A STUDY ON DEVELOPMENT OF NATURAL PRINTING PASTE FOR KNITTED FABRICS USING MADDER ROOT AND ECO-FRIENDLY BINDERS

B. Kaviya Sri[1], Benitta Christy P[2*]
[1]*M.Sc Student*, [2]*Assistant professor*
[1,2]*Department of Costume Design and Fashion,*
PSG College of Arts & Science,
Coimbatore, Tamil Nadu, India 641014

ABSTRACT- The environmental concerns associated with conventional textile printing processes have created a growing demand for sustainable and eco-friendly alternatives. This study focuses on the development of a natural printing paste using madder root as a plant-based pigment, combined with biodegradable binders for application on knitted cotton fabrics.The research emphasizes replacing synthetic binder systems with natural materials such as acacia gum and mango kernel starch, while ensuring adequate printing performance and durability. The prepared printing paste was applied through a block printing technique and evaluated for parameters including print uniformity, penetration, fastness properties, and antibacterial performance.The findings indicate that the developed formulation delivers satisfactory printing quality along with moderate to good fastness characteristics. Additionally, the printed fabric exhibited effective antibacterial activity, highlighting its potential for use in sustainable and functional textile applications.

Keywords*:* Acacia gum, Eco-friendly binder, Madder root, Mango kernel starch, Natural pigment, Natural printing paste

1. INTRODUCTION

Textile printing plays a crucial role in enhancing the aesthetic and commercial value of fabrics within the fashion and apparel industry. Despite its significance, conventional printing techniques largely depend on synthetic dyes, binders, and chemical auxiliaries, many of which are associated with serious environmental pollution and potential health risks. The discharge of these chemicals into water bodies and ecosystems has raised major concerns, driving the need for cleaner and more sustainable alternatives(1,5,11).

In recent years, the shift towards sustainable and eco-conscious textile production has significantly increased the demand for natural pigments and biodegradable processing materials(2,6,11). Plant-based colorants, particularly madder root, have gained renewed attention due to their renewable nature, low toxicity, and historical relevance in traditional textile practices. Madder root is especially valued for its ability to produce stable reddish shades through naturally occurring anthraquinone compounds(7,13).

Unlike dyes, pigments do not form chemical bonds with textile fibers and instead remain on the surface of the fabric. Therefore, an effective binder system is essential to ensure proper adhesion, durability, and wash resistance of the printed design(5,6). However, most commercially used binders are synthetic and derived from petrochemical sources, making them non-biodegradable and environmentally harmful. This creates a strong need to explore natural binder alternatives that can provide comparable performance while enhancing sustainability (3,6,11).

In this context, the present study investigates the development of a natural printing system by combining madder root pigment with eco-friendly binders such as acacia gum and mango kernel starch. These natural materials are biodegradable, non-toxic, and capable of forming a film that helps in pigment fixation (3,9,16). The study aims to evaluate whether such a formulation can achieve satisfactory printing performance while reducing environmental impact.Knitted cotton fabrics, chosen as the substrate in this study, present additional challenges due to their looped structure, elasticity, and higher absorbency compared to woven fabrics. These characteristics can affect print clarity, penetration, and uniformity. Therefore, careful optimization of paste viscosity, binder concentration, and application technique is essential to achieve consistent and high-quality results (8,10). Overall, this research contributes to the development of sustainable textile printing techniques by integrating natural pigments and biodegradable binders, while also addressing functional performance aspects such as durability and antibacterial properties (4,12,20).

II. METHODOLOGY

2.1 Knitted fabric

Knitted cotton fabric was selected as the substrate due to its wide usage in apparel and its high absorbency(10). However, its looped structure and elasticity present certain challenges in printing, such as uneven penetration and reduced sharpness (8).

2.2 Materials

2.2.1Madder root

Madder root was selected as the primary natural pigment source due to its ability to produce stable reddish shades, attributed to the presence of anthraquinone compounds such as alizarin and purpurin(7,13,19). These compounds are known for their relatively good colour stability and compatibility with textile substrates, making madder a suitable choice for natural pigment-based printing systems.

2.2.2Acacia gum

Acacia gum was utilized as a natural binder because of its excellent film-forming properties and water solubility, which aid in effective adhesion of pigment particles onto the fabric surface(3,16).

2.2.3 Mango kernel starch

mango kernel starch was incorporated as a natural thickening agent to enhance the viscosity of the printing paste, ensuring proper consistency, improved print definition, and uniform application during the screen printing process(9).

2.3 Fabric Preparation

The fabric was subjected to a scouring process to eliminate impurities such as natural oils, waxes, and other surface contaminants. This treatment enhances the wet-ability and absorbency of the fabric, allowing better interaction with the printing paste. Improved fabric cleanliness ensures uniform penetration of the pigment and binder system, leading to enhanced print quality, consistency, and overall performance of the printed material(8).

2.4 Pigment Extraction

Madder root powder was subjected to aqueous extraction by boiling in water to release its colouring compounds, primarily anthraquinone derivatives such as alizarin and purpurin(7,13). The heating process facilitates the efficient extraction of these pigments into the solution. The resulting extract was then filtered to remove insoluble residues and impurities, yielding a clear and concentrated pigment solution suitable for printing paste formulation(19). Proper extraction and filtration are essential to ensure uniform colour development and prevent blockages during the Block printing process.

2.5 Binder Preparation

Acacia gum was dissolved in warm water under continuous stirring to obtain a uniform and viscous solution, ensuring complete hydration of the gum particles. Separately, mango kernel starch was dispersed in water and heated to induce gelatinisation, resulting in a thick and cohesive paste(3,9,16). The gelatinised starch was then gradually blended with the acacia gum solution to develop a stable and homogeneous natural binder system. This combination enhances film-forming ability, improves viscosity control, and facilitates effective adhesion of pigment particles onto the fabric surface during the printing process.

2.6 Paste Formulation

The extracted pigment solution was gradually incorporated into the prepared binder system under continuous stirring to ensure uniform dispersion of pigment particles throughout the mixture. This controlled mixing helps prevent lump formation and improves the overall stability of the printing paste. The viscosity of the formulation was carefully adjusted to obtain an appropriate consistency suitable for block printing. Proper viscosity is essential to ensure even transfer of the paste from the block to the fabric surface, resulting in clear design definition and uniform colour application(8,9).

2.7 Printing Process

The prepared printing paste was applied onto the knitted cotton fabric using a hand block printing technique. Uniform pressure was carefully maintained during the printing process to ensure consistent transfer of the paste from the block to the fabric surface. This helped achieve even print distribution, clear motif definition, and uniform colour application across the fabric(8).

2.8 Fixation and Washing

The printed samples were initially air-dried to remove excess moisture, followed by steaming to enhance pigment fixation and improve the interaction between the binder and the fabric surface. After fixation, the samples were gently washed to remove unfixed pigments and excess paste residues. The fabrics were then dried under controlled conditions to obtain a clean and stable printed finish with improved durability(6,8).

III. RESULTS AND DISCUSSION

3.1 Tensile Strength Test

The tensile strength of the printed fabric was evaluated to assess its resistance to applied force (6). The results showed no considerable reduction in tensile strength after printing, indicating that the developed natural printing paste does not weaken the fabric structure.

Calculated Values:

- Mean (Before) = 320.8 N
- Mean (After) = 314.8 N
- Standard Deviation ≈ ±2.5

Result:

The tensile strength results indicate no significant reduction after printing, confirming that the natural printing paste does not adversely affect fabric strength.

3.2 Abrasion Test

Abrasion resistance testing revealed that the printed samples exhibited moderate resistance to surface wear (6,8). Slight colour fading was observed after repeated abrasion cycles; however, the print remained visible and intact.

Calculated Values

- Mean = 2.54%
- Standard Deviation ≈ ±0.1

Result

The abrasion test shows moderate resistance to wear, with slight weight loss observed after repeated cycles.

3.3 Air permeability Test

Air permeability testing was conducted to evaluate the breathability of the printed fabric (8). The results indicated a slight reduction in air permeability compared to the untreated fabric due to the formation of a thin binder film on the surface.

Calculated Values

- Mean (Before) = 120
- Mean (After) = 110
- Standard Deviation ≈ ±2

Result

A slight reduction in air permeability was observed after printing due to the formation of a binder film; however, the fabric retained adequate breathability.

3.4 Wash Test

The wash fastness of the printed samples was evaluated using standard washing conditions. The results indicated moderate to good wash fastness, with minimal colour loss observed after washing. Slight fading was noticed, which is typical for natural pigment systems; however, the overall colour retention remained satisfactory (6,11).

Grey Scale Standard

5 = No change (Excellent)

4 = Slight change (Good)

3 = Noticeable change (Moderate)

2 = Significant change (Poor)

1 = Severe change (Very Poor)

Table 4: Wash Fastness Test

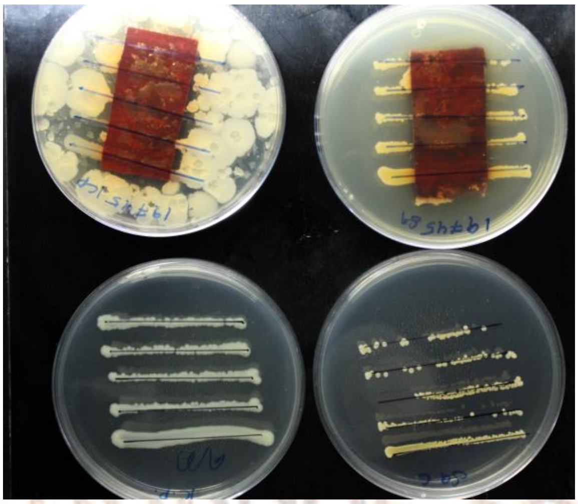
SAMPLE	WASH CYCLE	MEAN RATING	STANDARD DEVIATION	RESULT
S1	1 cycles	3.8	±0.2	Good
S2	5 cycles	3.5	±0.3	Moderate
S3	10 cycles	3.5	±0.3	Moderate

3.5 Antibacterial Testing

The antibacterial performance of the printed fabric was evaluated using the AATCC 147 parallel streak method. The test was conducted against both Gram-positive Staphylococcus aureus and Gram-negative Klebsiella pneumonias to assess the broad-spectrum antibacterial effectiveness of the developed material (4, 12, 20). This method enables the observation of bacterial growth inhibition in direct contact with the fabric, thereby indicating its bacteriostatic activity.

Table 5: Antibacterial Activity Results

Organism	Zone (mm)	Observation
Staphylococcus aureus	0	No growth
Klebsiella pneumonia	0	No growth



IV. CONCLUSION

The present study successfully developed an eco-friendly and sustainable natural printing system for knitted cotton fabrics using madder root as the primary pigment and biodegradable binders such as acacia gum and mango kernel starch. The formulated printing paste demonstrated good applicability for block printing, producing uniform prints with satisfactory colour clarity and penetration.

The evaluation of performance properties revealed that the printed fabrics exhibited moderate to good wash fastness, along with acceptable abrasion resistance and durability. Mechanical properties such as tensile and tearing strength were not significantly affected, indicating that the printing process preserved the structural integrity of the fabric. Although a slight increase in stiffness and a minor reduction in air permeability were observed due to the formation of the binder film, the fabric retained adequate flexibility and breathability for comfortable wear. Furthermore, the antibacterial assessment confirmed effective bacteriostatic activity against both Gram-positive and Gram-negative bacteria, enhancing the functional value of the printed fabric. This combination of aesthetic, mechanical, and functional properties highlights the potential of the developed system. Overall, the study demonstrates that natural pigment-based printing using eco-friendly binders can serve as a viable alternative to conventional synthetic methods. This approach not only reduces environmental impact but also supports the development of sustainable and functional textiles, making it highly relevant for future applications in eco-conscious fashion and textile industries.

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