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Unlocking the Potential of Natural Dyes: A Sustainable Approach

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Abstract
Natural dyes or pigments are natural colourants that are purely extracted from natural resources such as plants, invertebrates or minerals. These dyes are eco-friendly dyes that promote sustainable solution to textile industries. Natural dyes are biodegradable in nature and cause no harmful effects to the environment. Natural dyes are rich in antimicrobial and antibacterial properties. This review paper explores the potential sources of natural dyes. It also highlights the benefits of natural dyes along with their classification and application in various sectors such as textile, food, cosmetic, pharmaceuticals etc. This sustainable approach is an alternative option against synthetic dyes.
Keywords: Natural dyes, sustainability, eco-friendly

INTRODUCTION

India has blessed with vast variety of natural flora and fauna. It has more than 500 varieties of naturally occurring resources. Natural colorants are one the precious hidden treasures to mankind. Natural dyes or pigments are natural colourants that are purely extracted from natural resources such as plants, invertebrates or minerals [1]. Apart from this, these dyes are also extracted from the leaves of plants, roots, barks, insect secretions, fungi, minerals etc. As per the early records, the use of natural dyes is as old as Indus Valley Civilization. The practice of natural colorants was found in the Greco Roman periods. From the ancient texts and manuscripts of our Vedas, the Atharveda showcases the use of natural dyes. The wall painting of Ajanta, Ellora and Sithannvasal, Mithila paintings strongly depicts the legacy of natural dyes from the ancient's times in India[2]. On the basis of archeological findings in Egypt, traces of naturally dyed textiles was found in tombs and buried sites which comprise of fragments of naturally dyed cloth of linen and wool using plant based dye such as indigo, madder and safflower. Thus, the use of natural dyes from ancient times played a significant role in the life of mankind.

With the emergence of synthetic dyes in 19th and 20th century, the charm for natural dye declined and slowly come to an end. The first synthetic dye was invented by Sir William Henry Perkin in 1856 [3]. Perkin's accidental discovery of mauve dye leads dynamic revolution in the textile industry. The pervasive acceptance of synthetic dyes fastens the demand for dyeing of textiles which results in production of larger quantities. Synthetic dyes are versatile and offer wide variety of colours. These dyes are cost effective and have excellent fastness properties. Due to the increase awareness and environmental concern, the use of synthetic dyes has declined. Many countries have banned synthetic dyes as they are not only harmful for human body but also release toxic chemicals which are carcinogenic in nature. In comparison to synthetic dyes, natural dyes or colorants are eco-friendly in nature[4]. These dyes are biodegradable and cause no harmful effects to the environment. Natural dyes are rich in antimicrobial and antibacterial properties. Dyeing textiles with natural colorants produce a wide range of soft and luxurious earthy shades. This earthy hue captivates the human eyes and gives a cooling sensation to the wearer.

Keeping environmental concern in mind, many industries started using natural dyes. This initial step indicates a smarter approach towards environmental commitment and adoption of sustainable practices. This review paper focuses on the classification of natural dyes and their applications in different sectors such as textiles, food, pharmaceuticals and cosmetics industry.

Classification of Natural Dyes

Natural dyes are obtained from from plants, animals and minerals sources. Majority of natural colorants are extracted from plant based sources such as roots, fruits, bark, leaves, wood, and other organic sources such as fungi and lichens. The use natural dyes were around 2600 BC [5]. As per the records, it was found that the dyeing was carried out by using plants, barks & insects in China about 5000 years ago. There are many natural sources through which natural dyes can be obtained. These dyes produce unique range of earthy colours.

a) On the basis of origin

On the basis of origin, natural dyes are categorized into three types plant based or vegetable dyes, animal dyes, and mineral dyes.

1. Plant based dyes: These dyes are extracted from different parts of plants such as petals, roots, barks, berries, stem, leaves etc.
2. Animal based dyes: These dyes are extracted from insects. Insects namely Lac, Cochnieal and Kermes are known for dye yielding colorants.
3. Mineral based dyes: These dyes are extracted from natural mineral resources such as chrome-yellow, iron buff, narkin yellow, Prussian blue etc [6].

Plant based dyes

- Indigo plant: The botanical name of indigo is *Indigofera tinctoria* commonly known as true indigo. It is one of the oldest and most widely used natural dyes.The leaves of this plant are commonly used to produce a range of blue shades.
- Madder plant: The botanical name of madder is *Rubia tinctorum*. The madder plants are cultivated to produce a red coloured dye known as alizarin. Different shades of red and pink are obtained from this dye. The vibrant colour of this dye often used to dye wool and silk.
- Weld plant : The species of this plant produces range of yellow colour. The botanical name of weld dye is *Reseda luteola*. For extraction of colour, the leaves and stems of weld plant are used. This dye exhibits a good range of lightfast properties and is often used to dye cotton and linen.
- Turmeric plant: This dye yields natural bright yellow colour which is obtained from the roots of the turmeric plant. The botanical name for Turmeric is *Curcuma longa.* It is highly used to add colour in food items and also contains medicinal properties. This natural colorant is used to dye cotton,wool and silk.
- Pomegranate rinds: The botanical name for rinds of the pomegranate fruit is *Punica granatum*. It is used to produce a range of red and pink shades. The vibrant color of Pomegranate rinds is often used to dyeing of wool and silk.
- Onion skins : The scientific name for onion skins is *Allium cepa* .and it to produces a range of brown and yellow shades. Onion skins dye is known for its subtle color and is often used to dye cotton and linen.
- Coffee beans: The coffee beans known to produce a range of brown and beige shades. The botanical name for coffee beans is *Coffea Arabica*. This dye is highly valued for its subtle color and is often used to dye cotton and linen.
- Tea leaves: The botanical name for tea leaves is *Camellia sinensis*. The leaves of the tea plant are used to produce a range of brown and beige shades. This dye produces soft and muted shades of color and is often used to dye cotton and linen.
- Safflower flowers: The delicate flowers of the safflower plant are known for its yellow and orange shades of colour. The botanical name for Safflower is *Carthamus tinctorius*. The vibrant color range of this dye is used to for dyeing of wool and silk.
- Henna leaves: The botanical name for Henna is *Lawsonia inermis*. The leaves of the henna plant are used to dye hair and textile fibres. Traditionally, it is also used for decorating human body parts such as hands and legs. It produces a beautiful and aromatic range of red and brown shades [6].

Animal-Based Sources

- Cochineal insects: The scientific name of Cochineal insects is *Dactylopius coccus*. The dried cochineal insect bodies of female cochineal insect are used to extract natural dyes which produce shades of red and pink colour. It is highly expensive dye and is often used to dye wool and silk.
- Lac insects: The scientific name of Lac insects is *Kerria lacca*. A range of red and purple shades are obtained from lac insect. This dye is used for dyeing wool and silk.
- Silk worm cocoons: The scientific name of Silk worm is *Bombyx mori.* The cocoons of the silk worm exhibit a range of yellow and golden shades.
- Kermes insects: The kermes insects are known for its natural shades of red and crimson. The scientific name of Kermes insects is *Kermes vermilio*. The extracted dye is used in dyeing wool and silk [6].

Mineral-Based Sources

- Chrome green-from a compound of chromium and oxygen.

- Chrome red-from from a compound of chromium and lead.
- Chrome yellow-from a compound of chromic acid and lead
- Prussian blue from a compound of iron and cyanide.
- Iron oxide : Iron oxide produces a wide range of yellow, brown and red shades. It is used to dye wool and silk.
- Titanium dioxide: A range of white and opaque shades are obtained from Titanium dioxide dye and is used to dye wool and silk.
- Ochre : Ochre is known for its range of yellow, brown, and red shades. This dye is used in dyeing of wool and silk.
- Malachite : Malachite produces excellent shades of green and blue used to dye wool and silk.
- Lapis lazuli : Lapis lazuli is used to produce a range of blue and purple shades [6].

b) **On the basis of chemical structure**

- Indigoids: Indigo, Turian purple and Woad falls in this class. It is found in the plants in the form of glucoside indicant.
- Anthraquinones: These dyes carries anthraquinone structure and extracted from plants and insects. Due to anthraquinone structure, this class of dye yields red colour. Dyes such as Madder, Lac, Cochnieal, Kermes are categorized in this group.
- Alpha-Naphthouinones: This class of dyes contains alpha-naphthoquinone structure such as 2-hydroxy 1-4-naphthoquinone. Henna, Lawsone and Juglone are the examples of this class.
- Flavones: These dyes yields yellow colour and are derivatives of hydroxyl and methoxy substituted flavones or isoflavones. Natural weld dye is an example of this class.
- Carotenoids: These dyes are characterized by long chain conjugated double bonds. Natural dyes such as Saffron, Annatto belongs to this class.
- Dihydropyrans: Natural dyes such as Logwood and Sappan belongs to this category. Logwood produces dark black colour on protein and cellulosic fibres.
- Anthocyanidis: Natural dye carajurin belongs to this class. A dye under this category produces natural shades of blue and orange [7].

c) **On the basis of colour**

Natural dyes exhibit a wide spectrum of colours. These dyes can be classified on the basis of colour or hue.

- Red: this colour index is a combination of 32 different colours. The prominent members of this family include maddar, manjistha, Brazil wood, *Morinda*, cochineal and lac dyes.
- Blue: this colour consists of four natural blue dyes. Indigo, Kumbh and flowers of JapaneseTsuykusa falls in this category. Since ancient times, the use indigo blue is known for dyeing of cotton and woollen fabrics.
- Yellow: there are 28 shades of yellow colour and these are used in dyeing of protein and cellulosic fibres. Barberry, Tesu flowers, Kamala, Turmeric and Marigold etc are the sources that yields yellow colour.
- Green: the occurrence of green colour is very rare. Hence it is made by combining yellow and blue colour. Woad and Indigo produces natural green colour.
- Black and Brown: this colour contains six black natural dyes and this colour is obtained from carbon, caramel and lac. Brown colour is procured from Cutch.
- Orange: this colour is obtained by combination of two colours namely red and yellow. Annatto and Barbeny are the sources that produce natural orange colour [7].

Advantages of natural dyes

- Natural dyes are considered to be environmental friendly dyes as they are biodegradable in nature which does not result in pollution.
- These dyes are eco-friendly dyes as they are extracted from natural resources.
- Natural dyes are non-toxic dyes as it does not contain any harmful chemicals. Hence it is safe for skin.
- Natural dyes produce unmatched soft earthy shades which pleases human eye.
- Most of the natural dyes contain anti-bacterial properties hence naturally dyed fabric is safe for the wearer.
- It is a labour intensive industry, hence open job opportunities for the people who are engaged in agriculture and other industrial units [6].
- A wide range of colours can be achieved by combining different natural colours. By using mordants, it is easy to create new range of natural shades [8].

Disadvantages of natural dyes

- Highly expensive dyes in comparison with synthetic dyes.
- The extraction process is laborious and time consuming.

- The colour of natural dyes has poor fastness properties, hence fades after a span of time.
- Natural dyes showcase batch to batch variability which makes difficult to achieve same shade of colour [6].

Application of Natural Dyes

- Textile Industry: Natural dyes are used in textile industries for dyeing of fibre, yarn, fabric or other textile materials. It plays an important role in organic and sustainable textiles.
- Food Industry: Natural dyes are extensively used in the food industry. These dyes not only adds colour to the food items but also improves the appearance of the food products such as sauces, beverages, bakery, candies etc.
- Cosmetic Industry: A natural dye yields anti-oxidant, anti-microbial and anti-inflammatory properties. These dyes are highly used in cosmetics and skin care ranges.
- Pharmaceutical Industry: Natural dyes used in medicine production and skin care treatment.
- Art and Craft Industry: Natural dyes used in production of art and craft materials such colours, clay etc.
- Leather Industry: These dyes are used for colouring leather products.
- Paper Industry: These dyes are used for colouring paper and other cellulose based products.
- Agriculture Industry: These dyes are used in colouring of animal feed and other agriculture products [6].

CONCLUSION

Since, ancient time's natural dyes have played a significant role. Natural dyes have deep connection with our culture and history and also reflect the age-old traditions and craftsmanship of different countries. These dyes are non-toxic and biodegradable in nature which is an alternative option against synthetic dyes. Natural dyes are environment friendly which help in reducing environmental pollution. These dyes have poor fastness properties. Despite of several challenges, the demand of natural dyes is increasing. The interest of consumers are shifting towards eco-friendly and sustainable products. With the growing demand of natural dyes more researches must be conducted to understand the challenges and minimizing their limitations. Not only this, there is a need of smart solutions and innovation techniques for extraction and other processes which benefits the textile industry. Also there is need to improve fastness properties of natural colorants and there are more resources yet to be discovered. The future prospects of natural dyes are promising as it provides job opportunities, growth, innovation and sustainability.

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