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Phytopigments as Natural Food Colorants: A Comparative Study with Synthetic Additives

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Abstract:

Food coloring is the addition of chemicals to food and drink to improve their look and make them more appealing. Food coloring has become widely used in the food business because it enhances food's visual attractiveness and affects consumers' preferences and appetites. Natural and artificial food colors are the two main categories into which food colors can be divided. Fruits, vegetables, plants, and minerals are examples of natural food coloring sources. Carrots, spinach, turmeric, and beetroot are a few examples. Conversely, artificial food colors are made chemically and are frequently found in processed meals like ice cream, cakes, soft drinks, and candy. Food coloring is the addition of chemicals to food and drink to improve their look and make them more appealing. Food coloring has become widely used in the food business because it enhances food's visual attractiveness and affects consumers' preferences and appetites. Natural and artificial food colors are the two main categories into which food colors can be divided. Fruits, vegetables, plants, and minerals are examples of natural food coloring sources. Carrots, spinach, turmeric, and beetroot are a few examples. Conversely, artificial food colors are made chemically and are frequently found in processed meals like ice cream, cakes, soft drinks, and candy.

Keywords: Food coloring, Natural, Artificial, Carrots, Spinach, Turmeric, Beetroot.



Graphical Abstract: Natural Colour Sources

Introduction:

Food colour is an essential attribute that significantly influences consumer perception, acceptance, and preference for food products. Visual appeal is often the first factor that attracts consumers, and colour plays a vital role in determining the quality, freshness, and taste expectation of food. To enhance or restore the natural appearance of food, various colouring agents are added during processing, preparation, or storage.¹

Historically, natural substances were widely used to impart colour to food. Ingredients such as turmeric, saffron, beetroot, spinach, and other plant-based materials were commonly utilized to achieve vibrant colours. These natural food colourants are derived from fruits, vegetables, flowers, and minerals, and are generally considered safe for consumption. In addition to improving appearance, many natural pigments also offer nutritional and therapeutic benefits due to the presence of bioactive compounds such as antioxidants, vitamins, and phytochemicals. Natural food pigments, also known as phytopigments, include major classes such as chlorophylls (green pigments found in leafy vegetables), carotenoids (yellow to orange pigments found in carrots and mangoes), anthocyanins (red to purple pigments found in berries and beetroot), and betalains (red and yellow pigments found in beetroot). These pigments not only provide colour but also contribute to health by reducing oxidative stress and supporting overall well-being.²⁻³ With the rapid development of the food industry, synthetic or artificial food colourants were introduced to meet the growing demand for visually appealing and long-lasting food products.

Synthetic colours are chemically manufactured and widely used in processed foods such as candies, soft drinks, bakery products, ice creams, and packaged snacks. These colourants are popular due to their bright appearance, uniformity, cost-effectiveness, and high stability under various processing conditions such as heat, light, and pH changes.⁴

However, the use of synthetic food colourants has raised significant health and safety concerns. Several studies have reported that excessive consumption of certain artificial colours may lead to allergic reactions, hyperactivity in children, and other adverse health effects. As a result, regulatory authorities across the world have imposed restrictions and guidelines on the use of synthetic food additives.⁵

- In recent years, there has been a growing consumer preference for natural, safe, and environmentally friendly food ingredients. This shift has increased interest in the use of natural food colourants as alternatives to synthetic dyes. Despite their advantages, natural pigments have certain limitations, including lower stability, sensitivity to environmental conditions, and shorter shelf life compared to synthetic colours.⁶

Among natural sources, beetroot is one of the most widely used materials for obtaining red colour. It contains betalain pigments, particularly betacyanins, which are responsible for its deep red colour. These pigments can be easily extracted by simple methods such as grating and juice extraction, making beetroot an economical and accessible source of natural food colour. The extracted colour can be used in various food products such as sweets, beverages, and desserts, providing a healthier alternative to artificial colourants.⁷

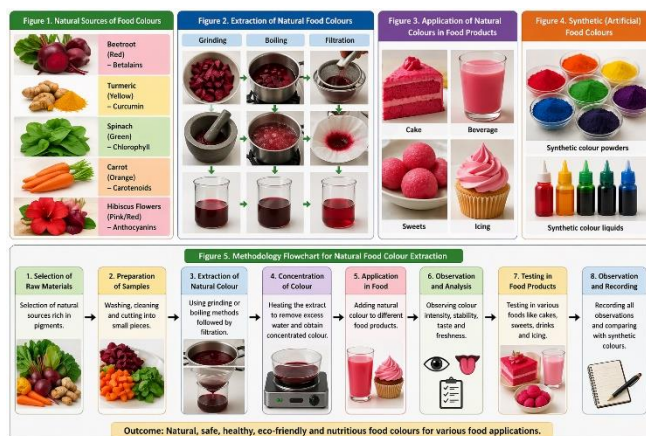
This study focuses on understanding the importance of food colours, exploring different types of natural and synthetic colourants, and evaluating their advantages and disadvantages. It also emphasizes the preparation and application of natural food colour extracted from beetroot as a safe and sustainable option. The increasing demand for clean-label products and health-conscious consumption highlights the need to promote natural food colourants in modern food systems.⁸

Methodology:

The present study was designed to evaluate natural food colourants extracted from plant sources and compare their applicability with synthetic additives. The methodology involves selection, extraction, application, and evaluation of natural pigments.

Materials

Natural sources rich in pigments were selected, including turmeric, beetroot, spinach, carrot, and hibiscus flowers. These materials were chosen due to their availability, safety, and high content of natural colouring compounds such



as curcumin, betalains, chlorophyll, carotenoids, and anthocyanins.

Experimental Procedure

The selected raw materials were thoroughly washed with clean water to remove dust, impurities, and contaminants. After washing, the materials were cut into small pieces to facilitate efficient extraction of pigments. The extraction of colour pigments was carried out using simple and effective methods: **Grinding Method:** The plant materials were crushed using a grinder or mortar and pestle to release the pigment-containing juice. **Boiling Method:** Selected materials were boiled in distilled water to extract colour compounds. The resulting mixture was then filtered using filter paper or a clean muslin cloth to obtain a clear coloured extract. The filtered extracts were subjected to gentle heating to evaporate excess water. This process helped in obtaining a more concentrated form of natural colour, improving its intensity and usability.

The figure presents a detailed and systematic representation of the sources, extraction methods, applications, and comparative aspects of natural and synthetic food colourants. It is organized into multiple sections to illustrate the complete workflow involved in the development and utilization of natural food colours.

The first section (**figure 1**) highlights the **natural sources of food colourants**, including beetroot, turmeric, spinach, carrot, and hibiscus flowers. Each source is associated with specific pigment classes such as betalains (beetroot), curcumin (turmeric), chlorophyll (spinach), carotenoids (carrot), and anthocyanins (hibiscus). These pigments are responsible for producing a wide range of colours from red and yellow to green and orange.

The second section (**figure 2**) illustrates the **extraction process of natural food colours**. It demonstrates commonly employed techniques such as grinding, boiling, and filtration. Grinding helps release intracellular pigments, while boiling enhances pigment extraction through heat treatment. Filtration is subsequently used to obtain a clear coloured extract, free from solid residues.

The third section (**figure 3**) depicts the **application of natural food colourants in various food products**, including cakes, beverages, sweets, and icing. This demonstrates the practical usability of natural pigments in enhancing the visual appeal of food items while maintaining their safety and nutritional value.⁹⁻¹⁰

The fourth section (**figure 4**) provides a representation of **synthetic (artificial) food colourants**, commonly available in powder and liquid forms. These are widely used in the food industry due to their high stability, intense colour, and cost-effectiveness, although they may raise potential health concerns when used excessively.

The final section (**figure 5**) presents a **methodological flowchart** outlining the step-by-step process involved in natural food colour extraction and application. The workflow includes selection of raw materials, sample preparation, extraction of pigments using grinding or boiling methods, concentration of the extract, application in food products, observation and analysis, testing in different food matrices, and systematic recording of results.

Overall, the figure provides a comprehensive visual summary of the study, emphasizing that natural food colourants are safe, eco-friendly, and nutritionally beneficial alternatives to synthetic additives. It also highlights the feasibility of simple extraction methods for obtaining plant-based pigments suitable for food applications.

Literature Review:

The application of food colourants in the food industry has been widely explored due to their significant role in enhancing the visual appeal and consumer acceptability of food products. Colour is considered one of the most influential sensory attributes, as it directly affects perception, taste expectations, and purchasing decisions. According to reports by the Food and Agriculture Organization, food colours are defined as substances added to food to restore or improve colour that may be lost during processing, storage, or handling.¹¹

Scientific studies and regulatory evaluations by the World Health Organization classify food colourants into two main categories: natural and synthetic. Natural food colours are derived from plant and animal sources, including commonly used materials such as beetroot, turmeric, spinach, and other plant-based extracts. These natural pigments are generally regarded as safer for human consumption and environmentally sustainable due to their biodegradable nature.¹²

Research in the field of Food Science indicates that synthetic food colourants are extensively used in processed and packaged foods. Their popularity is mainly due to their high stability, intense colouring properties, uniformity, and cost-effectiveness. Synthetic dyes are widely applied in products such as confectionery, beverages, bakery items, and ready-to-eat foods. However, several studies have raised concerns regarding their safety, suggesting that excessive intake of certain artificial colourants may lead to adverse health effects, including allergic reactions, behavioral changes, and hyperactivity in children.¹³

In recent years, there has been a growing interest in replacing synthetic food colourants with natural alternatives. Researchers are focusing on the extraction and application of phytopigments such as anthocyanins, carotenoids, chlorophyll, and betalains. These natural pigments not only provide colour but also exhibit functional properties such as antioxidant, anti-inflammatory, and health-promoting effects. Advances in extraction techniques and stabilization methods have further supported the potential use of natural food colours in the food industry.¹⁴

Methodology for Extraction and Application of Natural Food Colours

Natural food colourants possess several distinctive characteristics that make them preferable over synthetic additives:

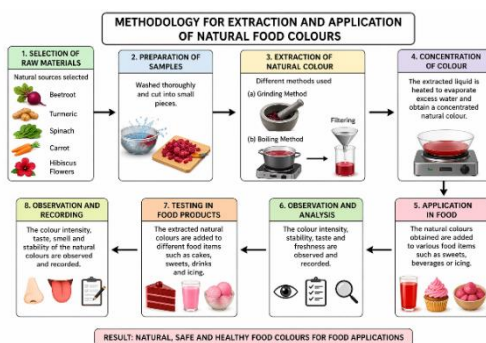


Figure 3.1: Methodology for extraction and application of natural food colours.

The **figure 3.1** illustrates a systematic workflow for the extraction, processing, and application of natural food colourants derived from plant-based sources. The methodology is presented in a sequential manner, highlighting each stage involved in obtaining and evaluating natural pigments for food applications.¹⁵

The process begins with the **selection of raw materials**, where naturally pigmented sources such as beetroot, turmeric, spinach, carrot, and hibiscus flowers are chosen based on their colour intensity and safety for consumption. These materials are rich in bioactive pigments including betalains, curcumin, chlorophyll, carotenoids, and anthocyanins. Following selection, the **preparation of samples** is carried out. The raw materials are thoroughly washed to eliminate impurities and then cut into smaller pieces to facilitate efficient extraction of colour compounds. The next stage involves the **extraction of natural colour**, which is performed using two primary techniques: the grinding method and the boiling method. In the grinding method, plant materials are crushed to release pigment-containing juice, whereas in the boiling method, heat treatment is applied to extract pigments into water. The extracted mixture is subsequently filtered to obtain a clear coloured solution. The filtered extract undergoes **concentration**, where gentle heating is applied to remove excess water and enhance the intensity of the pigment. This results in a more concentrated and usable natural colour solution. The concentrated colour is then utilized in the **application stage**, where it is incorporated into various food products such as sweets, beverages, cakes, and icing to evaluate its colouring efficiency. Subsequently, **observation and analysis** are conducted to assess key parameters including colour intensity, stability under different conditions, taste, and overall freshness of the food products. The methodology further includes **testing in different food matrices**, allowing evaluation of the compatibility and performance of natural colourants in diverse food systems. Finally, **systematic observation and recording** of results are performed, documenting characteristics such as colour strength, sensory attributes, and stability over time.¹⁶⁻¹⁸

Overall, the **figure 3.1** demonstrates a comprehensive and practical approach for the development and evaluation of natural food colourants. The outcome emphasizes the potential of plant-derived pigments as safe, eco-friendly, and health-promoting alternatives to synthetic food colours.¹⁹⁻²⁰

Result and Discussion:

The extracted natural food colourants from beetroot, turmeric, spinach, carrot, and hibiscus were evaluated for their colouring ability, stability, and overall acceptability in food applications. Their performance was compared with synthetic food colourants.

1 Observational Results

Source	Pigment Type	Colour Obtained	Intensity	Stability	Application Suitability
Beetroot	Betalains	Deep Red	High	Moderate	Juices, sweets, desserts
Turmeric	Curcumin	Bright Yellow	High	High	Rice, snacks, curries
Spinach	Chlorophyll	Green	Moderate	Low	Sauces, soups
Carrot	Carotenoids	Orange	Moderate	High	Bakery, beverages
Hibiscus	Anthocyanins	Pink/Red	Moderate	Low	Drinks, syrups
Synthetic Dye	Artificial	Various	Very High	Very High	All processed foods

The study clearly indicates that natural food colourants can effectively replace synthetic additives in many food applications, though with certain limitations.

Colour Intensity:

Synthetic dyes exhibited superior intensity; however, beetroot and turmeric also provided satisfactory colour in food products.

Stability:

Natural pigments such as anthocyanins and chlorophyll showed sensitivity to environmental factors like temperature, light, and pH. In contrast, synthetic colours remained stable under all tested conditions.

Safety and Health Aspects:

Natural colourants were found to be safer due to their plant origin and absence of toxic chemicals. Additionally, they provided health benefits due to the presence of antioxidants and bioactive compounds.

Application in Food Products:

Natural colours performed well in fresh and minimally processed foods. However, their use in industrial-scale processing may require stabilization techniques.

Consumer Preference:

Increasing awareness about health and clean-label products has shifted consumer preference toward natural food colourants.

Comparative Analysis

Parameter	Natural Food Colours	Synthetic Food Colours
Source	Plant-based	Chemical
Safety	High	Moderate
Stability	Low to Moderate	High
Cost	Moderate to High	Low
Nutritional Value	Present	Absent
Environmental Impact	Eco-friendly	Non-biodegradable

Conclusion

The present study demonstrates that natural food colourants derived from plant sources such as beetroot, turmeric, spinach, carrot, and hibiscus can serve as effective alternatives to synthetic food colours. These natural pigments not only enhance the visual appeal of food but also offer additional health benefits due to their nutritional and antioxidant properties. Although synthetic food colours provide superior stability and intensity, their potential health risks make natural colourants a safer option. Among the studied materials, beetroot and turmeric showed the most promising results in terms of colour intensity and applicability. However, limitations such as low stability and shorter shelf life of natural pigments need to be addressed through advanced processing and preservation techniques. Overall, the use of natural food colours aligns with the growing demand for safe, healthy, and eco-friendly food products.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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