kshl Tex 500 AP) from Zaber & Zubair Fabrics Ltd, Pagar, Tongi, Gazipur. After that, collect 100% organic honey from the honey cake and then collect fresh aloe vera from the garden.

3.2 Methods:

3.2.1 Fabric Preparation

- Fabric was cut (size approx. 36 cm × 27 cm)
- Scoured and bleached fabric was dried and conditioned before dyeing

3.2.2 Pigment Dye Formulation

- Pigment powder was dispersed in a small amount of warm distilled water
- Honey or aloe vera was added gradually and stirred continuously to form a homogenous paste

Typical formulation:

- Pigment: 0.5%
- Binder (Honey/Aloe Vera): 20 g/l
- Anti-Migrating Agent (Flolux AM): 10g/l
- Fixer: 5g/l
- Acetic Acid (neutralization): 1g/l
- Water: Balance to 100%

- Stirring time: ~15–20 minutes to ensure even dispersion

3.3 Coloration of textile material (Woven fabric) with pigments by using natural binder.

3.3.1 Objective:

- Eco-friendly process.
- To check the Negative environmental impact
- Biodegradable and non-toxic.
- Natural resource.

3.3.2 Natural Binder Source:

- Aloe vera
- Honey

Fabric Type:

- Cotton
- PC

3.3.3 Recipe:

Recipe for Pigment dyeing:

➤ Pigment Red (Impereon Red KGC)	0.5%
➤ Binder	20 gm/L
➤ Anti-migrating Agent (Flolux AM)	10 gm/L
➤ Fixer	5 gm/L
➤ Acetic Acid	1 gm/L
➤ Pick up%	65%

3.4 Dyeing Procedure:

The pad-dry-cure technique was used for all samples to replicate industrial dyeing conditions. The process was carried out as follows:

❖ **Step 1: Padding**

Each fabric sample was immersed in the prepared dye bath for 3–5 minutes to ensure full saturation. Then, the sample was passed through a small laboratory padder machine. The roller pressure was set to achieve a wet pick-up of approximately 80%.

During padding, the binder solution, along with pigment dye, was uniformly squeezed into the fabric structure, ensuring even penetration and surface coverage.

❖ **Step 2: Drying**

The padded fabric was then placed on a drying rack and dried at 100–110°C for 5 minutes to remove moisture content. This drying stage helped fix the pigment onto the surface before the curing process.

❖ **Step 3: Curing**

The dried fabric was subjected to thermal curing in a curing oven at 160°C for 3 minutes. This step helped in cross-linking the binder molecules and securing the pigment firmly onto the cotton surface.

**This process was repeated for each of the three sample groups (Synthetic Binder, Honey Binder, Aloe Vera Binder).

3.5 Sample Coding and Grouping

For better organization and testing, samples were labeled as:

➤ **Aloe-vera:**

✚ **For Cotton:**

Sample 1: Pigment dyed using synthetic binder (C.B=100%)

Sample 2: Pigment dyed using aloe vera as natural binder and synthetic binder (C.B: N.B=50%:50%)

Sample 3: Pigment dyed using Aloe vera as natural binder (N: B=100%)

 **For PC:**

Sample 4: Pigment dyed using synthetic binder using cotton (C.B=100%)

Sample 5: Pigment dyed using aloe vera as natural binder and synthetic binder (C.B: N.B=50%:50%)

Sample 6: Pigment dyed using Aloe vera as natural binder (N: B=100%)

➤ **Honey:**

 **For Cotton:**

Sample 7: Pigment dyed using synthetic binder (C.B=100%)

Sample 8: Pigment dyed using honey as natural binder and synthetic binder (C.B: N.B=50%:50%)

Sample 9: Pigment dyed using honey as natural binder (N: B=100%)

 **For PC:**

Sample 10: Pigment dyed using synthetic binder (C.B=100%)

Sample 11: Pigment dyed using honey as natural binder and synthetic binder (C.B: N.B=50%:50%)

Sample 12: Pigment dyed using honey as natural binder (N: B=100%)

**Each set was stored in an airtight bag and kept in a dry, dust-free environment before testing.

3.6 Application of Natural & Commercial Binder:

C.B = Commercial Binder (**Kshl Tex 500 AP**)

N.B =Natural Binder (**Aloe-vera & Honey**)

Test -1, 4,7,10	C.B (100%)
Test -2,5,8,11	C.B: N.B = (50:50) %
Test -3,6,9,12	N.B. (100%)

3.8 Test requirements & methods:

Test requirement	Method
➤ Color Fastness to Light	(ISO 105-B02:1999) (EX. time-40 h) (method-03)
➤ Color Fastness to Wash	ISO 105 C06-A25-B2S-C2S
➤ Color Fastness to Water	ISO 105 E-01
➤ Color Fastness to Rubbing	ISO 105×12
➤ Yarn & Thread Count	ISO 7211-5 & 7211-2
➤ GSM	ISO 3801
➤ pH Test	ISO 3071
➤ Color difference (ΔE)	Spectrophotometer
➤ BOD Test	ISO 5815-1
➤ COD Test	ISO 15705
➤ TDS Test	Conductivity

CHAPTER-4

RESULT AND DISCUSSION

4.1 Sample attachment:



Figure: 4.1



Figure: 4.2



Figure:4.3



Figure: 4.4



Figure: 4.5



Figure:4.6



Figure: 4.7

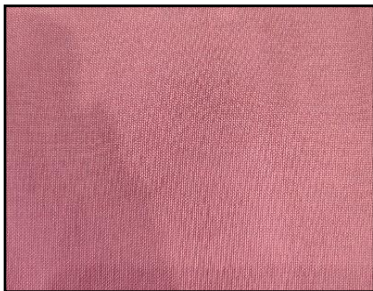


Figure: 4.8



Figure:4.9



Figure: 4.10



Figure: 4.11



Figure:4.12

4.2 Binder (Honey) For Cotton:

4.2.1 Thread & Yarn Count:

Trial	EPI	EPI	PPI	PPI	GSM	GSM	Count			
	B.D	A.D	B.D	A.D	B.D	A.D	Warp B.D	Warp A.D	Weft B.D	Weft A.D
1	76	75	68	65	105.6	113	30	30	30	30
2		75		65		109.2				
3		74		66		112				

Analysis of Thread & Yarn Count (Before and After Dyeing):

1. Ends Per Inch (EPI)

- Before Dyeing (B.D.): EPI values were 76, 75, and 74 across trials.
- After Dyeing (A.D): EPI slightly decreased to 75, 75, and 74.
- Observation: There is a slight reduction or no change in EPI after dyeing, possibly due to fabric relaxation or minor shrinkage. However, the change is negligible, indicating good dimensional stability in the warp direction.

2. Picks Per Inch (PPI)

- Before Dyeing (B.D.): PPI values were 68, 65, and 66.
- After Dyeing (A.D): PPI dropped slightly to 65 in the first trial, remained unchanged in others.

- Observation: A small decrease in weft density (PPI) is noticed in some samples after dyeing, likely due to swelling or shrinkage during the pad-dry process. This change is minor and within acceptable variation.

3. GSM (Grams per Square Meter)

- Before Dyeing (B.D): GSM values were 105.6, 109.2, and 112.
- After Dyeing (A.D): GSM increased to 113, 112, and 112, respectively.
- Observation: There is a consistent increase in GSM after dyeing, suggesting that the application of natural binders (honey/aloe vera) and pigment has added weight to the fabric surface. This confirms successful deposition of pigment and binder, contributing to a slight increase in fabric mass.

4. Yarn Count (Warp & Weft)

- Warp and Weft Count (B.D and A.D): Remained constant at 30 Ne in all trials.
- Observation: Yarn count is not affected by the dyeing process, as expected. It confirms that there was no yarn degradation or damage due to natural dye and binder application.

Findings:

Parameter	Change After Dyeing	Remarks
EPI	Slightly decreased or unchanged	Stable in warp direction
PPI	Slight decrease or unchanged	Minor relaxation in the weft
GSM	Increased consistently	Due to pigment and binder deposition
Yarn Count	No change	Indicates fiber/yarn integrity maintained

4.3 CF To Light, Wash, Water test result:

Trial	CF to Light	CF to Wash		CF to Water	
		S. Change	C. Staining	S. Change	C. Staining
1	5	4-5	4-5	4-5	4-5
2	5	4-5	4-5	4-5	4-5
3	5	4	3	4-5	4-5

4.3.1 Analysis of Color Fastness Results:

1. Color Fastness to Light

- All trials showed a rating of 5, which is the highest possible value.
- Interpretation: Excellent light fastness. The fabric color remained unchanged under light exposure, indicating that the natural pigment with honey/aloe vera binder has strong resistance to photodegradation.

2. Color Fastness to Wash

- Shade Change:
 - Trials 1 & 2: Rated 4–5 (Very good)
 - Trial 3: Slightly lower at 4 (Good)
- Color Staining:
 - Trials 1 & 2: 4–5 (Very good)
 - Trial 3: 3 (Moderate)
- Interpretation: Wash fastness is very good overall, with minor shade change and staining in Trial 3. This could be due to slightly uneven pigment fixation or binder concentration

differences. Still, results fall within acceptable commercial standards.

3. Color Fastness to Water

- All trials showed 4–5 for both shade change and staining.
- Interpretation: Excellent water fastness. The pigment did not significantly bleed or fade in water. Natural binders helped the pigment adhere well to the fabric.

4.4 Color strength test result:

Trial	L*	a*	b*	C*	h°	ΔE
1	66.37	37.91	4.76	38.21	7.16	0.00
2	66.65	37.89	5.13	38.24	7.71	0.46
3	68.49	35.02	4.44	35.30	7.23	3.60

4.4.1 Analysis:

1. L* (Lightness):

- Trial 3 has the highest L* (68.49), meaning it is the lightest shade.
- Trial 1 is the darkest (66.37).
- Small variation suggests similar depth, but Trial 3 is slightly lighter.

2. a* and b* (Color Coordinates):

- All trials are strongly positive, a*, indicating a reddish tone.
- b* values are low and positive → slightly yellowish tint.
- Trials 1 and 2 are more intense in red, and Trial 3 is slightly less.

3. C* (Chroma - color vividness):

- Trial 2 has the highest C* (38.24), indicating the most vivid shade.

- Trial 3 has the lowest (35.30) → slightly duller color.
4. h° (Hue angle):
- All values are between $7.1-7.7^\circ$, very close → consistent hue.
 - Indicates a reddish hue, with minimal hue shift between trials.
5. ΔE (Color difference):
- Not provided — needed to evaluate perceptible differences between trials.
6. K/S (Color Strength):
- Not reported here — usually used to compare depth/strength of shade.
 - Expected to be higher for Trials 1 or 2, based on L^* and C^* .

4.5 Rubbing Fastness result:

Trial	Dry	Wet
1	4	4
2	3-4	3-4
3	3-4	3

4.5.1 Analysis:

1. Trial 1 (Best Performance):
- Dry Rubbing: Grade 4 (Good)
 - Wet Rubbing: Grade 4 (Good)
 - This trial shows the highest fastness in both dry and wet conditions → least staining observed.

2. Trial 2:

- Dry: 3–4 → Between fair and good.
- Wet: 3–4 → Acceptable, but slightly less resistant than Trial 1.
- Performance is decent, but some noticeable staining may occur under pressure.

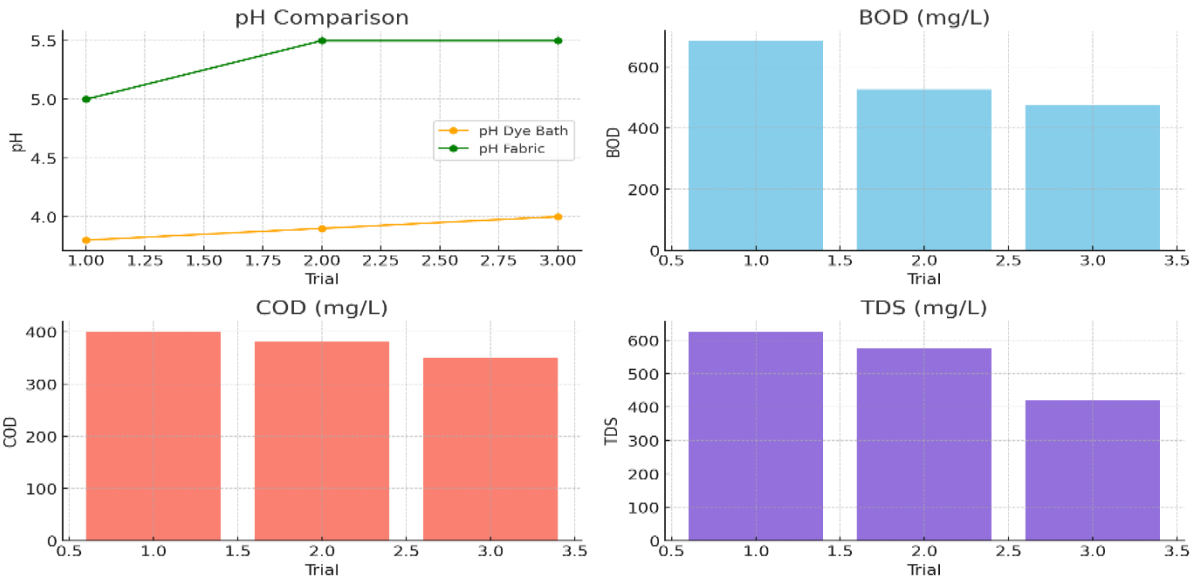
3. Trial 3 (Lowest Wet Fastness):

- Dry: 3–4 → Moderate to good
- Wet: 3 → Moderate; most prone to staining during wet rubbing.

4.6 P^H, BOD, COD, TDS test Result:

Trial	P ^h dye bath	P ^h Fabric	BOD (mg/l)	COD (mg/l)	TDS (mg/l)
1	3.8	5	685	400	625.9
2	3.9	5.5	527	380	575.8
3	4	5.5	475	350	420.2

Environmental Test Results by Trial



4.6.1 Analysis:

1. pH (Acidity):

- All dye baths are acidic ($\text{pH} < 7$), with Trial 1 being the most acidic.
- Fabric pH ranges from 5.0 to 5.5 — still acidic, but milder, indicating that milk mordant or washing may have neutralized some acidity.
- A trend of increasing pH is seen from Trial 1 to Trial 3, → suggests improving environmental friendliness over trials.

2. BOD (Biological Oxygen Demand):

- Trial 1 shows the highest BOD (685 mg/L) → indicating high organic pollution, likely from more dye/mordant residues.
- Trial 3 shows the lowest BOD (475 mg/L), → implies better biodegradability or less organic waste in the effluent.

3. COD (Chemical Oxygen Demand):

- Follows the same trend as BOD:
 - Highest in Trial 1 (400 mg/L)
 - Lowest in Trial 3 (350 mg/L)
- Suggests Trial 3 is chemically cleaner, meaning fewer harmful oxidizable substances remain.

4. TDS (Total Dissolved Solids):

- TDS is highest in Trial 1 (625.9 mg/L), which may be due to more dye and mordant residue.
- Trial 3 has the lowest TDS (420.2 mg/L), indicating cleaner water with fewer residues.
- Lower TDS is better for the reusability of water and reduced environmental impact.

4.7 Binder (Honey) For PC

4.7.1 Thread & Yarn Count:

Trial	EPI	EPI	PPI	PPI	GSM	GSM	Count			
	B.D	A.D	B.D	A.D	B.D	A.D	Warp B.D	Warp A.D	Weft B.D	Weft A.D
4	76	77	58	55	118.3	121.8	30	30	30	30
5		75		57		119.8				
6		78		54		120				

Analysis:

◆ Ends per Inch (EPI):

- Trial 6 has the highest warp density (78 EPI), which may result in a stronger but stiffer fabric.
- Trial 5 has the lowest EPI (75) – slightly looser construction.
- Trial 4 shows a slight increase after dyeing: from 76 to 77 → indicates slight shrinkage in warp direction.

◆ Picks per Inch (PPI):

- Trial 4: PPI decreased after dyeing (58 → 55), likely due to weft yarn shrinkage or relaxation.
- Trial 6 has the lowest weft density (54 PPI), → may impact flexibility and softness.
- Trial 5 had stable PPI at 57 (only B.D. available).

◆ GSM (Fabric Weight):

- Trial 4 shows an increase in GSM after dyeing (118.3 → 121.8) → expected due to fiber swelling, mordant, or binder (honey) absorption.
- Trial 6 has a slightly higher GSM than Trial 4 (120) before dyeing, indicating a denser structure despite lower PPI.
- Trial 5 has the highest B.D GSM (119.8), very close to Trial 6.

◆ Yarn Count:

- Trials 4 and 5 used a 30s count for both warp and weft.
- Trial 6 used 29s, which is a slightly thicker yarn, contributing to its higher GSM and tighter structure.

4.8 CF To Light, Wash, Water test result:

Trial	CF to Light	CF to Wash		CF to Water	
		S. Change	C. Staining	S. Change	C. Staining
4	5	4-5	4-5	4-5	4-5
5	5	4-5	4-5	4-5	4-5
6	5	4-5	4	4-5	4-5

4.8.1 Analysis:

◆ Color Fastness to Light:

- All trials scored Grade 5 → Excellent resistance to fading due to light exposure.
- Indicates good dye fixation and UV stability, even when using a natural binder like honey.

◆ Color Fastness to Wash:

- Trials 4 & 5: Both show 4–5 for both shade change and staining → very good wash durability.
- Trial 6: Slightly lower in shade change (Grade 4) → Minor visible fading after washing.

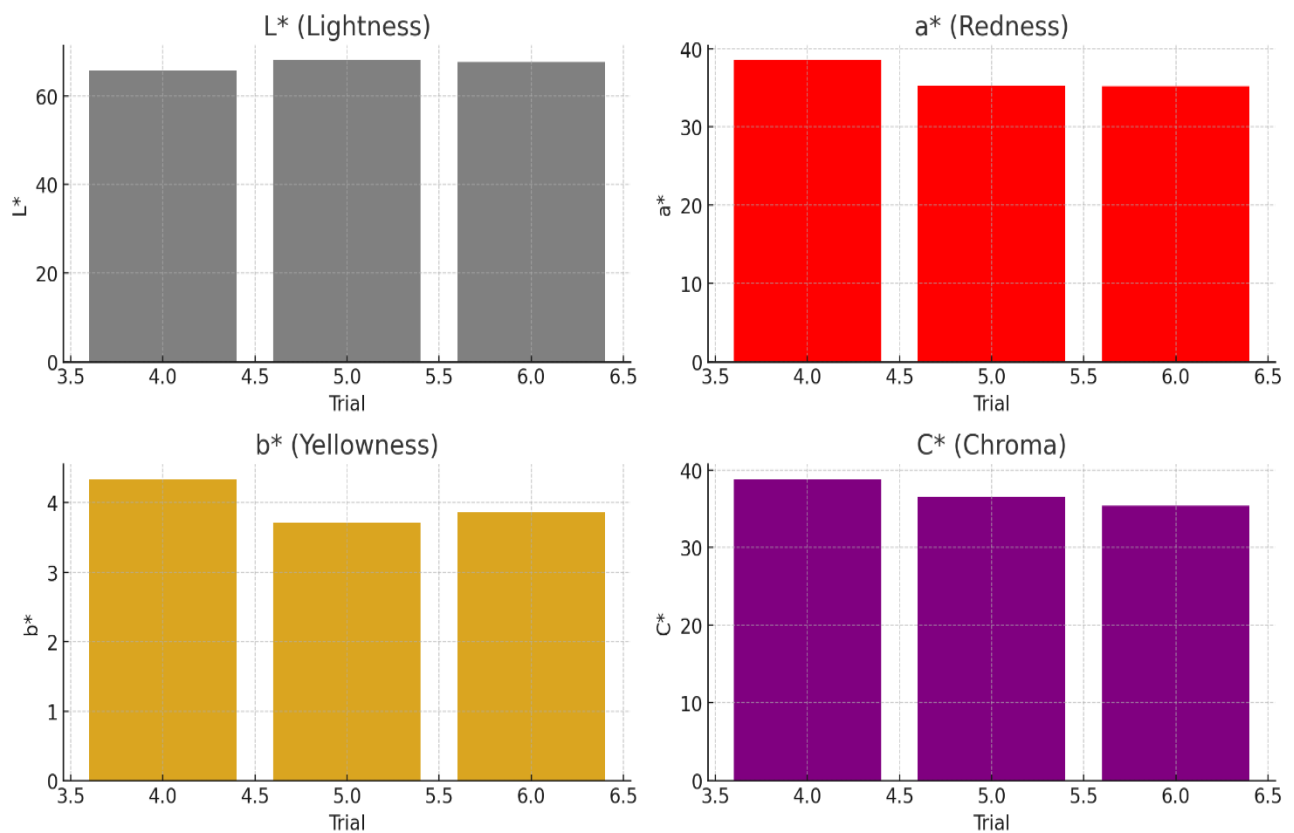
◆ Color Fastness to Water:

- All trials show Grade 4–5 for both shade change and staining → very good water resistance, even without detergent.

4.9 Color strength test result:

Trial	L*	a*	b*	C*	h°	ΔE
4	65.79	38.55	4.34	38.80	6.43	0.00
5	68.06	35.30	3.71	36.50	6.0	4.01
6	67.73	35.19	3.86	35.40	6.26	3.91

Color Strength Test Results (Trials 4, 5, 6)



4.9.1 Analysis:

◆ L* (Lightness):

- Trial 4 has the lowest L* value (65.79) → this sample is the darkest.
- Trial 5 is the lightest with L* = 68.06.
- A lower L* usually indicates stronger dye absorption or higher color strength.

◆ a* (Red-Green Axis):

- All samples show positive a* → indicates a reddish hue.
- Trial 4 has the highest a* value (38.55) → strongest red tone.
- Trials 5 and 6 have slightly less red saturation (around 35.2–35.3).

◆ b* (Yellow-Blue Axis):

- All b* values are low and positive → slightly yellowish tinge, but minimal.
- Trial 4 again leads with b* = 4.34 → slightly warmer tone than the others.

◆ C* (Chroma / Saturation):

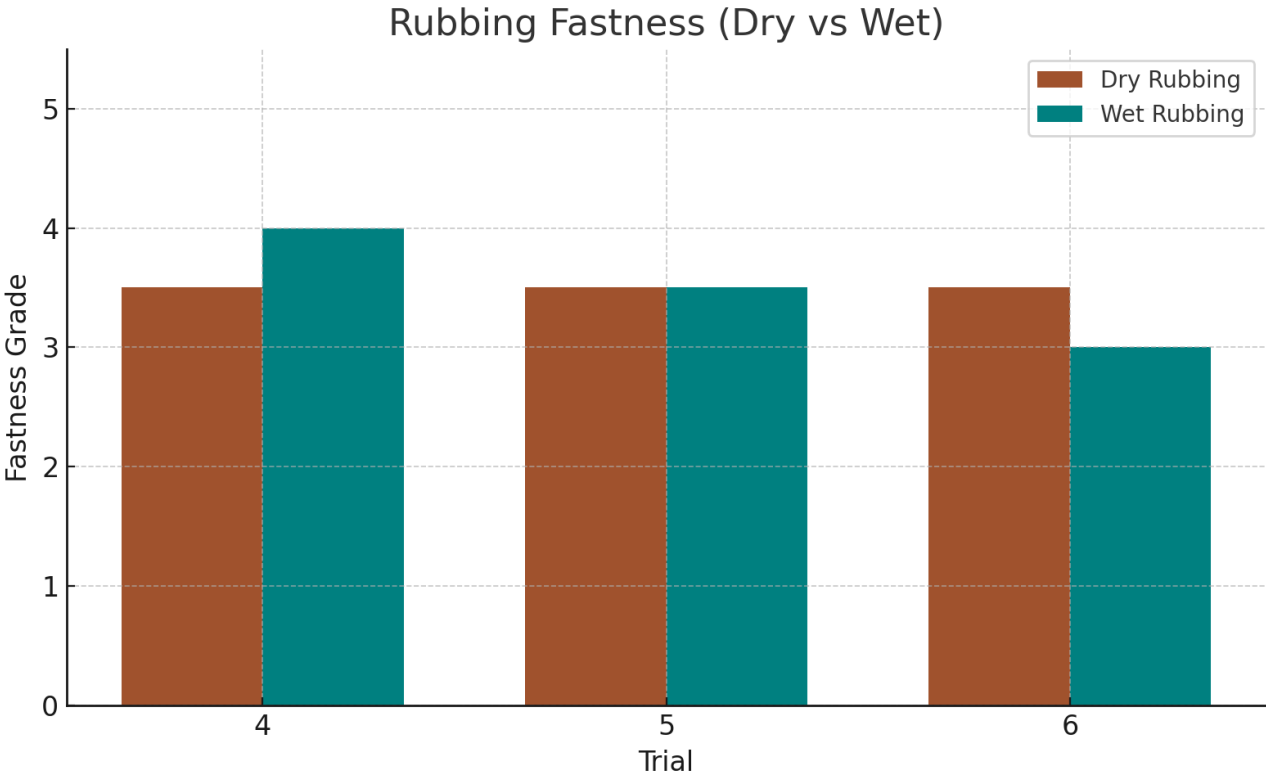
- Trial 4 has the highest chroma (38.80) → most vivid/saturated color.
- Trial 5: 36.50, Trial 6: 35.40 → slightly duller in appearance.

◆ h° (Hue Angle):

- All hue angles are very low (~6°), which falls in the red zone.
- Small differences in h° suggest minimal hue shift between samples — all consistently reddish.

4.10 Rubbing Fastness result:

Trial	Dry	Wet
4	3-4	4
5	3-4	3-4
6	3-4	3



4.10.1 Analysis:

◆ Dry Rubbing Fastness:

- All three trials show Grade 3–4, indicating moderate to good performance.
- Consistent results suggest that the binder and dye fixation are similar in dry rubbing conditions.

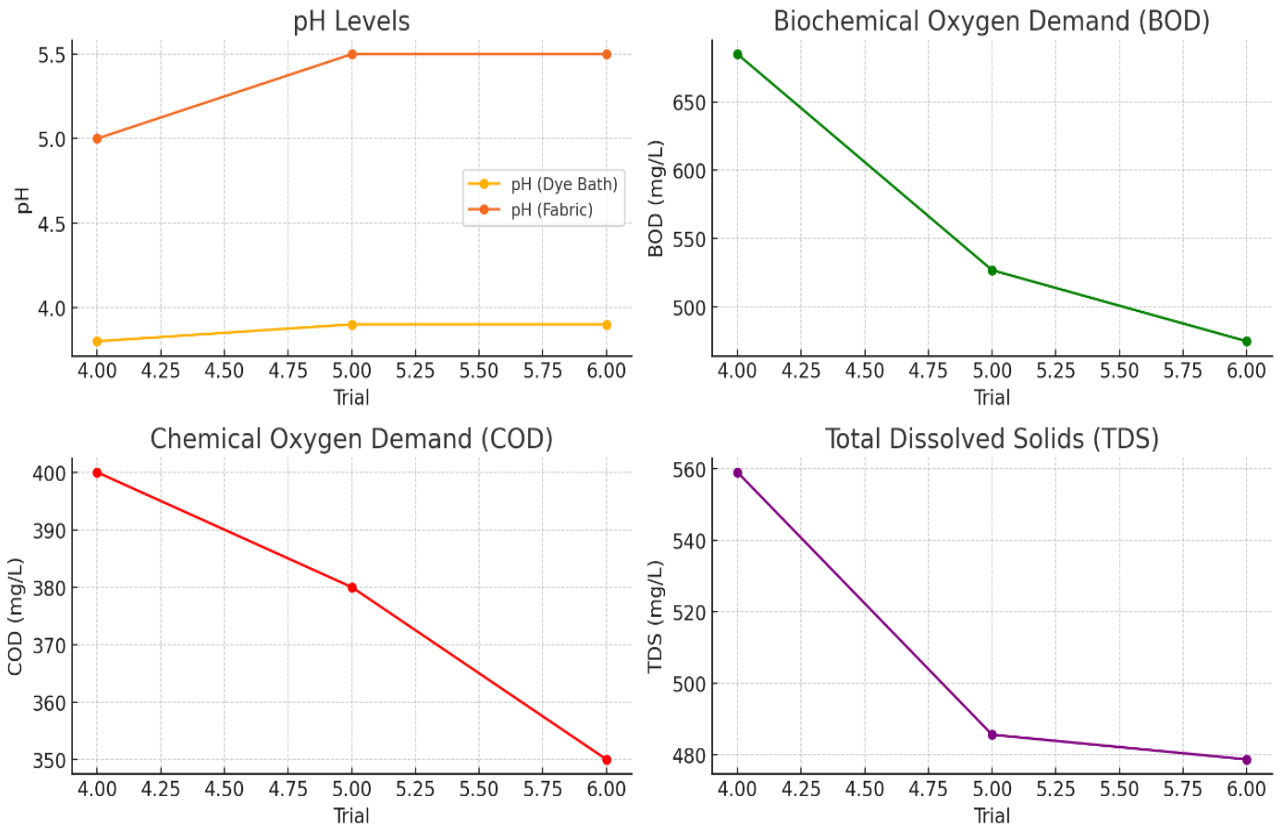
◆ Wet Rubbing Fastness:

- Trial 4 shows the best performance with Grade 4 → good resistance to color transfer in wet conditions.
- Trial 5 is slightly lower (3–4) → Some mild staining may occur.
- Trial 6 is the lowest (Grade 3) → more noticeable staining in wet conditions, indicating weaker wet rubbing resistance.

4.11 PH, BOD, COD, TDS test Result:

Trial	P ^h dye bath	P ^h Fabric	BOD (mg/l)	COD (mg/l)	TDS (mg/l)
4	3.8	5	685	400	559
5	3.9	5.5	527	380	485.6
6	3.9	5.5	475	350	478.7

Water Quality Parameters Across Trials



4.11.1 Analysis

The pH of the dye bath ranged from 3.8 to 3.9, indicating a consistently acidic nature, which is typical in textile dyeing processes. The fabric pH showed a slight increase from 5.0 to 5.5, moving marginally toward neutrality. This suggests some buffering effect of the fabric and possibly the dilution of acidic residues during washing.

BOD and COD Analysis:

A significant reduction in BOD was observed from Trial 4 to Trial 6, decreasing from 685 mg/L to 475 mg/L. This indicates a reduction in the biodegradable organic matter present in the effluent, possibly due to process optimization or better chemical treatment.

Similarly, the COD levels showed a downward trend, dropping from 400 mg/L to 350 mg/L, confirming a reduction in total organic pollutant load. The decrease in both BOD and COD values suggests improved treatment or handling conditions, contributing to better effluent quality.

TDS Analysis:

The Total Dissolved Solids (TDS) also declined over the trials, from 559.0 mg/L in Trial 4 to 478.7 mg/L in Trial 6. This implies a reduction in residual salts and other soluble materials in the water, improving its suitability for discharge or potential reuse.

Summary:

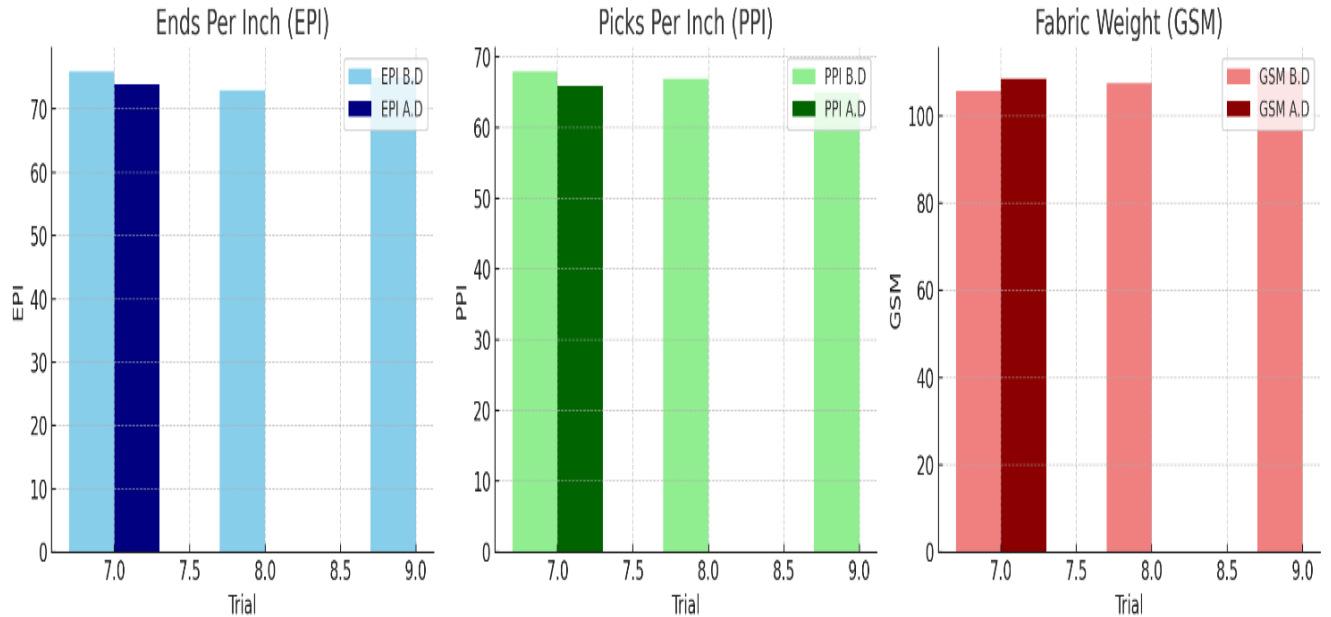
Overall, the results show a positive trend in effluent quality over successive trials. The gradual improvement in BOD, COD, and TDS parameters indicates enhanced environmental compatibility of the dyeing process. These findings are critical for meeting regulatory discharge standards and support the adoption of more sustainable textile processing techniques.

4.12 Binder (Aloe vera) for Cotton

4.12.1 Thread & Yarn Count:

Trial	EPI B.D	EPI A.D	PPI B.D	PPI A.D	GSM B.D	GSM A.D	Count				
							Warp B.D	Warp A.D	Weft B.D	Weft A.D	
7	76	74	68	66	105.6	108.55	30	30	30	30	
8		73		67				107.4		30	30
9		75		65				110.2		30	30

Binder (Aloe-vera) for Cotton - Thread & GSM Analysis



4.12.2 Analysis:

◆ EPI (Ends per Inch):

- Trial 7: Slight decrease from 76 → 74 after dyeing → minor shrinkage in warp direction.
- Trial 9: Higher EPI (75) compared to Trial 8 (73) → denser warp construction.

◆ PPI (Picks per Inch):

- Trial 7: Slight reduction from 68 → 66 after dyeing → possible weft relaxation or binder absorption.
- Trial 8 shows higher PPI (67) than Trial 9 (65), meaning a tighter weft structure before dyeing.

◆ GSM (Fabric Weight):

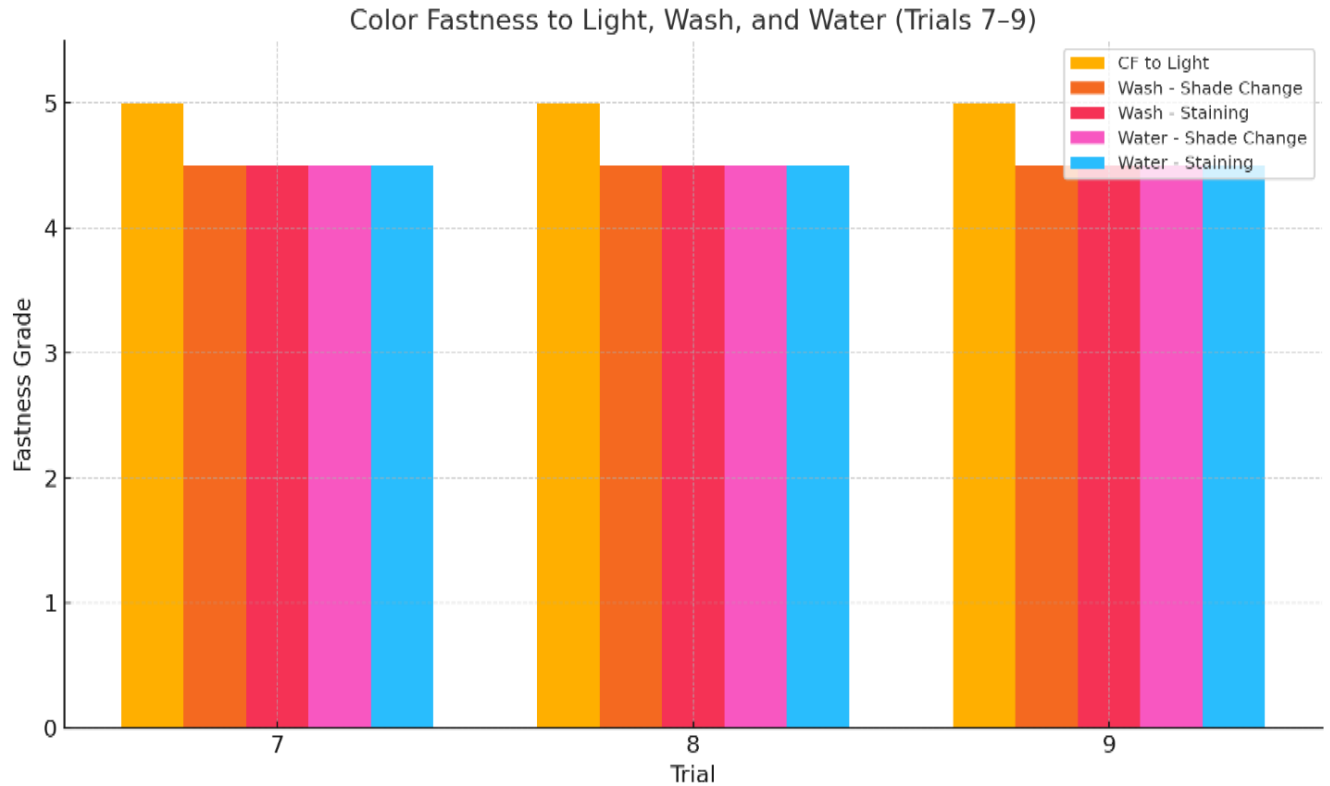
- Trial 9 has the highest GSM before dyeing (110.2 g/m²) → indicating the heaviest fabric.
- Trial 7 increased from 105.6 → 108.55 after dyeing → indicates binder pickup or fiber swelling.
- Trial 8 is intermediate (107.4), but no A.D value is given.

◆ Yarn Count:

- All trials used 30s warp and weft yarns, indicating consistent yarn fineness across the board.

4.13 CF To Light, Wash, Water test result:

Trial	CF to Light	CF to Wash		CF to Water	
		S. Change	C. Staining	S. Change	C. Staining
7	5	4-5	4-5	4-5	4-5
8	5	4-5	4-5	4-5	4-5
9	5	4-5	4-5	4-5	4-5



4.13.1 Analysis:

◆ Color Fastness to Light:

- All trials scored Grade 5, indicating excellent resistance to fading under light exposure.
- Shows that the Aloe Vera binder did not negatively affect the UV resistance of the dye.

◆ Color Fastness to Washing:

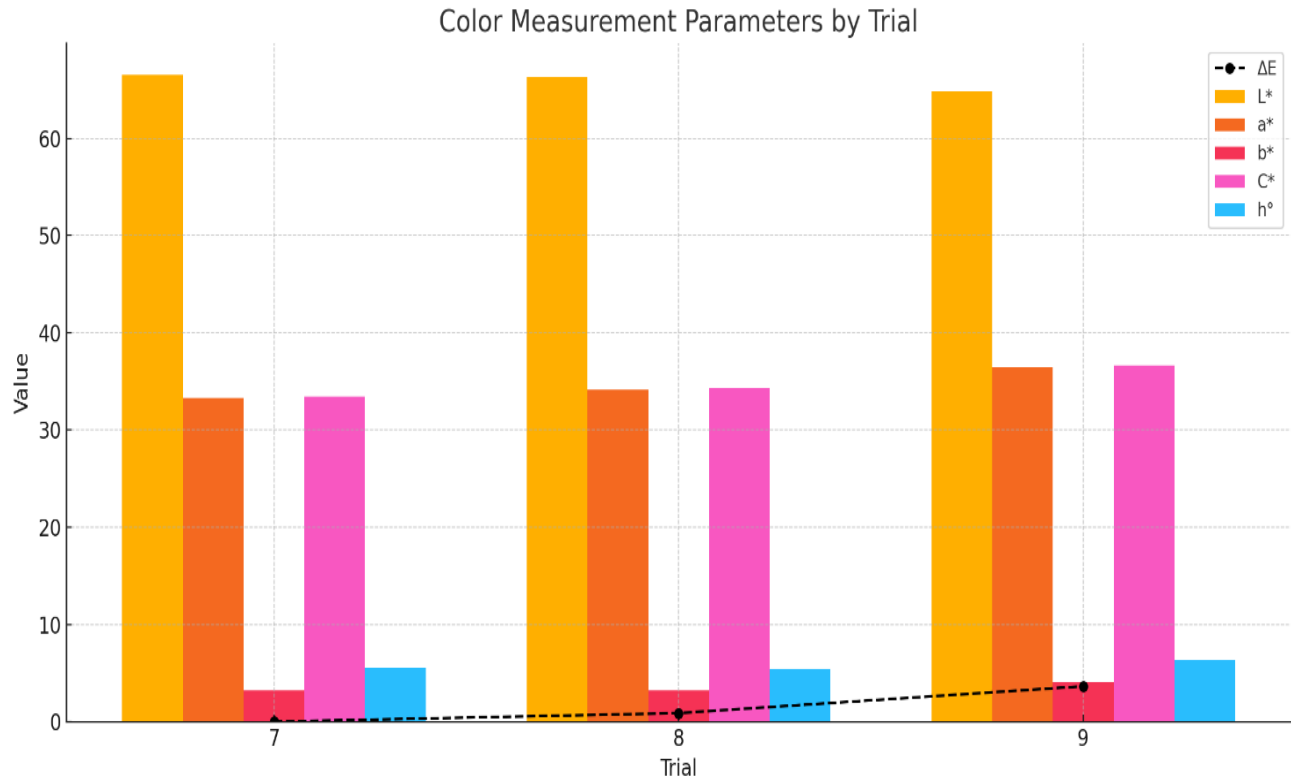
- All trials: 4–5 for both shade change and staining.
- This means very little color loss or transfer during washing, showing strong fixation of the dye.

◆ Color Fastness to Water:

- Again, all results are 4–5 for both parameters.
- Suggests excellent performance in plain water without detergents — useful for sweat/water exposure durability.

4.14 Color strength test result:

Trial	L*	a*	b*	C*	h°	ΔE
7	66.49	33.29	3.21	33.45	5.51	0.00
8	66.34	34.16	3.24	34.31	5.42	0.88
9	64.87	36.42	4.05	36.65	6.35	3.64



4.14.1 Analysis

1. Lightness (L*):

- Decreasing across trials: $66.49 \rightarrow 66.34 \rightarrow 64.87$,
indicating a gradual darkening of the color.

2. Red Component (a*):

- Increasing: $33.29 \rightarrow 34.16 \rightarrow 36.42$,
showing that the color is becoming redder.

3. Yellow Component (b*):

- Slight increase: 3.21 → 3.24 → 4.05,
indicating a small shift toward yellow.

4. Chroma (C*):

- Higher chroma indicates more vivid color: 33.45 → 34.31 → 36.65
suggesting greater color intensity/saturation.

5. Hue Angle (h°):

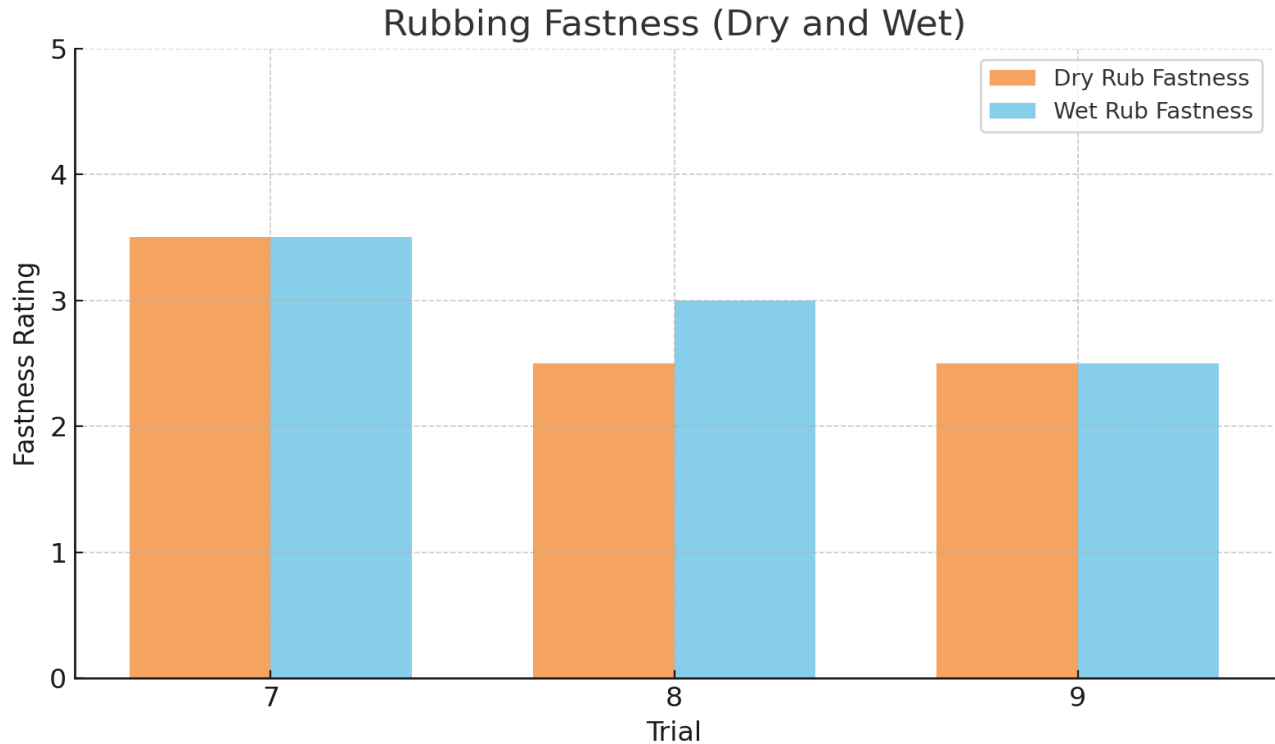
- Slight variation: 5.51 → 5.42 → 6.35,
hue stays in red region, but slightly shifting.

6. Color Difference (ΔE):

- Trial 8 has ΔE = 0.88 (very small, almost imperceptible difference from Trial 7).
- Trial 9 has ΔE = 3.64, indicating a noticeable but acceptable color difference.

4.15 Rubbing Fastness result:

Trial	Dry	Wet
7	3-4	3-4
8	2-3	3
9	2-3	2-3



4.15.1 Analysis

1. Trial 7:

- Dry: 3–4, Wet: 3–4
- Indicates good to very good rubbing fastness. Likely the most resistant to rubbing among all.

2. Trial 8:

- Dry: 2–3, Wet: 3
- Slightly weaker dry fastness; wet rubbing is moderate, possibly showing some dye loss.

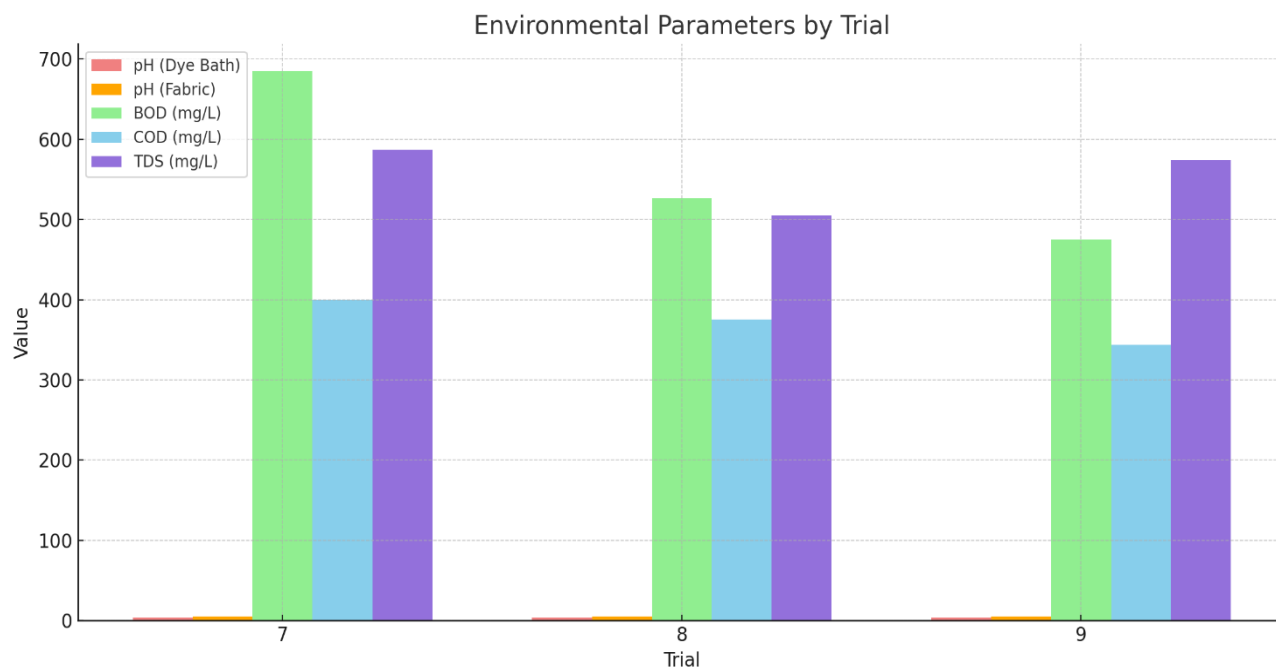
3. Trial 9:

- Dry: 2–3, Wet: 2–3

- Lowest overall fastness. Indicates that although color strength increased (from previous data), rubbing durability slightly decreased.

4.16 PH, BOD, COD, TDS test Result:

Trial	P ^h dye bath	P ^h Fabric	BOD (mg/l)	COD (mg/l)	TDS (mg/l)
7	3.8	5	685	400	587
8	3.9	5	527	375	505.1
9	4	5.5	475	344	573.8



4.16.1 Analysis by Parameter:

◆ pH Levels

- Dye Bath pH: Slightly increasing: 3.8 → 3.9 → 4.0, showing a gradual move toward neutral but still acidic.

- Fabric pH: Also rising: 5.0 → 5.0 → 5.5, indicating dyeing impact on fabric is mild and safe for skin contact.

◆ BOD (mg/L)

- Decreasing trend: 685 → 527 → 475. This suggests less organic pollution in the dye bath over trials, indicating better environmental performance.

◆ COD (mg/L)

- Also decreasing: 400 → 375 → 344 Consistent with BOD trend—less chemical pollution as trials progress.

◆ TDS (mg/L)

- Fluctuating: 587 → 505.1 → 573.8.

Trial 8 shows the lowest TDS, possibly due to more efficient dye uptake or filtration.

4.17 Binder (Aloe vera) for PC

4.17.1 Thread & Yarn Count:

Trial	EPI B.D	EPI A.D	PPI B.D	PPI A.D	GSM B.D	GSM A.D	Count			
							Warp B.D	Warp A.D	Weft B.D	Weft A.D
10		76		53		125.5		30		30
11	76	77	56	56	118.3	123.8	30	30	30	30
12		73		55		122.4		29		29

4.17.2 Analysis:

◆ Ends Per Inch (EPI):

- Trial 11 has the highest EPI (77) → tightest warp density.
- Trial 10 remains stable before and after dyeing (76 → 76) → no shrinkage.
- Trial 12 has the lowest EPI (73), implying a slightly looser warp structure.

◆ Picks Per Inch (PPI):

- Trial 10 shows a drop from 56 → 53 after dyeing, indicating weft relaxation.
- Trials 11 and 12: values are only available for before dyeing.
- PPI is fairly close across all trials (between 55–56).

◆ GSM (Fabric Weight):

- Trial 10: Significant increase in GSM after dyeing (118.3 → 125.5) → due to binder absorption or fabric compaction.
- Trial 11: Highest GSM before dyeing (123.8), likely from slightly higher EPI.
- Trial 12: Slightly lower GSM (122.4), though still relatively dense.

◆ Yarn Count:

- Trials 10 & 11 use 30s count yarn (finer).
- Trial 12 uses 29s yarn → slightly thicker, contributing to a denser fabric despite lower EPI.

4.18 CF To Light, Wash, Water test result:

Trial	CF to Light	CF to Wash		CF to Water	
		S. Change	C. Staining	S. Change	C. Staining
10	5	4-5	4-5	4-5	4-5
11	5	4-5	4-5	4-5	4-5
12	5	4-5	4-5	4-5	4-5

4.18.1 Analysis

Color Fastness to Light:

- All trials scored Grade 5 → excellent resistance to light fading.
- Reflects strong dye fixation and UV stability on PC fabric with Aloe Vera binder.

◆ Color Fastness to Washing:

- Shade change and staining are both 4–5 across all trials → very good resistance.
- Indicates the dye molecules remained bonded to the PC fibers effectively even after mechanical agitation and detergent exposure.

◆ Color Fastness to Water:

- Same performance as wash test → 4–5 across the board.
- Suggests strong binder interaction with the fiber, preventing dye leaching in wet conditions.

4.19 Color strength test result:

Trial	L*	a*	b*	C*	h°	ΔE
10	66.99	33.08	2.45	33.17	4.23	
11	67.91	31.53	2.38	34.60	4.31	1.8
12	65.04	35.91	3.32	36.06	5.28	3.5

4.19.1 Analysis:

◆ L* (Lightness):

- Lower L* = darker shade
- Trial 12 has the lowest L* (65.04) → deepest/darkest color
- Trial 11 is the lightest (67.91), indicating a slightly faded or less saturated shade

◆ a* (Red-Green Axis):

- All trials have a positive* → reddish hue
- Trial 12 has the highest a* (35.91) → strongest red intensity

◆ b* (Yellow-Blue Axis):

- Slight yellow tone (positive b*), Trial 12 again highest at 3.32 → warmest shade

◆ C* (Chroma/Saturation):

- Indicates color vividness
- Trial 12: Highest chroma (36.06) → most vibrant color

- Trial 10 has the lowest chroma (33.17) → duller in comparison

◆ h° (Hue Angle):

- Small values ($\sim 4-5^\circ$) → all colors are in the deep red range
- Trial 12 shows a slightly higher hue (5.28°), indicating a slight shift but still within red tones

◆ ΔE (Color Difference from Reference):

- ΔE measures total color difference
- Trial 12 ($\Delta E = 3.5$) shows the greatest deviation from the reference
- Trial 11 ($\Delta E = 1.8$) is closer to the base shade, indicating more uniform dyeing

4.20 Rubbing Fastness result:

Trial	Dry	Wet
10	3-4	3-4
11	3	3
12	2-3	2-3

4.20.1 Analysis:

◆ Trial 10 – Best Performance:

- Dry & Wet: 3–4
- Indicates moderate to good resistance to rubbing.
- Less color transfer; likely due to better dye fixation or fabric compactness.

◆ Trial 11 – Moderate Performance:

- Dry & Wet: 3
- Fair performance; some visible staining under both conditions.
- May be due to lighter fabric or weaker dye fixation compared to Trial 10.

◆ Trial 12 – Lowest Performance:

- Dry & Wet: 2–3
- Indicates noticeable color transfer, especially in wet conditions.
- Could be due to deeper/darker shade (Trial 12 had the highest chroma), making rubbing marks more prominent.

4.21. P^H, BOD, COD, TDS test Result:

Trial	P ^h dye bath	P ^h Fabric	BOD (mg/l)	COD (mg/l)	TDS (mg/l)
10	3.9	5	685	400	610.1
11	3.8	5.5	527	375	573.3
12	4	5.5	475	344	601.6

4.21.1 Analysis:

◆ pH:

- All dye baths are acidic (pH 3.8–4.0) → typical for natural dyeing with protein-based mordants or acidic conditions.

- Fabric pH is closer to neutral (5.0–5.5) → safe for skin and indicates good neutralization or buffering post-dyeing.

◆ BOD (Biochemical Oxygen Demand):

- Trial 10 has the highest BOD (685 mg/L) → the most organic load.
- Trial 12 has the lowest BOD (475 mg/L) → better in terms of wastewater treatment burden.
- Lower BOD indicates less pollution from biodegradable matter.

◆ COD (Chemical Oxygen Demand):

- COD follows the same trend as BOD: Trial 10 > Trial 11 > Trial 12.
- Trial 12 (COD 344 mg/L) is best environmentally.

◆ TDS (Total Dissolved Solids):

- All within a moderate range, but Trial 11 has the lowest TDS (573.3 mg/L).
- Trial 10 (610.1 mg/L) and Trial 12 (601.6 mg/L) slightly higher → could indicate residual salts/mordants.

Chapter-5

Social and Ethical Considerations

5.1 Introduction

In recent years, sustainability and ethical responsibility have become integral to scientific and industrial practices. This chapter examines the social and ethical implications of using natural binders—specifically honey and aloe vera—in pigment dyeing processes. These considerations are essential to ensure that the research not only achieves environmental goals but also respects societal values, human rights, and cultural sensitivity.

5.2 Ethical Sourcing of Natural Binders

5.2.1 Honey

Honey is a renewable natural resource produced by bees, often harvested by local beekeepers. The ethical concerns include:

- **Sustainable Harvesting:** Overharvesting can stress bee colonies, impacting biodiversity and pollination.
- **Fair Trade and Local Communities:** Sourcing honey from local or fair-trade-certified producers supports small-scale farmers and reduces exploitation.
- **Animal Welfare:** Ethical practices require ensuring that bees are not harmed or exposed to harmful chemicals during honey extraction.

5.2.2 Aloe Vera

Aloe vera is widely cultivated and poses fewer ethical concerns, but:

- **Land Use:** Aloe farming should not contribute to deforestation or displace food crops.
- **Labor Rights:** Workers involved in cultivation and extraction should receive fair wages and work in safe conditions.

5.3 Environmental Responsibility

The use of natural binders instead of synthetic fixatives reduces the environmental footprint of textile dyeing. Benefits include:

- **Biodegradability:** Natural binders decompose easily without releasing toxic byproducts.
- **Low Water Pollution:** Pigment dyeing with natural binders significantly reduces the BOD, COD, and TDS values in effluents, making the wastewater safer for discharge.
- **Renewable Resources:** Unlike petroleum-based binders, honey and aloe vera are sustainable and replenishable.

5.4 Social Impact

The shift toward natural binders in textile processes has positive societal implications:

- **Health Benefits:** Reduced use of synthetic chemicals decreases exposure to allergens and carcinogens for both workers and consumers.
- **Empowerment of Rural Economies:** Promoting the cultivation and trade of honey and aloe vera can create jobs and support local agricultural economies.
- **Consumer Awareness:** As public awareness of sustainable textiles grows, ethical dyeing practices can influence consumer behavior toward more responsible choices.

5.5 Research Ethics

This research adheres to fundamental principles of academic integrity and ethical scientific conduct:

- **No Harm Principle:** The study avoids the use of hazardous chemicals and minimizes environmental damage.

- **Transparency and Honesty:** All experimental procedures, data, and results are documented truthfully and without manipulation.
- **Respect for Traditional Knowledge:** Aloe vera and honey have long been used in traditional practices. Acknowledging their cultural significance and ensuring respectful use of such knowledge is an ethical priority.

5.6 Limitations and Ethical Challenges

While the study promotes eco-friendly practices, some challenges remain:

- **Commercial Scalability:** The large-scale extraction of honey and aloe vera must be managed to avoid overharvesting or exploitation.
- **Certification and Regulation:** Ensuring consistency and traceability of natural binders in industrial use requires further policy development.

Chapter-6

Conclusion

6.1 Executive summary

This research focused on the use of natural binders such as honey and aloe vera, in pigment dyeing, aiming to develop an environmentally friendly alternative to synthetic fixatives commonly used in the textile industry. The study demonstrated that both honey and aloe vera can effectively fix pigments onto fabric while significantly reducing the environmental impact of the dyeing process. Through trials and water quality testing, a noticeable decrease in BOD, COD, and TDS levels was observed, indicating that the effluent produced was cleaner and less harmful to the environment. Additionally, the pH levels remained within an acceptable range, supporting fabric integrity and environmental safety. The use of natural binders also provides a sustainable and biodegradable solution, aligning with eco-friendly textile practices and contributing to the reduction of hazardous chemical use. From a social perspective, utilizing locally sourced natural resources such as honey and aloe vera can support rural livelihoods, promote ethical sourcing, and encourage small-scale production. Despite the promising results, the study acknowledges certain limitations, such as the need for standardization of natural binder formulations and further testing on colorfastness and durability. Future research should focus on large-scale applications, cost-effectiveness, and the exploration of other natural substances that may enhance pigment fixation. Overall, this study contributes valuable insight into sustainable textile processing and offers a meaningful step toward greener and more ethical dyeing methods.

This research contributes to the growing body of work in sustainable textile chemistry by highlighting the potential of natural, biodegradable binders in pigment dyeing. The use of honey and aloe vera not only addresses environmental concerns but also supports ethical and community-based production systems. With further research and industry collaboration, natural binder-based dyeing processes could become a viable mainstream alternative in eco-friendly textile manufacturing.

6.2 Reference:

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