INTERNATIONAL JOURNAL FOR INNOVATIVE RESEARCH IN MULTIDISCIPLINARY FIELD
ISSN(O): 2455-0620 [Impact Factor: 9.47]
Monthly, Peer-Reviewed, Refereed, Indexed Journal with IC Value : 86.87
Volume - 11, Issue - 04, April - 2025

DOIs:10.2015/IJIRMF/202504037 --:-- Research Paper / Article / Review

Exploring the potential of Indian madder root as a natural dye for textile application

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Abstract: *This study explores the feasibility of using soap-nut powder (Sapindus mukorossi) as a natural bleaching agent and Indian madder root (Rubia cordifolia) as a dye for cotton textiles in the production of eco-friendly children's clothing. Natural scouring and bleaching were achieved using soap-nut extract, where saponins function as bio-surfactants to effectively degrease and naturally whiten the fabric. The dyeing process employed Indian madder root to impart a range of reddish hues to the cotton, with various mordanting techniques enhancing dye uptake and colour fastness. Notably, alum and bio-mordants provided superior fastness properties, yielding shades from soft pink to deep red. Subsequent fabric performance evaluations confirmed the treated cotton's softness, durability, and comfort, affirming its suitability for sensitive applications such as children's apparel.*

Key Words: *cotton textile, eco- friendly, Indian madder root, Natural scouring, natural bleaching, natural dyeing, soap-nut.*

1. INTODUCTION:

The world of natural dyeing is often regarded as a sustainable method of applying color to textiles, especially when comparing it to the harmful synthetic methods of dyeing, which are associated with severe ecological and health damage. When it comes to natural dyeing, cotton stands out as the preferred fiber for textile dyeing as it is easily absorbent, soft, and comfortable. As a natural fiber, cotton readily interacts with plant-based dyes, making it a suitable choice for eco-friendly textile production [1]. Cotton fabric is an excellent choice for natural dyeing, a process that is sustainable and environmentally friendly, employing plant dyes, minerals, and other natural substances to impart color and beauty to the fabric. Natural dyeing of cotton fabric presents an alternative and environmentally friendly solution to chemical dyeing, which is harmful to the environment and human health. The process not only produces a range of vibrant and muted colors but also maintains the natural texture and breathability of the cotton fabric, creating a truly sustainable and gorgeous fabric [2].

Pre-treatment is very important in natural dyeing as it increases the dye's absorptivity of the fabric, enhances color fastness, and produces even dye penetration. Cotton is a cellulosic fiber that naturally contains impurities like waxes, pectin's, and oils. Pre-treatment is required to improve dye uptake [3]. Indian Madder Root powder, which comes from the root of the Rubia cordifolia plant, is an ancient natural dye that has been coveted for its brilliant, rich, and long-lasting colors. Coming from traditional Indian and Asian textile traditions, Indian Madder Root powder provides an environmentally friendly and sustainable option for natural dyes, enabling textile artists and textile enthusiasts to create distinctive, handwoven cotton fabrics that reflect the splendor of nature. [4]. Natural dyeing is a centuries-old, eco-friendly practice of dyeing textiles using plants, minerals, and other earth-based substances to obtain rich, distinctive colors. Not only is natural dyeing a way of minimizing the ecological footprint of chemical dyes, but it also honors the beauty of nature and the tradition of artisanal craftsmanship. Through using the colors of nature, natural dyeing provides a unique and innovative means of creating textiles that not only please the eye but also have kinder effects on the planet [5].

2. RESEARCH METHOD

2.1 Selection of material

Cotton is a prime material for natural dyeing due to its inherent fiber structure and high absorbency. Cotton's ability to absorb and hold natural dyes creates a wide and rich range of colors. The presence of cellulose in the fiber provides a good adhesion to natural dyes, which in turn provides good colorfastness and durability. The breathability and texture of cotton also enhance the ability to accentuate the individual and subtle variations that are a feature of natural dyes.

2.2 Scouring and bleaching using soap nut:

Scouring cotton fabric is a pretreatment process that is utilized to remove natural impurities such as waxes, oils, and pectin from the fabric by using a chemical or enzymatic treatment. The first step is to weigh the dried de-sized cotton fabric. Immerse the de-sized fabric into the scouring bath containing 1% of soap-nuts and 2% of soda ash to the weight of the fabric with the M:L ratio of 1:20 of distilled water in the bath at the temperature of 60^0 C – 80^0 C for 1 hour. Then the fabric is taken out from the solution bath and washed in the hot water followed by cold water and finally dried. Cotton fabric bleaching is a chemical treatment process that involves decolorization or whitening of the fabric for the removal of natural pigments and impurities for the improvement of its appearance and purity. The scoured cotton fabric after dried is weighed and the reading is noted. Immerse the scoured cotton fabric into the bleaching bath containing 1% of soap-nuts and 3% of lime juice to the weight of the fabric with M:L ratio of 1:20 of distilled water in the bath at the temperature of 80^oC – 90^0 C for 1- 2 hours. Then the fabric is taken out from the solution bath and washed in the hot water followed by cold water and finally dried.

2.3 Mordanting:

Alum (aluminium sulphate) is a suitable mordant for dye fixation in cotton fabric due to its ability to form a stable complex with the natural dyes, resulting in improved colourfastness and lightfastness. Alum's positively charged ions bind with the negatively charged dye molecules, facilitating their attachment to the cotton Fibers and enhancing colour yield.

2.4. Dyeing cotton fabric:

The dried bleached cotton fabric is weighed, and the weight is noted. Then immerse the cotton fabric into the dye bath containing 20% of dye powder (Indian madder root) and 15% of mordant (alum) to the weight of the fabric with the M:L ratio of 1:20 of distilled water in the bath at the temperature of 90^0 C – 100^0 C for 60- 90 minutes. Then the fabric is taken out from the dye bath and washed in the hot water followed by cold water and finally dried.

2.5 Testing for dyed sample:

2.5.1 AATCC 147 (Anti-bacterial test)

AATCC 147 is a qualitative testing method used to determine the presence or absence of antibacterial properties in natural dyed cotton fabric. The test determines whether microorganisms, specifically bacteria, can proliferate on the fabric surface when saturated with the bacteria. A bacterial suspension is inoculated onto the fabric for a 24-hour incubation period. Both the treated fabric and untreated control fabric are inoculated. After incubation, the treated fabric is compared to the untreated control for bacterial growth. The results of the test will be classified as either "pass" or "fail", indicating presence or absence of antibacterial activity, respectively.

2.5.2 FTIR Test:

Fourier Transform Infrared Spectroscopy (FTIR) testing is employed in the analysis of the chemical composition of fabric derived from natural dyes. The FTIR test identifies specific functional groups and chemical bonding in the fabric to gather data about the molecular structure of the natural dye, and how that structure may or may not adhere to the cotton fibres.. FTIR test results are presented as a spectrum, showing absorption peaks that correlate to specific chemical bonding.

2.5.3 Fe-SEM Test:

Field Emission Scanning Electron Microscopy (FE SEM) test is applied to characterize the surface morphology of natural dyed cotton fabric. The FE SEM test produces detailed images of the surface of the fabric that enable assessment of the dye coverage, Fiber structure, and any surface changes. The FE SEM test obtains information about the interaction between the natural dye and cotton Fibers and allows for visualization of the presence of impurities or residues on the fabric surface.

2.5.4 Ends per inch & Picks per inch:

The ends per inch (EPI) of cotton fabric that has been dyed naturally indicates the number of warp yarns in an inch of fabric. A higher EPI means denser fabric and a tighter weave, which translates into stronger and better texture. The picks per inch (PPI) of natural dyed cotton fabric is defined as the number of weft yarns in one inch of fabric. PPI, like ends per inch (EPI), is a measure of fabric density and how tightly the fabric is woven. A higher PPI means the fabric is denser and tightly woven, giving the fabric more durability, texture, and colourfastness.

2.5.5 Tensile strength:

The tensile strength of naturally dyed cotton fabric is its capacity to resist tensile forces without rupturing or excessively stretching. Tensile strength is generally expressed in either pounds per square inch (psi) or Newtons per square meter (N/m^2). The methodology involves cutting the fabric into standard strips, approximately 2.5 cm in width and 20 cm length, and testing the strips in both the warp and the weft.

2.5.6 Colourfastness:

The tests for colourfastness in naturally dyed cotton fabrics assess their ability to resist colour fading or bleeding under a variety of circumstances, including exposure to light, washing, wet, and dry rubbing. A sample of fabric is exposed to a controlled environment of light, water, or rubbing, then assessed for the change in colour using a colorimeter or grey scale. Results are ranked on a 1 to 5 scale, signifying 5 as excellent colourfastness and 1 as poor.

3. RESULTS AND DISCUSSION:

3.1 AATCC 147 (Anti-bacterial test)

Figure1 : Antibacterial Activity

The antibacterial activity of the finished sample was evaluated according to AATCC Test Method 147, using *Staphylococcus aureus* (ATCC 6538) and *Klebsiella pneumoniae* (ATCC 4352). Based on the results of the test, the sample demonstrated moderate antibacterial activity against both bacterial strains.

3.2 FTIR Test

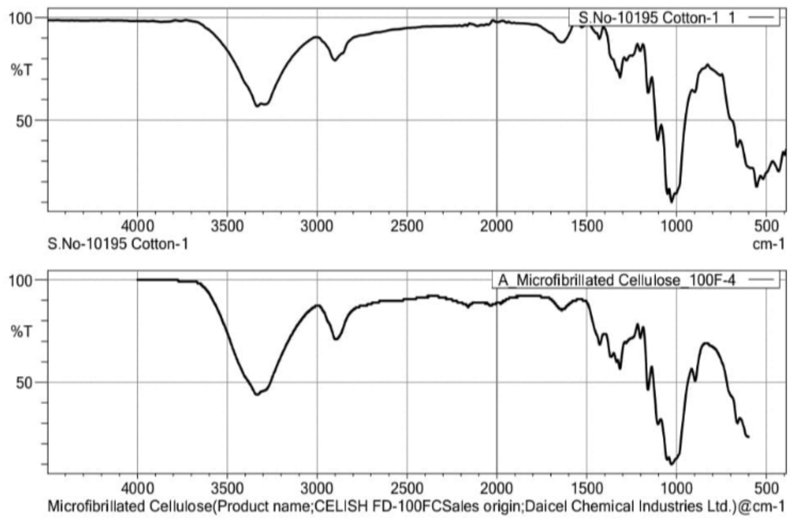


Figure 2: FTIR for sample FS

The above-mentioned graph shows the broad Peak around 3300–3400 cm^{-1}: Both samples: show a broad absorption band in this region, attributed to O–H stretching vibrations, characteristic of hydroxyl groups in cellulose. Peak near 2900 cm^{-1} - Both samples: A peak in this region corresponds to C–H stretching vibrations from aliphatic groups (CH and CH_2). Region 1500–1000 cm^{-1} - This region contains several important functional group vibrations: C–O–C and C–O stretching typical for the polysaccharide structure of cellulose. Peaks around 1050–1150 cm^{-1} are more defined in the micro fibrillated cellulose, indicating more ordered or exposed cellulose chains. Region below 1000 cm^{-1} -Contains skeletal vibrations and fingerprint region. Similar patterns in both, but micro fibrillated cellulose may show sharper features due to structural changes from fibrillation. Both spectra confirm the presence of cellulose. The micro fibrillated cellulose shows subtle differences such as: Slightly sharper and more intense O–H and C–O peaks. Possible structural rearrangements or higher accessibility of functional groups due to fibrillation. These changes are consistent with mechanical or chemical treatments used to obtain micro fibrillated cellulose from cotton or plant-based sources.

3.3 FE- SEM Test:

Figure 3: Analysis of FESEM

Results show the higher magnification (10k–20k×) reveals- Surface modifications, microcracks, or coating residues. Micro fibrillated cellulose texture, suggesting mechanical or chemical treatments. Medium magnification (2k–6k×) shows-Inter-fiber bonding and uniformity. Presence or absence of surface coating, deposits, or roughness. Lower magnification (100×–500×) highlights- Fiber arrangement and packing. Potential for coating penetration or treatment distribution at the fabric level. These SEM images provide a clear scale-wise morphological comparison of cotton and micro fibrillated cellulose samples. The progressive magnifications from macro to micro support the structural analysis of surface treatments, Fiber separation, or finishing effects.

3.4 Ends per inch & picks per inch

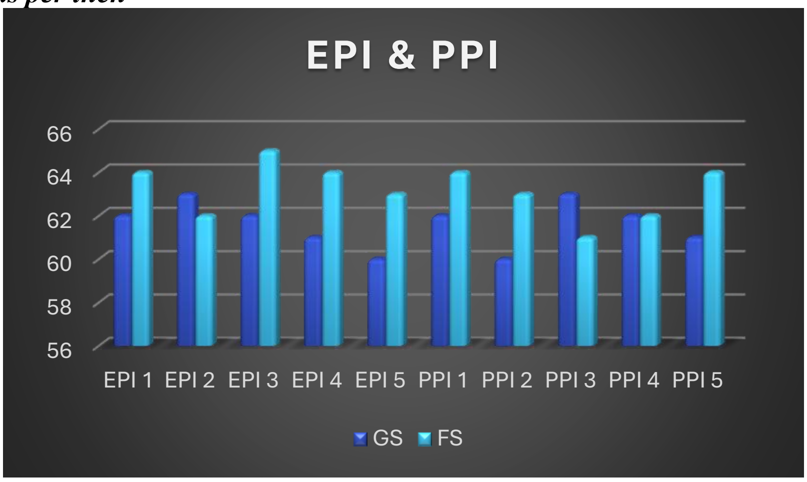
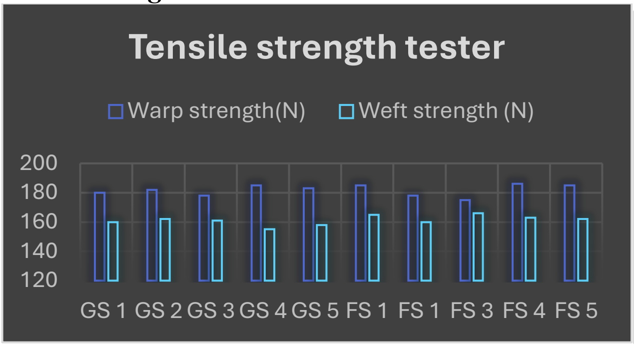


Figure 4: EPI & PPI

Based on the above graph, the following results were obtained to determine the Ends Per Inch (EPI) and Picks Per Inch (PPI) of both grey and finished fabric. Five readings were taken for each grey sample (GS) and finished sample (FS). The sample FS exhibited the highest EPI and PPI values compared to GS.

3.5 Tensile strength tester



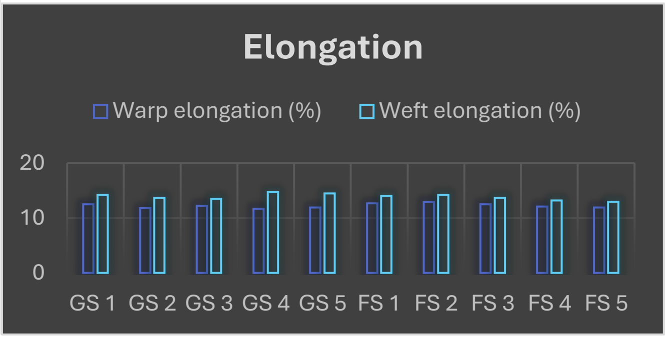


Figure 5: Tensile strength tester Figure 6: Elongation

The above-mentioned graphs show the following results were obtained to determine the tensile strength of grey and finished fabric. Five readings were taken for each grey sample (GS) and finished sample (FS). The FS sample exhibited the highest tensile strength in both the warp and weft directions compared to the GS.
Additionally, results were obtained to evaluate the elongation of grey and finished fabric. Five readings were taken from each GS and FS. The FS sample showed the highest elongation in the warp direction, while the GS sample exhibited the highest elongation in the weft direction.

3.6 Colour fastness:

Figure 7: Colourfastness

The result of this graph shows that the following results were obtained to evaluate the colour fastness to rubbing of the finished fabric. Readings were taken from the finished sample (FS) under both wet and dry conditions. The sample exhibited moderate to good colour fastness in wet rubbing and moderate colour fastness in dry rubbing. Overall, the fabric showed better colour fastness under wet rubbing conditions compared to dry rubbing.

4. CONCLUSIONS:

Natural dyeing of fabrics is a sustainable and environmentally friendly option compared to synthetic dyeing. Natural dyes are isolated from plants, minerals, and other organic matters can yield a wide variety of color shades and hues. Natural dyeing is done through pre-treatment, dyeing, and post-treatment procedures to gain desired colors and fastness. Cotton fabric is one of the most sought-after substrates for natural dyeing because it is breathable, absorbent, and durable. The application of natural dyes to cotton fabric not only eliminates environmental pollution but also encourages sustainable fashion practices. In general, natural textile dyeing is a feasible and appealing option for environmentally friendly and sustainable textile solutions.

REFERENCES:

1. Singh, R. (2020). Natural Dyeing of Cotton Fabric using Indian Madder Root. Journal of *Natural Fibers*, Volume 17(Issue 1), pages 1-12.
2. Banupriya, J., Maheshwari, V., (2013). Comparative study on antibacterial finishes by herbal and conventional methods on the woven fabrics. Journal of *Textile Science & Engineering* 3 (01), 123–128.
3. Kumar, A. et al. (2019). Natural Dyes and Their Applications. Journal of *Textile and Apparel Technology Management*, Volume 11(Issue 2), pages 1-15.
4. Sharma, P. et al. (2020). The Art of Natural Dyeing. Journal of *Textile Science and Engineering*, Volume 10(Issue 1), pages 1-10.
5. Kumar, A. (2020). "Cotton and Natural Dyes: A Historical Perspective". Journal of *Textile History*, Volume 51(Issue 2), pages 157-175.
6. Chaudhry, M. R. (2020). Cultivation and Harvesting of Cotton. Journal of *Cotton Research*, Volume 3(Issue 1), pages 1-15.
7. Kumar, A. et al. (2020). "Exploring the Potential of Cotton as a Sustainable Natural Fiber for Dyeing". Journal of *Sustainable Textiles*, Volume 1(Issue 2), pages 123-135.
8. Patel, D. et al. (2020). "Investigating the Effectiveness of Natural Pre-Treatment Agents on Cotton Fabric". Journal of *Sustainable Textiles*, Volume 1(Issue 1), pages 34-46.
9. Singh, R. et al. (2020). "Soap-nuts as a Natural Dyeing Agent and Finishing Treatment for Cotton Fabric". Journal of *Natural Fibers*, Volume 17(Issue 2), pages 257-267.
10. Patel, D. et al. (2020).” Indian Madder Root as a Natural Dye for Cotton Fabric: A Study on Color Fastness and Wash Durability". Journal of *Sustainable Textiles*, Volume 1(Issue 1), pages 47-59.
11. Gupta, S. et al. (2020). "Phyto-Geographical Distribution and Sources of Indian Madder Root in the Himalayan Region". Journal of *Botanical Research, Volume 11*(Issue 1), pages 1-12.