JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

NATURAL DYES AND THEIR APPLICATION ON CELLULOSIC FABRICS

K.P.Kalaivaanee[1], B.Abirami[2]
1. Research Scholar, 2. Assistant Professor
1. Department of Textiles and Apparel Design, Periyar University, Salem
2. Department of Costume Design and Fashion, Vellalar College for Women, Erode

Abstract

Since 1856, the textile industry has used natural dyes, a form of cellulosic fibre that may be printed with a wide range of hues. Cellulose is a natural polymer consisting of long chains of AGUs (anhydrous-D-glucopyranose units). Benefits include high specific characteristics, low density, cheap cost, abundant availability, and renewable nature. Renewable and biodegradable indoor and outdoor dyes cannot fulfil the vast demands of the textile industry since most land is used for food and feed production. Several international initiatives have been launched to address the issue of colour flaws, and the use of certain synthetic hues on endangered species is prohibited by the Global Organic Textile Standard (GOTS). Natural dyes are now exclusively used to irradiate textiles by traditional craftspeople, hobbyists, and small businesses in the cottage industry. Dyeing cellulosic fibres with a mordant did not appreciably improve their colourfastness, but mordanted cotton fibres absorbed more dye under the same dyeing circumstances. Protein and cellulosic textile substrates may be dyed and finished with Acacia auriculiformis. Experiments have revealed that by adding damping to the cellulosic process, thermal stability and colour retention are enhanced after washing. More education is required to increase demand and consumption.

Keywords: Cellulosic fibres, Textile Industry, Natural dyes, Mordant, Colorfastness

1. Introduction

Synthetic dyes were discovered in 1856, and since then, the textile industry has used natural colours much less often. Analytical methods such as infrared (IR) spectrophotometry have been used to determine which plants may be used to make dyes and evaluate their qualities. Different mordants were used to fix the dye into the fabric after it was extracted from various plant parts. Substantive and adjectival natural dyes are distinguishable. Evidence of wool, a protein-based fibre, dates back to 2000 B.C.E. The skill of dyeing wool reached new heights when Europe saw waves of migration, cultural change, and even invasion. (Sumathy, 2013)

Cotton, flax, hemp, jute, sisal, banana, coconut, and bamboo are some plant fibres that may be used to create cellulose, a natural polymer. Numerous synthetic items can benefit from their plentiful availability, low cost, renewable nature, eco-friendliness, low density, and high specific properties. Various environmental, climatic, harvesting, maturational, elevational, scaling and disintegrative, left-classificational, textile, and technological elements all shape cellulose's properties. Chemically speaking, cellulose is a polymer composed of long chains of anhydro-D-glucopyranose units (AGUs), with three hydroxyl groups per AGU (except at the two ends of the molecule).

The predominant usage of land for food and feed means that renewable and biodegradable indoor and outdoor dyes cannot meet the massive needs of the textile business. The Global Organic Textile Standard (GOTS) prohibits safe synthetic hues, and natural dyes cannot be used on endangered species. Several international efforts have been made to address the problem of colour flaws. Only traditional artisans, hobbyists, and small entrepreneurs in the cottage industry colour around 1% of textiles using natural dyes. (Hamdy & Hassabo, 2021)

2. Cellulosic Fibre

The cellulose polymer found in plants comprises hundreds to thousands of linked D-glucose units bonded together by hydroxyl groups (Scheme 7). The fibre's ability to respond, absorb water, and swell is due to many polar -OH groups in the cellulose macromolecule. Cellulosic fibres may be dyed with synthetic dyes, including direct, vat, azoic, sulphur, and reactive dyes. Natural colourants like henna, lawsone, acacia, gulzuba, onion skins, deodara, jackfruit, eucalyptus bark, and tea may be used to increase dye uptake by fibre and boost colourfastness. UV irradiation and mordanting with chemicals such as potash alum, ammonium sulphate, hydrosulfate, caustic soda, and copper sulphate have been studied as potential treatments for cellulosic fibres. Methanolic extracts of irradiated henna powder reportedly improved the colour strength and fastness attributes of irradiated textiles compared to non-irradiated fabrics dyed with the same extracts.

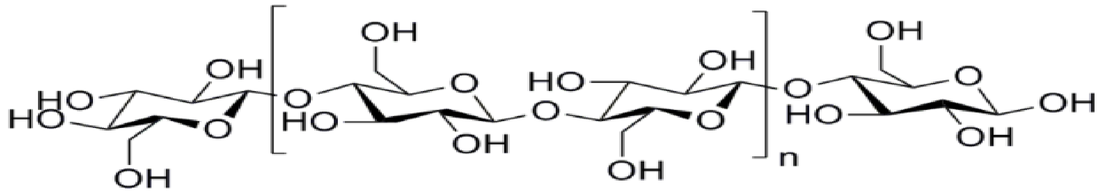

Fig 1. Polymerization of cellulose and its chemical structure

The study focuses primarily on the technical elements of extracting natural dyes and dyeing cellulosic fibres, which are essential to the process. Because they require less energy, water, and chemicals than traditional methods, cutting-edge processes like ultrasonic, microwave, enzyme, UV technology, chitosan, and plasma can reduce environmental impact and increase accessibility. Sustainable methods are needed to improve the supply of natural dyes, such as using agricultural and agro-processing industry wastes and carefully harvesting forest products. Genuine-coloured cloth manufacturers and consumers would benefit from creating accurate profiles and verification methods for natural dyes. If the aforementioned steps can be taken to enhance the supply of natural pigment, natural dyes might be used to lower the price of primary colours. Sustainable use of natural dyes for treating predominating tissues will only be possible if biotechnological interventions like tissue culture or genetic engineering make these dyes readily available in large quantities at low cost from microbes. (El-Hawary, 2020)

This is probably owing to the considerable sorption of degraded products on cotton garments brought about by the hydrolytic breakdown of the Lawsone colourant upon the UV treatment. It has been shown that mordanting of cellulosic fibres results in better dye absorption than does not. After mordanting, cotton fibres absorbed more dye than other cellulosic fibres of the same shade when subjected to the same dyeing conditions. However, dyeing cellulosic fibres with a mordant did not significantly enhance their colourfastness. (Bhuiyan et al., 2017)

You may use Acacia auriculiformis to dye and finish protein and cellulosic textile substrates at the same time. Acacia auriculiformis coloured wool and silk textiles have remarkable colour fastness to washing and sunlight. According to phytochemical analysis, the aqueous extract of the dye contains saponin, phenols, tannin, and glycosides. Fabrics coloured with Acacia auriculiformis aqueous extract (200 g/l) have the highest UPF value. Fabrics that have been dyed have shown to be highly resistant to both S. aureus and E. coli. Maximum resistance against E. Coli and S. aureus bacterial colonies is shown in silk fabric dyed at 90°C and 200 g/l dye concentration.

All other treated fabrics also perform exceptionally well, with 94% or higher reductions. In comparison to cellulosic fabrics, protein fabrics dyed with this natural dye have superior washing and light-fastness properties. (Chakraborty et al., 2020)

A cellulosic fibre, jute, may be printed on and used as a substitute for more expensive materials. It's completely safe for the environment since it's made from biodegradable basic ingredients. Applying colour to fibres in patterns or designs with clear contours is known as textile printing. All dyes, including direct, basic, acid, pre-metalized, vat, azoic (naphthol), reactive, sulphur, and natural dyes, can be used to print on jute fabrics. To increase rubbing fastness, jute fabrics are often printed with direct-styled pigment colours, emulsion thickening based on kerosene or White Spiritor mineral turpentine oil (MTO) and a Fixer-CCL (melamine formaldehyde resin). Jute is a significant cellulosic fibre that can be dyed and printed with a wide variety of colours; printing with natural dyes yields a very impressive result in terms of fastness against rubbing, light, and washing, and it is environmentally beneficial and non-toxic.(El-Sayed, et al., 2021)

Natural dyes fell out of favour as artificial alternatives became more widely available and affordable. Natural dyes have risen in prominence due to their widespread use; for example, Chromo treatment relies highly on natural colouring dyes. Few people outside of cottage businesses thoroughly understand dyeing processes, and the techniques used to gather and extract colours are still very primitive. To colour natural eco-friendly textiles in a range of soothing/uncommon shades with eco-friendly mordants and finishing agents, textile dyers need to be familiar with the chemistry of these natural colours and their added advantages of medicinal values, and use suitable binary or ternary mixtures of similar or compatible natural dyes. To achieve a consistent colour output and matching, textile dyers must strictly adhere to the standardised formula for selecting the fibre-mordant natural dye system. The use of natural dyes has seen resurgence in popularity in light of the current global emphasis on eco-friendly and biodegradable products. (Sumathy, 2013)

Cotton, wood viscose, and bamboo viscose fabrics were dyed using alkaline and aqueous extractions of padouk and moving sawdust. Cotton's general dyeability was found to be higher than that of bamboo and wood viscose, two other cellulosic supports. Padouk and moving natural dyes were extracted in water and alkaline solutions and then used to colour cotton fabric, wood viscose, and bamboo viscose. Both moving and padouk extracts were used to get the respective colours. Colour retention after washing was excellent. The colour contrast on cotton is superior to that on bamboo and wood viscose fabrics. This provides promising evidence that padouk and moving extracts may replace synthetic dyes as a viable option for colouring cellulosic textiles. (SahaTchinda et al., 2014)

Mordanting cotton and linen fabric was tested for its impact on thermal behaviour using thermo-gravimetric analysis (TGA), its differential (DTG), and differential scanning calorimetry (DSC). Changes in the thermal stability of the textiles under research were analysed using thermal analysis techniques such as differential scanning calorimetry (DSC) and thermal analysis gravimetry (TGA) and its derivative. It was found that mordanting these cellulosic materials after they had been dyed provided some insight into the structural alterations that had taken place. Mordant improves the thermal stability of cellulose, as seen by the peak moving to higher temperatures in mordanted vs un-mordanted coloured materials. From these results, we may infer that the structural characteristics of various materials can be predicted using the thermal analysis data, which also provides information on the materials' thermal degradation parameters and physical performance.(Ibrahim et al., 2011)

2.1 Natural Dyes

Dye pigments obtained from plants, insects, animals, or minerals are known as natural dyes. The usage of indigoid dyes dates back to the dawn of humanity. Indigo is the most common natural blue dye because of its use in denim. Traditional indigo was made from various plants, including woad, knotweed, and Pala Indigo. In 1987, when BASF first produced synthetic indigo, the demand for natural indigo began to fall.

Confectionery, food colouring, textiles, cosmetics, pharmaceuticals, leather processing, paper making, paint, ink, etc., rely heavily on natural dyes. There are several different ways to categorise natural dyes, but the most common ones are based on the materials used in their production, the methods by which they are applied to fabrics, and their chemical composition.

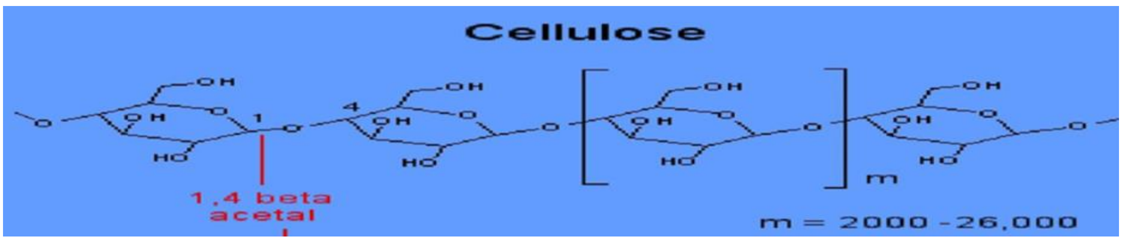

Fig 2. Long chains make up cellulose.(El-Hawary, 2019)

Farmers may diversify their income by cultivating essential colouring plants on unused land and poor soil. Consumers' confidence in natural dyes would be boosted, benefiting both manufacturers and consumers, with the implementation of proper systems for characterising and certifying natural dyes. Natural dyes will only be viable for industrial textile production if biotechnological processes like tissue culture and genetic engineering boost their availability to very high levels. At the current stage of development, natural dyes are only practical for use in limited quantities, but they provide a sustainable alternative to synthetic alternatives and a means of subsistence for a wide range of natural dye value chain participants.(Hamdy & Hassabo, 2021)

3. Eco-Friendly Textiles

Natural dyes are seeing a renaissance in popularity due to stricter environmental requirements in the textile and garment industry being enforced by governments concerned with environmental and health protection. Although natural dyes are sustainable colouring options, they require mordanting with metallic compounds due to their poor bonding with textile fibre materials. This calls for an updated study into using natural dyes on various natural fibres to create eco-friendly textiles. This review article provides an overview of the chemistry of natural dyes and highlights some of the most significant studies yet. Natural dyes are considered environmentally beneficial because of their one-of-a-kind characteristics; nonetheless, they need bridging chemicals to attach the dye molecules to the fibre owing to the weak interaction between the dye molecules and the fibre's active sites.

To connect the dye molecules to the fibre, mordanting chemicals are used. The effectiveness of natural dyes is diminished due to the use of synthetic mordanting compounds, some of which are hazardous. Spectral data gathering is necessary since natural dyes lack a shade card that can be used to match samples or replicate the shade. To enhance demand and consumption, more education about the benefits of natural dyes and coloured cloth is required. The manufacturing cost of natural dyes is high. Hence studies aimed at lowering that cost are warranted.

Workshops and symposia should be organised by large manufacturing companies, technical institutes, and research houses to propagate the benefits of natural dyes. The government should incentivize the development of natural dyes by smaller manufacturers. There must be intensive R&D into natural dyes to raise their standards regarding affordability, sustainability, and utility. (Kumar Gupta, 2020)

3.1 Cotton Fibres

Cotton is one of the most widely used fibres in clothing and other textiles. Cotton dyeing using synthetic anionic dyes is hard on the environment since it requires a lot of salt and alkali. Using natural dyes generated from plants has been seen as a potentially effective strategy for resolving this issue. The textile industry has long faced significant difficulties in optimising the dyeing process and predicting the values of colour coordinates of coloured fabrics. In this experiment, cotton was mordanted with alum and then dyed with one of two different natural dyes.

According to the data analysis, the colour coordinates may be determined using any of the three characteristics. The mean squared error (MSE) was used to evaluate the regression approach, and ANN models were weighted using back-propagation (BP) and optimisation methods to select the optimum model to predict the colour coordinates of cotton textiles. Using the PSO-FMIN method for ANN weighting improved the accuracy of colour coordinate predictions. Eco-friendly cotton dyed with two different natural dyes was studied. Key points include the use of an ANN model for colour coordinate prediction and the finding that utilising BP and other optimisation methods to fix the final weights and biases of the ANN structure did not provide satisfactory results. However, instead of only employing BP or optimisation methods, the colour coordinates' prediction accuracy improved dramatically when the end weights and biases of BP were used as the beginning point of the search.

We want to gather more fabric colour coordinate data in the future and then utilise other artificial intelligence techniques, like fuzzy logic and support vector machines, to make predictions about those colours and then compare those predictions to the existing findings. (Vadood, Haji, 2022)

This study aimed to examine whether or not the natural colourants Madder and Weld could be used to successfully dye cotton cloth pre-mordanted with three metallic salts. Researchers looked at how changing the mordant content, dyeing temperature, dyeing time, and electrolyte concentration affected the intensity of the coloured samples. The dye depletion into the cotton fibres was enhanced using low-temperature plasma treatment, an environmentally safe pretreatment. Dyeing cotton with madder and weld natural dyes resulted in an evaluation of the fastness qualities of cotton samples coloured under various circumstances, and the optimal proportion of each variable was determined to produce the maximum values of colour strength and fastness properties. The results demonstrated that these dyes, in conjunction with metal mordants, may be utilised to impart colour to cotton fibre. Adding sodium sulphate to the dye bath improves dye penetration. Dye absorption improves with longer and hotter dyeing processes. Cotton's dyeability when using natural dyes was enhanced by a plasma pretreatment, and the fastness qualities of the coloured samples were also improved. (Haji, n.d.)

3.2 Wool Fabric

By analysing cloth colour qualities and colourfastness to washing, this study looked at the efficacy of the dyeing process. It was discovered that the dye made from Spartium junceum L. is acidic (mordant), making it best suited for use on wool. The extracted dye exhibits UV absorption bands typical of flavonoids at maximum wavelengths of 224, 268, 308, and 346 nm. The chromatic (C*) and hue (h) qualities of coloured wool cloth pre-mordanted with 3% alum are excellent.

After 5 washes, the wool sample treated with 3% alum shows the greatest colourfastness qualities. Synthetic mordant will be phased out in favour of a more sustainable alternative, which will be the focus of future studies. The dyed wool samples are more vibrantly coloured than the cotton ones. This study indicated that compared to other dyed wool samples, those dyed and pre-mordanted with 5% alum had the lowest lightness value (L* = 69.96) and maximum chroma (C* = 51.64). Wool samples had far less discolouration after washing than cotton ones did. Wool samples treated with 3% alum performed best, with Delta E* of 0.87 after five washes, well within acceptable ranges. Due to considerations of circular economy, textile care, and eco-friendliness, this study has broad practical applications. Raw material for natural dye synthesis is discovered in the SJL plant's least-used area. The successful outcomes achieved after lowering the alum mordant content affect the way SJL natural dye is used, making it more eco-friendly and meeting the demanding requirements of a number of EU laws. Future studies aim to find a natural mordant that can be used instead of a synthetic one. These results also prompted a multidisciplinary strategy and more analysis of energy crop cultures.(Kovačević et al., 2021)

4. Systematic Reports on Dyeing of Textiles

Natural dyes are characterised and chemically/biochemically analysed in this paper, as well as studies on the extraction of colourants from various natural sources, the effects of multiple mordants and mordanting methods, conventional and non-conventional methods of natural dyeing, physicochemical studies on dyeing process variables and dyeing kinetics, the creation of novel shades and the analysis of colour parameters for textiles dyed with natural dyes, and the evaluation of compatibility. Insufficient scientific research and systematic reports on the natural dyeing of textiles have been found. It is impossible to improve computerised colour matching for natural dyes because of the textile industry's fundamental two dependent elements (dye and mordant) and colour development process. However, with the help of a computer program, it is possible to create a colour-matching database for any textile material's natural dyeing and predict how well those colours will blend together.(Samanta & Agarwal, 2009)

4.1 Ultrasonic Dyeing

This study investigates the feasibility of using soy protein as a bio-mordant with a natural dye derived from Syzygium cumini fruits in dying cotton fabric. Comparisons were made between sonochemical mordanting and dyeing and the more traditional water bath. Sonochemical-assisted dying dramatically improved dye absorption and K/S values compared to those achieved with a standard bath alone. The results of these experiments provide important clues for the creation of eco-friendly methods of using natural dyes and bio-mordants on raw cellulose-based materials. Sonic dyeing was cheaper at 9.56 €/kg than traditional dyeing at 9.91 €/kg. Dyeing a metal mordant is more expensive since it necessitates using a WWTP. The use of metal mordant is not environmentally friendly. This study used bio-mordants (soy protein powder) to test the efficacy of colouring cotton garments using a natural dye from Syzygium cumini fruits. When the concentration of SP mordanting was raised, K/S values also rose. Dyeing in an ultrasonic bath or a more traditional water bath is possible.

Dyeability and fastness using syzygium cumini dyes are improved by ultrasonic dyeing of cotton. The dyed fabrics produced in this investigation show moderate levels of colourfastness when treated with traditional dyeing techniques but excellent colourfastness when treated with ultrasonic baths. The UPF ratings of dyed fabrics (i.e., USB, CVB) are much higher than white cloth ones. Materials made employing ultrasonic processes to dye the cotton with natural dyes and bio-mordants are more durable and environmentally friendly. Since amino groups allow SGC dyes to chemically bond to their target fibres, we may want to experiment with dying other types of natural fibres like wool and silk in the future. (Periyasamy, 2022)

5. Modification Processes of Natural Dyes

Natural dyes and antimicrobials are experiencing a renaissance thanks to research into extraction, purification, and modification procedures and subsequent use in textiles. Textiles have been coloured with natural dyes since antiquity, but with the introduction of artificial synthetic dyes in the middle of the 19th century, the market for these products has been cornered owing to their superior qualities at lower prices. On the other hand, synthetic dyes pose significant dangers to human health and the environment. To counteract these cons, there has been a surge in interest in developing and using colours derived from plants and microbes across the globe. These natural colours may have significant therapeutic efficacy due to their intrinsic antibacterial qualities.

This article summarises the most recent findings from scientific studies on the extraction and use of natural dyes/antimicrobials in the textile industry. Extraction techniques, modern textile treatments, and early uses of natural dyes/antimicrobials in textile processing are discussed in depth. Dyestuffs derived from natural resources may be abundant and diverse and hold potential therapeutic action and antibacterial qualities. There are, however, downsides to using these natural dyes, such as their lack of repeatability, lengthy extraction processes, and poor fastness qualities. The natural colourant is just one factor; the mordant and mordant helpers also have a role in determining the final hue and colourfastness of the dyed fibre. Environmentally preferable alternatives to mordants, such as plasma therapy, are rapidly gaining ground and are likely to replace them.(Chungkrang et al., 2021)

6. Colour Fastness Properties of Natural Dyed Textiles

The ability of a material to retain its colour features or to minimise the transfer of its colourants to touching white surfaces is known as its "colour fastness." The two most common evaluation methods are the degree of staining or the degree to which the original colour was lost. Perspiration fastness is solely evaluated for clothing. However, light fastness, wash fastness, and rub fastness are all examined for all fabrics.

6.1 Light Fastness

Generally speaking, the light fastness of natural dyes is low to medium, especially for those made from flower petals. Much effort has been put into enhancing the soft, fastness qualities of various naturally coloured fabrics. Cook has thoroughly analysed the steps to improve the dyes' colourfastness on different textile fibres. The hues of museum textiles are typically altered from their original colours since most natural dyes have low light stability compared to the finest synthetic dyes. Duff et al. described the colour changes in terms of the Munsell scale and CIE colour parameters, while Padfield and Landi assessed the relative light stability of various dyes.

The fastness ratings of wool coloured with nine natural dyes were comparable to those of Padfield and Landi in daylight fading after being subjected to a Microscale MBTF fading lamp. According to the LF ratings established by the blue wool standards, yellow dyes have a low rating, red dyes have a moderate rating, and indigo has a high rating. As described by Gupta, light and other colour fastness attributes were shown to be affected by the chemical structure of natural dyes. Tin and alum mordants induced far greater fading than chrome, iron, or copper mordants, although turmeric, fustic, and marigold colours faded more than the other yellow dyes. The photofading of carthamin in cellulose acetate film was studied by Oda, who found that different additions had different effects. Fabrics dyed with natural pigments have had their lightfastness enhanced by many researchers, including Cristea and Vilarim, Lee et al., Michael and Zaher, and Gupta et al.

Samanta et al. recently reported that using 1% benzotriazole under certain circumstances increased the light fastness of natural-coloured jute fabrics from 0.5 to 1.0 units. They've also examined and reported benztriazole's effect on jute's mechanism of action.

6.2 Wash Fastness

Using a washing formulation used in conservation work, Duff et al.182 tested natural dyes' light fastness and washed fastness at both conventional conditions (50°C) and 20°C. The ISO II test reveals that natural dyes have a fair amount of wash fastness on wool. Indigo and logwood are reported to be the quickest dyes. Few distinctions between domestic and imported examples of yellow, red, red/purple, green, and brown could be made. Wash fastness was observed to be increased to about 1 unit after treatment with 2%CTAB or sand fix-HCF, as reported by Samanta et al..

6.3 Rub Fastness

Most natural dyes have moderate to excellent rub fastness and don't need to be treated afterwards. Good rub fastness on jute and cotton textiles was observed for jackfruit wood, manjistha, red sandalwood, babool, and marigold by Samanta et al.. According to Sarkar, marigold has excellent cotton, silk, and wool rub fastness. The dry and wet rub fastness of Acalypha-dyed silk was investigated by Mahale et al. According to Khan et al., cutch and ratan jot have mediocre wet rub fastness but moderate to high dry rub fastness.

Samanta et al. investigated the characteristics and compatibility of using a binary combination of jackfruit wood and other natural dyes to colour cotton garments. Remember that the chemical nature and kind of mordants employed have just as much of an impact on the colour fastness of natural dyes as the natural colourants themselves. The use of natural after-treatment compounds to enhance the wash and light fastness of natural dyes is an area that needs more investigation.

7. Natural Dye Henna

Henna, sometimes called Lawsone, is a naturally occurring reddish-orange pigment used centuries to colour everything from hair and skin to fabric. Its colour blends well with the natural world, and its low chemical reactivity does not damage the ecosystem. These article overviews recent studies on henna dye, including its background, chemical makeup, and chromatic capabilities. It also covers how chemically modifying textile fibres may increase dyeability and overall colourfastness and the impact of various mordants and mordanting procedures on dye absorption. Lawsone is the primary bioactive component of henna leaf, which people have used to dye their skin and hair since prehistoric times.

The use of henna in textile dyeing has been the primary subject of this study. Due to its acidic composition and proton-releasing capabilities, henna finds widespread use in the textile dying industry. However, because of its dissimilarity to protein and polyamide fibres, henna binds to them more easily, resulting in superior fastness and a more vibrant colour. Although henna is inherently ionic, it can be used to colour hydrophobic fibres at a high enough temperature to impart excellent colourfastness properties against washing, perspiration, and light with a corresponding reduction in colour intensity. (Bhuiyan et al., 2017)

This study aimed to determine the light fastness of cotton textiles dyed with natural pigments, such as mehndi/henna, turmeric, tea leaf, and pomegranate. The results showed that they/henna dye interacted with the cellulose of cotton in an alkaline environment, creating a covalent connection between the dye and the cellulose that could not be broken down even after repeated treatments with hot steaming water under neutral pH. Natural powder dyes were gathered and dissolved in the appropriate chemicals and auxiliaries before colouring 100% cotton mercerized garments. Natural dyestuffs were used in a continuous dyeing process enabled by the "Pad Dye Pad Steam" machine's open-width shape, and the colours were fixed with a steamed wash. The dyeing procedure and colour fastness testing were conducted using the AATCC and ISO standard test procedures.

The lab spectrophotometer "Data Colour Spectra Flash SF600" measured dye absorption and colour strength. This study had a practical application, and the results benefited workers in the textile industry whose duties included dying textiles with natural dyes and regulating their colourfastness. The greatest colourfastness qualities were shown by mehendi/henna dye across all studies. This occurred because, under alkaline conditions, the mehendi/henna dye created a covalent connection with the cellulose of cotton, securing the dye to the fibres for an extended period. Covalent bonds are established between the dye molecules and the terminal reactive group in mehendi dye, making the dye an intrinsic fibre component.

Mehedy dyestuff has the greatest colour fastness qualities since they were fixed with cellulose using an alkaline catalyst. The potential for using natural dyes to colour cotton garments might be expanded with further research. (Islam et al., 2020)

8. Natural Colorants

Through colour analysis and colourfastness testing, this study looked into the viability of natural colourants for dyeing flax fabrics. For cochineal dyed fabrics, pre-mordanting improved colour strength and fastness properties, while meta-mordanting was preferable for enhanced colour strength for red sandalwood and osage orange dyed fabrics. More diversity occurs with natural colourants due to differences in origin and species, extraction method, and dyeing process than synthetic dyestuffs with known compositions. As the data showed, all the natural colourants tested in this research showed signs of having issues with sweat fastness. Natural colourants are a potential commercial alternative to synthetic dyes for the textile and clothing sectors, and it is believed that with enough study, they may be adapted to approach the rigorous functional characteristics of synthetic dyes.(Sarkar and Seal, 2003)

Pigment printing using two natural dyes (alkanet and rhubarb) has been researched for its potential to be used on raw materials (wool, silk, cotton, and flax). Several variables have been investigated for their impact, including dye concentration, thickening agent nature, fixation method, dye concentration, and mordant type. Meypro gum was shown to have the highest K/S value of any thickener tested. The K/S quickly rises from 10 to 40 g/kg printing paste as the concentration of the natural dye powder increases. Use 20 g of mordant per kilogramme of printing paste for optimal results.

Different mordants produced varying colour yields, and the results for colour fastness ranged from very good to excellent. Pigment printing on natural fibres (wool, silk, and flax) has been investigated, and it has been found that alkanet and rhubarb powder might be used. Based on the study's results, it was determined that Meypro gum is the optimal thickener since it produced the greatest K/S values; nevertheless, the K/S value of printed products varies depending on the kind of printed cloth and the dye concentration used. (Rekaby et al., 2009)

This paper summarises recent research on modifying commonly used natural fibres like cotton and silk to improve their ability to absorb natural dyes and the various ways these dyes can be applied to give fabrics an antimicrobial, UV-resistant, or insect-repellent finish. Since natural dyes are safe for humans and the environment, so they have received much attention from scientists looking for new ways to use them in the textile industry. Integrating different surface modification methods with natural dyes would facilitate ecological and green textile dyeing, which may lead to identifying new and useful application domains. There is a continuous study to better understand how natural dyes might be used. However, sustainable bio-resource exploitation requires immediate action in the form of widespread commercial adoption and manufacture of natural dyes.(Singh et al., 2021)

9. Application of Natural Dyes for Enhanced Fabric Finishing

Sustainable methods of delivering functional textile finishes using natural dyes are now required for effective and enhanced features. The resulting fabric gains additional properties using natural dyes, including antibacterial activity, UV protection, flame resistance, allergy protection, deodorising abilities, and insect repellency. The fabric finishing industry invests much in R&D to provide high-quality textiles with improved functional features.

9.1 Antimicrobial Finishing

Discolouration, skin infection, unpleasant odour production, product deterioration, and allergic reactions are only some of the negative outcomes associated with the proliferation of microbial species in textile materials. Scientists are working to solve this problem by creating functional textile textiles that meet comfort and health needs (Fauziyah, 2019). The use of synthetic antimicrobial textile agents such as nanoparticles of noble metals and metal oxides, triclosan, chitosan, poly biguanides, and triclosan, as well as organometallics, phenols, organosilicon, quaternary ammonium compounds, N-halamines, and chitosan, has been documented in the scientific literature(Simoncic, 2010). However, eco-friendly finishing chemicals that inhibit microbiological growth on textile fabric are needed because of the threats to human health and the environment posed by conventional alternatives(Paul, 2014). Recently, effective finishing agents have been developed thanks to studies into the antimicrobial properties of organically derived colours. It has been discovered that catechu extract, when applied as a natural dye on wool, is efficient against a wide range of microorganisms.

9.2 UV-Protective Finishing

Since prolonged exposure to sunlight has been linked to various debilitating skin conditions, manufacturers are increasingly incorporating UV-blocking agents into their textiles. Inorganic blockers deflect the UV radiations that fall on the cloth, whereas organic blockers absorb them. Organic compounds like tannins may effectively screen the sun's rays because of their high absorption of ultraviolet light. The Ultraviolet Protection Factor (UPF) measures how well a cloth blocks the sun's rays. The chemical composition of the textile, as well as its porosity, thickness, and mass per unit area, all have significant impacts on its capacity to block ultraviolet radiation. (Grifoni, 2011)

The increased ability to absorb UV radiation shown by cotton textiles dyed with eucalyptus leaf extracts makes them a promising candidate for use as an anti-UV textile agent(Pisitsak, 2016). Although natural dyes can improve the UV protection of textiles, they are not without drawbacks. (da Silva, 2018) Enhancing the longevity of natural paint is necessary for greater UV protection. (Park, 2016)

9.3 Insect Repelling Property

Protection from mosquito bites and other insect-borne illnesses is only one of many benefits of wearing insect-repellent clothing. Concerns about their environmental impact have led to the widespread adoption of natural alternatives to several commercially marketed insect repellents. Silver oak, walnut husk, and pomegranate peel natural colours, for example, all contain significant tannin content and have been demonstrated to efficiently repel insects. These colours have high levels of tannin—47.87%, 44.31%, and 45.23%%, respectively—and effectively deter insects. (Shakyawar, 2016)

10. Application on Cellulosic Fabrics

Natural dyes may be used to colour both natural and synthetic fibres. However, the results will vary depending on the fibre type, the dye bath's temperature and duration, and the dye molecules' pH. Dye bonding with fibre is crucial to the fastness qualities of dyes on textile substrates. Because of their weak affinity and substantivity, natural dyes have difficulty penetrating cellulosic fibres. Dye fastness on cellulosic fibre is achieved by mordanting treatment. The pH of the dye bath is typically neutral. Using sodium hydrosulfite, cotton is naturally indigo dyed in a stainless steel vat at an alkaline pH. Dye samples benefit from more wash fastness after the mordanting technique. Mordanting may be done in three different ways. (Kumar Gupta, 2020)

Environmental concerns and the enactment of legislation to safeguard the environment have become a worldwide phenomenon, necessitating the adoption of new, eco-friendly industrial methods and the elimination of poisonous emissions. Due to the widespread pollution caused by the textile industry's use of toxic chemicals and chemical dyes, non-harmful dyes and a preference for using natural raw materials have become increasingly popular. There was a 22% increase in polyphenols utilising the ultrasonic approach compared to the rapid solvent extraction method, as reported by Cai et al. Ultrasound extraction of olefin leaves resulted in a higher yield of phenolic compounds (47mg) than traditional extraction (27mg), as reported by Péreza et al. Ultrasound extraction of phenolic compounds from pomegranate peels was 87% faster than soaking and resulted in higher antioxidant activity (more than 22%), as reported by Pan et al. Cotton textiles were coloured with natural colouring components taken from Turmeric Curcuma Longa and studied by Kamel et al., who used both conventional heating and ultrasonic power to get different results. (El-Hawary, 2019)

11. Advantages of natural dyes

11.1 UV-Protective Fabrics

Fabrics with built-in ultraviolet (UV) protection are essential for preventing sun damage, including tanning, skin cancer, and premature ageing. To create sun-protective materials, scientists have turned to natural colours. Sarkar and Grifani tested the UPF of cotton cloth coloured with madder, indigo, and cochineal. The UPF value of wool, silk, and cotton might increase using metallic mordants. The UPF value of yarn naturally dyed with orange peel extract was significantly improved.

11.2 Insect Proof

In moist and warm environments, cellulosic fabrics like wool are susceptible to attack by moths and fungi. Wool may be dyed using natural insect-proof and repellent dyes, such as those based on anthraquinones, indigo, and madder.

12. Conclusion

This study aimed to examine the efficiency of dyeing wool fabric using natural dyes, namely ZnO nanoparticles (ZnO NPs) from Electric Arc Furnace Dust (EAFD) byproducts. Artocarpus heterophyllus Lam and Ceasalpinia sappan Linn's heartwood were used to creating the natural dye solutions that were then used to colour the cellulose fibres. Scanning electron microscopy (SEM), analysis showed that the surface of the alkaline-bleached fibres was smoother than the surface of the alkaline-stained fibres. When the fibres were dried, they became more resistant to heat and light. Spartium junceum L. produces an acidic dye (mordant dye) with UV absorption bands at maximal wavelengths of 224, 268, 308, and 346 nm, characteristic of flavonoids. Coloured wool fabric pre-mordanted with 3% alum has excellent chromatic (C*) and hue (h) properties. Because of its focus on the circular economy, the maintenance of textiles, and environmental friendliness, this study has many potential applications. Cotton fabrics' dyeability and colourfastness may be improved using natural dyes like mehendi/henna, turmeric, tea leaf, and pomegranate. To colour 100% cotton mercerized clothes, natural powder dyes are collected and dissolved in chemicals and auxiliaries. Natural dyes may be used to repel insects, and organic components like tannins can block the sun's rays to provide a UV-protective finish. Hair, skin, and fabric have all been dyed with henna, a natural reddish-orange colour, for ages.

REFERENCES

1. B. Simoncic, B. Tomsic, Text. Res. J. 80 (2010) 1721–1737.

2. Bechtold, T., Turcanu, A., Ganglberger, E., & Geissler, S. (2003). Natural dyes in moderntextile dyehouses How to combine experiences of two centuries to meet future demands? Journal of Cleaner Production, 11(5), 499 – 509.

3. Bhuiyan, M. A. R., Islam, A., Ali, A., & Islam, M. N. (2017). Colour and chemical constitution of natural dye henna (Lawsonia inermis L) and its application in the colouration of textiles. Journal of Cleaner Production, 167, 14–22.

4. Chakraborty, L., Pandit, P., & Roy Maulik, S. (2020). Acacia auriculiformis—A natural dye used for Simultaneous colouration and functional finishing on textiles. Journal of Cleaner Production, 245, 118921.

5. Chungkrang, L., Bhuyan, S., & Phukan, A. R. (2021). Natural Dyes: Extraction and Applications.International Journal of Current Microbiology and Applied Sciences, 10(01), 1669–1677.

6. Crews P C, J Am Inst Conserv, 21 (1982) 43.

7. Cristea D & Vilarem G, Dyes Pigm, 70 (2006) 238.

8. D. Grifoni, L. Bacci, G. Zipoli, L. Albanese, F. Sabatini, Dyes Pigm. 91 (2011) 279285.

9. D.B. Shakyawar, A.S.M. Raja, A. Kumar, P.K. Pareek, Indian J. Fibre Text. Res. 40 (2015) 200–202.

10. Duff D G, Sinclair R S & Stirling D, Studies in Conservation, 22 (1977) 161.

11. El-Hawary, N. (2019). High-Performance Natural Dyes for Cellulosic Fibers Review—Part1. Journal of Textiles, Coloration and Polymer Science, volume 16, July 2019 pp.1-13.

12. . El-Hawary, N. (2020). High-Performance Natural Dyes for Cellulosic Fibers: Review –part 2. Journal of Textiles, Coloration and Polymer Science, 0(0), 0–0.https://doi.org/10.21608/jtcps.2020.19140.1032

13. El-Sayed, G., Othman, H., & Hassabo, A. (2021). An Overview on the Eco-friendlyPrinting of Jute Fabrics using Natural Dyes. Journal of Textiles, Coloration and Polymer Science, Vol. 18, No. 2, pp. 239-245 (2021)

14. El-Zaher, N. A., El-Bassyouni, G. T., Esawy, M. A., & Guirguis, O. W. (2021).Amendments of the Structura and Physical Properties of Cotton Fabrics Dyed with Natural Dye and Treated with Different Mordants. Journal of Natural Fibers, 18(9), 1247–1260. https://doi.org/10.1080/15440478.2019.1689884

15. Eskani, I. N., Rahayuningsih, E., Astuti, W., & Pidhatika, B. (2023). Low Temperature In Situ Synthesis of ZnO Nanoparticles from Electric Arc Furnace Dust (EAFD) Waste to Impart Antibacterial Properties on Natural Dye-Colored Batik Fabrics. Polymers, 15(3), 746. https://doi.org/10.3390/polym15030746

16. Gupta D, Colourage, 46 (7) (1999) 35.

17. Gupta D, Gulrajani M L & Kimari S, Colour Technol, 120 (2004) 205.

18. H Oda, Colour Technol, 117 (4) (2001) 204.

19. Haji, A. (n.d.). Dyeing of Cotton Fabric with Natural Dyes Improved by Mordants and Plasma Treatment.

20. Hamdy, D., & Hassabo, A. (2021). Various Natural Dyes from Different Sources. Journal of Textiles, Coloration and Polymer Science, 0(0), 0–0. https://doi.org/10.21608/jtcps.2021.79786.1066

21. Ibrahim, S. F., El-Amoudy, E. S., & Shady, K. E. (2011). Thermal Analysis and Characterization of Some Cellulosic Fabrics Dyed by a New Natural Dye and Mordanted with Different Mordants. International Journal of Chemistry, 3(2), p40. https://doi.org/10.5539/ijc.v3n2p40

22. Islam, S., Alam, S. M., & Akter, S. (2020). Investigation of the Colorfastness Properties of Natural Dyes on Cotton Fabrics.

23. J. Park, J.K. Seok, H.-J. Suh, Y.C. Boo, Evid. Based. Complement. Alternat. Med. 2014 (2014) 429246.

24. Kasiri, M. B., & Safapour, S. (2014). Natural dyes and antimicrobials for green treatment of textiles. Environmental Chemistry Letters, 12(1), 1–13. https://doi.org/10.1007/s10311-0130426-2

25. Khan M A , Khan M, Srivastav P K & Mohammad F, Colourage, 56 (1) (2006) 61.

26. Kovačević, Z., Sutlović, A., Matin, A., & Bischof, S. (2021). Natural Dyeing of Cellulose and Protein Fibers with the Flower Extract of Spartium junceum L. Plant. Materials, 14(15), 4091. https://doi.org/10.3390/ma14154091

27. Kumar Gupta, V. (2020). Fundamentals of Natural Dyes and Its Application on Textile Substrates. In A. Kumar Samanta, N. S. Awwad, & H. Majdooa Algarni (Eds.), Chemistry and Technology of Natural and Synthetic Dyes and Pigments. IntechOpen. https://doi.org/10.5772/intechopen.89964

28. Lee J J, Lee H H, Eom S I & Kim J P, Colour Technol, 117 (2001) 134.

29. M.G. da Silva, M.G. da Silva, M.A.S.D. de Barros, R.T.R. de Almeida, E.J. Pilau, E. Pinto,G. Soares, J.G. Santos, J. Cleaner Prod. 199 (2018) 807–816.

30. M.Hegazy, B., Othman, H., & Hassabo, A. (2022). Polyanion Biopolymers for Enhancing the Dyeability andFunctional Performance of Different Textile Materials using Basic and Natural Dyes. Egyptian Journal of Chemistry, 0(0), 0–0.https://doi.org/10.21608/ejchem.2022.113792.5168

31. Micheal M N & Zaher N A El, Colourage, 2005, (Annual) 83.

32. N. Fauziyah, Department of Biology, Faculty of Mathematics and Natural Sciences, University of Brawijaya, Malang, Indonesia, L. Hakim, J. Indonesian Tourism Devel. Stud. 3 (2015) 41–44.

33. P. Pisitsak, J. Hutakamol, R. Thongcharoen, P. Phokaew, K. Kanjanawan, N. Saksaeng, Ind. Crops Prod. 79 (2016) 47–56.

34. Padfield P & Landi S, Studies in Conservation, 11 (1966) 161.

35. Periyasamy, A. P. (2022). Natural dyeing of cellulose fibres using Syzygium cumini fruit extracts and a biomordant: A step toward sustainable dyeing. Sustainable Materials and Technologies, 33, e00472. https://doi.org/10.1016/j.susmat.2022.e00472

36. R. Paul, Functional Finishes for Textiles: Improving Comfort, Performance and Protection, Elsevier, 2014.

37. Rehman, F. U., Adeel, S., Haddar, W., Bibi, R., Azeem, M., Mia, R., & Ahmed, B. (2022). Microwave Assisted Exploration of Yellow Natural Dyes for Nylon Fabric. Sustainability, 14(9), 5599. https://doi.org/10.3390/su14095599

38. Rekaby, M., Salem, A. A., & Nassar, S. H. (2009). Eco-friendly printing of natural fabrics using natural dyes from alkanet and rhubarb. Journal of the Textile Institute, 100(6), 486–495. https://doi.org/10.1080/00405000801962177

39. Saha Tchinda, J.-B., Pétrissans, A., Molina, S., Ndikontar, M. K., Mounguengui, S.,Dumarçay, S., &

Gérardin, P. (2014). Study of the feasibility of a natural dye on cellulosic textile supports by red padouk (Pterocarpus soyauxii) and yellow moving (Distemonanthus benthamianus) extracts. Industrial Crops and Products, 60, 291–297.
https://doi.org/10.1016/j.indcrop.2014.06.029

40. Samanta A K, Aqarwal Priti & Darra Siddhartha, J Natural Fibres, (1) (2009) 27.

41. Samanta, A. K., & Agarwal, P. (2009). Application of natural dyes on textiles. INDIAN J. FIBRE TEXT.RES.

42. Sarkar D, Mazumdar K & Datta S, Man-made Text India, 49 (1) (2006) 19.

43. Sarkar D, Mazumdar K, Datta S & Sinha D K, J Text Assoc, 66 (2) (2005) 67.

44. Sarkar, A. K., & Seal, C. M. (2003). Colour Strength and Colorfastness of Flax Fabrics Dyed with Natural Colorants. Clothing and Textiles Research Journal, 21(4), 162 166.https://doi.org/10.1177/0887302X0402100402

45. Saxena, S., & Raja, A. S. M. (2014). Natural Dyes: Sources, Chemistry, Application and Sustainability Issues.In S. S. Muthu (Ed.), Roadmap to Sustainable Textiles and Clothing (pp.37–80). Springer Singapore. https://doi.org/10.1007/978-981-287-065-0_2

46. Senapitakkul, V., Vanitjinda, G., Torgbo, S., Pinmanee, P., Nimchua, T., Rungthaworn, P., Sukatta, U., &Sukyai, P. (2020). Pretreatment of Cellulose from Sugarcane Bagasse with Xylanase for Improving Dyeability with Natural Dyes. ACS Omega, 5(43), 28168–28177.
https://doi.org/10.1021/acsomega.0c03837

47. Singh, M., Vajpayee, M., & Ledwani, L. (2021). Eco-friendly surface modification of natural fibres to improve dye uptake using natural dyes and application of natural dyes in fabric finishing: A review. Materials Today: Proceedings, 43, 2868–2871. https://doi.org/10.1016/j.matpr.2021.01.078

48. Vadood, M., & Haji, A. (2022). Application of ANN Weighted by Optimizatio Algorithms to Predict the Color Coordinates of Cellulosic Fabric in Dyeing with Binary Mix of Natural Dyes. Coatings, 12(10), 1519. https://doi.org/10.3390/coatings12101519.