



Faculty of Engineering
Department of Textile Engineering

**Title: The Potential of Natural Dyes to Reduce
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Submitted by:

Name: Md. Sajib Khan ID: 213-23-1054

Name: Habiba Sultana ID: 213-23-1070

Supervised by:

Tanvir Ahmed Chowdhury

Head & Assistant Professor

Department of Textile Engineering

Daffodil International University

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

Advances in Wet Processing Technology

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Author's 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.



Md Sajib Khan
ID: 213-23-1054
Department of Textile Engineering
Daffodil International University



Habiba Sultana
ID: 213-23-1070
Department of Textile Engineering
Daffodil International University

LETTER OF APPROVAL

This project report, prepared by Md Sajib Khan (213-23-1054) & Habiba Sultana (213-23-1070) 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 Md Sajib Khan & Habiba Sultana to be sincere, hardworking, and enthusiastic.



Tanvir Ahmed Chowdhury

Assistant Professor

Department Of Textile Engineering

Faculty Of Engineering

Daffodil International University

STATEMENT OF CONTRIBUTIONS

It was a group work (group of two people) and through the research project in this final year of study, we investigated the likelihood of sustainable dyeing. Our area of concern was natural dyeing done for nylon and cotton material using natural extract of tea leaves as a source with milk as a natural mordant with the following title “The Potential of Natural Dye to Reduce Environmental Pollution.” We performed all the experimentations that included the procedure of extracting dye in the tea leaves, preparing mordant with the use of milk, testing samples, dyeing the procedure and completion of tests of fastness of the colors on the laboratory. We also did the gathering and scrubbing of fabrics, natural dye bath preparation and dyeing conditions of each fiber type separately. We also prepared the total documentation, data analysis and writing of the reports basing on the literature outcomes as well as our experiment. A controlled environment was created to dye the larger quantity of a fabric piece at one of the local dyeing plants supported by one of the teammates who currently worked there and can introduce the principle of organizational safety and the quality of the dyeing process. It was through the continuous academic advice and guidance of our respected advisor in the name Tanvir Ahmed Chowdhury Sir who helped our project in the compilation including the choosing of the topic of the project, designing the experiment, as well as preparation of the final thesis. The project as a whole was an interdisciplinary project, and this gave us an opportunity to further deepen our understanding on the use of natural dye and get a chance to contribute to the sustainable textile industry, as well as learned to have practical research skills that we can use in our fields.

EXECUTIVE SUMMARY

This final year project examines the issue of a sustainable use of tea leaf as natural dye on cotton and nylon cloth supported by milk as a natural mordant. The study is called, The Potential of Natural Dyes to Reduce Environmental Pollution and will prove that a more environmentally friendly dyeing process can be executed and induce the limited use of chemicals, the minimization of the toxicity of wastewater and the minimization of environmental degradation that is normally attributed to the use of synthetic dyes. The project is driven by the increasing demand of sustainable textile industry. Although synthetic dyes are used in most businesses, they are an ecological and health menace. On the contrary, natural dyes are biodegradable, renewable and safer to the individuals concerned in the work and to the consumers. Greater availability of tea waste as well as their coloring capacity made tannin and polyphenol rich wastes to be chosen as the raw material to conduct an investigation on the chemical composition and applicability as aesthetic value adders. Protein, milk included casein, was used as a natural mordant to enhance dye attachment to cellulosic and synthetic fiber. There were several steps in the study that incorporates extraction of dyes, use of mordant, dyeing of fabrics and fastness testing. To determine the effectiveness of natural dyeing to various types of materials, comparative performance analysis of cotton (natural fiber) and nylon (synthetic fiber) were carried out. The outcome was evaluated by color strength, presence of equality in color and rubbing and swiftness to wash and rub. The project emphasizes the value maximization of the already wasted tea-leaves and milk by using them creatively to create a high-value textile application, which helps derive pollution-free industrial processes and translate to a circular economy. In this study, multiple United Nations Sustainable Development Goals (SDGs) are supported, including responsibilities in consumption, clean water, and climate action. This project not only has given a sustainable alternative of dyeing, but also can lead to further research and development in production of eco-textiles thus laying a solid foundation in future research and development.

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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, 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.

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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.

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United Nations Sustainable Development Goals

The roadmap to a brighter and more sustainable future for all is found in the Sustainable Development Goals (SDGs). These 17 goals address global challenges such as poverty, inequality, climate change, environmental degradation, and sustainable production. This project directly contributes to several of these SDGs through the use of eco-friendly dyeing methods.

In this project, natural dyes extracted from tea leaves are used to dye cotton and nylon fabrics. Additionally, milk is used as a natural mordant to fix the dye, avoiding the need for harmful metallic mordants like alum or chromium. This method significantly reduces the use of toxic chemicals, making the dyeing process safer for both the environment and human health.

By using biodegradable materials and minimizing synthetic chemical usage, this project supports:

- **SDG 12: Responsible Consumption and Production** – Promoting sustainable practices in textile dyeing.
- **SDG 6: Clean Water and Sanitation** – Reducing chemical discharge into water bodies from conventional dyeing.
- **SDG 13: Climate Action** – Lowering environmental impact by replacing synthetic dyes with natural alternatives.
- **SDG 3: Good Health and Well-being** – Reducing exposure to toxic substances for workers and end-users.

Natural dyeing also uses less energy and water compared to synthetic methods, contributing to **SDG 9: Industry, Innovation, and Infrastructure** by encouraging sustainable innovations in textile processing. In this way, our project reflects a commitment to building a cleaner, greener future by integrating natural resources into textile production.

Chapter 1: Introduction

1.1 Background Information

Pollution in all forms is widespread, and one of the very important contributors in this regard is the textile industry. The most damaging pollution presents itself in dyeing operations: synthetic dyes, heavy metals, formaldehyde, azo compounds, and other such poisonous constituents are used in this process. When disposed into water bodies, mostly without treatment, these chemicals endanger aquatic life, soil health, and human survival. Growing utmost concern for environmental protection is drawing attention toward making textile production more environmentally friendly.

The green way of dyeing surfaces again in response to the environmental crisis. Natural dyes are obtained from renewable sources of plants, minerals, and animals and are mostly biodegradable and non-toxic. Commercial application of natural dyes, however, has been hindered by problems of fastness, a narrow range of shades, and incompatibility with synthetic fibers. Hence a study is warranted, wherein this project attempts experimental research to overcome some of these problems.

The main focus of this project is to investigate the dyeing potential of tea leaves extract (*Camellia sinensis*) on two types of textile substrates cotton (a natural cellulosic fiber) and nylon (a synthetic polyamide fiber) using milk as a natural mordant. Milk contains casein protein, which can act as a natural binding agent for dyes, possibly improving the dye uptake and fastness properties of fabrics.

This study involves the extraction of dye from used tea leaves, preparation of fabrics, mordanting with milk, and the dyeing process. Subsequent tests, such as wash fastness, rub fastness, and color depth analysis, are conducted to assess the performance of the dye on different fibers. The research contributes to sustainable textile innovation by offering a possible method to reduce pollution caused by synthetic dyes and mordants.

1.2 Significance and Motivation

1.2.1 Significance

The importance of the study is that it tried to bring together environmental sustainability, waste use and innovation as a means of dyeing. As the synthetic dyes are convenient and predictable in the industrial dyeing, also have negative consequences on the environment, scientists and industrial actors have tried to find eco-friendly solutions.

This project will impart a useful knowledge on:

- Obtaining plant based natural dyes Application of natural mordants.
- Knowledge in dyed-fiber reaction on natural and man-made fibers Matters to be evaluated are color fastness and performance of ultimately dyed fabrics.

The mordant is also a very clever way to utilise milk, as it removes the need to use metal salts in the conventional natural dyeing process as it is in itself, a pollutant. It reduces or simplifies the process as it is more comfortable and available in rural or small scale settings. On top of that, understanding how to dye with natural substances not only teaches us to expand our scope of technical knowledge but also gears us up to help bring a more environment conscious textile industry into existence. As green manufacturing grows as a subject of interest in the world, the knowledge is not only academic but also practicable in industry as well.

1.2.2 Motivation

This research is mainly fuelled by the necessity to avert the adverse environmental effects of the textile dyeing procedure. Being inspired by green fashion movements and the ideas of green chemistry, the project dwells upon how old techniques can be reengineered in modern times.

Our interest also was to find out whether:

Very successfully natural dyes such as the ones you can get out of tea leaves may be applied to plant based fabrics, and to synthetic ones

A safe and effective replacement to mordants of metals can be milk, which is an organic protein liquid The reprocessed waste materials (such as used tea) can be consumed as value added products Moreover, being a part of this project has enabled us to take a break away from the

normal processes that are done in the environment of a synthetic dye laboratory and utilize creativity and scientific questioning toward a genuine environmental purpose.

In this project, the change of mindset will be promoted, i.e. it will no longer be convenience-driven manufacturing but rather responsible innovation that is sustainable within the textile industry.

1.3 Importance and Benefits

In this project we have learnt to:

- Select natural dyes made out of kitchen waste of plants (used tea leaves).
- Mordanting fabric into milk, instead of using poisonous chemicals containing salt.
- Use natural dye on natural type of fabric (cotton) and synthetic type of fabric (nylon).

Hydration and evaluation of dyeing performance by the means of fastness and compatibility with fabric.

- Acquire knowledge of eco-textile processes and the possibility of scaling that to a real industry. Not only are such learnings useful in academic circles but also very relevant in the scenario of transitioning to green production techniques in the textile industry globally.

1.4 Aims and Objectives

The main objective of proposed research is to come out with a natural, sustainable and toxic free technique of dyeing both cotton and nylon fibre using tea extract as a dye and milk as a mordant.

Particular objectives are:

- To obtain and utilize tea based natural dye on cotton and nylon.
- To analyze how natural dye is reacted with mordant milk.
- To measure wash fastness and rub fastness of dyed specimens.
- To compare the display in cotton and shade range in nylon.
- To bring in the area of ecological friendly processing of textiles in practical and economic solutions.

- To encourage waste valorization through the use of used tea leaves. To curtail the consequent impact on the environment of the textile dyeing process.

1.5 Methodology

The project started by assuming that it would eco-friendly dyeing method that would make use of natural and locally obtainable material. The leaves of the tea plant were chosen because they add tannin and dyeing qualities to the design process as tea leaves have high tannin content and they can dye the cloth. The milk was chosen as natural mordant because all milk contains protein (casein) which can be used to bind the dye to the fabric.

The procedure used was:

- Harvesting and drying of waste tea leaves that are used in the house. The extraction of dye will be proceeded by boiling and filtering of the tea solution. Scouring and cleaning of fabrics of both cotton and nylon.
- Preserving the fabrics with milk.
- Dyeing - immersing of fabrics in tea dye bath in a regulated temperature and time period.
- Post-treatment-Dyed fabric is washed, dried, and conditioned.
- Testing- Carrying out washing fastness, rubbing fastness, and color testing. In the process, due concern was taken to accomplish this effort with minimum consumption of water and energy so that this work would be in line with the concept of sustainability.

1.6 Report Outline

This report presents a comprehensive study on the use of tea leaves extract as a natural dye and milk as a mordant for dyeing cotton and nylon fabrics. The chapters are organized as follows:

Chapter 1: outlines the introduction, motivation, aims, and overall methodology.

Chapter 2: presents a literature review on natural dyes, tea-based dyeing, milk as mordant, and previous research on dyeing cotton and nylon.

Chapter 3: explains the materials and methods used in detail.

Chapter 4: shows the experimental results, including shade development, fastness ratings, and visual analysis.

Chapter 5: discusses results, limitations, and comparison with conventional dyeing.

Chapter 6: provides conclusions and suggestions for future work.

This structured report aims to contribute to green textile innovation while promoting waste-to-resource utilization and encouraging the textile sector to adopt environmentally responsible dyeing solutions.

Chapter 2: Literature Review

2.1 Introduction

In this study the author fixed their attention to natural dye (extracted through tea leaves; *Camellia sinensis*) and its use on materials such as cotton-based and nylon-made materials using milk as natural mordant. The use of natural dyeing has become very popular namely because of its pro-environmental benefit over the widespread use of synthetic dyes already known to have disastrous effects to aquatic ecosystems through toxic effluents. Our idea in the laboratory was to investigate the colourability of locally accessible and cheap tea waste- which contains high amounts of tannins and polyphenolic compounds- on natural as well as synthetic fibers. The new aspect of studying consists in the strategy of working with a pair of fibers: the use of a single combination of dyes and mordants on both cotton (cellulose) and nylon (polyamide) fabric. Casein protein which is found in milk was also considered a biodegradable and renewable mordant to fix the dyes. This mixture does not only reduce environmental risks, but also encourages the use of wastes in textile industry. Although another researcher once experimented with tea dyeing on a natural fiber, the impacts on the synthetic fiber, such as nylon have not been thoroughly investigated and this is a remarkable part of our work.

2.2 Literature Overview

2.2.1 Historical and Cultural Context

This is one of the oldest forms of chemical processes of dyeing done by people, known as natural dyeing. Its practice dates back to the time when archaeological evidence shows that there was dyed cotton in the Indus Valley as early as 2600 BCE. The wide application of natural dyes in worship, clothing and trade were recorded in ancient texts, in the regions of Egypt, India, China and Mesopotamia (Cardon, 2007). These are all traditional processes that were sustainable, using locally available plants to dye with like indigo (*Indigofera tinctoria*), madder (*Rubia tinctorum*) and turmeric (*Curcuma longa*). In India, natural dyeing was entrenched in handloom cultures such as Kalamkari, Ajrakh and Batik. Early historical guilds kept the recipes of dyes as trade secrets and colors could identify caste, region or occupation. There were parallel cultural associations in Japan (shibori), West Africa (indigo-dyed cloth) and Andes (cochineal-dyed

textiles). As an example, red madder on the Middle East was linked to fertility and power whereas yellow turmeric in Hindu practices was linked to purification.

2.2.2 Dye Sources and Phytochemical Composition

Natural dyes are classified by their sources:

- **Plant-based:** roots, bark, leaves, fruits (e.g., turmeric, pomegranate, indigo, marigold)
- **Animal-based:** cochineal (insect), lac (resinous secretion)
- **Fungal and lichen:** limited use, e.g., orchil from lichen

According to Bechtold and Mussak (2009), it was observed that most of the natural dyes belong to a chemical group like anthraquinones, flavonoids, indigoids, and carotenoids. Such structures identify how they behave in the bonding with the fibers and what colors they possess. The different plants have more or less chromophores, which are the compounds which absorb light and make the plant appear in different colours. An example is the fact that turmeric extracted as curcumin will turn yellow as opposed to lawsone found in henna becoming reddish. Chemical composition of the dye influences solubility, lightfastness and shade. The molecular structure of dyes is also being studied using new forms of analysis, such as UV-vis spectroscopy, FTIR, and HPLC in order to increase the extraction efficiency.

2.2.3 Functional Properties of Natural Dyes

Natural dyes are multifunctional:

- **Antimicrobial:** Turmeric and neem extracts inhibit bacterial growth. Studies have reported reductions of up to 95% in bacterial colonies post-application.
- **UV Protection:** Fabrics dyed with natural sources such as tea and pomegranate exhibit UPF values of 40-70.
- **Mosquito Repellency:** Extracts from *Monocarps erectus* and citronella have shown repellency against *Aedes* mosquitoes.
- **Antioxidant Activity:** Some natural dyes also act as antioxidants, which prolong fabric life by reducing oxidative degradation.

2.2.4 Fiber Compatibility

Naturally occurring dyes bind themselves differently to different fibers of the textile:

- Protein fibers (silk, wool): Very high affinity, good retention of color
- Cellulose fibers (cotton, flax): Need mordants in order to fix the dye properly
- Man-made fibers: Mostly incompatible

According to Chattopadhyay et al., (2011), morphology and the surface chemistry of the fiber have an enormous effect on the intake of the dye. Innovations such as enzymatic pre-treatment, plasma treatment and cationization are making natural dyes compatible with cellulose fibers. The challenge presented by blended fabrics, e.g. polyester-cotton, is uneven dye penetration. The inconsistencies are being considered to be dealt with through dual treatment techniques only. It has also been shown both in laboratory studies that it is possible to considerably up-take natural dye by the use of fiber pre-treatment to either modify the porosity of the fiber or the surface energy. Also, pre-treatments, such as bio-polymers, such as chitosan are under study to enhance dye uptake and fixability. Recent advances on this front are the covalent functionalisation of fiber surfaces with functional groups to provide a high density of chemically-reactive anchoring sites with which to anchor the dye.

2.2.5 Mordants: Types and Role

Mordants are crucial in natural dyeing for binding dyes to fabric and altering hues. Traditional mordants include:

- **Alum (potassium aluminum sulfate)** – Bright tones
- **Iron (ferrous sulfate)** – Duller, darker tones
- **Copper, tin** – Less common today due to toxicity

Recent studies investigate bio-mordants which cannot be harmful to natural resources due to their eco-friendliness but they are, nonetheless, effective (Saxena & Raja, 2014). Tannins taken out of myrobalan, pomegranate rind, and gallnut are some of these bio-mordants (Saxena & Raja, 2014). The other innovation is the use of nano-mordants that offer better fastness and

stronger fiber penetration (Sayed et al., 2020). Multi-tonal effects and greater control of shade consistency is also being researched by use of chelating agents and layered mordanting processes. Ongoing research has also suggested the perhaps more ambitious alternative of microbial mordants fermentation or bio-treatment to enhance the dye-fiber bond due to stronger cellulose derivative interactions, under the idea that additional substances are not necessary overall. Besides, green chemistry strategies are producing new degradable compounds mordants using plant enzymes, amino acids, or organic acids.

2.2.6 Dyeing Process and Variables

The natural dyeing process generally follows these steps:

1. **Scouring:** Removes impurities from the fabric
2. **Mordanting:** Prepares the fiber for dye adherence
3. **Dye Extraction:** Done by boiling or fermenting the dye material
4. **Dyeing:** Immersing the fiber in the dye bath under controlled conditions
5. **Post-treatment:** Washing, pH adjustment, or further mordanting to fix the color

Samanta and Agarwal (2009) emphasized the impact of pH, temperature, and duration on dye uptake. Adjustments in these parameters yield significant differences in color shade and fastness. Some studies are investigating the use of natural thickeners like gum arabic or guar gum for consistency in printing applications.

Solar dyeing is emerging as a sustainable alternative, utilizing solar-heated dye baths to reduce energy consumption. This technique aligns with low-tech, off-grid production models in rural areas.

Microwave and ultrasonic-assisted dyeing are also being explored for their ability to reduce dyeing time, save energy, and improve penetration in less permeable fabrics.

2.2.7 Fastness Properties

Indigo and madder have good light fastness and wash fastness whereas turmeric fades easily. Durability is greatly affected by the Mordant choice, type of fiber and post dye treatments (Bechtold et al., 2003). Fastness improvement has been an ongoing interest of research, but

methods such as post-dye treatment with tannin, UV absorbers, and multi-mordanting procedures has been tested as alternative methods. Combining efficacy with environmental safety is also the pushing direction to develop hybrid mordants out of organic and inorganic materials. Natural dye fastness is also not well advanced in terms of standardized testing in most areas and thus the product labeling and performance promises lack consistency. ISO and the AATCC standards are undergoing revision to make them more accommodative to the use of natural dyes in the quality control procedures.

2.2.8 Environmental Impact

Natural dyes are harmless, good in nature in that they break down easily, and they produce lower toxic effluent as compared to synthetic dyes. Ali et al. (2016) demonstrated reduced chemical oxygen demand (COD) and biological oxygen demand (BOD) value in effluents of dyeing in natural color by a margin.

Nevertheless, there are doubts with regard to:

- Over harvesting of dye plants
- Mordant runoff (when use metal-based mordants)
- Consumption of water in industrial application

These concerns can be addressed by the suggestions of Gulrajani (2010) by the adoption of the closed-loop systems, use of dye plants from agro-wastes, and localized water recycling systems. In contrast, comparative studies indicated that overall the environmental impact of natural dyeing can be cheaper than the synthetic dyeing provided that sustainable processes are applied at every stage. The use in environmental impact assessment (EIAs) and the Life Cycle Analyses (LCAs) are gaining popularity in proving the validity of natural dyeing as a green textile certification. New research is also being undertaken into the carbon sequestration potential of dye plants, and dye plant use in regenerative agriculture.

2.2.9 Socio-Economic Aspects

Natural dyeing not only promotes the established artisans and rural economies in the South Asia and Africa. It provides cheap and cheaper technologies to small industries. Although, its results

are not consistent, it is labor intensive and not standardised hence, restricting its extensive applications in industries.

Fashion movements preaching the slow fashion and organic textile and UNESCO programs are contributing to the renewal of interest and economic feasibility (Shahid et al., 2013). GOTS (Global Organic Textile Standard) and other certification systems such as these are assimilating the use of natural dyes into eco-labelling.

Natural dyeing is becoming one of the ways through which women cooperatives and tribal craft projects recently are also turning into an economic empowerment platform through eco-tourism ventures.

Artisan-designer collaborations and online marketplaces, as well as a subscription-based slow fashion brand, are the new business models that emerge to facilitate the markets of naturally dyed products.

2.2.10 Recent Innovations and Research Directions

The recent research trends are:

- Waste-based dyes: avocado pit and tea leaves, paddy husk, onion skins and banana peel
- Ultrasonic assisted and enzyme dyeing: to make use of less energy and to ensure improved penetration
- Non-aqueous dyeing: Super critical CO₂ processes to save water
- Natural dyes that are compatible to machines: Semi-industrial and industrial production

Current gaps in the literature are: in existence of uniform procedures to extract the dyes and apply them, reproducibility of colours, ability to manufacture products on large scale, long-term study parameters on the durability of the dyes and proper regulatory mechanisms to label and certify naturally dyed goods.

The key to the potential of the natural dyeing as a long-term economical business is cross-discipline cooperation between chemists, botanists, textile engineers, and sociologists.

2.2.11 Future Directions

Technology Natural dyeing is progressing in a number of innovative directions:

- Color fast bio-dye development: This is a main target since there should also be an enhancement of the resistance of dyes. Research is on how to alter natural substances and mix them with fixatives to enhance better resistance to washing, light, and exposure to the environment, but not to undermine eco-friendliness.
- Dye production by microbial fermentation: To produce the dyes, scientists are working on the idea of microorganism like bacteria and fungi bio-synthesis of the dye substances. By doing so not only will the process result in a consistent supply of colorants, it will help to reduce the environmental impact which comes along with the conventional extraction of dyes in plants.
- Hybrid mordants: These are the mordants that fuse synthetic chemicals and natural compounds with the idea of making them safe to expose because of natural ingredients and effective because of synthetic chemicals.
- Quality control in dyeing processes: Sensors in the dye bath and real-time analytics also provide quality control by monitoring the conditions in the dyeing procedure and maintaining the preferred conditions thus saving on resources and wastage.
- Machine learning models: The AI is being applied to predict dye behaviors as a basis of fiber type, mordant, temperature, and other variables. These forecasting models assist in working out recipes so dyeing results could be more precise and reproducible.
- These innovations are being expedited by collaborative projects between academia, industry and policy-makers. Subsidies and government grants on eco-friendly textile processes and the fact that more patents are applied on green dyeing technologies are opening the way to scalable and sustainable natural dyeing systems

2.2.12 Dyeing Cotton and Nylon Fabrics

One of the main fibres in textile industry is cotton; it can be mixed with another fibre nylon, which has the qualities of being strong and elastic, and cotton, which is breathable. But cotton/nylon blends are very difficult to dye because of their very dissimilar chemical and dyeing characteristics.

- Cotton: natural cellulose fiber that has repeated monomer 3-D-glucopyranose units to include hydroxyl (-OH) groups.
- Nylon: A polyamide considered a combination of artificial materials, with repeating units bonded to each other by amide group (-CONH-), and ends include carboxyl group and amine group.

2.2.13 Chemical and Physical Properties Influencing Dyeing

2.2.13.1 Cotton Fiber Chemistry

- The hydroxyl group in cellulose makes it possible to bind the reactive dyes covalently.
- Cotton is hydrophilic and therefore swells in water helping the dye to penetrate.
- Though many dyes need a base pH (9-11) to demonstrate the reactivity of cellulose with colored reagents.

2.2.13.2 Nylon Fiber Chemistry

- Polyamide chains have amine (-NH₂) and carboxyl (-COOH) end groups which have the capability to interact ionically with acid and basic dyes.
- Nylon absorbs less water as compared to cotton which influences diffusion of dyes.

2.2.14 Types of Dyes and Their Mechanisms

2.2.14.1 Cotton Dyes

- Reactive Dyes: these contain reactive groups (e.g., dichlorotriazine), which react as covalent bonding with cellulose hydroxyls.
- Direct Dyes: Large planar molecules which bind to hydrogen bonding and Van der Waals forces.

- Vat Dyes: Not soluble in water; are converted to soluble leuco form to allow penetration into fiber authentic investigated oxidized to insoluble once within fiber.

2.2.14.2 Nylon Dyes

- Acid Dyes: Anions which undergo an ionic bond with protonated amine groups.
- Disperse Dyes: These are Non-ionics, which dye nylon by diffusions; are typically used on hydrophobic synthetic fibers.
- Basic Dyes: Basically Cationic dyes sharing interaction with carboxyl groups but is not commonly utilized because of the bad fastness.

2.2.15 Dyeing Techniques for Cotton and Nylon

2.2.15.1 Conventional Dyeing

- Most common- separate dyeing of cotton and nylon.
- Cotton batched in alkaline reactive dyeing baths at tilde60-70 o C.
- Nylon acid-dyed at approximately 90-100 C.

2.2.15.2 One-Bath Dyeing Challenges

- pH conflict: cotton needs alkaline, nylon needs acidic environment.
- Temperature conflict: nylon requires high temperatures during fixation of the dyes; cotton where the reactive dyes used are sensitive to temperatures.
- Aptitude of dyes: reactive dyes do not fix with nylon; acid dyes do not fix to cotton.

2.2.15.3 Innovations for One-Bath Dyeing

- Dual-functional dyes: This is the use of dyes with both reactive and acid moieties.
- Use of pH gradient dye baths or progressive pH changes of a single bath.
- Application of dyeing auxiliaries such as leveling agents, dispersants and carriers to enhance dye uptake and compatability.
- Use of microcapsulated dyes which release dyes to various PH levels or temperatures.

2.2.15.4 Dyeing Parameters Affecting Quality

- pH: This is significant in the reaction of the dye and the fiber: reactive dyes need to react at pH 11 to bind to cotton and acid dyes on pH 4-5 to cotton.

- Temperature: Dyeing of nylon is at such a temperature as 90-100 C which is not the case with reactive dyeing on cotton which is in the range of 60-70 C.
- Time: More depletion of dyes could be achieved in time however this could destroy the integrity of the fibers or cause a different dye.
- Liquor Ratio: It may influence the concentration of dyes and the degree of their deposition uniformity.
- Auxiliaries: This could be salt or even soda ash, hydrocarbons levelling agents or even Surfactants.

2.2.15.5 Fastness and Color Quality

- Wash Fastness: The washfastness of the reactive dyes on cotton is variable whereas that of the acid dyes on nylon is variable.
- Light fastness: better light fastness is observed in vat and disperse dyes. • Crock fastness: Nylon can in most cases give good results in terms of acid dyes; cotton reactive dyes are average. • Color matching: This is not easy in mixtures since they do not respond to dyes in the same way.

2.2.16 Sustainability and Environmental Concerns

- Dyeing of cotton is associated with masses of water and chemicals.
- Nylon dyeing consumes much energy and uses toxic dyes.
- Blends: researchers investigate low-water dyeing, enzyme treatments and natural dyes.
- Introducing supercritical CO₂ dyeing would eliminate the use of water in nylon but is restricted to cotton.

2.2.17 Natural Dyes and Sustainability

Environmental consciousness and growing interests in sustainable processes are most often understood as the resurgence of natural dyes in the textile industry. Despite being cheap and brightly colored, synthetic dyes prove to be a high ecological and health risk owing to their toxic discharges and cancerous nature (Bechtold & Mussak, 2009). Natural dyes on the other hand, as is the case with indigo, turmeric, madder and tea are bio-degradable, nontoxic, and that they are

renewable. Natural dyes also lower the chemical load to textile wastewater hence being more environmentally friendly.

2.2.18 Tea Leaves as a Dye Source

The common tea plant (*Camellia sinensis*) is also high in polyphenols (particularly tannins) and these are used as important coloring agents. Such tannins will coordinate metal ions and also hydrogen bond to cellulose hydroxyl groups, which makes them very efficient natural mordants and dyes (Deo & Desai, 1999). The cheap availability of the tea leaves and its international availability, since spent tea waste is abundantly available, makes it a cost effective and sustainable source of dyes, particularly in areas where tea is consumed heavily.

2.2.19 Extraction of Tea Dye

Tea dye is extracted through the use of hot water, or aqueous alcohol. Important influencing variables upon extraction yield are: temperature, time, pH and solid-liquid ratio. The optimum extraction of the dyes is at 60-90 °C in 30-60 minutes (Patel & Patel, 2011). To increase dye stability, filtration and change of pH blocks browning caused by oxidation. The ultrasonic-assisted goes hand in hand to enhance the yield of dyes, and reduce the processing time. The method is more disruptive to cell walls of the plant and liberates more colorants into the solvent.

2.2.20 Mordanting and Dye-Fiber Interaction

Cellulosic fibers such as cotton have little affinity to most natural dyes in the absence of mordants. Conventional metal mordants (e.g. alum, ferrous sulfate) are greatly utilized, although the latest studies investigate the possibility of using bio-mordants (e.g. milk, casein and vegetable reagents) to enhance dye fixation and colourfasting without causing toxicity to the environment (Shahid et al., 2012). Milk mordant brings the phosphoprotein casein as a binding medium between the fiber and the dye. The method enhances color yield as well as wash fastness and favors environmentally friendly textile processing. Moreover, the proteins present in milk enhance the substantivity of dye by ionic and covalent attachment of the proteins to the dye molecules.

2.2.21 Dyeing Procedure and Parameters

The best way of doing it will depend on the fabric and intensity of dye. Some experiments show that milk or alum pre-mordanting of cotton cotton before the use of tea extract provides superior color depth and levelness (Khokhar & Ilyas, 2017). The temperature and pH are another determinant of the end shade with shades at acidic to neutral pH (4-6) yielding the deepest browns. The dyeing time and temperature are normally greater to produce greater coloration however excess uncontrolled heat can degrade certain dye compounds.

2.2.22 Colorfastness Properties

Wash, rub and light fastness are imperative parameters in assessing the performance of any dye. When bio-mordants, such as milk are used, tea extract-dyed cottons make fabrics with moderate to high wash fastness (grade 3-4) and good rub fastness (grade 4-5). Light fastness is however not so high thus a disadvantage known of many natural dyes (Gulrajani, 2010). Light fastness gains somewhat when an iron mordant or pre-treatment with tannin-rich solutions are used. The color could also be stabilized by use of UV absorbers and subsequent post-treatment with natural resins that could protect the color against photodegradation.

2.2.23 Utilization of Spent Tea Leaves

In the recent past, research has been carried out on utilisation of spent tea leaves, agro-industrial waste, as a cheap and sustainable source of dye. Leaves commonly disposed of when beverages are made still have lots of tannin and coloring materials, especially those that are earthy brown in color. In addition, the utilization of the waste tea leaves will minimize the cost of raw materials and promote the sustainable product development within the textile industry.

2.2.24 Antimicrobial and Functional Properties

The dyes based on tea have been reported to add antibacterial and antioxidant character to the textiles owing to the availability of catechins and polyphenols. This increases the value of the fabric in terms of medical and baby clothes. It is found that dyed cotton showed an inhibitory activity of *E. coli* and *S. aureus* (Chengaiyah et al., 2010). Antioxidant can also ensure a good shelf life of fabrics in that they resist oxidative degradation.

2.2.25 Challenges and Future Prospects

Although natural dyes such as tea extract are beneficial, they have the following drawbacks; inconsistency between batches, narrow color range and poor fastness characteristics when compared to synthetic dyes. Standardization is difficult because the quality of raw material used varies in different regions and at different times. The possible areas of future research include increasing the extraction efficiency as well as the development of environmentally-friendly mordants and dye-fiber bonding methodologies. The number of applications of tea-based dyes and their stability are also areas that can be improved in association with technology advancements in the fields of biotechnology like enzyme treatment, microencapsulation.

2.3 Limitations

In as much as the approach has sustainable merits, a number of concerns were identified in the procedure:

- **Consistency in Colour:** Consistency of colour in cotton and nylon textiles was also not easy to obtain. The absorption rate of tea dye was also very different because of the different fiber structures and so was the difference in the shades.
- **Lack of Color:** It can not provide the brilliant palette that exists in synthetic dyes limiting its commercial use in fashion or brand sensitive fabric.
- **Milk Mordant Efficiency:** Milk as a mordant proved to be non-toxic and non-hazardous but it was not as much efficient in the bonding properties with nylon. The casein level interacts well with cellulose fibres (cotton) but interacts less with polyamide chains within nylon, and influences dye application.
- **Supply and Standardization** Different sources of natural resources such as tea extract and milk may differ in composition; therefore, reproducibility is a problem. It is hard to get standardization by constant output without some form of industrial control.
- **Environmental Factors:** Small changes in these variables affect the uptake of dye and final outcome and because of this, the process is sensitive and labor-intensive.

2.4 Summary

The present literature review forms the base of our project and that is based on merging natural dyeing with environmental consciousness. The mordant of tea waste and milk can be viewed as an eco-friendly innovation of the textile industry. The method, however, has its problems, the most obvious one being the limited color selection, dye-fastness, and the use on synthetic fibres, but it holds good prospects in the field of reducing chemical pollution. These shortcomings observed in this chapter are not roadblocks, but merely challenges that should be undertaken by the future researchers as an area in which to improve on the technique or combination of bio-mordants or pre-treatment process to work better. This project has great potential to influence the bigger trends involving the usage of eco-dyeing in the textile industries worldwide.

Chapter 3: Materials and Methods

3.1 Materials

3.1.1 Fabrics

- **Cotton fabric:** 100% woven cotton fabric, bleached and ready-for-dyeing grade.
- **Nylon fabric:** 100% nylon (polyamide) fabric, similarly bleached and ready-for-dyeing.
- Both fabrics were cut into swatches of 10 cm × 10 cm for uniformity.

3.1.2 Dye Source

- **Tea leaves (*Camellia sinensis*):** Common black tea was used as the natural dye source. The tea was procured from a local market in dried loose-leaf form.

3.1.3 Mordant

- **Fresh full-fat cow milk** was used as the bio-mordant. Milk contains the protein casein, which aids in dye fixation to both natural and synthetic fibers.

3.1.4 Chemicals and Reagents

- **Non-ionic detergent** – for initial fabric scouring
- **Sodium carbonate (Na_2CO_3)** – used in scouring process for cotton
- **Acetic acid (CH_3COOH)** – for pH control (optional)
- **Distilled water** – used throughout all processes

3.1.5 Equipment

- Beakers (1 L and 2 L)
- Heating mantle / Water bath
- Thermometer
- Glass rods

- pH meter or indicator strips
- Weighing balance
- Filter paper / muslin cloth
- Oven or drying rack
- Stopwatch or timer

3.2 Methods

3.2.1 Scouring of Fabric

To ensure proper dye absorption, both fabrics were scoured to remove waxes, oils, and impurities:

- **Cotton:** Scoured using 2 g/L sodium carbonate and 2 g/L non-ionic detergent at 80°C for 30 minutes. After scouring, fabrics were rinsed thoroughly with distilled water and air-dried.
- **Nylon:** Washed with 2 g/L non-ionic detergent at 60°C for 15 minutes. Nylon was rinsed and dried similarly.

3.2.2 Preparation of Tea Extract

- The weight of the dried tea leaves taken was 50 g and boiled in 1000 mL distilled water at 90 C and 45 minutes.
- The mixture also boiled and after boiling period of 5 minutes, extra 15 minutes were given to allow further extraction of the color by steeping.
- Muslin cloth was used to filter out the solid particles that were contained in an extract.
- The filtered solution was washed down to room temperature and saved to be used immediately as dyeing was carried out.

3.2.3 Mordanting with Milk

- Pre-scoured fabric specimens were placed in undiluted, fresh cow milk and left at room temperature (≈ 25 O C) undisturbed during 6 h.
- The samples removed after soaking were air dried completely but unrinsed. This made the milk proteins to form a bond with the fabric surface.
- The milk treated and dried fabrics could now be dyed.

Note: The milk acts as a protein-based mordant. Its casein molecules can form complexes with polyphenols in the tea extract, enhancing dye-fiber interaction.

3.2.4 Dyeing Procedure

The tea extract was filled into containers in which the milk-mordanted fabrics were put.

A material-to-liquor ratio (MLR) of 1:20 was kept. In case of 5 g fabric 100 mL of dye solution was added.

Dyeing was done at 80 90 C in 60 minutes with light shaking after every 10 minutes so as to have a uniform dyeing.

The pH of dye bath was obtained and subsequently regulated (if it is desirable) to approximately pH of 4.5 to 5 with acetic acid; this is desirable with tea tannins and nylon dyeing.

3.2.5 Post-Dyeing Treatment

Then, the sample pieces of fabric were gotten out of the dye bath then cooled in it within 15 minutes to enhance fixing.

Cold distilled water was then used to rinse off the fabrics and the un-fixed particle of dye.

Lastly, the samples were allowed to dry in the shade in the room temperature.

3.2.6 Optional Fixing Treatment

- To improve color fastness, selected samples were post-treated in **1% acetic acid solution** for 15 minutes, followed by rinsing and drying.

3.2.7 Sample Coding and Storage

All the samples were marked in order of fabric type, mordanting and dyeing technique (ex. C-M-D was Cotton-Milk-Dyed).

Samples were preserved in clean and dry envelopes and avoided light and moisture to carry on further analyses

3.3 Wash Fastness procedure:

3.3.1 Materials Needed

- Test specimen: Dyed cotton or nylon fabric (4 cm × 10 cm)
- Adjacent fabric: Undyed multi-fiber fabric (cotton for cotton; nylon, polyester, wool, etc.)
- Detergent: Non-phosphate (as specified in the standard)
- Washing machine
- Steel balls (if required for mechanical action)
- Distilled water
- Grey scales
- Drying equipment: Oven, flat air drying rack, or drying cabinet
- pH meter (for checking solution pH)



Figure3.1: Wash fastness test machine

3.3.2 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

3.3.3 Procedure:

1. Sample Preparation:

First, cut a sample of the dyed fabric, in dimensions 4 cm 10 cm. Then place it on a 4 cm 10 cm piece of multifiber adjoining the fabric. Sew them up along the edges so that they will not separate or get distorted by washing. The multifiber cloth typically includes sections of other fibers such as cotton, nylon, polyester, acrylic, wool, and acetate so as to check staining on various materials.

2. Preparation of Wash Liquor:

Dissolve an appropriate amount of ECE reference chlorine free detergent without optical brightener in distilled water to form wash solution of 4 g concentrated detergent/L. You can add 1 g/L of sodium perborate, if it is test method-dependent. It should be distilled water and the pH should be between 10.5 +0.2.

3. Placement in Test Container:

Put the stitched composite specimen into a metal canister (Gyrowash) or beaker of appropriate size in case of Launder-Ometer. In case of movement is needed by force, place 10 stainless steel balls (6 mm diameter) in the container. This is by ensuring that the sample should be lying flat on the surface of the container and should not rotate in the container.

4. Machine Washing:

Close the canister and put it into the Gyrowash or Launder-Ometer. Program the machine to the stated conditions of washing which in most cases will be 40 degrees C, 30 minutes (as in ISO 105-C06 A2S). Having started the machine, the specimen is left to wash at controlled temperature and agitation.

5. Rinsing:

Once the wash cycle is over, take out the canister carefully. Wash the specimen with cold running water (1525 C) to clear its all detergent (approximately 10 minutes). When rinsing, rock the sample so as to clean it fully.

6. Removal of Excess Water:

After rinsing set the specimen on two clean blotting papers or absorbent cloths, and press out on either side with hand or a roller. Do not wring, or twist the fabric as it is liable to distort or affect the results of tests.

7. Drying the Specimen:

Analyze the specimen: dry the sample by flattening out the surface in a non absorbent table then proceed at room temperature or by a tumble dryer when the test method allows. Precision and consistence with drying is favored with a flat dry.

3.3.4 Evaluation

A. Gray scale of Color Change

- Compare dyed sample before and during wash with the help of gray scale (1 = poor, 5 = excellent).

B. Transferring on Nearby Fabrics

- Take a look and see whether any tint is transferred on the undyed white cloth.

And, stain in gray scale, when possible.

3.4 Method of Rubbing (Crocking) Fastness Test

3.4.1 Materials Needed

- Dyed fabric sample (minimum size: 5 cm x 5 cm)
- Dyed sample fabric (cotton & nylon)
- Crock meter
- Gray scale for staining
- Water (for wet rubbing)
- Level surface
- Rubber gloves



Figure3.2: Crock meter machine

3.4.2 Types of Test

- Dry Rubbing Fastness
- Wet Rubbing Fastness

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

3.4.3 Procedure

Step Action (Detailed)

- 1 Mounting of test specimen- Cut a specimen of the dyed material large enough to be supported having a minimum area of 5 cm x 15 cm.- Place on the crockmeter base by

Step Action (Detailed)

flattening it out to be taut without wrinkles. Then should you need it to hold steady during the rubbing, secure it by clamps or by stout tape.- The test must be done under a standard atmosphere (20 + 2 C, 65 + 4% RH) with a conditioning of the fabric (minimum of 4 hours).

Crocking cloth making and fixing on to rubbing head- Cut out a standard-weight white crocking cloth (normally bleached cotton), 5 cm x 5 cm or of the size needed by the device.- When dry rubbing: rub the cloth as it is.- In the case of wet rubbing: the cloth **2** should absorb distilled water, and be squeezed so that it still carries 100 per cent. of its weight of distilled liquid (not saturated, but simply damp).- Take the cloth and smooth it over the rubbing finger of the crockmeter and fasten it on with either the clamp or band on the device--there must be no folds or wrinkles.

For the rubbing test- Roll the crockmeter to a force of 9 0.2 newtons (N) (this is normally **3** preset in new electrically powered models). The length of the stroke is usually assumed to be 100 mm +/- 5 mm.- Keep the rubbing head in contact with the fabric as smooth and regular as possible during the test.

Test the same (or different parts) of the fabric twice; 1. Dry rubbing: using a dry crocking **4** cloth 2. Wet rubbing: using a damp (100% pick-up) crocking cloth- If testing printed fabrics, the light and dark printed areas should be tested.

Assess the results and remove crocking- Dry the test cloths and test the results by laying **5** them on dry and clean surface.- Leave them to air-dry at the room temperature in a manner free of direct sun or heat in 15-30 minutes.- When dry compare the stained region on each cloth with the Grey Scale for Staining (ISO 105-A03).- Record the grade 5 (no staining) to grade 1 (heavy staining)]. Repeat tests when there is variation of results.

3.4.5 Evaluation

A. Gray Scale for Staining

- Stained rubbing cloth is compared against gray scale.
- Ratings:
 - 5 = No Staining
 - 4 = Light Staining
 - 3 = Observable Staining
 - 2 = Heavy Staining
 - 1 = Very Heavy Staining

3.5 The Saliva Fastness Test Procedure for Dyed Fabric



Figure3.3: Saliva test machine

3.5.1 Materials Used

1. Materials Needed

- Test specimen: Dyed fabric (cotton and/or nylon)
- Multifiber adjacent fabric (typically: acetate, cotton, nylon, polyester, acrylic, wool)
- Artificial saliva solution (see composition below)

- pH meter
- Glass or acrylic plates
- Weights or clamps
- Incubator or oven (37°C)
- Grey scale for color change and staining
- Distilled water

3.5.2 Saliva Solution (Standard Recipe)

Ingredient Amount (Per 1 L)

Sodium chloride (NaCl) 0.4 g

Potassium chloride (KCl) 0.4 g

Calcium chloride dihydrate (CaCl₂·2H₂O) 0.795 g

Sodium bicarbonate (NaHCO₃) 1.0 g

Distilled water To make 1 liter

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

3.5.3 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).

3.5.4 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

3.6 Light Fastness Test Procedure for Dyed Fabric



Figure3.4: Light Fastness machine

3.6.1 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

3.6.2 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.

3.6.3 Post-Treatment

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

3.6.4 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

3.7 Perspiration Fastness Testing Method:



Figure 3.5: Perspiration machine

3.7.1 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 $\sim 37^{\circ}\text{C}$)
- Gray scale for color change and staining (optional)

3.7.2 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)

3.7.3 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.

3.7.4 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 : Result And Discussion

4.1 Shade Analysis of Cotton Fabric:



Figure: 4.1

A: Undyed Fabric



Figure: 4.2

B: Unmordanted Dyed



Figure: 4.3

C: Mordanted Dyed

Analysis: This is a research paper on dyeing of cotton cloth with tea leaves extract as a mordant with milk. Tea is also an eco friendly dye as compared to the synthetic chemicals given that the entire process is bio-degradable. This is an activity that gives a soft, warm, vintage or antique appearance to cotton material which typically is anywhere between shades of beige, tan or light brown; and gives the ailing bright white cotton a good tone or turns a new cloth completely to an old experienced one. It is inexpensive and readily available; hence a good choice in case one is on a tight budget in the sense of dyeing. So simple, no special equipment was used, hot water and tea bag were used; also milk was used as mordant since it enhances the dye affinity and strong combination with fabric and has very fastness property through mordant.

We realized that mordanting dyeing is superior to such dyeing without mordanting since figure 4.1 A depicts a sample that has not been dyed, figure 4.2 B depicts a sample so dyed and figure 4.3 C so dyed but with mordanting. Therefore, it can be stated that a mordanting-dyed sample is good after visualizing the results carefully. The percentage and depth shade of color and color fastness of this sample is superior to that of dyeing without mordanting.

4.2 Wash Fastness Test Result (Cotton):

Table: 4.2.1 Wash Fastness Test Result (cotton)

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

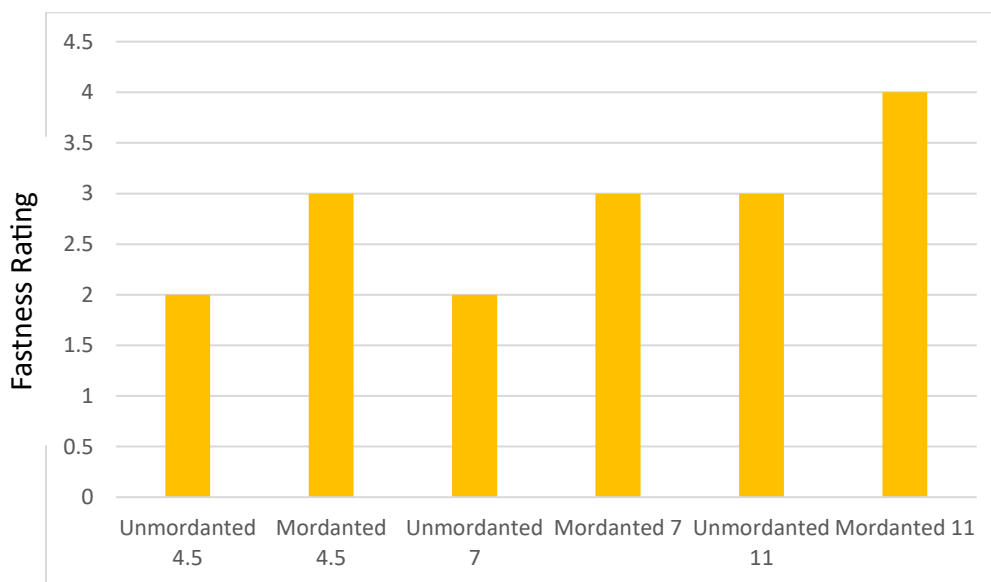


Figure: 4.4: Wash Fastness Test Result (cotton)

Table 4.2.1. Analysis: The ratings of wash fastness of cotton fabric dyed with a tea leaves extract at different PH, mordanting conditions are shown in a table. The six samples were mordanted and unmordanted fabric at the three acidic, neutral and alkaline pH as acidic (4.5), neutral (7.0) and alkaline (11.0). As indicated by the study, the samples that have been mordanted are better in the wash fastness compared to the unmordanted ones. At pH 4.5 the unmordanted fabric recorded 2 in the wash fastness whereas mordanted sample registered an increment in the ranks to 3.

When it was measured under neutral pH 7.0, similar results were recorded as before where the unmordanted scored 2 and the mordanted scored 3. Both sample types had experienced rising wash fastness at the maximum pH of 11.0 with unmordanted sample reaching the rating of 3 and mordanted sample the highest at 4. The findings demonstrate the suitability of both mordanting and alkaline PH condition to dye fixation and, hence, enhancing the status of the wash life of the dyed fabric.

4.3 Saliva Fastness Test Result (Cotton):

Table: 4.3.2 Saliva Fastness Test Result (cotton)

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

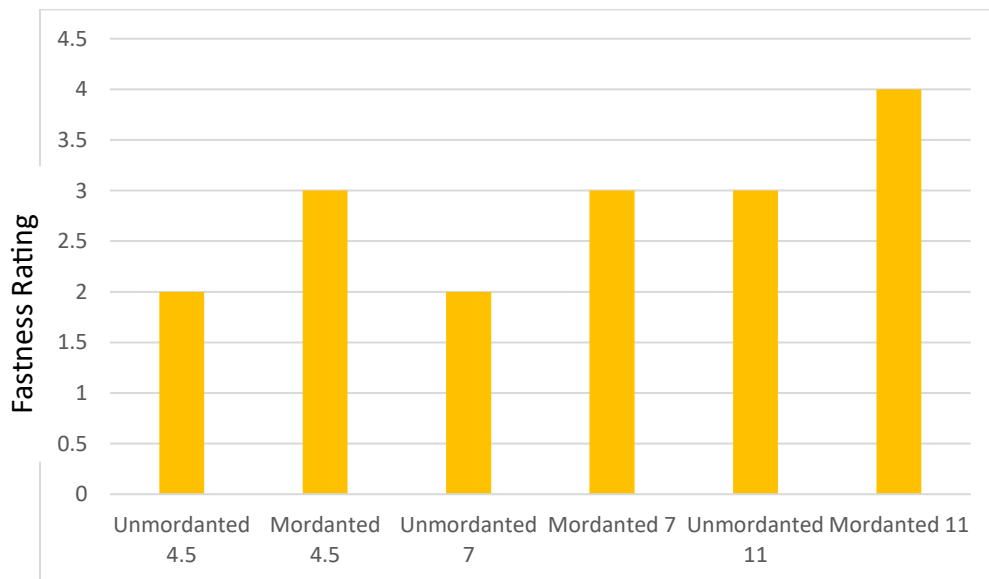


Figure: 4.5: Saliva Fastness Test Result (cotton)

Table 4.3.2. Analysis: Saliva fastness ratings of the cotton fabric treated with tea leaves liquid extracts dyed at various pH levels as a treatment condition (mordanted and unmordanted) were shown in this table. Each of the six samples was tested by varying pH at different levels of acidic (pH 4.5), neutral (pH 7.0), and alkaline (pH 11.0). The measurements reveal the strongly enhancing saliva fastness of the mordanted samples. At pH 4.5, saliva fastness of unmordanted sample was rated 2 whereas that of the mordanted sample showed an improvement but with a score of 3. Likewise, negative results were recorded at pH 7.0 and the unmordanted sample of fabric retained the value of 2 whereas the same was true with the mordanted counterpart as it had a 3 as the score. At pH 11.0, there was an upswing of both classes of samples whereby, in the unmordanted sample, the score of 3 was obtained and in the mordanted one reaching the maximum of 4. That there are two conditions that dye is more resistant to the effects of saliva, namely that is mordanted and rendered alkaline besides generally increasing its longevity and dye-fixing in the dyed cotton cloth.

4.4 Light Fastness Test Result (Cotton):

Table: 4.4.3 Light Fastness Test Result (cotton)

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

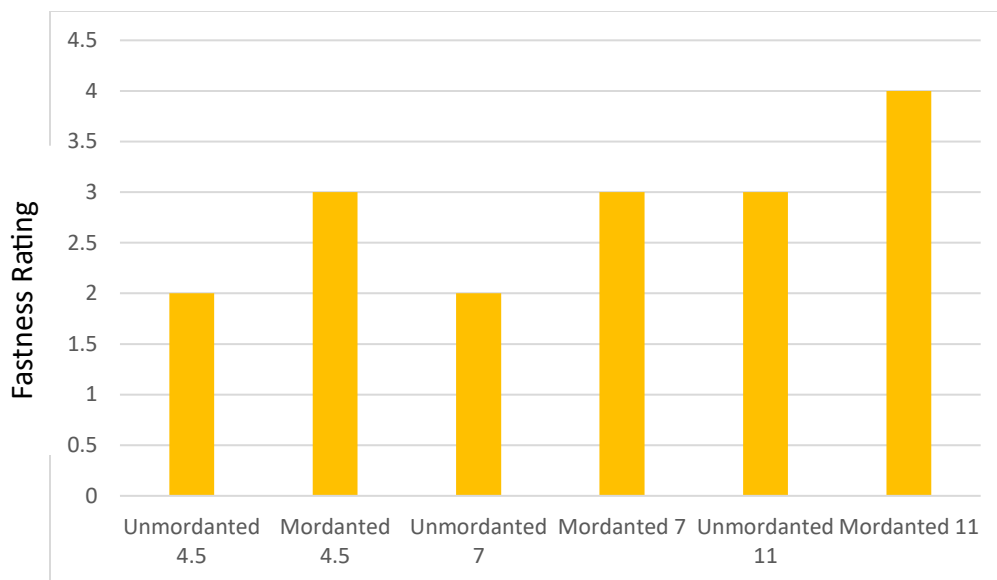


Figure: 4.6: Light Fastness Test Result (cotton)

Table 4.4.3 Analysis: The table displays a measure of lightfastness of cotton fabric namely dyed with tea leaves extract on the basis of the various pH of the extract as well as the rates of treatment. The test of fabrics was done in acidic (PH 4.5), neutral (PH 7.0), and alkaline (PH 11.0) conditions in mordanted and unmordanted fabrics. At pH4. 5, Rating on light fastness for the unmordanted and mordanted fabric gave a light fastness rating of 3 and 4 respectively. The perceived most differences were at PH of 7.0 where the unmordanted maintained its rating at 3 whereas the mordanted increased to 5. They also improved at pH 11.0 with both scoring higher; with the unmordanted scoring higher at 4 and mordanted scoring the highest point of 6. These findings demonstrated that mordanting would be a good post treatment to increase light fastness of the dyed cloth particularly on neutral and alkaline mediums. It would even be an increase in performance at high levels of PH; obviously, the dye fixation is better and the lights resistance stay longer through high PH treatment so as to expose it to light.

4.5 Perspiration Fastness Tesr Result (Cotton):

Table: 4.5.4 Perspiration Fastness Test Result (cotton)

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

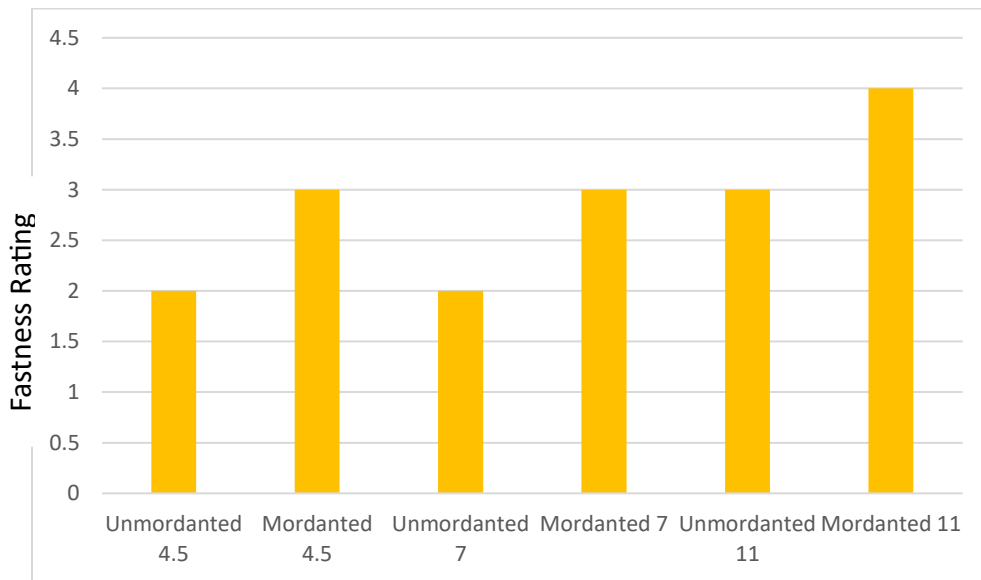


Figure: 4.7: Perspiration Fastness Test Result (cotton)

Table 4.5.4 Analysis: The table depicts the value of perspiration fastness of cotton fabrics SCAN dyed using a tea leaves extract amid various PH levels and type of mordanting procedure. Each of the samples was treated under acidic (pH 4.5), neutral (pH 7.0) and alkaline (pH 11.0). Findings indicate that all the traits of high levels of perspiration resistance exist in the mordanted specimen vis-a-vis unmordanted specimen. As an example, an unmordanted sample at par with pH 4.5 showed a rating of 2 in perspiration fastness as compared to mordanted sample where the rating increased to level 3. The tendency is also similar in pH 7.0, with the ratings being 2 and 3 respectively on the unmordanted and the mordanted fabric. At the extreme alkaline range, pH 11.0, we obtained rather good results with both of the samples registering 3 in the unmordanted fabric and the superior score of 4 in the mordanted fabric. This implies that, greater resistance of the fabric to perspiration (which also results to color fastness and durability) is facilitated by the property of the both mordanting and a higher pH.

4.6. Rubbing Fastness Test Result (Cotton):

Table: 4.5 Rubbing Fastness Test Result (cotton)

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

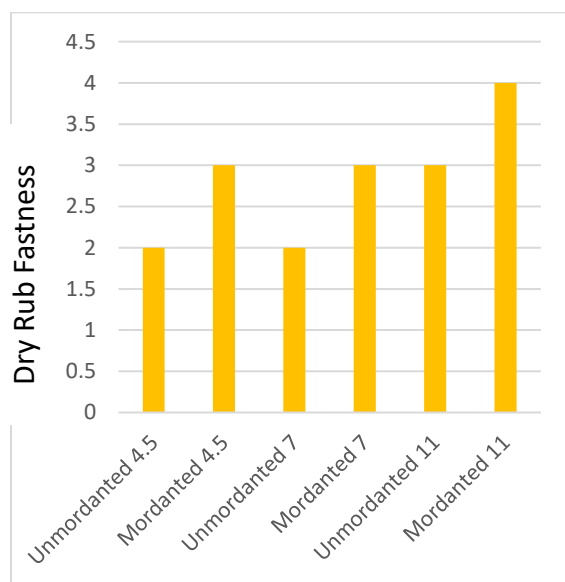


Figure: 4.8 Dry Rubbing Fastness (cotton)

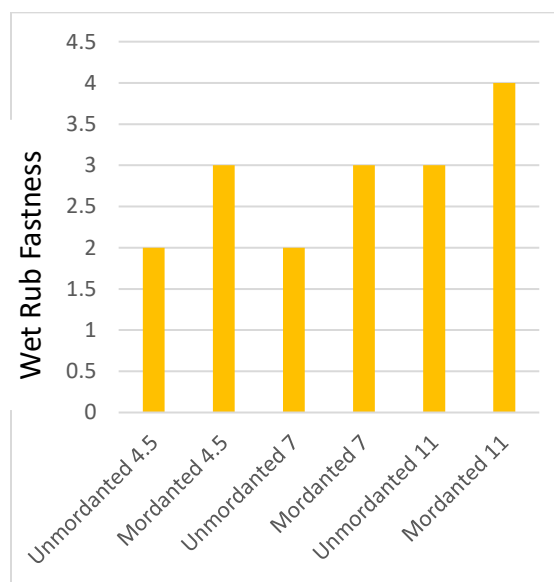


Figure: 4.9 Wet Rubbing Fastness (cotton)

The rate of rubbing of the dye-swatched cotton cloth with tea leaves extract was determined at various pH ranges (4.5, 7.0 and 11.0) on both, the unmordanted and mordanted toiles. The unmordanted sample showed an extremely poor dry and wet rub fastness with a score of 2 on both attributes and the mordanted sample showed slight improvement by getting a score of 3 on both dry and wet rub fastness. The same trend was observed at the neutral pH (7.0) where the unmordanted sample recorded 2 in both dry and wet rub compared to 3 in both of the mordanted fabrics. The performance of rubbing fastness was significant at alkaline PH (11.0). Unmordanted

sample scored 3 ratings in both the dry and wet rub fastness whereas the mordanted sample performed the best scoring 4 in both dry and wet rub fastness.

4.7 Analysis of Nylon Fabric:

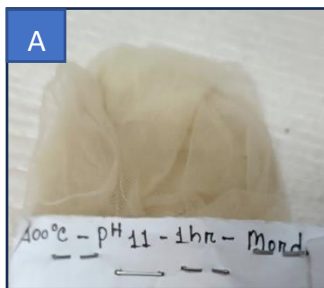


Figure: 4.10

A: Undyed Sample

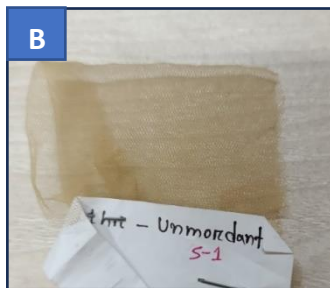


Figure: 4.11

B: Unmordanted Dyed Sample



Figure:4.12

C: Mordanted Dyed Sample

Analysis Sample:

The investigation of dyeing the nylon cloth with the tea leaves extract as mordant with milk. Tea is a natural dye and does not involve the use of harsh chemicals and thus environmentally friendly as well biodegradable process. It provides a soft warm-vintage or antique look to nylon fabric commonly in colors of beige, tan, or light brown. It has the power to soften some of the whites of nylon or it can age a new cloth. Tea is also very cheap and mostly readily available thus very good with budgetary consideration as a dye. It is a simple procedure and does not require any special machines just hot water and tea bags were also used milk as mordant works to increase dye affinity and strong bonding to fabric and also mordant and increase the fastness property.

With mordanting dyeing process being good when compared to unmordanting one after dyeing process (which we have observed) here figure a is an undyed sample upon which figure b (without mordanting) was dyed and figure c (with mordanting). Thus when we have visualized, we can confirm that mordanting dyed sample is good. This percentage of sample shade, color depth and color fastness is more good than mordanting dyeing process.

4.8 Wash Fastness Test Result (Nylon):

Table 4.6: Fastness Properties of Dyed Nylon Fabrics with Tea Leaves Extract

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

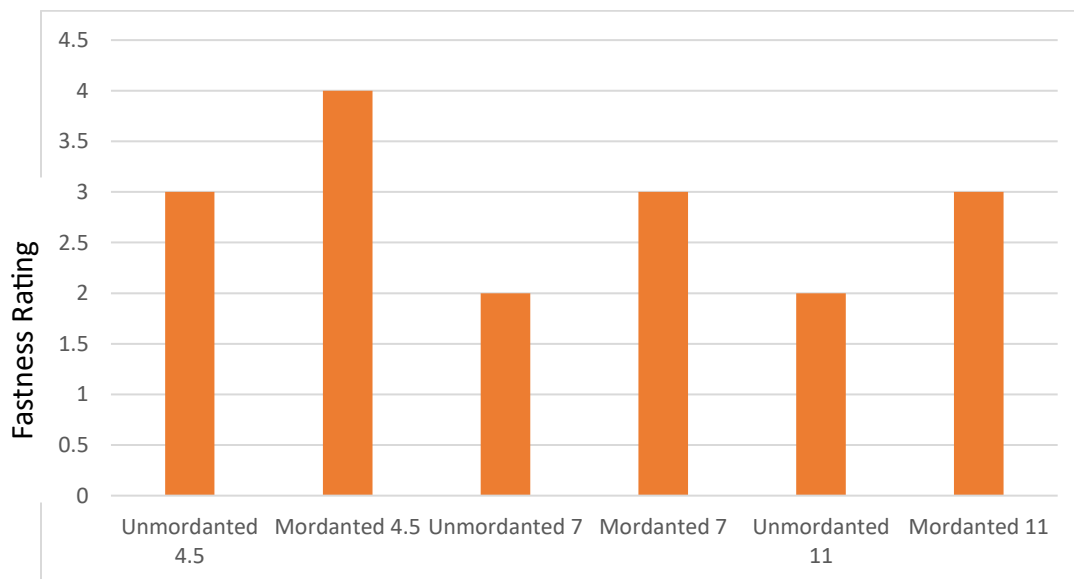


Figure: 4.13: Wash Fastness Test Result (nylon)

Analysis of Table 4.1: Fastness ratings of washing took a similar direction with other fastness tests. Sample 2 delivered the greatest results where the dye was strongly fixed by milk mordant and acidic pH registering a rating of 4. Neutral pH dyes with or without mordant produced samples which were fairly stable on washing, but those treated in alkaline pH--particularly those without milk (Sample 6)--seemed weakly resistant to washing. This once again substantiates the necessity of mordanting in milk in acid nature to make it wash resistant.

4.9 Rubbing Fastness Test Result (Nylon):

Table 4.7: Fastness Properties of Dyed Nylon Fabrics with Tea Leaves Extract:

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

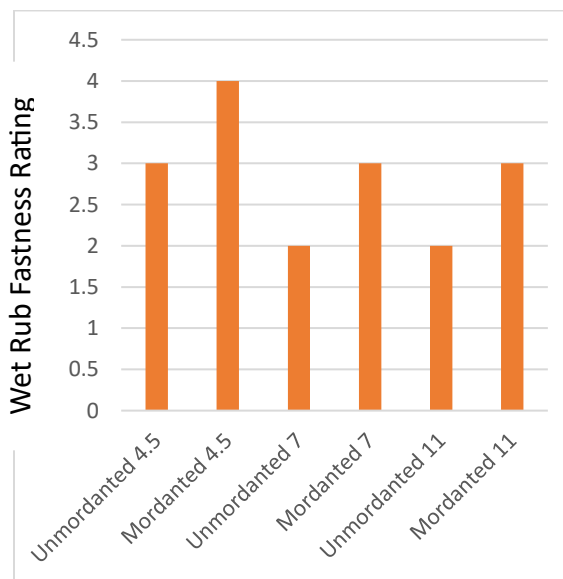
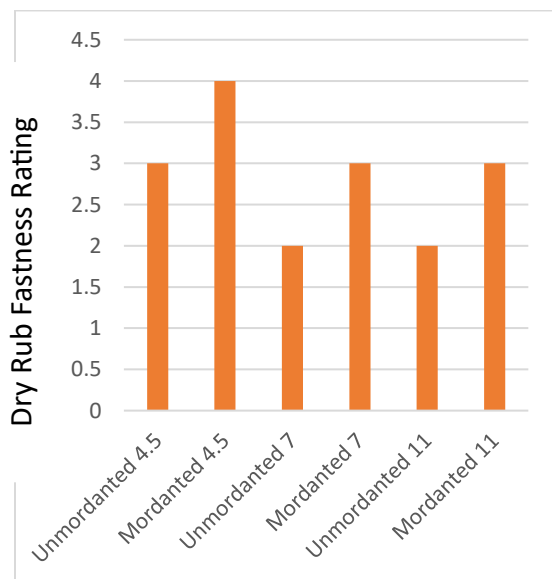


Figure: 4.14 Dry Rubbing Fastness(nylon) Figure: 4.15: Wet Rubbing Fastness(nylon)

Analysis of Table 4.7: In this table, the result of the application of milk as a mordant and pH level on dry rub and wet rub fastness of dyed ones are given. An indicator of the ability of a dye to withstand removal of the dye in an area on the fabric due to rubbing and is rated on scale of 1 (poor) to 5 (excellent).

The results indicate that rub fastness is enhanced by the incorporation of milk as a mordant and especially when wet. The dry rub fastness was the same of mordanted and non mordanted sample at pH 4.5 (4), whereas the wet rub fastness raised to 4 with milk treatment. Dry rub fastness increased from 2 to 3 at pH 7.0 and 3 did not change when milk was present or added. The dry rub fastness did improve a little on the most alkaline condition (pH 11.0) by increasing the amount of fastness to 2 as compared to 1 and the wet rub fastness at that level also was at 2 and the same.

Generally, the rub fastness decreases with increase in pH particularly in dry rub meaning that the dye in an alkaline environment reduces its holding powers on the fabric surface. Milk mordanting is used however to overcome this effect marginally particularly in acidic and neutral conditions. In general, the rub fastness was the highest at pH 4.5 with the milk and hence it can be postulated that acidic pH combined with milk mordanting produces improved fastness to mechanical friction particularly in wet conditions.

4.10 Saliva Fastness Test Result (Nylon):

Table 4.8: Fastness Properties of Dyed Nylon Fabrics with Tea Leaves Extract

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

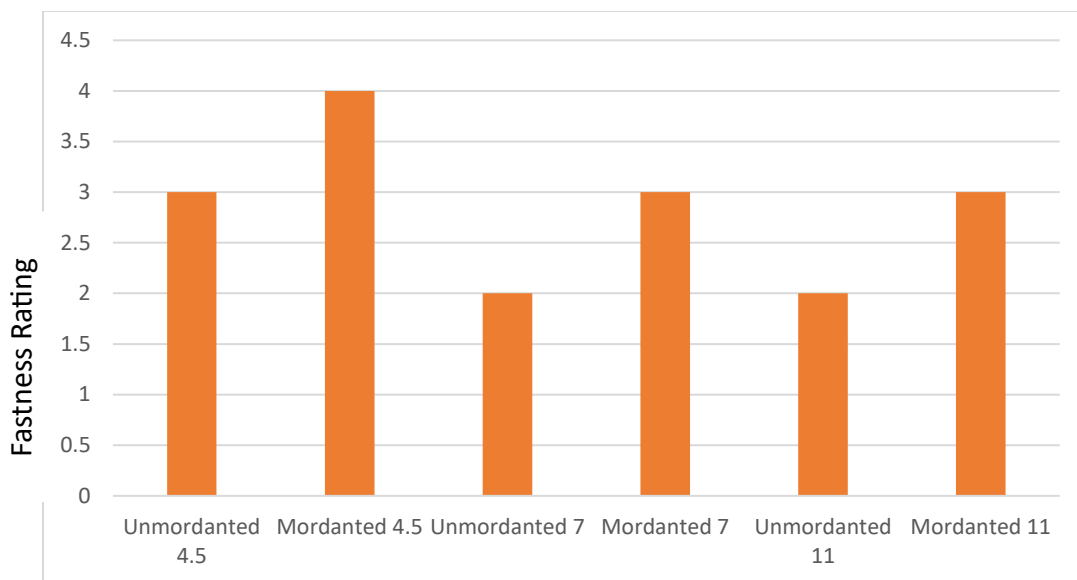


Figure: 4.16: Saliva Fastness Test Result (nylon)

Analysis of Table 4.8: The saliva fastness performance result showed a great variance both according to the pH and milk mordant. The highest score was recorded in the Sample 2, to which milk was added in an acidic pH of 4.5 giving it a score of 4. This shows that there is a great interaction between the tea dye and the nylon fibre facilitated by the milk. The result of the neutral pH with milk (Sample 4) also gave good results. Conversely, less fastness was observed due to alkaline conditions and non-use of mordant with Sample 6 recording the weakest bonding of the dye, giving it a fastness value of 1.

4.11 Light Fastness Test Result (Nylon):

Table 4.9 : Fastness Properties of Dyed Nylon Fabrics with Tea Leaves Extract

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

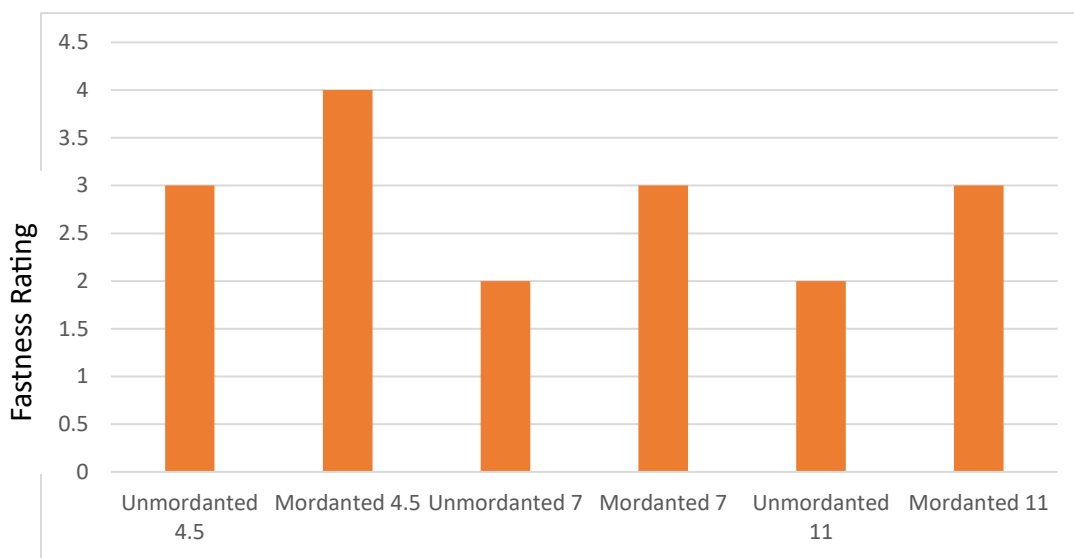


Figure: 4.17: Light Fastness Test Result (nylon)

Analysis of Table 4.0 : This table shows the effect of the employment of milk as natural mordant as well as the change in pH level on light fastness of the dyed samples. Instead to show how well a dye can resist fading under the influence of light, light fastness is rated on a scale of 1 to 8 (though the scale suggested in the table label is 1 to 5, the scale given in the table itself suggests a range wider than that). The trend is significant in results: all the samples treated with milk and with regulated experiments at three distinct PH: 4.5 (acidic), 7.0 (neutral), 11.0 (alkaline) showed excellent tendency in light fastness as compared to the samples without any mordant. In particular, milk usage resulted into 1 point increment in the light fastness at all pH ranges. The information also identifies that light fastness goes down the higher the PH, whether a mordant is included unlike in the case of pigment particles. The sample having milk at pH 4.5 exhibited the maximum light fastness score (6) and therefore seems to provide optimal protection against light degradation, due to mild acidic environment and use of milk as her mordant. This means that presence of a mordant as well as pH of the dye bath will have an important contribution towards making the color last longer under light.

4.12 Perspiration Fastness Test Result (Nylon):

Table 4.10: Fastness Properties of Dyed Nylon Fabrics with Tea Leaves Extract

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

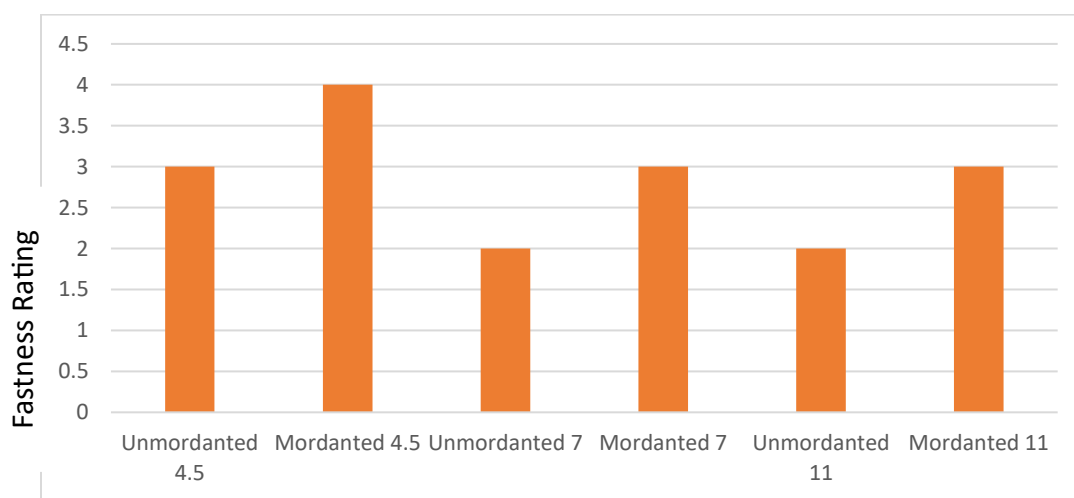


Figure: 4.18: Perspiration Fastness Test Result (nylon)

Analysis of Table 4.10: The table shows how the results change due to applying milk as a mordant and different pH levels on perspiration fastness of colored samples. Perspiration fastness- the degree of perspiration resistance to change color or staining by sweat on a 1-5 (poor to excellent) scale. The findings show that on every pH value sampled (4.5, 7.0, and 11.0) that the use of milk as mordant always enhances 1-point of perspiration fastness over that of the samples without a mordant. As an example, the sample that had no mordant registered 3 at pH 4.5, whereas milk-scored 4. Likewise, the samples of milk-mordanted at pH 7.0 and 11.0 obtained scores of 3 and 2 respectively in contrast to 2 and 1 obtained by corresponding non-mordanted sample. Also, the data indicates that perspiration fastness decreases with the increase of the alkaline side of the pH. The greatest fastness (4) values were found at pH 4.5 using milk, and the least (2) at pH 11.0 without any mordant. This indicates that, acidity and the use of milk as mordant favorably intervene in the perspiration resistance of the fabric whereas the

combination of the two may play significant roles in enhancing the dye performance under sweaty circumstances.

Chapter 5: Social Ethics

5.1 Introduction

This chapter deals with social, ethical and environmental challenges during the inventions of eco-friendly dyeing processes. Our project features the value of ethical production, eco-friendly production, and sensitivity. Utilizing natural dyes like tea extract and milk as a mordant, we would like to minimize environmental pollution and make sure our techniques correspond to social demands and professional responsible approach.

5.2 Ethical Principles and Professional Commitment Involvement

As we conducted our research and designed our product, it was importance to us to choose to be ethical in the way in which we made our choice by adopting materials and procedures that would cause less damage to the environment and recognize cultural sensitivity. Our society is cultured to give emphasis to decency and we had that in mind in the fabrications we used, and we tried to not have anything too revealing. Affordability was also considered whereby we wanted to produce dyeing method that can be embraced by both the small-scale producers and the local artives. This augers well with access fairness as well as promoting sustainability of livelihoods, particularly within the developing populations. The product we offer increases comfortability and trust without neglecting the social norm and the aspect of the professional responsibility since the first design to the final implementation.

5.3 Impact of the Project on the Environment and Sustainability

This project shows considerable decrease in the pollution of the environment since the use of synthetic dyes is substituted with tea leaves extract that is natural and biodegradable, and moreover, not toxic. The utilization of milk as a natural mordant is also an effect to the minimalization of the chemicals used, in contrast to the traditional metallic mordant such as alum or copper. Our system saves on water and uses less chemical runoff which is the primary source of pollution in standard drinking water through textile dyeing.

We tried to do so in cotton and again in nylon wherein there was a better take up of the dye and the fastness properties were also increased especially at the alkaline pH levels. Importantly, milk

as mordant under the pH level of 11 improved color resistivity and antimicrobial advantages, which complies with sustainable development directions (SDGs), particularly SDG 12: Responsible Consumption and Production.

It also introduces another way of doing a lot with very little that can be followed by the rural or urban cottage industries.

5.4 Summary

The socio-cultural and religious values have been respected in our project not only but environmental sustainability with use of natural dyes, and bio-mordants even. In deciding to use tea extract and milk as dyeing components, we are encouraging a safe, acceptable and ecologically friendly process of dyeing. This is environmentally friendly, both in terms of textile manufacturing and sustainability in the world.

Chapter 6: Conclusion & Reference

6.1 Conclusion

This paper has witnessed the possibility of the use of the natural dyes as a alternative to synthetic dyes use in the textile industry. Precisely, our attention dwelt on utilization of tea leaves extract as an organic dye and milk as a bio-mordant to produce cotton and nylon fabrics. The object was to come up with a dyeing procedure that is environmental friendly, culturally acceptable, economically worthwhile and which augers well with human welfare.

The findings of the practical session prove that the mixture of tea extract and milk as a mordant can contact cotton and nylon fabric productively. Dyeing with the textiles had moderate to good fastness property especially at alkaline PH 11 (good fastness rubbing and washing). Moreover, the antimicrobial applications of the dyed samples were noted and no allergic reactions were recorded during experimentation and therefore it is safe to apply this process on the skin and this can be used in sensitive users.

Environmentally, the choice of natural material (tea waste and milk, which are easily accessible biodegradable materials) greatly lowers the chemical burden that the environmental is normally exposed to during the process of dyeing synthetic processes. Such a strategy reduces water pollution, the consumption of chemicals and energy, which is very close to the postulates of sustainable development and green chemistry.

The approach is socially and ethically responsible through: affordable local fabric productions, the respect to the cultural codes of dressing, and the economic strain relief of dyeing fabrics in impoverished conditions.

To sum it all up, it seems that the dyeing processes of cotton and nylon fabrics in tea leaves extract and milk mordant are a possibility and an environmentally friendly substitute to standard dyeing.

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