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Review

## Alternatives for Natural Colorants

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	<b>Abstract</b>
Published on: 24 Sep 2025	<p>Natural colourants derived from plant, animal, and mineral sources have gained renewed attention as sustainable alternatives to synthetic dyes and pigments. This review explores the historical context, classification, extraction methods, and applications of natural colourants across food, textile, cosmetic, and pharmaceutical industries. Emphasis is placed on key botanical sources such as turmeric, indigo, saffron, annatto, and beetroot, as well as microbial and insect-derived pigments like cochineal. Recent advancements in stabilization techniques and encapsulation have improved the functional performance of natural dyes, addressing issues such as colour fastness and sensitivity to pH, light, and temperature. Challenges remain in terms of large-scale production, standardization, and regulatory approval. Nevertheless, increasing consumer demand for eco-friendly and non-toxic products is driving innovation and market growth. The review highlights current research gaps and suggests future directions for developing cost-effective, stable, and vibrant natural colourant systems. While natural colourants are valued for their eco-friendliness and low toxicity, they often suffer from limitations such as poor stability, low colour intensity, and limited availability. As a result, alternatives to natural colourants have emerged to meet industrial demands for consistent, vibrant, and stable pigments. This review evaluates current alternatives including synthetic dyes, bioengineered pigments from microorganisms, and nano-encapsulated natural derivatives. Synthetic colourants, although widely used, raise concerns regarding toxicity and environmental impact. Meanwhile, advances in biotechnology have enabled the production of natural-like pigments via microbial fermentation, offering a more sustainable and scalable solution. Encapsulation and stabilization technologies are also improving the performance of natural extracts. The review compares the properties, applications, regulatory status, and environmental profiles of these alternatives, highlighting innovations that balance functionality with safety. Future research is directed toward hybrid approaches that combine natural aesthetics with modern material science to meet consumer and regulatory expectations.</p>
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2025  All rights reserved.  <a href="https://creativecommons.org/licenses/by/4.0/">Creative Commons Attribution 4.0 International License.</a>	<b>Keywords:</b> Synthetic dyes, Natural dyes, Alternatives, Synthetic, Colourants.

## INTRODUCTION

### SYNTHETIC DYES

In the 1770s, indigo and nitric acid combined to create picric acid, the first synthetic colour ever documented. Perkins' synthesis of mauveine (mauve) in the UK in 1856 is regarded as the beginning of the synthetic dye business. The sector grew swiftly, notably in the UK, Germany, and Switzerland. Significant dyes have since been found, including alizarine red (1868) by Grabe and Lieberman, indigo (1870) by von Bayer azo dyes (1880), anthraquinone vat dyes (Bohn, 1901), disperse dyes for cellulose (1922), and Fiber reactive dyes (ICI, 1956). Nowadays, a wide variety of synthetic dyes are available. They are better than natural dyes for almost all applications due to their tinctorial strength, concentration, colour range, and colour fastness, especially to light and detergents. They are reasonably priced and offer additional benefits, such as the ability to colour synthetic Fibers and the potential elimination of the need for mordants. Dye manufacturers and processors must typically adhere to legal restrictions regarding possible health risks, wastewater disposal, and other environmental standards.

### NATURAL DYES

The following lists the plant dye families that are thought to be the most significant (along with examples of pigments and sources). Numerous dyes are frequently found in a single plant species, and some dyes may be found in plant species other than those that are traditionally utilized as sources. It is possible to employ this naturally occurring dye mixture or to isolate a specific dye for usage alone.

The use of natural colour additives in place of artificial ones in food and beverages is growing. This is partially a response to customer worries about the safety of specific artificial food Colouring, as well as safety assessments and industry mandates.

Food colour is a significant sensory quality that frequently influences a product's commercial success. Consumers frequently utilize colour to indicate a number of food product attributes, including Flavor, safety, nutritional value, and more. Food colouring is estimated to have originally been used around 1500 BCE. Many natural pigments are used as food colouring as well as a chemical that promotes health and well-being by preventing or even repairing diseases, in contrast to synthetic colours like tartrazine and Carmoisine that may damage liver function and induce oxidative stress.

### ALTERNATIVES OF NATURAL COLOURANTS TURMERIC



**BIOLOGICAL SOURCE** It made up of both fresh and dried rhizomes from the plant **curcuma longa linn.** Another name for turmeric is Indian saffron.

**FAMILY:** Zingiberaceae.

**COLOUR:** Yellow orange

**CHEMICAL CONSTITUENTS:** Demethoxycurcumin, bisdemethoxycurcumin, and curcumin collectively known as curcuminoids are the primary polyphenolic constituents found in turmeric rhizome.

**USES:** Turmeric powder produces a yellow pigment that can be used as a natural preservative (antioxidant and antibacterial) and to supply study samples, such as soy bean oil and chicken breast fillets, a yellow color with desirable qualities when they are refrigerated at  $4 \pm 1^\circ\text{C}$ . Accordingly, this study suggested that turmeric powder's yellow pigment be used as a natural food colouring and preservative in a variety of products, as well as a substitute for artificial colours that have negative health consequences.

## ALTERNATIVES FOR TURMERIC IN SYNTHETIC



TARTRAZINE belongs to the Coloursraising significant concerns regarding consumer safety at low doses relevant for real-life human exposure. Scientific literature continues to grow after the European Food Safety Authority (EFSA) re-evaluation in 2009 and the Joint FAO/WHO Expert TARTRAZINE:

Tartrazine Committee on Food Additives (JECFA) in 2016. this review aims to collect recent knowledge on the toxicity issues of tartrazine, namely its genotoxicity, cytotoxicity, carcinogenicity, reproductive, developmental, and neurotoxicity, alterations of blood biochemical parameters, and Hematotoxicit

## 2. BEETROOT



### BIOLOGICAL SOURCES

**BOTANICAL NAME:** *Beta Vulgaris L*

**FAMILY:** Amaranthaceae previously placed in Chenopodiaceae

**GEOGRAPHICAL SOURCES:** Beetroot is now widely cultivated in temperate and subtropical climates around the world

**MAJOR PRODUCING COUNTRIES:** Russia, China, France, Germany, Poland, India.

Grown mainly in cooler regions such as:

- Himachal Pradesh
- Ooty [Tamil Nadu]
- Karnataka [Hill areas]
- Maharashtra [Pune, Satara]

**COLOUR:** Deep red to Reddish –Purple

Eco-friendly and non-toxic colorants are in greater demand, particularly for applications that are sensitive to human health, like colouring food and dyeing children's textile and leather clothing. Natural dyes have recently become a significant substitute for potentially hazardous synthetic dyes in many applications, necessitating the development of appropriate and efficient extraction techniques.

It has been investigated how various process parameters, including ultrasonic output power, time, pulse mode, solvent system effect, and beetroot quantity, affect extraction efficiency. The extraction efficiency of colorant derived from beetroot is discovered to be significantly improved by the application of ultrasound.

## USES:

### 1. HERBAL POWDERS AND CAPSULES

- Used to colour herbal powders [e.g., ashwagandha, triphala blends] to enhance the appearance
- often added in herbal capsules and supplements as a natural red-pink tint

### 2. HERBAL TEAS AND INFUSIONS

- Added to herbal tea blends [e.g., hibiscus, rose, Lemongrass] to give a reddish-pink
- Enhances visual appeal and provides mild earthy-sweet flavor

### 3. HERBAL COSMETICS

- Natural lip balms, face packs and cheek stains made with herbs
- Gives a rosy red tint when mixed with herbs like sandalwood, turmeric or aloe vera

## ALTERNATIVE FOR BEETROOT IN SYNTHETIC

Allura Red Food Color



## ALLURA RED AC

An azo dye called Allura Red AC (E129) is frequently found in beverages, juices, baked goods, meat, and confections. Due to the reaction of aromatic azo compounds ( $R = R' = \text{aromatic}$ ), high consumption of Allura Red has been linked to negative health effects in humans, such as allergies, food intolerance, cancer, multiple sclerosis, attention deficit hyperactivity disorder, brain damage, nausea, cardiac disease, and asthma. Naturally occurring compounds or additives isolated from natural sources and synthetic chemicals that were widely employed in the food business many years ago are the two categories into which the additives used in food processing can be separated. The tinctorial strength of natural colour additives is lower than that of synthetic colours due to their greater sensitivity to light, temperature, oxygen, pH, and colour consistency, as well as their low levels of microbiological contamination and comparatively low production cost.

## 3. ANNATO



**BIOLOGICAL SOURCE:** *Bixa Orellana linn*

**FAMILY:** Bixaceae

**GEOGRAPHICAL SOURCE:** Annatto is tropical regions of the americase

- South America
- Africa [Nigeria, Kenya]
- Southeast Asia
- Phillippiness

- India
- Sri Lanka

Annatto and ultrafiltrated annatto powder have been used to color cotton and wool textiles without the use of mordants. Regarding the amount of salt and the pH of the dyebath, the ideal dyeing conditions were identified. By tracking the dye uptake at different dyeing temperatures and time intervals, the dyeing characteristics of annatto and ultrafiltrated annatto were investigated.

**USES:**

- Food industry used to impart yellow to orange-red colour in cheese ,butter ,margarine ,rice ,snacks
- cosmetics Used in lipsticks, soaps , and lotion for colouring

**INDUSTRIAL USES**

- Used in textile dyeing and body paints by indigenous cultures
- Also applied in printing inks and varnishes.

**ALTERNATIVE FOR ANNATTO IN SYNTHETIC**



**SUNSET YELLOW**

A authorized food colour, sunset yellow FCF (SY), is widely employed in many different food preparations and frequently exceeds the allowable limits (100–200 mg/kg). Although SY has been the subject of numerous toxicity research, its immunomodulatory qualities have not yet been investigated. Splenocytes were extracted, cultured, and exposed to immunophenotypic study of the cell surface, mixed lymphocyte reaction (MLR) assay, and mitogen stimulated proliferation assay (lipopolysaccharide, LPS, or concanavalin A, Con A) in order to examine the Immunotoxic qualities of SY.

**4. ANTHOCYANNINE**



**BIOLOGICAL SOURCE:** Brassica Aleracea var

**FAMILY:** Brassicaceae

**GEOGRAPHICAL SOURCE:** Europe, Asia, North America, South America

Many centuries ago, anthocyanins were added to the human diet. Traditionally made from dried leaves, fruits (berries), stored roots, or seeds, they were part of the herbal treatments utilized by Chinese, Europeans, and Native Americans in North America.

In the past, a variety of ailments, including hypertension, pyrexia, liver issues, Diarrhea and vomiting, urinary tract infections and kidney stones, and the common cold, have been treated using anthocyanin-rich mixes and extracts (albeit not pure substances). There have even been claims that they can improve blood circulation and vision.

#### **USES:**

##### **1.FOOD AND BEVERAGE**

Anthocyanins are used as natural food colourants to replace synthetic dyes [like red 40 or blue] offering clean-label and health-conscious alternatives.

**Beverage:** Juices, sports drinks, carbonated drinks, teas

**Dairy Products:** yogurts, ice creams, Flavored milks

**Confectionery:** Gummy, Candies, Jelly, Marshmallows

**Baked goods:** Cakes, frostings filling [used in pH-stable formats]

##### **2. Herbal Teas and Infusions**

Anthocyanin-rich plants like hibiscus are used for their vibrant red colour and tangy Flavor.

Adding purple basil or butterfly pea flower (though this contains anthocyanin-like flavonoids called Ternatins) creates visually appealing brews.

pH-sensitive color change: anthocyanins shift color from red (acidic) to blue/purple (neutral) to green/yellow (alkaline), which can be used in functional teas.

##### **3.Capsules and Powders**

Herbal capsules (e.g., elderberry extract) are often standardized for anthocyanin content.

Dried anthocyanin-rich herbs can be powdered and blended with other herbal powders for added color and antioxidant benefits.

##### **4. Herbal Cosmetics**

Used in natural skin care and hair products derived from herbs, for both color and antioxidant effects.

##### **5.Foods/Herbal Supplements**

Used in natural gummies, lozenges, or syrups alongside herbal extracts.

#### **ALTERNATIVE FOR ANTHOCYANINS IN SYNTHETIC ERYTHROSINE**



The food colouring erythrosine B (ErB) has a polyiodinated xanthene structure and is cherry-pink in colour. Widely used in foods, medications, and cosmetics, it is unique in this family and has been approved by the US Food and Drug Administration (FDA). ErB is allowed to be used, but because of its high iodine concentration, it has been shown to affect thyroid function and affect Behaviour in children.

#### **CONCLUSION**

Natural colorants like annatto, beetroot, turmeric, and anthocyanins provide safe, environmentally beneficial, and health-promoting substitutes for artificial colours. In contrast to artificial colouring agents like tartrazine, Allura red, sunset yellow, and erythrosine, which are frequently linked to long-term health hazards, allergies, and toxicity, natural dyes offer additional functional advantages like antimicrobial, antioxidant, and therapeutic qualities in addition to their colouring effects. Growing consumer awareness and the need for safe, sustainable, and natural products are pushing a trend towards herbal and plant-based pigments, despite the cost, stability, and intensity benefits of synthetic colours. Therefore, in order to develop healthier alternatives to

synthetic dyes in the food, cosmetic, and pharmaceutical industries, it is imperative to investigate, standardize, and enhance the extraction and use of natural colorants.

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