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Natural Dye Extraction From Jamun Tree Bark

Dr. Saravanya.K. S[1], Hemavathy. S[2]

[1]Assistant professor and Head, Department of Fashion Technology, Arunachala Arts& Science (Women) college, Vellichanthai, Tamilnadu, India.

[2]M. Sc Textiles and Fashion Designing, Department of Fashion Technology,

Arunachala Arts& Science (Women) college,

Vellichanthai, Manonmaniyam Sundharanar University, Tamilnadu, India.

Abstract: Natural dyes obtained from plant sources are increasingly preferred due to their eco-friendly, biodegradable, and non-toxic properties. This study focuses on the extraction of natural dye from the bark of the Jamun tree (*Syzygium cumini*) and its application on natural fabrics such as lotus and linen. The aim of the study was to extract dye from jamun bark and evaluate its dyeing performance, antimicrobial activity, and color fastness properties on lotus and linen fabrics using a natural mordant. The method used involved collecting jamun tree bark, drying and grinding it into small particles, and extracting the dye through aqueous boiling. After dyeing, the samples were tested for antimicrobial activity and evaluated for color fastness properties including washing, crocking (rubbing), and sunlight exposure. The important results showed that the jamun bark extract produced attractive brown shades on both lotus and linen fabrics. Myrobalan mordant improved dye absorption and color stability. The dyed fabrics exhibited noticeable antimicrobial properties and showed satisfactory fastness to washing, crocking, and sunlight.

Keywords: Jamun bark, Natural dye extraction, Terminalia chebula (Myrobalan mordant), Antimicrobial activity, Color fastness properties, Lotus and linen fabrics

Introduction

In recent years, the textile industry has promoted sustainable solutions, minimized the use of synthetic chemicals, and explored eco-friendly alternatives. As a result, there is now a lot of interest in investigating naturally occurring biomaterials, especially when it comes to creative use of biological resources such as insects, which have gained global interest as a potential major source of protein due to the current food scarcity scenario in many developing nations and the prospective challenges of feeding over 9 billion people by 2050[1].

Natural fibers are renewable and biodegradable raw materials directly obtainable from plant, animal, or mineral sources and are widely used as foundational components of textile products. They are characterized by a cellular structure with a notably small diameter relative to length, enabling them to be spun into yarns and processed into fabrics. Natural fibers include cellulose-rich plant fibers such as cotton, flax, and jute and protein-based animal fibers like wool and silk. Due to their sustainable production, environmental compatibility, and versatile applications in textiles and composite materials, natural fibers have gained renewed research interest in the context of sustainable material science[2].

Synthetic dyes are integral to numerous industries due to their vibrant hues and cost-effectiveness. However, despite their industrial success, synthetic dyes pose significant challenges related to occupational hazards, environmental toxicity, and escalating global use. For example, workers involved in the production and application of synthetic dyes face numerous health risks. Many dyes contain toxic substances that can cause skin irritations and respiratory issues, and even prolonged exposure leads to hormonal disruptions. Notably, certain azo dyes have been scrutinized for their potential carcinogenic effects; when they decompose, they can release aromatic amines, some of which are known carcinogens and endocrine disruptors[3].

Linen fabric is a natural textile made from the fibers of the flax plant (Linum usitatissimum). It is a cellulosic fiber known for its strength, durability, and smooth texture. Linen is highly breathable and moisture-absorbent, making it comfortable to wear in warm climates. However, it is slightly stiff and wrinkles easily. This fabric is widely used for clothing, home textiles like bed sheets and curtains, and eco-friendly products. Due to its natural origin, linen is biodegradable and is often preferred for natural dyeing and sustainable textile applications[4].

Lotus fabric as a rare and sustainable textile produced from fibers extracted from the stems of the lotus plant (Nelumbo nucifera). The fabric is lightweight, breathable, and biodegradable, and traditionally produced through manual processes[5].

The biological treatment of synthetic dyes, showing how microorganisms like bacteria, fungi, and algae can help decolorize and reduce environmental impact of dye pollution. It highlights those synthetic dyes are widely used but pose problems in wastewater treatment and environmental contamination[6].

Jamun is native to India and has 400–500 varieties; however, only a few varieties of Jamun produce edible fruits. Jamun can be found along the roadside in tropical and subtropical regions in the Indian subcontinent. It has a remarkable ability to adapt to a variety of climatic conditions, including alkaline soils (pH 10.5); therefore, it is widely planted in semi-arid regions. Jamun is grown as a minor commercial crop in different parts of India and throughout the world for its fruits/timber. Usually, two varieties of Jamun, namely Rama Jamun and Raja Jamun, are cultivated in northern India for their fruits and seeds. These varieties have small seeds and large quantities of pulp. Another seedless variety is commonly grown in Varanasi. The Jamun fruits have a sub-acidic spicy flavor and are used to prepare squashes, juices, jams, jellies, pickles, wines, and cookies. Jamun fruit squash is a highly refreshing drink to quench thirst during the summer. Jamun is a rich source of various nutrients like proteins and iron[7].

Natural fibers have protein (keratin) and cellulose, etc., which provide basic requirements such as moisture, oxygen, nutrients and temperature for bacterial growth and multiplication. This often leads to objectionable odor, dermal infection, product deterioration, allergic responses and other related diseases. This necessitates the development of clothing that could provide a desired antimicrobial effect. A variety of antimicrobial textile materials are reported, employing different approaches like development of antibacterial nylon fiber by attaching a phosphate glass as an antibacterial agent. surface coating by trialkoxysilyl quaternary ammonium salt, antibacterial fiber by graft polymerization of cellulosic fiber with polyvinyl pyrrolidone, by treatment with potassium iodide solution; microencapsulation or in solubilization of chemical reagents in/on the fiber such as nitro compounds: 5-nitrofurfural, 5- nitro-2-furfurulidene-3-amino-2-oxazolidone, etc., on acrylic, nylon, cellulose, polypropylene and polyethylene fiber[8].

REVIEW OF LITTERTURE

2.1 NATURAL DYES:

Natural colourants and dyestuffs are an important group of non-wood forest products which find use in industries producing confectionery, other food products, textiles, cosmetics, Medicines, leather, paper,paint, ink, etc. This article reflects on comparison of natural and synthetic dyes because number of problems and questions arise in connection with the use of natural dyes. Are natural dyes really an environmentally friendly alternative of syntheticdyes? Is industrial and general use of natural dyes in the textile industry practicable beneficial and sustainable? Let's try finding some answers with regard to the modern scientific knowledge. **[Kanina - o.p.s.(December 2015)]**

Policies and increasing awareness of the environment are causing a revolutionary change in the textile sector towards sustainability. The search for environmentally friendly substitutes for conventional synthetic dyes and mordants, which frequently present serious dangers to human health and the environment, is at the heart of this movement.The current research meets consumer needs for ethical and ecologically conscious products by emphasizing the significance of using eco-friendly techniques in textile dyeing through an in-depth analysis **[Arnob Dhar Pranta,et.al.(2024)].**

The ultimate objective is to encourage the use of natural dyes in textile production by Identifying obstacles and creating plans for supply chain dynamics, market acceptance, and economic viability. By tackling these objectives, researchers hope to promote sustainability and creativity in the textile sector by expanding knowledge of and use of natural dyes **[Arnob Dhar Pranta,et.al.(2024)].**

2.3 JAMUN BARK POWDER AS NATURAL DYE:

Syzygium cumini, the scientific name of Malabar plum, Java plum, Black plum, Jambolan or Jamun, is a common fruit tree in India and other countries in the Asian subcontinent. The plant is also found in other tropical and subtropical regions of the world.The *S. cumini* (Myrtaceae) tree is a traditional medicine plant used for the treatment of various diseases.[5] The tree has a great importance as most of the parts of the tree, like the bark, leaves, seed, and fruits are used as medi-cine. Overall, the plant is rich in anthocyanins, glycoside, pelagic acid, isoquercetin, kaemferol, and myrecetin. The java plum seeds contain the alkaloid, jamb sine, and the glycoside jam Bolin or antihelix, which can lower blood pressure and can impede the conversion of starch into sugar as it contains ellagic acid, which is a well-known antioxidant. The seeds are rich in flavonoids, contain small amounts of protein and calcium, and have a high total phenolic content with significant antioxidant activity. So java plum seeds are used extensively in medicine, whereas the fruit pulps can be used as a natural colorant fortextiledyeing. **[Mustafizur_Rahman, et.al (2023)]**

2.3 LINEN:

Linen, Fibre, yarn, and fabric made from the flax plant. Flax is one of the oldest textile fibres used by humans; evidence of its use has been found in Switzerland’s prehistoric lake dwellings. Fine linen fabrics have been discovered in ancient Egyptian tombs. The fibre is obtained by subjecting plant stalks to a series of operations, including retting (a fermentation process), drying, crushing, and beating. Linen is stronger than cotton, dries more quickly, and is more slowly affected by exposure to sunlight. Low elasticity, imparting a hard, smooth texture, makes linen subject to wrinkling. Because linen absorbs and releases moisture quickly and is a good conductor of heat, linen garments feel cool to wearers. Fine grades of linen are made into woven fabrics and laces for apparel and household furnishings. **[Robert Curley,(2025)]**

Linen is the textile made from fibers extracted from the flax or flaxseed plant (Linum usitatisimum). The word linen originates from its Latin name Linum and the Greekword (λίνον) linon. **[Pandey,(2009)]**. Linen is a highly sought after textile fabric by high-end fashion designersas well as discerning consumers. It has the advantage ofsuperior comfort, breathability and elegance over cotton. It also imparts a graceful luster to the garments, thus making it a popular choice for summers even though it is more expensive than cotton. Recent research has also ledthe development of an indigenous high yield variety of linen called, Tiara. **[Chaudhary, et. al.(2015)].**

2.4 LOTUS:

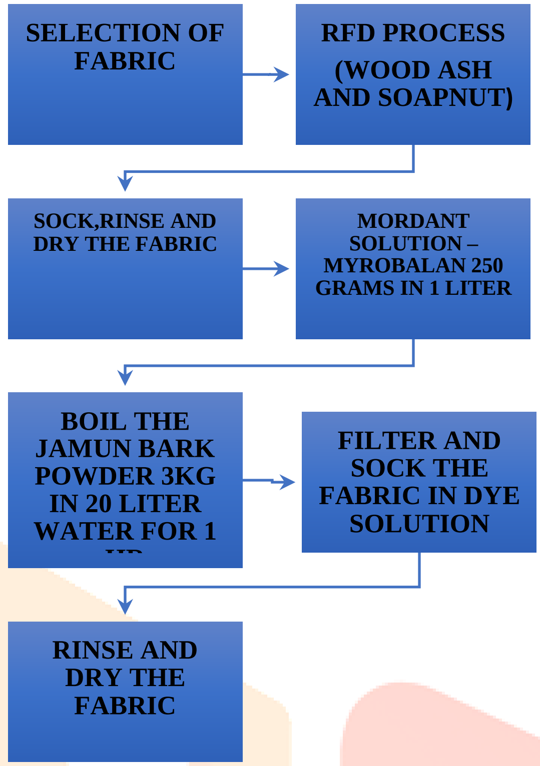
To overcome these limitations, we explore the feasibility of using lotus fiber as a novel plant-based scaffold for CM production. Lotus fiber, derived from lotus roots and petioles, is primarily composed of cellulose, hemicellulose, lignin, and pectin. Specifically, cellulose and pectin are recognized by the FDA as dietary fiber components. Additionally, the FDA's 2018 guidance on dietary fiber declaration in nutrition and supplement labeling reinstated “mixed plant cell wall fibers” as dietary fiber, which includes lignin as a natural component of plant cell walls. Although hemicellulose is not explicitly listed, it is implied as part of the “mixed plant cell wall fibers.” These components ensure the biocompatibility and edibility of lotus fiber. **[Volume 51, September (2025)]**

Materials and Methods

Materials

The fabrics selected for dyeing were lotus and linen, both known for their natural fibers and good dye absorption properties. The natural dye source Jamun tree (Syzygium cumini), which contains tannins and natural pigments suitable for textile coloration. Myrobalan (Terminalia chebula) was used as a natural mordant to improve dye fixation and color strength. Water, heating equipment, beakers, filter cloth, and other laboratory materials were also employed during the experiments.

Methods:



Selection of fabric:

Linen fabric and lotus fabric were selected as the textile substrates for this study due to their natural origin, eco-friendly nature, sourced from tha s u v e- a h on line websites. Linen and lotus fabrics were selected for this study because they are natural, biodegradable, and suitable for eco-friendly dyeing processes. Linen fabric has good absorbency, strength, and breathability, which allows effective dye penetration. Lotus fabric was chosen due to its unique plant-based origin, sustainability, and traditional value in eco-textiles. Effective dye absorption was observed on the treated fabric. The natural dye was well absorbed due to the presence of tannins and mordanting.


Linen **Lotus**

Fabric Preparation (RFD Process)

The lotus and linen fabrics were first scoured to remove impurities, dust, and natural oils. The fabrics were soaked in warm ash water for 20–30 minutes, rinsed thoroughly with clean water, and dried. This pre-treatment improved dye absorption and ensured uniform coloration.

Dye Extraction

Jamun tree bark was collected, washed, and dried under shade. The dried bark was cut into small pieces and ground into powder. The powdered bark was mixed with water and boiled for 45–60 minutes to extract the dye. The solution was cooled and filtered through cloth to obtain a clear dye extract.

Dye Extract from Jamun bark powder

Filtertion

Mordanting and Dyeing

The pre-treated fabrics were mordanted using a myrobalan solution. They were soaked in the mordant bath and heated for 30 minutes to allow proper absorption. After mordanting, the fabrics were immersed in the prepared dye extract and heated at moderate temperature for approximately 45 minutes. The dyed fabrics were then rinsed with water and dried in shade.

Boiling Myrobalan as a Mordanting

Socking and Boiling the Fabric

Visual Inspection:

Visual inspection is a preliminary assessment carried out to examine the overall condition and appearance of the fabric. This evaluation is conducted under adequate lighting to clearly observe the dyed surface. During this process, factors such as color consistency, brightness, texture, and visible imperfections like stains, patchiness, uneven dye distribution, or fiber damage are carefully checked. The purpose of visual inspection is to ensure that the dye has been applied uniformly and that the fabric maintains an acceptable aesthetic quality. It also serves as an initial step to verify the effectiveness of the dyeing process before conducting further tests.

Fabric Weight:

Fabric weight is measured in grams per square meter (GSM), which indicates the mass of the material within a specific area. This measurement helps classify the fabric as light, medium, or heavy weight and plays a vital role in determining its comfort, durability, and handling characteristics. After the dyeing process, slight variations in GSM may occur due to the absorption of dye, application of mordants, or retention of moisture. An increase in GSM may suggest additional material deposition or changes in fiber structure. Therefore, assessing fabric weight is useful for analyzing structural differences between untreated and dyed samples.

Fabric Thickness:

Fabric thickness refers to the distance between the top and bottom surfaces of the material and is typically measured using a thickness measuring instrument under standard pressure. Thickness influences several performance aspects such as thermal protection, softness, and bulk properties. Dyeing and finishing processes may alter the thickness of the fabric due to fiber swelling, chemical interactions, or moisture absorption. Even a minor change in thickness can indicate modifications in the internal structure of the fabric. Hence, measuring thickness provides valuable information about dimensional stability and the impact of processing treatments on the textile material.

Testing Methods

The dyed fabrics were evaluated for various performance properties.

- **Crocking Test (Rubbing Fastness):** This test was carried out to determine the resistance of the dyed fabric to rubbing in both dry and wet conditions.
- **Sunlight Fastness Test:** The dyed fabrics were exposed to direct sunlight for a specific period to evaluate color fading due to light exposure.
- **Washing Fastness Test:** The dyed fabrics were washed using standard washing conditions to observe color retention after laundering.
- **Antimicrobial Test:** The dyed fabrics were tested against selected microorganisms to evaluate their antimicrobial activity and determine the effectiveness of the natural dye in inhibiting microbial growth.

Result and Discussion

The performance of Jamun bark dye on lotus and linen fabrics was evaluated through color fastness tests (washing, sunlight, and crocking) and antimicrobial activity. Results were averaged from three replicates to ensure reliability.

Visual Inspection:

Visual inspection was carried out to observe the colour appearance and uniformity of the dyed fabrics. After dyeing with Jamun bark extract, the lotus and linen fabrics were examined under natural daylight to evaluate the colour shade, brightness, and evenness of dye distribution. The dyed samples showed brown colour shades with good visual uniformity and no visible patchiness. The lotus fabric exhibited a slightly deeper shade compared to linen, indicating better dye absorption. The mordanting process using myrobalan improved the colour depth and helped achieve uniform dye fixation on both fabrics.

SL.NO.	OVERALL APPEARANCE	COLOR INTENSITY	SHADE UNIFORMITY	FABRIC TEXTURE
CONTROL FABRIC	5	5	5	5
LOTUS	4	4.5	5	5

Fabric Weight (GSM):

Fabric weight was determined in terms of grams per square meter (GSM). A fabric sample was cut into a standard size using a GSM cutter. The circular specimen was then weighed using a digital weighing balance. The weight obtained was converted into GSM using the standard calculation method. The test was repeated for three samples and the average value was recorded to ensure accuracy.

SL.NO	FABRIC WEIGHT	MEAN
CONTROL FABRIC	1.14 1.16 1.15 1.19 1.21	0.69g
DYED LOTUS FABRIC	1.23 1.29 1.25 1.24 1.29	1.24g

Fabric Thickness:

Fabric thickness was measured to determine the structural characteristics of the lotus and linen fabrics. The thickness of the fabric samples was measured using a Thickness Gauge under standard testing conditions. Small fabric specimens were placed between the pressure foot and the base plate of the instrument, and the thickness value was recorded in millimetres (mm).

SL.NO.	FABRIC THICNESS	MEAN
CONTROL FABRIC	0.227 0.239 0.226 0.231 0.226	0.2298mm
DYED LOTUS FABRIC	0.344 0.318 O.328 0.311 0.326	0.3254mm

Color Fastness to Washing

The washing fastness test assessed the ability of the dyed fabrics to retain color during laundering. Lotus fabric showed a rating of 3–4, indicating slight lightening after repeated washing. Linen fabric performed better, with a rating of 5, reflecting stronger fiber structure and better dye retention. The use of myrobalan mordant enhanced dye fixation in both fabrics.

SL.NO.	DYED SAM PLE	WASHING TEST
1.	LINEN	4-5
2.	LOTUS	5

Color Fastness to Sunlight

Sunlight fastness measured resistance to fading under natural light exposure. Lotus fabric retained color moderately well, with ratings of 4–5 after 24 hours and 4 after 48 hours. Linen fabric showed ratings of 4 and 3–4, indicating slightly higher susceptibility to fading. The tannins in Jamun bark contributed to UV resistance, though lotus fibers allowed more light penetration.

SL.NO	DYED SAMPLE	24 HOURS SUNLIGHT	48 HOURS SUN LIGHT
1.	LINEN	4	3-4
2.	LOTUS	4-5	4

Color fastness to crocking

Crocking fastness evaluated resistance to color transfer during rubbing. Lotus fabric exhibited excellent dry crocking fastness (rating 5) and good wet crocking fastness (rating 4). Linen fabric showed consistent ratings of 4 for both dry and wet conditions. The mordant improved dye fixation, though lotus fibers' porosity contributed to slightly lower wet crocking performance.

SL.NO.	DYED SAMPLE	WET SAMPLE	DRY SAMPLE
1.	LINEN	4	4
2.	LOTUS	5	4

Antibacterial activity

Antimicrobial testing revealed that Jamun bark dyed fabrics inhibited the growth of Staphylococcus aurous and Escherichia coli. Lotus fabric showed larger zones of inhibition (27 mm and 29 mm) compared to linen (10–11 mm), indicating stronger antibacterial activity. Positive control (ciprofloxacin) confirmed activity, while negative control showed no inhibition.

Bacteria	Linen (+ve)		Lotus (+ve)		Negative control
Staphylococcus aurous	10mm	27mm	9mm	26mm	NZ
Escherichia coli	11mm	29mm	8mm	30mm	NZ

The results demonstrate that Jamun bark dye, when applied with myrobalan mordant, produces stable brown shades with satisfactory fastness properties. Linen fabric generally showed better washing and sunlight fastness due to its denser fiber structure, while lotus fabric exhibited superior crocking resistance and stronger antimicrobial activity. The antimicrobial effect is attributed to tannins and phenolic compounds present in Jamun bark, which inhibit bacterial growth.

Conclusion

The present study demonstrated that natural dye extracted from the bark of the Jamun tree (Syzygium cumini) can be effectively used for dyeing natural fabrics such as lotus and linen. The extracted dye produced stable brown shades and showed satisfactory color fastness properties. Among the two fabrics, linen exhibited better washing and sunlight fastness due to its compact fiber structure, while lotus fabric showed better crocking resistance and higher antimicrobial activity. The presence of natural compounds such as tannins and phenolic substances in Jamun bark contributed to the antimicrobial properties of the dyed fabrics. Overall, the study highlights that Jamun bark is a sustainable and eco-friendly natural dye source that can be utilized in textile dyeing, supporting environmentally friendly and biodegradable textile production.

Conflict of interest

The authors declare that they have no conflict of interest in the publication of this article.

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