Natural Dyes Extracted from Flower Crops: A Review of Recent Advances

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Abstract:

Over the past few decades, researchers worldwide have been motivated to explore alternative renewable bio-based materials for colouring purposes, aiming to minimize the negative environmental impact associated with the use of synthetic dyes. Natural dyes extracted from flower crops have gained increasing attention in recent years due to their potential as a sustainable alternative to synthetic dyes, which have negative environmental impacts. A variety of exquisite shades, ranging from delicate pastels to vibrant and striking tones, can be derived by extracting pigments found in numerous flowers. Unlike synthetic dyes, natural dyes are renewable, biodegradable, and non-toxic. Moreover, natural colourants offer diverse practical finishing characteristics, such as insect repellent, deodorizing, anti-feedant, antimicrobial, fluorescence, and UV protection properties. This review provides an overview of the recent advances in the extraction and application of natural dyes from flower crops along with the classification of natural dyes. The review is mainly focused on the different ornamental plant sources of natural dyes, various flowers used for extraction of dyes and the application of natural dyes in the industries like textile, cosmetic and food industries. The review also discusses different challenges and opportunities in the development of natural dyes from flower crops.

Keywords: Synthetic dyes, Extraction methods, Plant-based dyes, Eco-friendly dyes, Colourfastness, Hue.

1. Introduction:

In our daily lives, colour is significant since it serves as a vital visual sign when it changes. Throughout the beginning of time, the vibrant and calming colours of nature have mesmerised humans [1]. Both pigments and dyes are included in these colorants. The coloured substances known as dyes have a strong affinity for textile fibres and fabrics through various physical and chemical interactions. Textile fibres and pigments do not interact or have any physical or chemical affinity [2]. In the past, people have coloured food, clothing, and cosmetics with a variety of plant parts, including their roots, stems, barks, berries, leaves, and flower extracts [3-4]. W. H. Perkin synthesized dye in a lab in 1856, and as a result, there is now a difference between natural and synthetic dyes. Rapid advancements in synthetic dye research, development, and application cause a dramatic decline in the usage of natural colours [5]. Over the past few decades, scientists from all over the world have been

driven to investigate new renewable bio-resource natural materials for colouring that would reduce the harmful environmental effects of using (azo and benzidine) synthetic dyes [6]. As a result, many European nations, the USA, Germany, and India have enacted environmental and ecological legislation to limit their use [7]. Natural dyes have again emerged as promising green chemistry alternatives for synthetic dyes with a wide range of applications other than textile colouring as a result of growing environmental and waste management concerns [8-10].

The textile business has been transformed by increased awareness among researchers of environmental preservation, eco-safety, and health issues, as well as sustainable materials made from non-food crops that are pollution free, nontoxic, and sustainable [4]. Due to differences in pricing, end product durability, design, handling convenience, and product safety, the textile sector has gained more attention across the globe [4, 11]. New dyeing technologies have been created as a result of excessive water and auxiliary chemical use in dyeing and functional finishing in many textile sectors [5, 12, 13]. Wide-ranging contaminants are present in the wastewater from wet textile processing, necessitating the development of highly sophisticated cleaner production strategies in order to reduce them [1, 4, 14-16].

Many flowers contain pigments that can be extracted to create a range of beautiful colours, from soft pastels to bright, bold hues. Some commonly used flowers for natural dyeing include marigold, chamomile, hibiscus, and madder. Marigold produces a bright yellow or orange dye. The petals can be dried and then used to make the dye, or the fresh petals can be simmered in water to extract the colour [17]. Chamomile, a small white or yellow flower, can produce a range of soft yellows and greens. The flowers can be used fresh or dried to create the dye [18]. Hibiscus flowers produce a range of pinks, reds, and purples, depending on the variety. The flowers can be dried and then used to create the dye [19]. Madder, a plant with small yellow flowers, produces a range of reds, oranges, and pinks [20]. The roots of the plant are used to create the dye, which can be extracted by boiling them in water [21]. Overall, flowers can provide a variety of colours for natural dyeing, and their use can help to promote sustainability and reduce the environmental impact of the textile industry.

Natural dyes are extracted from plants, and they are biodegradable and non-toxic. Unlike synthetic dyes, which are made from petroleum-based chemicals and are harmful to the environment, natural dyes do not cause pollution [22]. Some synthetic dyes associated with hyperactivity in children and causes allergic reactions in sensitive individuals while some synthetic dyes have been found to be carcinogenic and to disrupt hormonal balance in animal studies. Tartrazine (Yellow 5) has been found to associated with hives, asthma and anaphylaxis [23] and mixture of synthetic dyes found to be increases hyperactivity in children with attention deficit hyperactivity disorder (ADHD) [24]. Red 2G synthetic dye has been shown to cause liver cancer in rats [25] while Red 3 has been shown to disrupt thyroid hormone synthesis in rats [26]. On the other hand natural dyes are safe and healthy to use. They do not contain harmful chemicals or toxins, which can cause allergic reactions or skin irritation so these dyes are often encourage to use in the textile industry to produce clothing, bedding, and other textiles that are hypoallergenic and safe for sensitive skin [27]. Many

cultures have a rich history of using natural dyes to create traditional textiles and clothing. For example, in India, natural dyes have been used for centuries to produce beautiful and vibrant textiles. By preserving these traditions, we can ensure that our cultural heritage is passed down to future generations [28]. The production of natural dyes can provide income for small-scale farmers and communities. By cultivating flower crops that are used for natural dye extraction, farmers can diversify their income and create sustainable livelihoods [29]. Using natural dyes promotes sustainability in the fashion industry by reducing the environmental impact of clothing production. By using natural dyes, we can reduce water consumption, energy use, and waste in the textile industry [30]. Ultimately, the environment, health, culture, economy, and sustainability all benefits from the extraction of natural dyes from flower crops.

With a focus on textile coloration and functional finishing features, this review paper brings together recent research on classification, sources, extraction methods, and application of natural dyes obtained from flower crops.

2. Natural dyes

Natural dyes are the dyes which are obtained from natural sources like plants, animals, and minerals. They have been used for thousands of years to dye textiles, clothing, and other materials. Unlike synthetic dyes, natural dyes are renewable, biodegradable, and non-toxic [31-32]. Natural flora and fauna offer a broad variety of exciting colours that give various synthetic and natural textile materials with harmonious, elegant, and austere shades. Additionally, natural colorants impart a variety of functional finishing properties like insect repellent, deodorising, anti-feedants, antimicrobial, fluorescence and UV protective properties. These properties have expanded the range of applications for natural colorants and contributed to their rising popularity in the creation of systematic, scientific, and diversified smart textile materials [7, 10, 33-35].

3. Classification of natural dyes

Natural dyes are classified based on their place of origin, application method, chemical composition and colour [36].

3.1. Based on Origin

Natural colorants are divided into four categories based on their origin: plant origins, insect/animal origins, mineral origins and microbial origins. Figure 1 shows the origin-based classification with various illustrative examples (Fig. 1). It is possible to extract natural colorants from plant's flowers, leaves, fruits, seeds, bark, stem, and roots. Flowers have been employed extensively among the many plant parts, and they are currently the main source of large-scale pigment extraction [37]. Researchers have already reported encouraging outcomes when using colour-rich extracts from numerous flowers that produce dyes, including marigold, calendula, celosia, and gerbera to create eco-friendly and bioactive hues and tones [38-41]. However, it is important to remember that most plant dyes need mordants for better results, which will be covered in the upcoming section of this review.

The red dyes produced by the exudation of dried Cochineal, Kermes, lac, and mollusk bodies are within the animal or insect group of natural dyes. These red dyes have been used for many years to colour many kinds of fabrics [42-43]. Mineral origin refers to pigments made of inorganic metal salts and metal oxides. Cinnabar, red and yellow ochers, raw sienna, malachite, ultramarine blue, azurite, gypsum, talc, charcoal black, and other colours fall within this category. Ancient paintings and murals also used colorants with a mineral origin [44].

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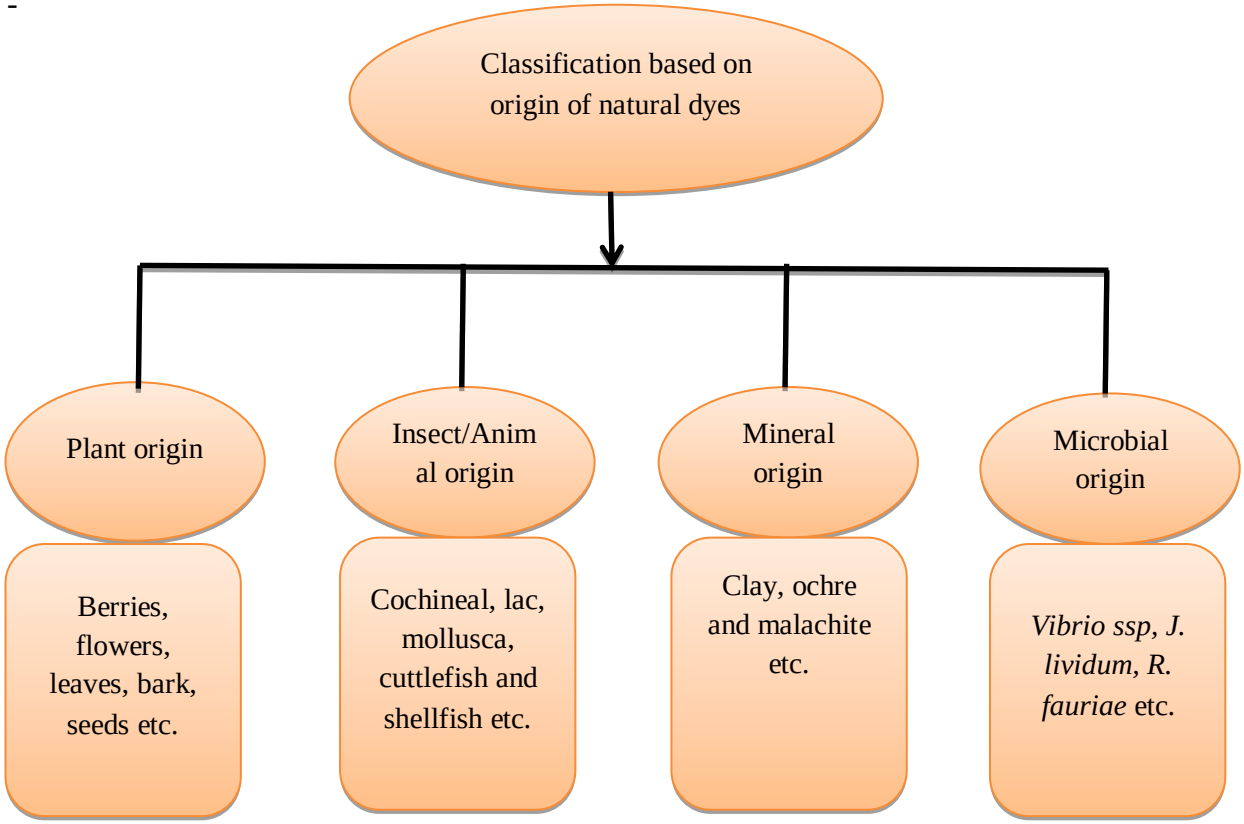

Figure 1. Classification on natural dyes based on their origin.

Natural pigments like carotenoids, flavonoids, quinones, riboflavin, and prodigiosin have been extracted from microorganisms like bacteria, algae, and fungi and then used to colour different types of textile fibres and fabrics as well as produce bioactive materials [45]. These kinds of pigments have been widely used in the pharmaceutical, food, and cosmetics industries because of their significant biological properties, such as anticancer activity [46]. These pigments have good fastness properties while being applied to textiles, in addition they also have antibacterial and antioxidant properties [45]. The extracted pigments are a variety of colours, including vivid red, bluish purple, violet and pink. The extracted pigments are resistant to changes in pH, light, and temperature. Its application scope in the printing of reusable and recyclable papers was expanded due to poor light fastness capabilities [47].

3.2. Based on Application

Based on their methods of application, Bancroft divided natural dyes into two classes in his book "Philosophy of Permanent Colours." Substantive dyes are coloured substances that directly dye textiles, such as indigo, turmeric, etc. Adjective dyes are a different kind of dyes that need a metal salt or mordant to enhance the contact between the dye and the fabric. Other categories for adjective dyes include monogenetic (just one colour, regardless of the mordant; annatto) and polygenetic (depends upon mordant; Logwood, Lac and Cochineal) [48].

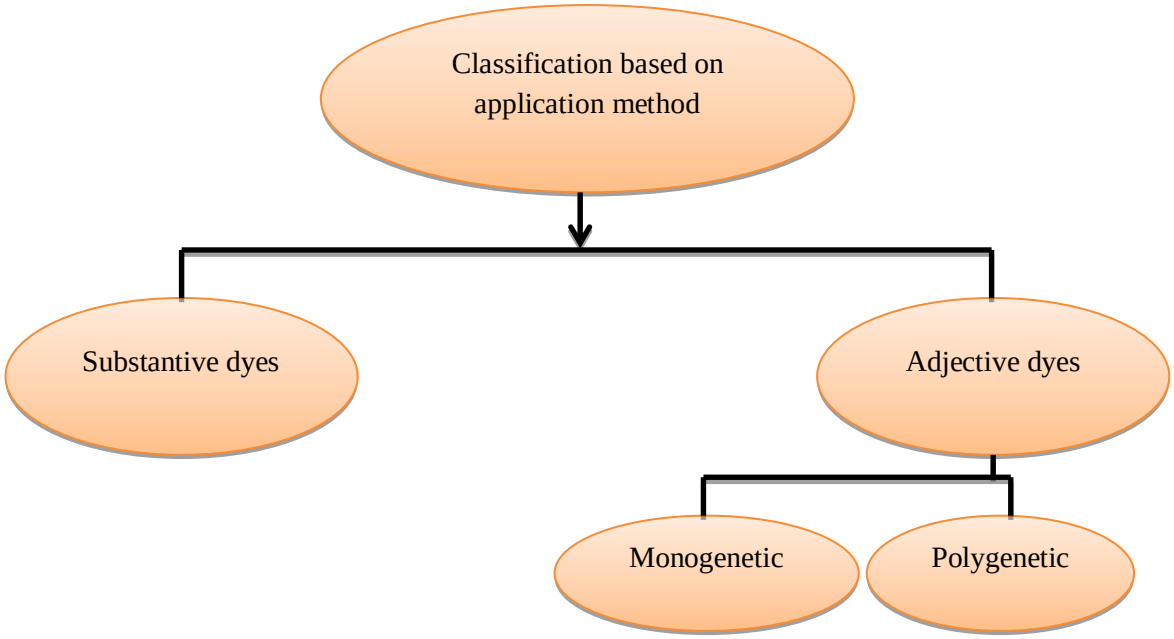

Figure 2: Classification on natural dyes based on their method of application.

3.3. Based on Chemical composition

Chemical composition based classification is accepted widely because it determine dyes on the nature of chemical constituents which are present in them [49].

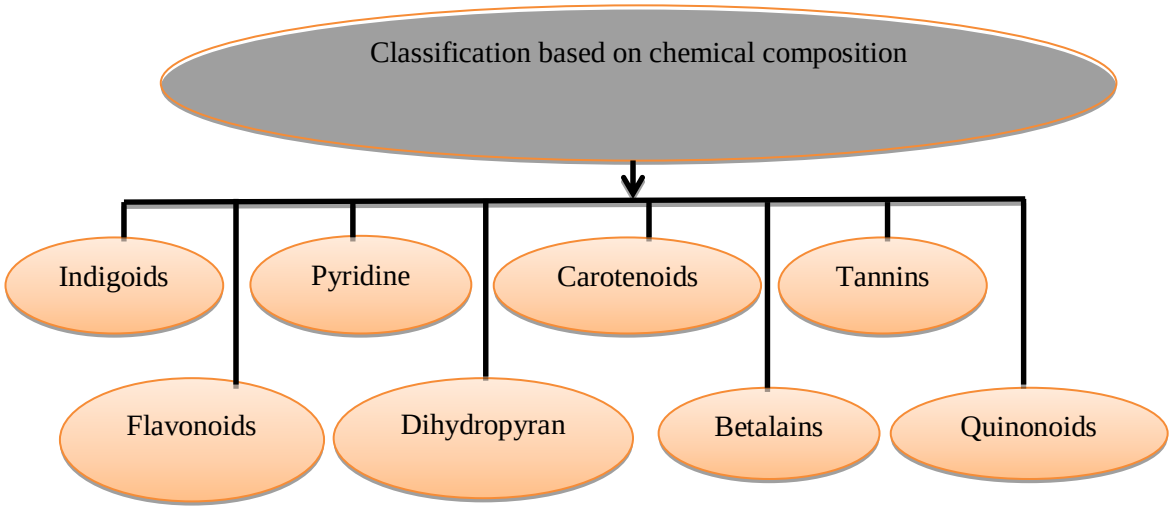

Figure 3: Classification on natural dyes based on chemical composition.

4. Properties of Natural dyes

Natural dyes come from a variety of plant, animal, and mineral sources, and each type of natural dye has its own unique properties. Some common properties of natural dyes include:

4.1. Hue: The hue of a natural dye refers to the colour it imparts to the fabric or material it is used on. According to Padmini, Kumar, and Philip [50], "Natural dyes can produce a wide range of hues, from earthy browns and greens to vibrant blues, purples, and reds".

4.2. Light fastness: Natural dyes can vary in their ability to resist fading when exposed to light [51]. As stated by Nartey et al., natural dyes, such as indigo and madder, are known for their excellent light fastness, while others may fade more quickly [52].

4.3. Wash fastness: Similarly, natural dyes can vary in their ability to resist fading when washed. According to Kılıç and Sağlam [53], some natural dyes may bleed or fade when exposed to water or detergents, while others are more resistant.

4.4. Dye concentration: The amount of natural dye used can affect the depth and intensity of the resulting colour [54]. Some natural dyes require a higher concentration to achieve a strong colour, while others are more potent and require less dye.

4.5. pH sensitivity: The pH of the dye bath can also affect the resulting colour of natural dyes. Some natural dyes, such as cochineal, are sensitive to pH changes and can produce different hues depending on the acidity or alkalinity of the dye bath [55].

4.6. Temperature sensitivity: The temperature of the dye bath can also affect the resulting colour of some natural dyes. For example, according to Kim et al. some natural dyes, such as onion skins, produce a different hue when heated compared to when they are simmered at a lower temperature [56].

Overall, natural dyes offer a unique range of colours and properties that are distinct from synthetic dyes, and they are increasingly being used in sustainable and eco-friendly textile production.

5. Natural dyes obtained from ornamental plants:

The majority of natural dyestuff and stains come from plants. They predominate as natural dye producers, yielding a variety of colours including red, yellow, blue, black, brown, and a mixture of these. The majority of plant parts, including the roots, bark, leaves, fruits, timber, seeds, flowers, etc., create colours. It's interesting to note that, of the nearly 2000 pigments that can be manufactured, only about 150 have been used commercially. In India alone, almost 450 species are known to produce dyes, of which 50 are thought to be the most significant. Some important dye yielding floricultural plants are given in the table 1.

Table 1: Various ornamental plants used for natural dye extraction.

Sr. No.	Scientific Name	Family	Plant part used	Colour obtained	Extracted colouring pigment	Reference
1	*Tagetes erecta*	*Asteraceae*	Flowers	Yellow	Lutein	[38]
2	*Bougainvillea glabra*	*Nyctaginaceae*	Bracts	Red	Betalain	[57]
3	*Clitoria ternatea*	*Fabaceae*	Flowers	Blue	Delphinidin	[58]
4	*Calendula officinalis*	*Asteraceae*	Flowers	Yellow	Carotenoids	[39]
5	*Magnolia champaca*	*Magnoliaceae*	Flowers	Pale yellow	Flavonoids	[59]
6	*Callistephus chinensis*	*Asteraceae*	Flowers	Pink	Flavonoids	[60]
7	*Hibiscus rosa sinensis*	*Malvaceae*	Flowers	Red	Anthocyanins	[61]
8	*Celosia cristata*	*Amaranthaceae*	Flowers	Brownish colour	Betacyanins (Betalain)	[40]
9	*Eucalyptus*	*Myrtaceae*	Tree bark	Yellow	Quercetin	[62]
10	*Butea monosperma*	*Fabaceae*	Flowers	Bright yellow	Isobutrin	[63]
11	*Plumeria rubra*	*Apocynaceae*	Flowers	Yellow	Quercetin	[64]
12	*Gernera jamesonii*	*Asteraceae*	Flowers	Red	Anthocyanin	[41]
13	*Lantana camara*	*Verbenaceae*	Flowers	Yellow	Anthocyanin	[65]
14	*Gomphrena globosa*	*Amaranthaceae*	Flowers	Purple	Betacyanins	[66]
15	*Nyctanthes arbortristis*	*Oleaceae*	Flowers	Yellow	Carotenoids	[67]
16	*Indigofera tinctoria*	*Fabaceae*	Leaves	Deep blue	Indigotine	[68]
17	*Ixora coccinea*	*Rubiaceae*	Flowers	Red and purple	Anthocyanin	[69]
18	*Nerium oleander*	*Apocynaceae*	Flowers	Dark blue	Polyphenols	[70]
19	*Bixa orellana*	*Bixaceae*	Seeds	Yellow	Carotenoids	[71]
20	*Nelumbo nucifera*	*Nelumbonaceae*	Seedpod	Reddish brown	Proanthocyanidins	[72]
21	*Lawsonia inermis*	*Lythraceae*	Leaves	Yellow	Quinonoid	[73]
22	*Tropaeolum majus*	*Tropaeolaceae*	Flowers	Yellow	Carotenoids	[74]

23	*Pandanus amaryllifolius*	*Pandanaceae*	Leaves	Green	Chlorophyll	[75]
24	*Opuntia ficus indica*	*Cactaceae*	Fruits	Yellow	Indicaxanthin	[76]
	Opuntia ficus indica	*Cactaceae*	Fruits	Red	Betalain	[77]
25	*Rhododendron arboreum*	*Ericaceae*	Flowers	Violet	Anthocyanin	[78]
26	*Rosa sp.*	*Rosaceae*	Flowers	Red	Anthocyanin	[79]
27	*Antirrhium majus*	*Plantaginaceae*	Flowers	Orange	Carotenes	[80]
28	*Gladiolus*	*Iridaceae*	Flowers	Red	Pelargonidin glycosides	[81]
29	*Mussaenda erythrophylla*	*Rubiaceae*	Flowers (Sepals)	Red	Anthocyanin	[82]
30	*Eichhornia crassipes*	*Pontederiaceae*	Flowers	Lavender	Anthocyanin	[83]
31	*Tecoma stans*	*Bignoniaceae*	Flowers	Yellow	Carotenoids	[84]
32	*Delphinium zalil*	*Ranunculaceae*	Flowers	Yellow	Flavanoid	[85]

6. Methods for extraction of natural dyes:

Natural dyes are hypoallergenic, non-toxic, and biodegradable from an ecological standpoint [86]. The societal benefits of utilising natural dyes include protecting dye shop employees from the negative health impacts of poisonous synthetic colours [87]. Their health will be safeguarded as a result of this. Natural dyes can also be applied gradually. Customers can use natural dyes to colour their own clothing.

The main criteria for evaluation of dyes obtained from natural sources is done from the perspectives of standardization [88-89], mass production application potential [90-91], environmental friendliness and colour fastness. They need to work with a wider variety of textile fibres and materials [92]. When dying textile materials, natural fixatives must be used.

One of the most important steps in the preparation of textiles for dying is the extraction of dyes from natural sources [93]. For a specific natural source, standardising the extraction process and maximising the extraction variables is also economically significant and affects the cost of the finished products [94]. Aqueous methanol, ethanol or water are used to extract many bioactive components [95].

Due to the fact that natural colouring agents do not exist in a single chemical form and that the plant matrix also contains a variety of non-dye plant substances, the extraction of natural dyes is a challenging process [96]. The composition and solubility characteristics of the colouring components must be clearly determined before performing an extraction process [97]. They have to employ a unique procedure to extract the dye from its source [98-99]. The methods listed below can be used to extract natural colours from their source materials. For

example enzymatic extraction method, supercritical fluid extraction method, aqueous extraction method, solvent extraction method and ultrasonic extraction method are currently the subject of extensive research due to their greater efficacy over traditional methods [93. 97, 100].

Table 2 provides information on the commonly used techniques for extracting natural textile colours, along with each technique's benefits and drawbacks.

Table 2: Methods for the extraction of natural textile dyes.

Extraction Method	Advantages	Limitations	Reference
Aqueous extraction	Low-cost, simple, environmental friendly	Low yield, low colourfastness, dye degradation during boiling	[101]
Enzymatic extraction	High yield, environmental friendly, mild conditions	Long extraction time, high cost of enzymes	[102]
Ultrasonic-assisted extraction	High yield, short extraction time, efficient	High cost of equipment, potential damage to dye molecules	[103]
Supercritical fluid extraction	High yield, high purity, selective extraction	High cost of equipment, high pressure and temperature requirements	[104]
Microwave-assisted extraction	Short extraction time, high yield, efficient	High cost of equipment, potential damage to dye molecules	[105]
Soxhlet extraction	High yield, efficient, easy scale-up	High solvent consumption, long extraction time, potential solvent residues	[106]
Acid extraction	High yield, intense colours, good colourfastness	Acidic waste disposal, potential dye degradation	[107]
Alkali extraction	High yield, mild conditions, good colourfastness	Alkaline waste disposal, potential dye degradation	[108]
Enzymatic-alkali extraction	High yield, mild conditions, efficient	High cost of enzymes, potential dye degradation	[109]
Enzymatic-acid extraction	High yield, intense colours, good colourfastness	High cost of enzymes, acidic waste disposal	[110]

7. Applications of natural dyes:

In the textile industry, natural dyes are often preferred for their eco-friendliness and biodegradability, as well as their aesthetic and cultural significance [111]. Natural dyes can be used to colour a variety of fabrics, including cotton, silk, wool, and linen.

In addition to textiles, natural dyes are also used in food and cosmetics. For example, beetroot extract is commonly used as a natural food colouring agent, while henna is used in cosmetics to dye hair and skin. Natural dyes are also used in traditional medicine for their therapeutic properties.

Some major industries which make a good use of natural dyes are as follows-

7.1. Textile industry:

Natural dyes extracted from flowers have been used for centuries in the textile industry, primarily for their aesthetic and cultural significance. They offer a range of hues that cannot be replicated by synthetic dyes, and they are often preferred for their eco-friendliness and biodegradability.

The use of flower-based natural dyes has gained renewed interest in recent years due to the growing demand for sustainable and environmentally friendly textiles. These dyes can be applied to a range of fabrics, including cotton, silk, wool, and linen.

For example, natural dyes extracted from marigold flowers have been used to dye cotton fabrics with shades of yellow, orange, and red [112]. Similarly, dyes extracted from hibiscus flowers have been used to colour silk fabrics with shades of pink, red, and purple [19]. Madder is a natural dye extracted from the roots of the madder plant. It is known for producing a range of red and orange shades that can be modified by changing the pH of the dye bath. Madder has been used for centuries in textile industries and is still widely used today [113]. Chamomile flowers can also be used to extract natural dyes for textile industries. Chamomile extract produces a range of yellow hues that can be used to dye natural fibres [114].

One of the challenges with using natural dyes extracted from flowers is achieving consistent colour results. This can be influenced by factors such as the type of flower used, the part of the flower used, and the extraction method [115]. However, advances in technology and techniques for natural dyeing are helping to overcome these challenges and make flower-based natural dyes more accessible for the textile industry.

7.2. Food industry:

Natural dyes extracted from flowers have been used for centuries to colour foods and beverages. These dyes are typically extracted from the petals or other parts of the flower, and can provide a range of colours from pink to purple to yellow [116].

One of the benefits of using natural dyes in food is that they are often safer than synthetic dyes, which have been associated with health risks [117]. In addition, natural dyes can provide health benefits, such as antioxidant and antimicrobial properties [116].

Commonly used natural dyes in the food industry include anthocyanins from flowers such as hibiscus and elderberry, as well as carotenoids from marigold and saffron [117]. Saffron is a spice derived from the dried stigmas of the *Crocus sativus* plant, and is known for its unique flavor, aroma, and deep yellow-orange colour. The natural pigments responsible for saffron's colour are called crocins, which are water-soluble carotenoids [118]. Saffron has been used as a natural food colorant for centuries, particularly in traditional dishes such as paella and biryani. In addition to its colour, saffron has also been reported to have various health benefits, including antioxidant, anti-inflammatory, and antidepressant properties [119]. However, due to its high cost, saffron is typically used sparingly in the food industry, and is often adulterated with cheaper alternatives.

In general, natural dyes extracted from flowers are a popular choice in the food industry due to their safety, health benefits, and vibrant colours.

7.3. Cosmetic industry:

Natural dyes extracted from flowers are commonly used in the cosmetic industry to provide a range of colours for various products, including lipsticks, eye shadows, and blushes. These dyes are typically extracted from the petals or other parts of the flower, and can provide a range of colours from pink to purple to yellow [120].

One of the benefits of using natural dyes in cosmetics is that they are often safer than synthetic dyes, which have been associated with skin irritation and allergic reactions [120]. In addition, natural dyes can provide additional benefits, such as antioxidant and antimicrobial properties.

Rose flowers are commonly used to extract natural dyes for use in cosmetics due to their fragrant aroma and soothing properties. Rose extract is often used in skin care products, including toners, creams, and serums, to hydrate and soothe the skin [121]. Chamomile flowers are often used to extract natural dyes for use in cosmetics due to their soothing and anti-inflammatory properties. Chamomile extract is commonly used in skin care products, including creams, lotions, and serums, to calm and soothe irritated skin [122]. Commonly used natural dyes in the cosmetic industry include carotenoids from marigold and saffron, anthocyanins from flowers such as hibiscus and elderberry, and chlorophyll from plants such as spinach and alfalfa [123].

8. Future prospects and challenges:

8.1. Future prospects:

8.1.1. Growing demand for sustainable fashion: Natural dyes extracted from flowers have the potential to meet the increasing demand for sustainable fashion. According to a report by McKinsey & Company, the market for sustainable fashion is expected to grow by 15% to

20% annually, reaching up to $450 billion by 2025 [124]. Consumers are becoming more conscious of their fashion choices and are willing to pay a premium for sustainable and eco-friendly products. Natural dyes can be used to produce vibrant and unique colours, which can help meet this demand [125].

8.1.2. Technological advancements: Advances in technology can help increase the yield and quality of natural dyes to the environment [126].

8.1.5. High-Performance Dyes: Researchers are working on improving the colourfastness and lightfastness of natural dyes extracted from flower crops to make them more suitable for high-performance applications, such as outdoor textiles extracted from flowers [127]. For example, researchers at the Indian Institute of Technology (IIT) have developed a low-cost and eco-friendly technique for extracting natural dyes from flowers using enzymes [128]. Other researchers are exploring the use of ultrasound-assisted extraction, microwave-assisted extraction, and other methods to improve the efficiency of natural dye extraction [129].

8.1.3. Use in medical textiles: Natural dyes extracted from flower crops are being explored for their potential use in medical textiles due to their non-toxic and hypoallergenic nature. The use of natural dyes in medical textiles can reduce the risk of skin irritation and allergies in patients [130].

8.1.4. Antimicrobial Properties: Some natural dyes extracted from flower crops, such as marigold, have been found to have antimicrobial properties that can prevent the growth of bacteria on textiles. This makes them a promising alternative to synthetic antimicrobial agents, which can be harmful.

8.1.6. Application in Food Packaging: Natural dyes extracted from flower crops, such as safflower, have been investigated for their potential use in food packaging due to their non-toxic and biodegradable nature [131].

8.1.7. Use in Cosmetics: Natural dyes extracted from flower crops, such as hibiscus, are being explored for their potential use in cosmetics due to their vibrant colours and natural origin [132].

8.2. Challenges:

8.2.1. Lack of standardization: There is currently no standardized process for extracting natural dyes from flowers, which can lead to variations in colour and quality. This makes it difficult for manufacturers to produce consistent and reliable products [133].

8.2.2. Cost: Natural dyes extracted from flowers can be expensive compared to synthetic dyes, making them less accessible to consumers. However, as demand for sustainable fashion grows, economies of scale and technological advancements are likely to drive down the cost of natural dyes [134].

8.2.3. Colour Consistency: Another challenge of natural dyes extracted from flower crops is achieving consistent colour. The colour of natural dyes can vary depending on factors such as

plant variety, harvesting time, and processing conditions, which can make it difficult to achieve consistent shades [127].

8.2.4. Limited Availability: The availability of flower crops used for natural dyes can be limited due to factors such as seasonality and climate. This can result in inconsistent supply and potential shortages, which can make it difficult for industries to rely on natural dyes as a consistent source of colour [135].

8.2.5. Environmental Concerns: While natural dyes extracted from flower crops are generally considered more environmentally friendly than synthetic dyes, they can still have environmental impacts. For example, some natural dyeing processes can require large amounts of water and energy, which can contribute to water and air pollution [136].

8.2.6. Colourfastness: Achieving good colourfastness with natural dyes extracted from flower crops can be a challenge, especially in outdoor applications where exposure to sunlight and weathering can cause colour fading [127].

9. Conclusion:

The review of recent advances in natural dyes extracted from flower crops has shown that natural dyes extracted from flowers offer a sustainable alternative to synthetic dyes. Natural dyes have unique properties such as biodegradability, non-toxicity, and good compatibility with natural fibres, making them an attractive option for the textile industry. The use of flower crops as a source of natural dyes has gained attention due to their abundance, availability, and diversity of colours. However, challenges remain in the development of natural dyes, such as the need to improve the stability and fastness properties of the dyes. Despite these challenges, the increasing interest in natural dyes and the development of new extraction methods and technologies hold promise for the future of sustainable textile dyeing.

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