

RECENT ADVANCES IN PLANT WASTES BASED NATURAL DYES FOR TEXTILES

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I. INTRODUCTION

Natural dyes are chromophores obtained through extraction or isolation from various sources, including plants, invertebrates, and minerals. The prevailing composition of natural dyes consists of vegetable dyes derived from plant origins, comprising roots, berries, bark, leaves, and wood, as well as other biotic sources, such as fungi. [1]. Natural dyes are derived from naturally occurring sources such as plants, animals, etc. Sources of natural dyes are given below in Figure. 1

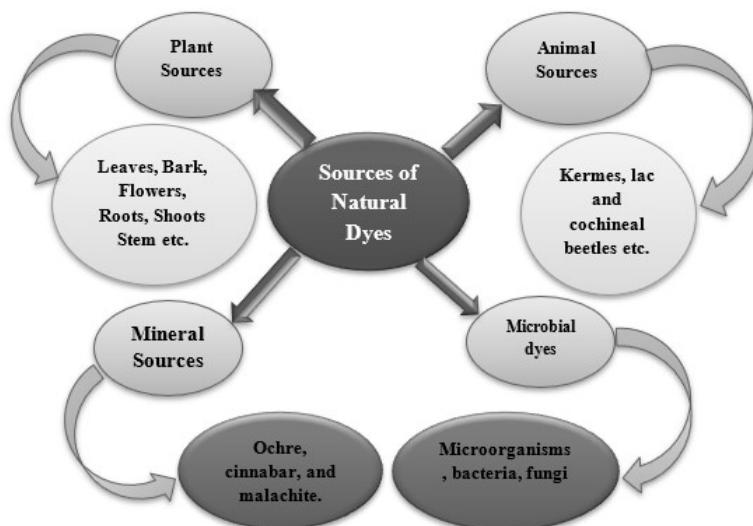


Figure.1 flow sheet diagrams of sources of natural dyes [1].

1. Plant Based Natural Dyes: Plant sources include roots, stems, leaves, etc.

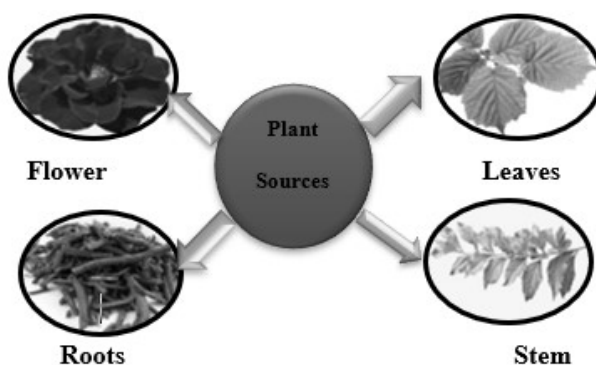


Figure.2 Flow sheet diagrams of plant sources in natural dye[2].

2. Animal sources of Natural dyes :Animal sources includes kermes, cochineal, lac, etc. (Figure 3)

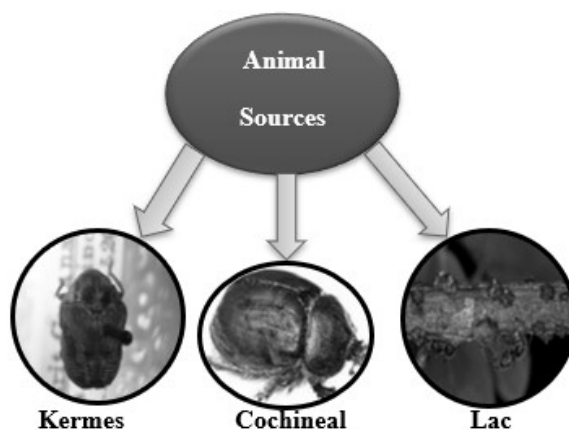


Figure 3: Flow sheet of animal sources in natural dyes [3].

- 3. Natural Dyes Based on Mineral Sources:** Mineral sources include ochre, cinnabar, and malachite (Figure 5).



Figure 4: Flowsheet diagram of mineral sources in natural dye [1].

- 4. Natural Dyes Based on Microbial Sources:** Microbial dyes include fungal, algal, bacterial, lichens, etc. (Fig. 5)



Figure 5: Flowsheet diagram of microbial dyes in natural dyes [3].

5. Classification of Natural Dyes: Classification of natural dyes based on sources, structure, color, and applications (Fig. 6)

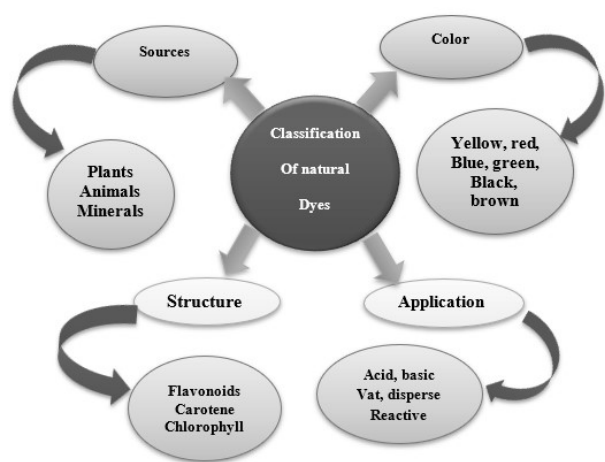


Figure 6: Flowsheet diagram of classification of natural dyes [2].

6. Applications of Natural Dyes: It includes agriculture, textile coloration, pH indicator, Food coloration, Cosmetics, Paint, UV protection, dye-sensitized cell, agriculture, etc. (Fig. 7)

Here is the flow sheet diagram:

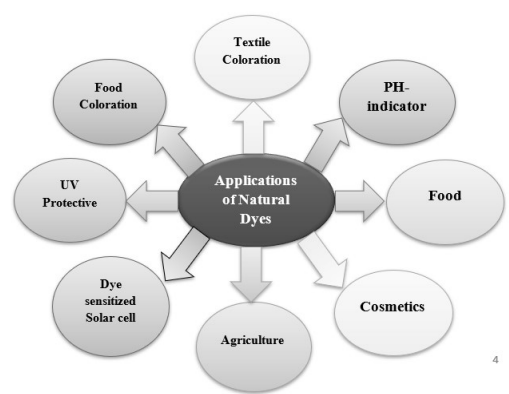


Figure 7: Flowsheet diagram of an application of natural dyes [1].

7. Natural Dyes Extraction Methods

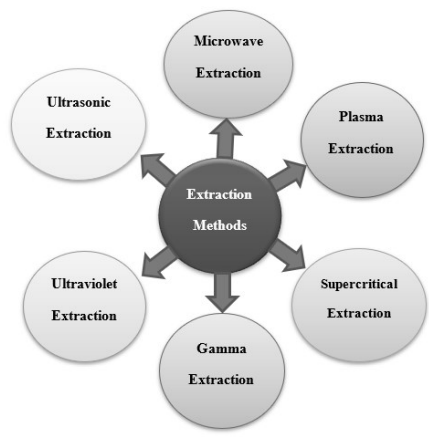


Figure 8: Flowsheet diagram of extraction methods of natural dyes [3].

II. MICROWAVE EXTRACTION

Natural dye posed a greener approach to the increased climate destruction caused by synthetic materials. But the extraction of natural dyes through the conventional has not been cost and time-effective, labour-intensive, and less green [2]. Advanced extraction methods were employed to overcome this problem, such as microwave-assisted extraction, ultrasonic extraction, plasma treatment, etc. [3]. Arain et al., (2019) carried out dyeing of polyester fabric with henna dye using a microwave extraction method. They used lemon as a bio-mordant to give the process an eco-friendly approach. They compared microwave-assisted extraction with the conventional extraction method. They analysed the coloring properties with SEM, WAXD (wide-angle X-ray diffraction), and ATR-FTIR and examined the structural changes induced by the microwave method [4]. They concluded that using the microwave technique improved the fixation and color characteristics of the dyeing with clearly reduced mordanting and dyeing time up to 60-65%.

Microwaves induce molecular heating in objects through a dual mechanism involving ionic conduction and dipole rotation. Positioned within the electromagnetic spectrum between X-rays and infrared rays, microwaves are non-ionizing electromagnetic waves characterized by frequencies ranging from 300MHz to 300GHz. These microwaves are generated by two types of oscillating fields perpendicular to each other: the electric and magnetic fields. The utilization of microwaves in the extraction and dyeing of textile fabrics represents a contemporary approach that offers advantages in terms of energy consumption, time efficiency, and labor reduction. The application of microwave radiation (MW) enhances the movement of dye material within the solvent, leading to significant mass transfer [5,6]. Additionally, microwave radiation provides uniform heating to the substrate, thereby enhancing natural fabric color through a distinctive mechanism.

In their study, Fu et al. (2019) elucidated the mechanism underlying microwave radiation in the extraction of natural colorants and its impact on fabric modification. Their research involved exploring the microwave dyeing of fabric at a frequency of 2.45GHz while employing microwave drying at power levels of 700W and 300W to assess the loss of tangential strength in the fabric resulting from microwave treatment. Furthermore, they evaluated the correlation between drying efficiency and the fabric properties affected by the microwave drying process [7].

Zuber et al. (2019) observed that the current work aims to extract tannin from neem bark under the influence of MW radiation for coloring silk fabric that has been chemically and biologically mordanted. Several media have been used to extract the colorant (tannin), and dyeing variables have been improved. Extracts from bio-mordants like turmeric, henna, pomegranate, and acacia have been used under specific circumstances to make the process more environmentally friendly and sustainable. When used to dye silk at 75°C for 65 minutes, it was discovered that MW radiation for 2 minutes applied to an acidified methanolic extract with a pH of 2 derived from 6 grams of powder produced good color strength by using Glauber's salt (3g/100 mL) as the strenuous negotiator. It is determined that MW treatment has improved the color properties under low circumstances and the tannin extraction from neem bark [8].

Adeel et al. (2020a) investigated that textile dyeing is gained popularity due to the resurgence of natural colorants and their eco-friendly behavior. They extracted dye from safflower in different media under microwave treatment for up to 6 min for fabric dyeing. They employed irradiation to encapsulate the colorant within an acidic medium, resulting in the achievement of vibrant color on silk fabric under milder dyeing conditions. Furthermore, their investigations demonstrated that the utilization of an eco-friendly bio-mordant, specifically turmeric extract, yielded high color strength and introduced novel shades. Their findings concluded that the mordant-treated fabric, dyed under reduced conditions and subjected to microwave treatment, exhibited favorable to excellent fastness ratings [9].

Adeel et al. (2020b) investigated the impact of the resurgence of ecological plant-based dyes on global community demands in every industry. Their research aimed to see if cinnamon bark could be used as a natural yellow colourant for silk dyeing. The yellow dye was extracted in various mediums and microwaved for up to 6 minutes. The results revealed that dyeing irradiated cloth at 35 °C for 45 minutes with an irradiated extract with a pH of 3 and 1g of salt as a levelling agent produced good results. As sustainable chemical mordants, salt of Al& Fe, as well as extracts of Acacia, Pine Nut Hulls, Pomegranate, and Turmeric as sustainable bio-mordants, had provided not only new hues but also improved fastness properties. Finally, employing bio-mordants, the microwave treatment not only enhanced the color extraction yield from cinnamon bark but also made the process more sustainable [10].

Amin et al., (2020) explored natural colorants from cochineal insects extracted with the help of a microwave to dye bio-mordanted silk. The natural colorant from cochineal was extracted utilising acidic, methanolic, and acidified methanol solubilised medium while microwave irradiating for 1-6 minutes. Bio-mordants have been used under ideal circumstances to make the procedure more environmentally friendly and long-lasting. It has been discovered that applying an acid-solubilized extract with a pH of 4 for 55 minutes at 55°C while using 5 g of Glauber's salt per 100 mL as an exhausting agent has produced silk fabrics with excellent color strength. Compared to commonly used chemical mordants, bio-mordants have great colour depth and outstanding ratings for fastness qualities, according to suggested ISO standards for colourfastness. MW treatment has been discovered to enhance the color features of bio-mordanted silk fabric and the dyeing performance of colorants isolated from cochineal in an acid-solubilized medium [11].

Gala et al., (2020) observed that Various parameters, including microwave power, material-to-solvent ratios, heating duration, and amount of extract, were analyzed based on the performance of the extraction process as well as the pigment component of the section, in addition to comparing how long each procedure, Soxhlet, and reflux, takes. Microwave extraction yielded the highest yield under optimal conditions, including 30 minutes of extraction time, 600 W of microwave power, and a material-to-solvent ratio of 0.02 g/mL. In contrast, reflux and soxhlet extraction yielded the highest yield only after 120 and 720 minutes of extraction, respectively [12,13].

Karadag et al. (2020) observed that Microwave irradiation and traditional dyeing procedures were used to colour organic cotton garments with different plants. Different techniques were used to examine the colored textiles. RP-HPLC-PAD was used to investigate coloring chemicals in dye extractions. The colored textiles' coloristic and color fastness capabilities were tested and compared. The materials colored using microwave and traditional

dyeing processes showed no signs of harm. They concluded that microwave treatment is cost and time effective [14].

The Blue pea flower (BPF) was used by Marsin et al. (2020) as a natural anthocyanin colorant for food and cosmetic coloring. Natural dyes must be enclosed because they are unstable. The BPF colorant may be encapsulated with the assistance of a microwave to maintain its color while being stored. Using 40% MD at 770 W for 10 minutes, the microwave-assisted encapsulation process resulted in a TAC of 27.03 mg/L, a color parameter index b^* value of 9, a water activity of 0.4941, and an encapsulation efficiency of 73.24%. By changing the pH, the blue BPF colorant can be transformed into different pigments. The results of this study can be used as a manual for future microwave-assisted BPF colorant powder production [15].

Sarfaraizi et al. (2020) discovered that a microwave-assisted extraction technique can be used to obtain an anthocyanin-based natural dye from Saffron petals. By optimizing extraction conditions such as temperature, time, and solvent-to-sample ratio, they found that a solvent-to-sample ratio of 77.5 ml/g was the critical factor for successful extraction. The microwave treatment effectively disrupted the cell wall and improved dye extraction efficiency. As a result, the microwave-assisted extraction method was identified as a fast and modern approach for obtaining the desired dye [16].

Laccic acid, a source of natural red dye generated from lac insects, has been studied in another work Adeel et al. (2021a) for the dyeing of wool fabric while being cooked in a microwave. The extract was created in an acidic medium, microwave-stimulated for up to 7 minutes, and then used to dye clothes. For comparison testing, chemical mordants were blended with environmentally friendly green mordants including acacia and turmeric extracts to produce new colours. The results showed that an extract made in an acidic medium after exposure for 5 minutes had a bright color when utilized for 65 minutes at 75°C on unirradiated fabric. The analysis of fastness attributes shows that, in the best-case scenario, the bio-anchors have given positive evaluations. The sustainability of the natural coloration process has allegedly improved thanks to this environmentally friendly instrument, which has also increased the natural anthraquinone dye's coloring production [17].

A study by Adeel et al. (2021b) focuses on the isolation and extraction of natural products using green technology. In this experiment, the natural coloring potential of Arjun bark for dyeing cotton fabrics was explored. Microwave radiation was used as a sustainable extraction process. With irradiation times ranging from 1 to 6 minutes, they conducted microwave-assisted extraction of the natural color from Arjun bark using various mediums. The cotton fabric was then dyed using the resultant extracts. Notably, the dyeing of a 50 mL extract of acidified methanol at 55 °C for 75 minutes resulted in an enhanced color yield (K/S), with a considerable improvement seen after 5 minutes of microwave radiation application. They came to the conclusion that, under ideal and minimal dyeing circumstances, microwave energy displayed excellent performance in separating the colorant from Arjun bark for dyeing cotton fabric [18].

Arain et al. (2021) studied the eco-friendly dyeing process in which the conventional mordanting method was compared with the modern approach such as microwave treatment used in natural henna dyeing and lemon as a source of bio-mordant used on polyester fabric.

They studied that the surface and structural changes induced by microwave henna dyeing and lemon mordanting of polyester fabric were analyzed using SEM, FTIR, and XRD techniques. They found that up to 60-65% of mordanting and dyeing time was reduced by using microwave treatment and improved fixation and color characteristics of the fabric. Hence they concluded that to produce natural garments and products which are safe to use and avoid the risk of health problems, bio-mordants in natural dyeing and microwave treatment could industrially be used [19].

Sharma et al., (2021) examined various process parameters; microwave-assisted extraction was used in this investigation; betacyanin and betaxanthine were extracted from inedible leaves. Several variables were explored, including microwave intensity, temperature, and time. A microwave extraction process lasting 15 minutes at 90 degrees Celsius and 450 watts of electricity yielded the highest betacyanin recovery (72.85 mg/g dry weight). Extraction from the green material using a 205 W microwave at 62 C for 15 minutes yielded the greatest concentration of betaxanthin (41.35 mg/g dw). Water was used as the solvent in green extraction since it is the most effective solvent for these compounds [20].

Ticha et al. (2021) investigated that *Juglans Regia* L bark can be used as a natural dye for textile application. As a result, a microwave was used to extract a bio-dye, and numerous factors were investigated, including microwave power, pH, and time. Coloured extracts were then utilised to dye wool garments. Colorimetric coordinates (L, a, b) and color strength (K/S) were utilized to evaluate the dyeing process's quality. The dye-fastnesses were also investigated. Finally, Infrared spectral analysis was used to characterize the wool samples [21].

Wang et al., (2021) observed that the following ethanol volume fractions and extraction times were used in the dyeing of wool fiber with walnut green peel pigment using microwave-assisted processes and extraction techniques: 60% ethanol, 1 min, 24:1 liquid-material ratio, and 450 W microwave power, while the optimal mordant fixation procedure was: 3 minutes mordant fixation time, 270 W microwave power, 7% mordant fixing agent, 22 g/L reducing agent dosage. As a result of the experiments, it was found that the use of microwave-assisted extraction of pigments increased the extraction efficiency by a great deal [22].

Akram et al. (2022) worked to use microwave radiation to extract a natural brown colorant from *Ficus religiosa* for cotton dyeing. Before and during MW treatment for up to 6 minutes, the dye was separated into aqueous and acidic conditions. The dye variables have been optimized to create new hues with good fastness properties, and 1–5g/100 mL of environmentally friendly chemical and biological mordants have been utilized. It has been discovered that after being microwaved for 4 minutes, irradiated aqueous extract (RE) with 3g/100mL of salt produced a high color yield on cotton fabric (RS). Materials with good color properties have been developed using 2% aluminium, 2% iron, and 3% tannic acid as a pre-chemical mordant, and 4% aluminium, 5% iron, and 2% tannic acid as a post-chemical mordant. When utilized as a post-bio-mordant, 3% of Kikar and 4% of pomegranate, as opposed to 2% of acacia and 4% of pomegranate extracts, have created good color attributes. MW treatment provides excellent long-term efficacy for separating dyes from peepal bark powder for cotton dyeing [23].

Gala et al. (2022) conducted a study that demonstrated the advantages of microwave-assisted extraction for obtaining natural colors from plants, such as reduced processing time and solvent usage. The objective of this study was to optimize the microwave-assisted extraction yields using Response Surface Methodology (RSM) with a Face-centered Composite Design (FCCD), which helped to minimize the number of experiments required. The effects of extraction time, microwave power, and feed/solvent (F/S) ratio on extraction yields were investigated. The results showed that the maximum extraction yield achieved using the FCCD design was 3.67%. This was achieved with a microwave power of 650 W, an F/S ratio of 0.0564 g/mL, and an extraction time of 50 minutes. The statistical analysis indicated that the model had significant p-values, while the lack of fit was found to be not significant [24].

Habib et al. (2022a) demonstrated that the current project aims to extract a natural reddish-brown colorant from peepal using M.W. radiation for silk dyeing. Both the fabric and the extract underwent M.W. treatments for 1, 2, 3, 4, and 5 minutes to assess variations in colour intensity. The colorant was separated in an acidic and aqueous environment. The dye parameters have been adjusted to create sustainable hues with good fastness, and 1.0–5.0 g/100 mL of eco-friendly chemical and biological mordants have been utilized. Materials with good color properties have been created using 3% aluminium, 4% iron, and 2% tannic acid (T.A.) as a pre-chemical mordant and 4% aluminium, 4% iron, and 3% tannic acid as a post-chemical mordant. As post-bio-mordant, acacia, turmeric, and pomegranate extracts exhibit better color properties than acacia, 3 percent turmeric, and 4 percent pomegranate extracts. M.W. treatment provides remarkable long-term efficacy for isolating colorants from peepal bark to dye silk [25].

Habib et al. (2022b) investigated the dyeing performance of a natural yellowish colorant derived from wild turmeric on wool using microwave (MW) treatments. MW treatment for up to 10 minutes was applied to both the extracts and fabrics. The study evaluated the fabric's external morphology and chemical composition changes through SEM and FTIR analysis before and after MW radiation. The use of bio-mordants, specifically acacia extract (1.5%), pomegranate (2%), and pistachio extracts (1.5%), resulted in high-strength colorfast shades. Conversely, lower concentrations of acacia extract (1%) and pomegranate (1%), and a higher concentration of pistachio extract (2%), had contrasting effects. Pre-dyeing treatment with aluminum salts (1.5%), iron salts (1%), and tannic acid (2.0%) produced optimal results, while post-dyeing treatment with pomegranate extract (1.5%) and iron salts (1.5%) exhibited exceptional color strength. The MW treatment demonstrated superior efficacy in enhancing the color potency of wool cloth, with the incorporation of bio-mordants promoting sustainability [26].

Naveed et al. (2022) performed that natural colors are now widely utilized since they are safer for the environment, less deadly, and do not harm human health. The cotton fabric and the combined powder (pomegranate rind and turmeric root) used in this investigation were exposed to radiation for 1 to 5 minutes. The optimal exposure duration for improving the dyeing behavior of cellulosic cloth is 3 minutes. Good color strength was seen when dyeing fabric at 65°C for 40 minutes in a pH=6 dyeing bath. The ideal ratio of pre-mordant (4% Cu) and post-mordant (8 percent chromium) was used to increase color fastness. It has been found that employing a mixture of irradiated pomegranate rind and turmeric root

powder in aqueous solubilization and microwaves improved irradiated cotton's color strength and fastness capabilities [27].

In their study, Yameen et al. (2022) conducted experiments to bio-dye cotton fabric using microwave irradiation methods with haar singhar flowers. The fabric and liquid extracts were subjected to 5 minutes of microwave treatment under various conditions. FTIR analysis was used to identify the untreated, undyed, and irradiated textile samples and the extract. The colored cotton fabrics were evaluated using the CIE-Lab system and the Spectra flash SF600 to determine color coordinates and color strength. Colorfastness attributes were assessed based on ISO standards, including light, dry and wet rubbing, and washing fastness. The cotton fabric was colored by applying 4g of powdered haar singhar extract and a salt solution of 1.5g/100 mL for 30 minutes at 60°C. Subsequently, after heating the aqueous extract in the microwave for 4 minutes, it exhibited excellent color strength and achieved desirable hues [28].

III. ULTRASONIC EXTRACTION

The utilization of ultrasonication (Figure 1.8) has emerged as a intense and promising field of research in the realm of Chemistry, as well as in the food and pharmaceutical industries. Traditional extraction methods often exhibit prolonged extraction durations and limited efficiency. However, the introduction of ultrasound technology has led to enhanced extraction capabilities, allowing for shorter extraction times and reduced temperatures. Ultrasound exerts a mechanical impact on the extraction process, primarily attributed to cell wall disruption within the matrix body, leading to increased mass transfer of active plant compounds. Ultrasound-assisted extraction (UAE) has recently been developed as a technique for the extraction of various pharmaceutically active substances, including polysaccharides, hydrocarbon saturated compounds, cellulose, flavonoids, fatty acids, esters, and steroids, from plant materials. Conventional approaches to isolate and purify compounds from crude plant extracts using classical techniques tend to be both costly and time-consuming.

Zuber et al., (2019) studied the isolation of natural dye from neem bark, containing tannin as a coloring component. For the isolation of the tannin, they used the ultrasonic extraction method and applied it to the silk fabric. They used chemicals and bio-mordant for improvement in shades. They used a methanolic extract of pH=5 and ultrasonic treatment for 30min and obtained the highest color strength of the dye with irradiated fabric for 65min at 75°C. They concluded that the use of mordants improved the color fastness properties and the ultrasonic method increased the extraction yield [29].

Ali et al., (2019) investigated that the Our study was designed to examine whether the dyeing behavior of wool fibers had been affected by pre-treatment with chitosan and then dyed with rhubarb as a natural dye by conventional (Con) or ultrasonic (US) methods using chitosan as a pre-treatment. Dye extraction and dyeing were studied to find out how to dye content, temperature, time, and pH impacted the results. Chitosan-pretreated wool fibers had significantly higher color strength (K/S) and overall color fastness values than untreated wool fibers. As a result, pre-treated wool fibers can be dyed using ultrasonic technology at lower temperatures than they would be dyed using conventional methods [30].

Amutha et al., (2020) studied that in addition to being eco-friendly and non-hazardous, natural dyes are also sustainable. Metal mordants, on the other hand, such as copper, chromium, tin, and zinc, may be hazardous to ecosystems if used in excess. Natural colors derived from the plants *Terminalia arjuna* and *Thispesia populnea* are used to color silk, cotton, and nylon. This study used ultrasonic bath dyeing, which utilizes significantly less energy than standard water bath dyeing. Ultrasonic dyeing uses less fuel than typical water-bath dyeing and produces less waste [31].

El-Khatib et al. (2020) studied that We pre-treated wool and silk fibers with neem oil using low-cost procedures including microwave heating and ultrasonic energy before dyeing them with natural colors like chlorophyll, saffron red, and yellow. According to the study, the color fastness of the dyes varied from excellent to good, depending on the method employed to remove the dye (microwave or ultrasonic). It was found that pretreated samples inhibited bacteria and fungi more than the fibers that had not been treated. This effect was in place at a higher percentage for the pretreated fibers [6].

Helmy et al. (2020) investigated that there is no doubt that ultrasonic power or microwaves are promising technologies for helping extraction processes compared to traditional heating techniques. Since plant tissues are composed of cellulose, starches, and pectins, readily available enzymes like cellulase, amylase, and pectinase have been used to break down these materials. This has permitted the extraction of colorant particles in a cost-effective manner. The use of ultrasonic and enzymes for textile treatment has also been investigated. It has been reported that combining ultrasound and enzyme treatment increased extraction yield marginally while decreasing treatment time and temperature [32].

Patil et al. (2021) conducted a study focusing on the disposal of pitaya peels during processing. They found that both the flesh and peel of the fruit have valuable potential as a food dye and colorant source. The investigation revealed that Dragon fruit peel, in particular, contains significant amounts of betacyanin pigment (0.15%) and pectin (10.8%), primarily concentrated in the peel. Additionally, the researchers observed that employing a rapid ultrasonication-microwave treatment resulted in higher levels of total saturated fatty acids ($10.39 \pm 0.15\%$) and monounsaturated fatty acids ($76.55 \pm 0.19\%$), which are desirable qualities for biodiesel production. Based on their findings, the authors concluded that the use of ultrasonication-microwave treatment holds promise as an efficient technique for extracting lipids from wet biomass [33].

Qadariyah et al. (2019) conducted a study to explore the extraction of Natural Ultrasound-assisted Process Dyes from Henna Leaves (*Lawsonia Inermis* L.). Henna leaves are known for containing Lawsone, a distinct orange-colored compound, making them a natural source of dye [34]. The researchers aimed to develop and investigate ultrasound-assisted extraction as a method for dye extraction. This extraction method is characterized by its high efficiency, ease of use, safety, and environmentally friendly nature. The study examined the impact of various factors such as the ratio of feed to solvent, extraction time, temperature, and solvent type on the extraction process. The highest yield of 17.96 percent was achieved by extracting Henna leaves at pH 1, with a 10-minute extraction time, a feed/solvent ratio of 0.02, and a specific solvent. Through qualitative and quantitative analysis of the extracted color, it was determined that the ultrasound-assisted method outperformed the soxhletation method in terms of effectiveness and efficiency [35].

Amesimeku et al. (2021) examined that in the study of this research, using a combination of ultrasonic and microwave irradiation; we investigated the dyeability of meta-aramid fabric with Basic Rhodamine Red, given that aramid fibers are relatively hard to dye due to their highly crystalline structure and compactness. Several factors influence dyeing properties, including temperatures, times, dye concentrations, liquor ratios, and carriers. Using a spectrophotometer, K/S values were used to determine the resulting color strength of each dye mixture [36].

Arifeen et al. (2021) observed that natural dyes, in particular, are expected to become more and more popular due to their non-toxic and biodegradable qualities. In the current study, juglone was used as a reddish-brown natural dye under US radiation as a green and eco-friendly method to increase the dyeability of walnut bark. Under optimum conditions, four bio-mordants, including Kikar bark, turmeric, henna, pomegranate, Fe, Al, and tannic acid, were also employed to produce the new colors. According to research, 3% turmeric extract as a pre-bio-mordant and 5% acacia extract as a post-bio-mordant grew good color qualities compared to their synthetic counterparts. It has been established that using ecologically friendly ultrasonic treatment to extract the reddish-brown color from walnut bark has improved the color ratings of the reddish-brown dye and provided value to the natural dyeing process [37].

Aryanti et al. (2021) observed that saponin was extracted and characterized from lerak (*Sapindus rarak* DC.), a natural surfactant, and its potential to solubilize reactive dyes and its ability to be solubilized in water. The most saponin was produced (27.87 mg saponin/100 mg feed) after ultrasonic treatment of the green material. The yield of the extract was essentially doubled when 40 minutes of extraction at 30 degrees Celsius were combined with a solvent/solute ratio of 10 mL/g. The output from the maceration-based extraction was roughly doubled as well. UAE results demonstrated that extraction time was improved, the temperature was lowered, and the amount of solvent required was lower when compared with maceration extraction (ME) [38].

Baig et al. (2021) conducted a study focusing on the extraction of natural dyes from various indigenous plant flowers. The researchers employed the ultrasonic method to extract marigold dye for the purpose of dyeing cotton fabric. Their findings indicated that under optimized conditions, the dyes produced a stable light yellow color on the fabric. The authors concluded that ultrasonic extraction is more efficient than conventional methods in terms of energy consumption, salt concentration, and reduction in dissolved solid contents, highlighting its advantages over traditional extraction approaches [39].

Bemcha et al. (2021) found dye's color intensity and durability on wool fabric treated with Ratanjot root using both conventional and ultrasonic dyeing procedures. The percentage of dye absorption increased from traditional heating procedures to 12.31% when ultrasonic waves were used to dye wool using the natural dye Ratanjot (*Onosma echioides*), exhibiting significant benefits over conventional heating methods. Ultrasonic heating outperformed more standard heating technologies in tests testing fastness grade. Furthermore, the material colored with ultrasonic waves produced a richer hue with good color intensity in just 75 minutes at a lower temperature of 60°C [40].

Lei et al. (2021) studied that this paper aims to present response surface approaches to find the best ultrasonic-assisted extraction (UAE) settings for recovering the most naturally colored pomegranate rind. We determined that by employing ideal conditions for extracting pomegranate peel dyes, we could reach a yield of 17.1 percent (PRD). The dyes derived from pomegranate rind were 17.2 percent, which was quite close to the 17.1 percent predicted. Under optimum UAE conditions, Fourier Transform-infrared and ultraviolet-visible absorption spectroscopy revealed that PRD experienced no significant structural changes. And those ultrasonic-assisted treatments could improve the antioxidant properties of natural pomegranate dyes by achieving a higher level of antioxidant content [41].

Sadeghi-Kiakhani et al. (2021) observed those Colorants from Hawthorn fruits were extracted using ultrasound-assisted extraction (UAE) as well as a variety of different solvents (including methanol, acetone, ethanol, water, and a combination of ethanol and water). When a mixture of water and ethanol was employed for conventional UAE procedures, synergistic dye extraction efficiency was attained; this discovery led to the selection of W1/4E as the optimal mixture. The response surface approach is one of the most successful ways of establishing the ideal extraction parameters (including, but not limited to, the temperature and time of the extraction process, as well as the initial pH of the fruit powder) (RSM) [42].

Hosseinnezhad et al. (2022) observed the choice of plant-based dyes and mordants was made in this study as the key strategy to limit the pollution caused by the dyeing process. The color and mordants were removed from the US medium to achieve maximum performance with the least pollution. The extraction efficiencies of madder, reseda, and walnut husk from water using US radiation were 23%, 33%, and 36%, respectively. The mineral mordant, Fe (ferrous) salt, was used as the mineral sarcastic, and the pre-mordanting process was applied to compare the results. FTIR analytical methods were used to evaluate the resulting extracts and the variations in the fibers. The amount of K/S (color strength) increases with the dye concentration, according to the study of the samples that had been dyed. Using ISO norms, the colorfastness characteristics of each piece were examined. The colored yarns had good, moderate, and excellent wash, light, and fastness, respectively [43].

IV. PLASMA EXTRACTION

Plasma extraction was achieved by applying a blood drop to a membrane stack through which plasma was drawn by capillary action. During plasma migration to a collection disc at the bottom of the membrane stack, blood cells were removed by a combination of adsorption and filtration.

Haji (2020a) studies employed a D-optimal design to analyze plasma with natural dye. According to treated dyeing parameters of plasma coloration technology, but fabric modification has also raised color strength and fastness. He increased plasma treatment time to get a high dye yield from euchromatin and cotton pods. Overall, his investigation using oxygen plasma reduces this fabric treatment as well, as the modification is functional, safe, and reliable for natural dyes [44].

Haji (2020b) improved cellulosic and proteinaceous fabric dyeing with oxygen plasma and chitosan solution. He dyed treated and untreated fabric with walnut dye, an acidic reactive dye. His studies recommended that using plasma-treated salt is unnecessary for the

exhaustion of dyes. He responds that the fastness properties of fabric after plasma have also been improved [45].

Haji and Naebe (2020c) explained the role of plasma treatment for surface modification of cellulosic, proteinaceous fabrics, and polymeric fabrics. Their experiments observed that the low yield of natural dyes, their sorption behavior onto fabric, and their colorfastness could be improved if the process was treated with plasma. Not only will the natural dyeing of fabric, synthetic or natural, be safe, but also the result will be excellent. He recommended that the combination of cleaner plasma and natural dyeing will open new doors for research to make the coloration process more safe, reliable, and sustainable for the globe [46].

Haji and payvandy (2020d) used cold plasma-treated wool before dyes modification. They optimized many factors such as oxygen plasma rate, power, and time using statistical tools such as ANM and ANFIS. According to their work, oxygen plasma can potentially improve the dyeing behavior of fabric. Still, the process can be cost, energy, and time effective using statistical design. ANFIS, as a statistical design method, can be improved with RSM and AMN to get a high color yield of natural dyes onto fabrics [47].

Naebe et al. (2021) observed plasma's role in textiles' anti-microbial finishes. According to their review under the pandemic scenario, it has become vital to search for such tools that should be safe and act as anti-microbial. It is necessary to prevent the fabric from microbes in textiles, so it is imperative to use plasma for anti-microbial finishes. They recommended that plasma application in materials as an anti-microbial finish technique should be welcomed because this ecofriendly treatment has the potential to produce a sustainable environment and healthy life [48].

V. CONCLUSIONS

The need for sustainability has grown dramatically in the modern world, partly as a result of greater understanding of the negative effects of synthetic dyes and their byproducts. As a result, the use of natural dyes has increased once again. This trend is welcomed by those who are concerned about their health as well as those who want to protect their cultural heritage. As a result, historical methods of separating dyes from plants rich in coloring compounds have been used; however, these processes have proven to be expensive, time-consuming, energy-intensive, and labor-intensive, leading to the use of more contemporary techniques like radiation procedures. Similar techniques include using modern methods to encapsulate useful molecules (colorants) obtained from plants, animals, and minerals and applying them to natural fabrics that have been bio- and chemically treated. Therefore, adding bio-mordants to these potent isolates for fabric dyeing is a promising strategy for researchers to improve their coloring qualities, furthering the quest for sustainable practices.

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