A Valuable Observation of an Eco-friendly Natural Dyes for Valuable Utilisation in Textile industry

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Abstract

The textile printing branch is becoming a widely-known technology for all fibers, textiles and garments in the textile wet processing industries. Printing is a kind of coloring in which colors are applied to regions of the cloth rather than the entire fabric. In this study, we highlighted the use of eco-friendly natural dyes as a colourant material to decrease the environmental effect. Natural and synthetic dyes are substances of great interest since they play a significant part in our daily lives. A wide range of technical and industrial uses for dyeing or printing cloth, paper, leather, and other materials. Some of these colors are poisonous, carcinogenic, and can irritate the skin and eyes. Many harmful and allergenic synthetic colors are now prohibited. Many colors, while not yet prohibited, may not be totally safe.

Keywords: Natural Dyes; classification; extraction methods.

1. Introduction

The textile printing branch is becoming a widely-known technology for all fibers, textiles and garments in the textile wet processing industries. Printing is a kind of coloring in which colors are applied to particular regions of the cloth rather than the entire fabric.[1, 2]

The resultant colorful patterns offer attractive and aesthetic qualities, which increase the value of tissue above flat tissue. The dye substance is glued to the design area with the assistance of a thickening agent. For effective printing, correct colors, brand sharpness, level, great hand and efficient application of dye are all necessary. The thickener kind used affects all these factors.[3]Thickener has been utilized as Essential component in textile fiber printing. They are highly molecular, highly viscous, robust, lengthy hydration times compatible with other printing pulp components and colorless. The printing paste is supplied with flexibility and adherence so as to create designs avoiding bleeding. The main objective of printing pastes is to hold, attach and move the dye into the fabric. [4-11]

2. Natural Dyes

Natural colors are derived from natural sources like plants, animals, and minerals. These dyes are often used to color fabrics, food, cosmetics, and pharmaceuticals.[12]

2.1. Definition

Natural dyes are colorants (dyes and pigments) derived from animal and vegetable materials without the use of chemicals. They are mostly mordant dyes, but there are also vat, solvent, pigment, and acid varieties.

The tendency to use natural dyes due to:

- There is no danger to one's health.
- Extraction and purification are simple.
- There is no effluent generation.

- Very long-term viability.
- Conditions for dying are mild.
- Renewable energy sources.[13]

2.2. Classification of natural dyes

Natural dyes can be classified based on its origin or its chemical constitute or application type as illustrated in **Figure 1**.

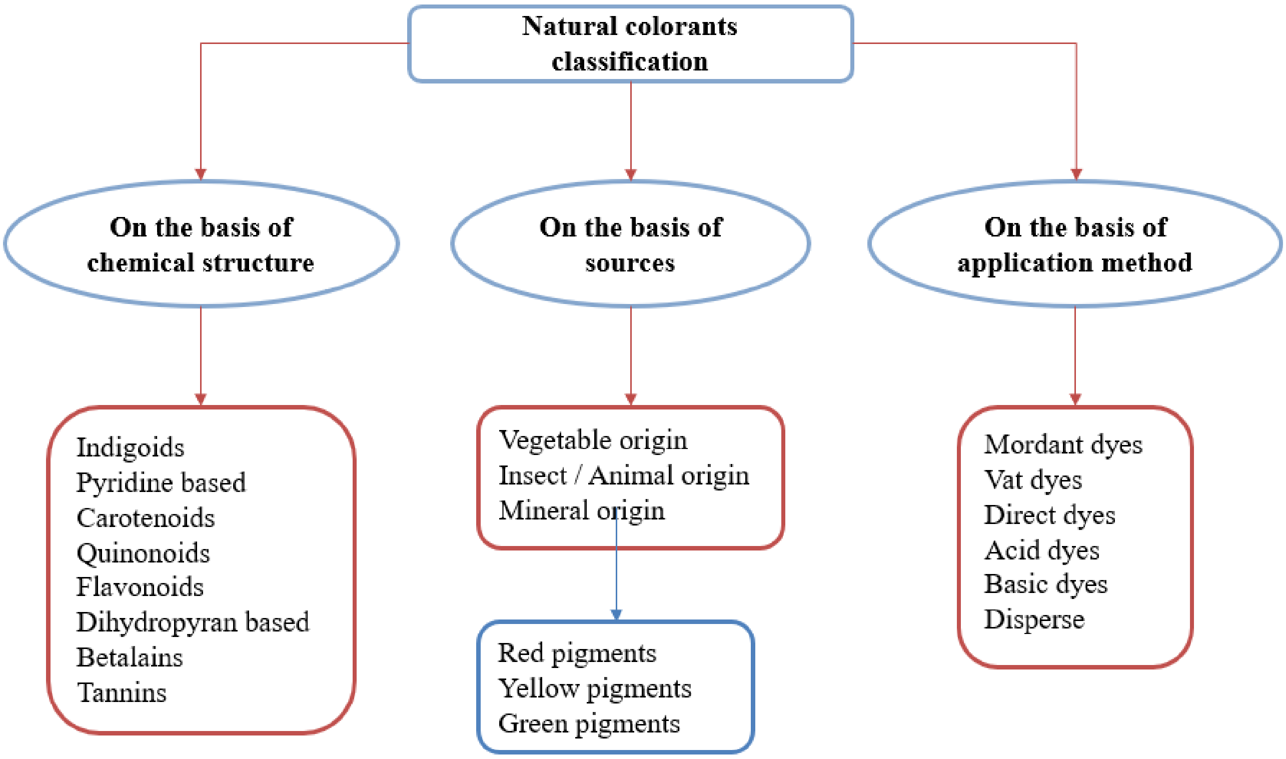


Figure 1: Classification of natural dyes[14]

2.2.1. Classification based on origin`

Plants, minerals, and animals are indeed the primary sources of natural dyes (see **Figure 1**). **[15]**

2.2.1.1. Plants

More than 2000 colors have been synthesized from plant components, but just 150 have been economically utilized. Color may be extracted from a variety of plant components such as roots, stems, bark, seeds, and fruit. Depending on whatever portion of the plant is taken, certain plants can produce over than one coloration.[16-18]

2.2.1.2. Minerals

Naturally occurring minerals serve as the basis for these colorants' creation. The pure natural organic molecules used to generate mineral colors are called organic components. Chrome yellow, iron buff, nankin yellow, Prussian blue, and manganese brown are some of the most significant mineral colorants.

2.2.1.3. Animals

Natural colors can also be obtained from animals. Dyes are generally derived from insect desiccated bodies; lac, cochineal, and structural characteristics are examples of popular dyes. Cochineal is a bright red dye generated by insects that live on cactus plants. As a result of the cochineal bug, cherries have a vivid crimson color.[19, 20]

2.2.2. Classification based on chemical constitution

Naturally occurring dyes are comprised of a complicated chemical composition. Instead of being a single entity, natural colors encompass a vast variety of chemical classes with distinct colors. Chemically speaking, dyes may also be categorized (see **Table 1**).[21]

Table 1: Classification of dyes based on chemical constitution[19]

Colours	Chemical classification	Common names
Yellow and Brown	Flavone dyes	Quercitron , Tesu
Yellow	Iso-quinoline dyes	Barberry
Orange – Yellow	Chromene dyes	Kamala

Brown	Naphthoquinone dyes	Henna , Alknet
Black	Benzophyrone dyes	Cochineal , Madder
Blue	Indigoid dyes	Logwood
Red	Anthraquinone dyes	Indigo
Neutrals	Tannins	Pomegranate, Eucalyptus

2.2.2.1. Anthraquinone dyes

Anthraquinone-based red dyes can be derived from plants, animals, or insects. Those dyes are characterized by high light and washing resistance. Madder (alizarin), lac dye (animal dye), kermes, and cochineal are some examples of this (insect dye). Alizarin, derived from European madder, is the most well-known natural dye (Rubia tinctorum).[14]

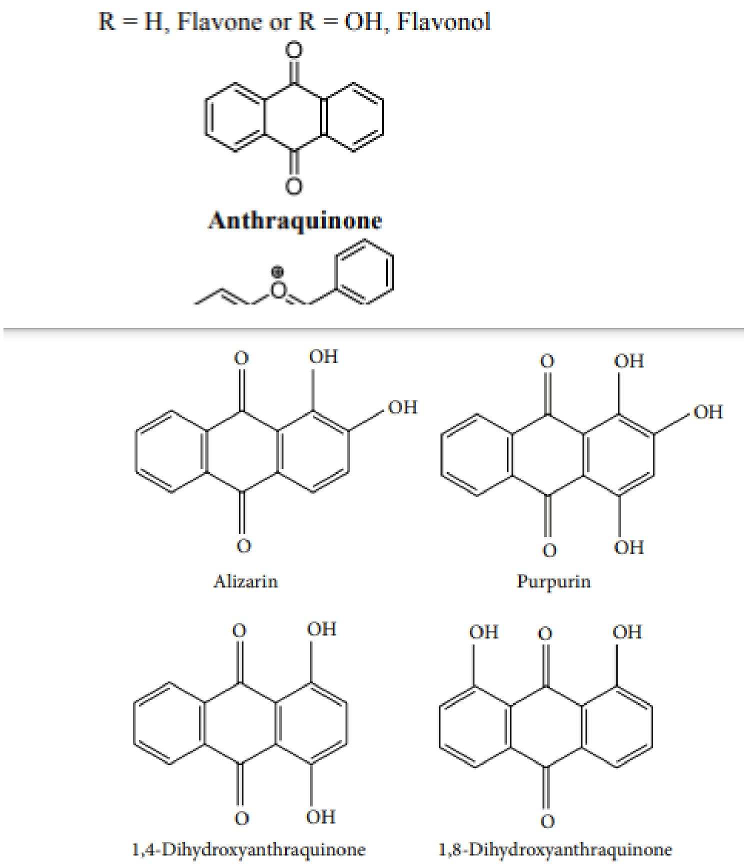


FIGURE 1: Chemical structure of the main compounds of madder.

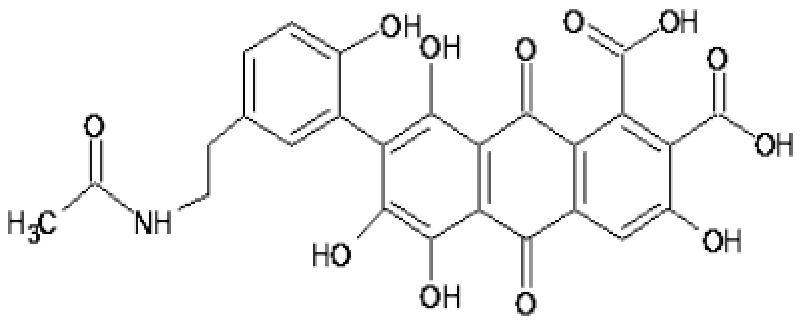


Fig. 1 Chemical structure of lac dye under investigation

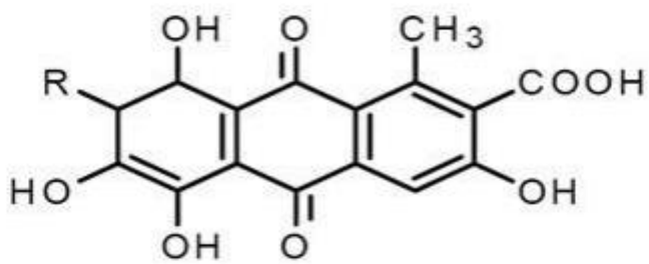


Figure 2: Molecular structure of cochineal carmine dye

2.2.2.2. Naphthoquinone

These include henna, walnut shell, and other natural dyes that create orange to reddish brown hues similar to anthraquinones. In henna, lawsone (2-hydroxy naphthoquinone) is the coloring agent, while walnut shells contain juglone (5-hydroxy naphthoquinone).

2.2.2.3. Indigoid dyes

It is crucial to note that indigo and tyrian purple are both natural dyes with indigoid structure. Indigo, which is believed to have originated in India, is one of the earliest natural dyes. 'Indican' is also the source of the name Indigo (see **Figure 2**). Indian heritage may be directly traced 4000 years to Indigofera tinctoria, which contains the glucoside indicator.[14, 22]

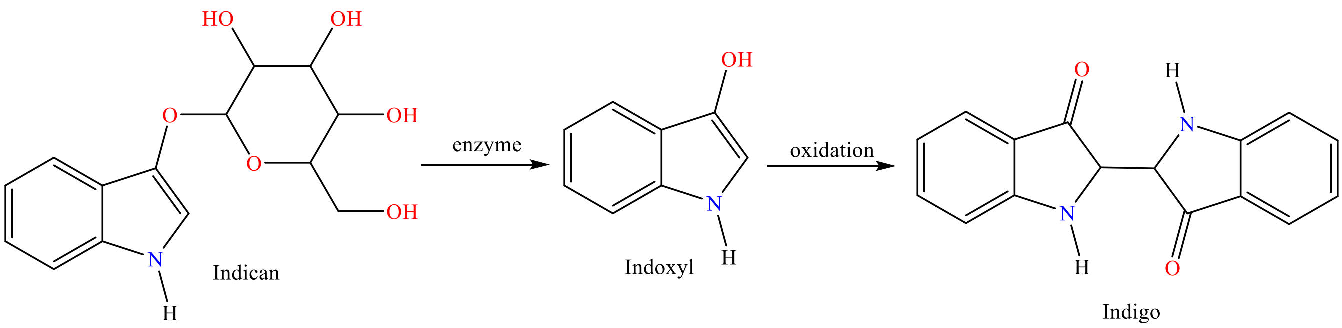


Figure 2: Chemical Structure of Indigo dye

2.2.2.4. Carotenoid dyes

This is owing to the existence of a long linked double bond in the pigment. The plant's tissues are protected by carotenoids, which absorb UV light. Carotenoids are classified as either carotenes or xanthophyll and are yellow, orange, or red in color Common carotenes include carrot beta-carotene (orange) and tomato lycopene (red). Annatto and saffron are good instances (see **Figure 3**).

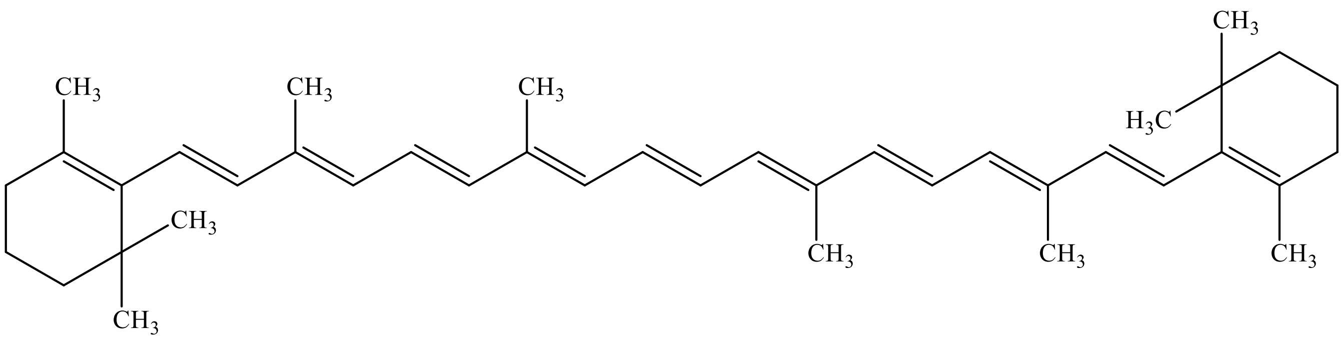


Figure 3: Chemical Structure of Carotenoid dye

2.2.2.5. Flavonoid dyes

There are two major structural classes of natural dyes: flavonoids and flavones. Flavones, flavanones (citrus fruit), isoflavones (pulses), anthocyanins, anthocyanidins, and proanthocyanidins are among the seven groups (e.g., black tea, green tea, apple, and blackberry). In nature, yellow is produced by flavonoids and isoflavones with hydroxyl and methoxy modified groups. Flavonoids include weld (Reseda luteola) and woad wax (Genista tinctoria) (see **Figure 4**).[23]

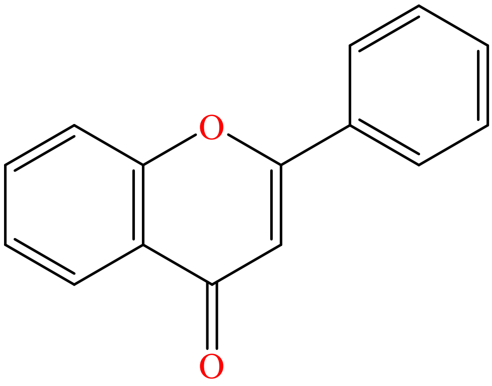


Figure 4: Chemical Structure of Flavones dye

2.2.2.6. Anthocyanins dyes

In plants, flavonoids are the most significant colorants, and they are found mostly in floral tissues. Pelargonidin, cyanidin, delphinidin, peonidin, petunidin, and malvidin are really the six major anthocyanin chromophores and glycosides. [24]In the food sector, anthocyanins play a key role due to their bright colors and dyeing abilities. They are also reasonably harmless from a health viewpoint (see **Figure 5**).

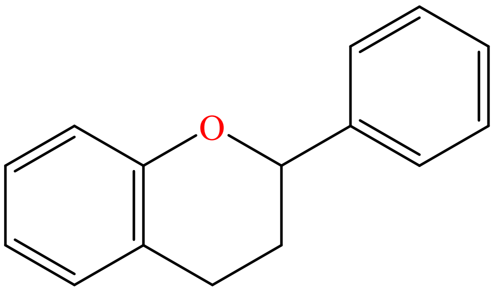


Figure 5: Chemical Structure of Anthocyanins dye

2.2.2.7. Dihydropyran dyes

Dihydropyrans are closely linked to flavonoids in terms of their chemical composition and structure. Logwood is primarily colored by haematin and haematoxylin, a leuco form (heartwood of Haematoxylon campechianum, CI natural black). Dark colors of silk, wool, and cotton can be achieved by using these natural dyes. Logwood, Brazil wood, and sappan-wood, for example (see **Figure 6**).[12, 24]

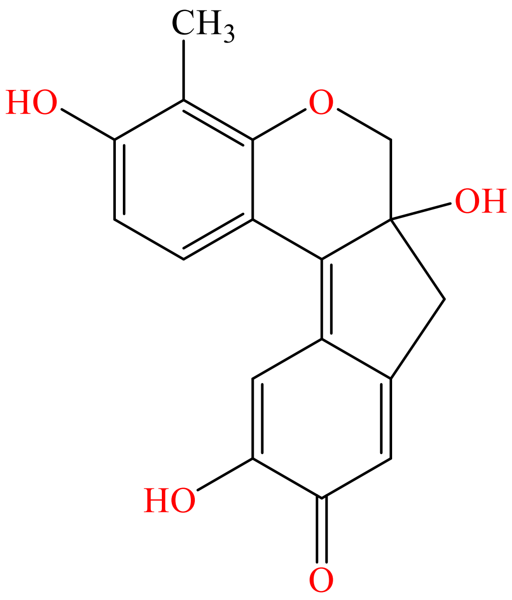


Figure 6: Chemical Structure of Dihydropyran dye

2.2.2.8. Tannin based dyes

Numerous plants typically used for coloring clothes include tannins, a polyphenolic molecule. As a rule, mordants are needed to fix tanin-based colors to cloth. Depending on the dye-mordant combination, this family of dyes also changes color with a change in mordant. In addition to its polyphenolic composition, Acacia catechu bark and wood dyes have Nilotic and babool bark, respectively.[19, 25]

2.2.3. Classification Based on Color

Natural dyes are typically classified based on the color they contribute to the textile material.[26-28]

2.2.3.1. Red

The Color Index offers 32 natural red dyes. The majority of the red pigments are found in the barks or roots of plants, or they are camouflaged in the bodies of dull grey insects. Madder (Rubiatinctorum), manjistha (Rubiacordifolia), Brazil wood/sappanwood (Caesalpineasappan), Al or morinda (Morindacitrifolia), cochineal (Coccuscacti), and lac dye are a few important members (Coccuslacca)[21]

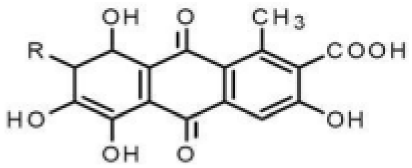
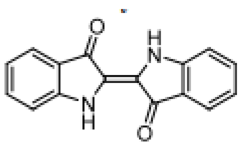


Figure 2: Molecular structure of cochineal carmine dye

2.2.3.2. Blue

There are just four blue natural dyes included in the Color Index: natural indigo, sulphonated natural indigo, Kumbh (Manipur), and Tsuykusa flowers from Japan, which are mostly used during manufacture of awobana paper [16].Indigo seems to be the only viable blue natural dye.[29]



Indigo

2.2.3.3. Yellow

As a result, yellow has been the most often used and plentiful natural dye. Twenty-eight yellow dyes are listed in the Catalogue of Colors. Berberisaristata (barberry), tesu blossoms (Buteamonosperma), and kamala are one of the most prominent sources (Mallotusphilippensis)[26, 30] Turmeric, kamela, tesu, marigold, larkspur, harshingar, annatto, berberis, and dolu are natural sources of yellow hue. Curcuma longa rhizomes are also the source of turmeric's color. Colorants such as rottlerin and isorottlerin are present in kamela, an orange-red powder that forms glandular pubescence on the bases of the tree Mallotusphillipinensis.

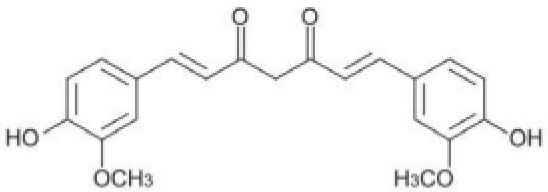


Figure 1: Chemical structure of turmeric (keto form) [5]

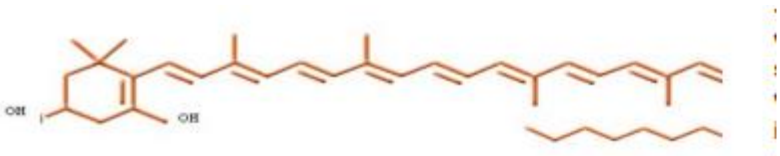


Figure 3. Chemical structure of carotenoid

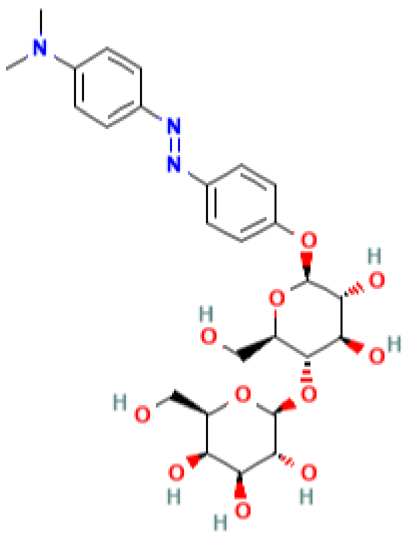
Marigold dye

2.2.3.4. Green

Plants can produce green colors are uncommon. Woad (Isatistinctoria) and indigo were used together with yellow dyes since antiquity to generate green colors. It was created by mordanting wool with alum and dyeing it yellow with dyer's green weed, then over-dying it with woad and indigo. Using an iron mordant to color yellow fabrics produces soft olive greens.

2.2.3.5. Black and Brown

Natural brown supplies are nearly limitless. Cutch is an old brown dye derived from the wood of acacia trees; specifically, Acacia catechu is being used to color cotton in a brown color. Six dyes are available in black, according to Color Chart. Iris plant roots, lac, charcoal, and caramel are other good examples of black color.[31]



Lac dye

210 2.2.3.6. Orange

Additionally, oranges may be created by combining red and yellow colors. Barberry, annatto, sweet pepper blood roots, etc. are all examples of nutrients orange color.[32]

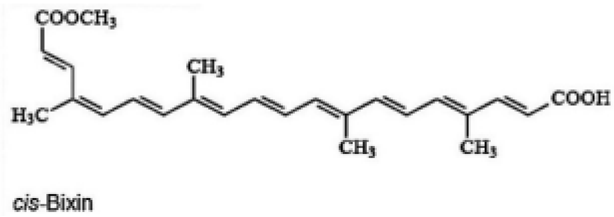


Figure 2. Structure of Bixin

annatto dye

Colour	Botanical	Parts used
Red dyes		
Safflower	Carthamus tinctorious	Flower
Caesalpina	Caesalpinia sappan	Wood chips
Maddar	Rubia tinctorium	Wood
Lac	Coccus lacca (insect)	Twigs inhabited by These insects
Yellow dyes		
Bougainvillea	Bougainvillea glabra	Flower
Golden rod	Solidago grandis	Flower
Teak	Tectona grandis	Leaves
Marigold	Tagetes species	Flower
Parijata	Nyetanthesar bortristis	Flower
Green dyes		
Tulsi	Ocimum sanctum	Leaves
Bougainvillea	Bougainvillea	Flower
Canna		Flower
Lily	Convallar majalis	Leaves and stalk
Nettles	Urtica diocia	Leaves
Brown dyes		
Caesalpina	Caesalpinia sappan	Wood chips
Bougainvillea	Bougainvillea glabra	Flower
Balsam	Impatiens balsamina	Flower
Marigold	Tagetes species	Flower
Black berries	Rubus fructicosus	Berries
Blue dyes		
Indigo	Indigofera tinctoria	Leaves
Woad	Isatis tinctoria	Leaves

Suntberry	Acacia nilotica	Seed pods
Pivet	Ligustrum vulgare	Mature berries After frost
Water lily	Nymphaea alba	Rhizomes
Black dyes		
Lac	Coccus lacca (insect)	Twigs inhabited by These insects
Alder	Alnus glutinosa	Bark
Rofblamala	Loranthus pentapetaius	Leaves
Custard apple	Anona reticulate	Fruit
Harda	Terminalia chebula	Fruit
Orange / Peach dyes		
Bougainvillea	Bougainvillea	Flower
Balsam	Impatiens balsamina	Flower
Dahlia	Dahlia species	Flower
Annatto	Bixa orellana	Seeds

2.2.4. Classification Based on Application

Natural dyes are further divided into mordant dyes, direct dyes, vat dyes, acid dyes and basic dyes, and dispersion dyes depending on how they are applied.

2.2.4.1. Mordant Dyes

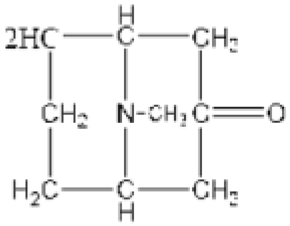
A mordant is required to apply these because they have no attraction for the fibers. They create complexes with the mordant, by definition. The three categories of mordants are I metallic mordants such as metal salts of aluminium, copper, tin etc. (ii) tannic mordants such as myrobalan and sumach (iii) oil mordants which form complexes with the primary metal mordant.

2.2.4.2. Vat Dyes

When reduced with sodium hydroxide, they become water-soluble, and their affinity for natural fibers is shown. That after dye has been applied to the fabric, it is oxidized to produce the dye's actual color, e.g., indigo.

2.2.4.3. Direct Dyes

There is no need to pre-treat the dye or the fabric before using direct dyes. This category includes a large number of natural dyes. Harda, pomegranate rind, and annatto are further examples.

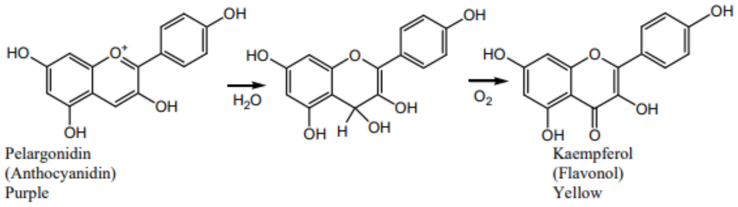


Scheme 1. Chemical structure of Punica –granatum.

pomegranate rind

2.2.4.4. Acid Dyes

Sulfonic or carboxylic groups are present in the structure of such dyes, making them the best choice for dyeing wool and silk in an acidic media. Saffron, for example, is more colorfast after being treated with tannic acid (also referred as back tanning).



saffron

2.2.4.5. Basic Dyes

Wool and silk have –COOH groups, which basic dyes ionize to produce coloured cations and electrovalent bonds with. Berberine, for example, is administered at pH values ranging from neutral to moderately acidic.

2.2.4.6. Disperse Dyes

Several natural dyes were thought to be structurally comparable to dispersed dyes. Due to the dyes' relative small size and solubility in water, they do not include any powerful solvent families. Synthetic fibres are dyed using all these dyes, which could be post-mordanted with chromium, copper, or tin salts. Silk and wool can also be treated using these techniques. Lawsone, henna, and several other flavone and anthraquinone dyes might be examples of such colors.[33]

2.3. Extraction of Natural Dyes

Extraction is important for the purification of natural dyes, as well as for the purification of crude dye-bearing substances, as natural dye-bearing materials contain only such a small percentage of coloring matter or dye. This is due to the fact that natural coloring ingredients are not made up of a single chemical entity and that the plant matrix comprises a range of no dye plant components. When beginning an extraction procedure, it is necessary to determine the type and solubility of the coloring ingredients. Color components can be extracted in several ways, including the following:

- Aqueous extraction.
- Alkali or acid extraction.
- Microwave and ultrasonic assisted extraction.
- Fermentation.
- Enzymatic extraction.
- Solvent extraction.
- Super critical fluid extraction.[12]

2.3.1. Aqueous Extraction

Plants and some other substances were previously dyed via aqueous extraction. To increase extraction yield, the dye-containing substance is first broken down into small particles or powdered and sieved. For the dye solution, it is boiling and filtered to eliminate no dye plant residues. To eliminate as much dye as practicable, the boiling and filtration procedure is repeated. While extracting color powder on a greater scale, stainless steel containers are utilized, and the time spent soaking the components in water can be shortened by boiling the solution for a longer amount of time instead of soaking things in water.

To remove leftover materials, centrifuges are often employed. Purified natural dye is more soluble when it is passed through trickling filters, which remove fine plant particles. As most dyeing procedures are carried out in aqueous conditions, the extract produced by this approach may be applied to textile materials with relative ease and convenience.

Only water-soluble dye components are extracted in this technique, although many dyes are insoluble in water. If the extract is to be condensed and converted to fine powder, it will need to be stripped of other water-soluble compounds, like sugars. Boiling temperature reduces the yield of heat-sensitive dye compounds, thus a lower temperature must be utilized for extraction in these cases.

2.3.2. Acid and Alkali Extraction Process

The glycoside form of many dyes allows them to be extracted under dilute acidic or alkaline conditions Glycosides are hydrolyzed more efficiently when acid or alkali is added, leading to a greater quality and high extraction of coloring ingredients.

It is necessary to employ an acid hydrolysis method to extract the dye from tesu (Buteamonosperma) flowers. In order to avoid oxidative degradation, certain flavone dyes are additionally extracted using acidified water phenolic dyes can benefit from alkaline extraction because they are soluble in alkali, which increases dye production.

2.3.3. Ultrasonic and Microwave Extraction

Those are all microwave and ultrasonic wave-assisted extraction methods that enhance extraction yield by lowering the amount of solvent, time, and temperature needed. As a result, these are called green processes. Ultrasonic techniques are superior for extracting heat-sensitive dye molecules. Microwave extraction involves treating natural sources with a little quantity of solvent in the absence of microwave energy sources. The microwave accelerates the operations, allowing the extraction to be finished in less time and with a higher yield.

2.3.4. Fermentation

Using enzymes generated by microorganisms in the environment or natural resources, this extraction method aids extraction. The most familiar application of this sort of extraction is indigo. Indigo leaves and twigs are steeped in warm water (approximately 32 °C) after harvest. The leaves' glucosideindican, which contains colored indigo, is broken down into simple sugars and indoxyl by the indimulsin enzyme, which is also found in the leaves. A 10- to 15-hour fermentation process produces indoxyl, which is subsequently oxidized by air into blue-colored indigotin, which falls to the bottom of the vat.

2.3.5. Enzymatic Extraction

Commonly available enzymes, such as cellulase, amylase, and pectinase, have been employed to loosen the surrounding material, allowing color molecules to be extracted under gentler circumstances. To extract dye from hard plant components such as bark, roots and the like, this technique may be useful.

2.3.6. Solvent Extraction

Biochemically, natural colouring substances may also be extracted utilizing organic solvents, like chloroform, chloroform-ethyl alcohol-ethyl alcohol-water-alcohol, etc. Using plant resources, water-soluble and water-insoluble compounds can be extracted by using the water/alcohol extraction technique Due to the fact that a greater number of chemicals and coloring components are extracted, the extraction yield is greater than with aqueous extraction. In addition, alcoholic solvents could also be treated with acid or alkali to promote the breakdown of glycosides and the releasing of colorant.

2.3.7. Supercritical fluid extraction

The solubility of a material increases with increasing pressure and temperature, therefore a gas function such as supercritical fluid can extract temperatures and pressures over critical levels. This state of affairs is required to keep the gas in its supercritical form. The use of carbon dioxide (CO_2) in supercritical fluid extraction is a good alternative to solvent extraction since it is non-toxic and leaves no wastes.[12, 14, 23]

2.4. Some application of natural textile dyes

Fabrics made from natural fibers are treated with natural dyes to increase their environmental friendliness. It is mostly used for dyeing fabrics, such as cotton and wool. Through use of indigo and some other natural dyes in printing is uncommon. Printed fabrics are often printed utilizing mordant substance, and the entire cloth is dyed, just the area printed with mordants is colored.[34]

Fabrics such as fibre, yarn, and fabric can be dyed using natural dyes as well as synthetic dyes. Due to spinning problems and the cost of coloured fibre, fiber training has the advantage of being able to easily alter hue.[35] Due of the design of wool, traditional dyers choose yarn coloring above any other material. hank dyeing is preferred by small-scale dyers owing to its simplicity and low cost, as well as its authenticity and economic efficiency. It is also compatible with their use of unrefined natural materials.[34]

In big pots, these artists generally make tainting by hand. Iron, stainless steel, copper, and aluminium are used to make the containers. Copper vessels are meant to be tinted to provide brilliant colors. It is recommended to use aluminium containers when using only one type of coloring, as they are generally dyed with a single hue. Containers made of inoxidized steel are ideal for the natural dyeing process. Hank-dyeing machines were more efficient when used on a larger scale. In order to get a uniform color, package dyeing requires small powders or concentrates that are filtered. Metal containers are also utilized at the cottage level to make colors. To thin larger lots, jiggers and winches were utilized. The right dyes or color carrying materials are selected based on the color needs. Several dye sources have been identified in the past. In general, barks containing tannins are used to produce brown and grey colors.[35]

Yellow hues are created using flavonoid-rich flowers and leaves. Animal and plant anthraquinone dyes can be used to create red hues. Indigo is used to create blue hues in general. You may choose from a variety of colors and mordants, or blend two dyes that have secondary hues like orange. As a result, the material is first tinted with Indigo, and then coated with the other color wherever blue is needed to create a secondary hue, in order to make green ***[34].***

3. Acknowledgments

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ملاحظة قيمة للأصباغ الطبيعية الصديقة للبيئة لاستخدامها القيم في صناعة النسيج

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الملخص العربي

أصبح فرع طباعة المنسوجات تقنية معروفة على نطاق واسع لجميع الألياف والمنسوجات والملابس في صناعات المعالجة الرطبة للنسيج. الطباعة هي نوع من التلوين يتم فيه تطبيق الألوان على مناطق معينة من القماش بدلاً من النسيج بأكمله. في هذه الدراسة ، سلطنا الضوء على استخدام الأصباغ الطبيعية الصديقة للبيئة كمادة ملونة لتقليل التأثير البيئي. تعتبر الأصباغ الطبيعية والاصطناعية مواد ذات أهمية كبيرة لأنها تلعب دورًا مهمًا في حياتنا اليومية. مجموعة كبيرة من الاستخدامات الفنية والصناعية لصباغة أو طباعة القماش والورق والجلود وغيرها من المواد. بعض هذه الألوان سامة ومسرطنة ويمكن أن تهيج الجلد والعينين. العديد من الألوان الاصطناعية الضارة ومسببة للحساسية محظورة الآن. العديد من الألوان ، على الرغم من عدم حظرها بعد ، قد لا تكون آمنة تمامًا.