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Review Article

Sweeteners and food colorants: Serious concerns in food safety

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Abstract

Food additives, such as sweeteners and food colorants, play an important role in the food supply. However, despite their widespread use in food, there are always concerns regarding their side effects on consumer health, and their excessive use can lead to adverse effects. This study aims to provide a brief overview of the beneficial and harmful effects of sweeteners and food colorants on human health. For this purpose, studies conducted on these food additives from 2001 to 2025 were reviewed. Related articles were collected by using the keywords "food additives, sweeteners, colorants, and health effects." From scientific databases, such as PubMed, Science Direct, Elsevier, and SID. Despite their widespread use in industry, artificial sweeteners and colorants can compromise food safety and lead to side effects such as gastrointestinal disorders, allergies, and even cancer. However, with an increase in consumer awareness, the demand for natural additives has increased. Therefore, dyes and artificial sweeteners should be limited and their natural types should be used instead.

Keywords: Food additives, Natural sweeteners, Natural colorants, Preservatives, Public health.

Introduction

Food additives, which include natural and artificial substances, are complex and have a wide range (Barzegar et al., 2024; Fadaei et al., 2025; Scotter & Castle, 2004). Generally, food additives are intentionally added to food in specific amounts to create special technological and sensory functions during the processing, packaging, and transportation stages of food, such as helping the process, preserving texture or appearance, and improving taste (De Nadra et al., 2007; Martins et al., 2019; Oyegbade et al., 2025; Vilas-Boas et al., 2020). Depending on their function in food, food additives include preservatives, colorants, acidity regulators, antioxidants, stabilizers and emulsifiers, sweeteners, and flavor enhancers. (Harshitha et al., 2024; Vilas-Boas et al., 2020). Thousands of years ago, salt and sugar were used as additives to increase the shelf life of food (WHO, 2018); however, a wide variety of food additives are being increasingly used in the food industry (Wu et al., 2022). On the other hand, with the emergence of modern lifestyles, people's preference has been drawn towards processed foods, so it is estimated that 75% of the contemporary diet consists of industrial foods. In line with this issue, more additives are used in the food industry. Studies have shown that each person may consume an average of 3.6-4.5 kg (or perhaps more) of food additives annually (Linke et al., 2018). In general, approximately 2500 chemicals are used as food additives, producing 5000 commercial products worldwide (Scotter & Castle, 2004).

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Achieving high levels of safety and ease of food supply are impossible without food additives. Moreover, such substances can bring significant sensory pleasure to consumers (Kang et al., 2021). Despite the aforementioned benefits, owing to their extensive use, they can accumulate in various organs in the body and pose potential risks to human health (Kapczuk et al., 2020). Additives, like any other substance, can cause side effects such as carcinogenesis, behavioral changes, and allergic reactions in the body (Linke et al., 2018). Permitted food additives do not cause health problems if used at recommended doses, and side effects may occur in unauthorized consumption or in consuming more than the permitted levels. Unfortunately, the unauthorized and excessive use of additives in the food industry is widespread for different purposes. Therefore, monitoring different foods for the presence of additives, their permissibility in a particular food, and attention to the recommended amount of additives can limit their complications caused by them. The current study, with a brief overview, provides helpful information to consumers and food producers about food sweeteners and colorants.

Literature review method

The present review aimed to review the articles published during the last two decades (2001-2025) on food sweeteners and colorants, as well as their consequences on consumer health, using the keywords food additives, natural sweeteners, artificial sweeteners, natural colorants, artificial colorants, health effects, advantages, and risks by searching the PubMed, Science Direct, Elsevier, SID, Magiran, Google Scholar, and World Health Organization (WHO) databases.

Sweeteners

Sweetness has always been a particular taste for humans, and sugar and sucrose are typically used as general sweeteners in individual diets. Continuous or excessive consumption of refined sugars may result in diabetes, obesity, overweight, and metabolic syndrome (Dutta et al., 2024; Wölnerhanssen et al., 2020). Hence, the application of alternative sweeteners in food has received increasing attention because of the increasing prevalence of sugar-related diseases (Carocho et al., 2017; Chakravartti et al., 2025).

Table 1 shows the acceptable daily intake and common commercial use of some sweeteners. Generally, sweeteners are divided into two groups based on their origin: natural and artificial. These compounds either stimulate sweet taste or increase the perception of sweet taste (Priya et al., 2011; Samreen & Dhaneshwar, 2023). Both sweetener groups (natural and artificial) play a key role in diet and have become highly popular among normal and overweight people, as well as among diabetic patients (Grembecka, 2015). However, artificial sweeteners are more economical than natural sweeteners, and are added to a wide range of foods, beverages, health products, and medicines as common sugar substitutes (Cao et al., 2020; Lin et al., 2019; Weihrauch & Diehl, 2004).

As mentioned above, frequent consumption and consumption of substances above the allowed limit can interfere with the metabolic activities of the human body and physiological responses (Thankachan et al., 2020). The risks due to the incidence of cancer, poisoning, and other health issues related to the consumption exceeding their limits have caused a serious debate about the adverse effects of artificial sweeteners on the industry, health, and human lifestyle (Carocho et al., 2017; Sun & Xu, 2025; Zhang et al., 2024). However, to date, side effects of natural sweetener consumption on human health have not been reported. Therefore, they are considered a more suitable, low-calorie, and almost safe alternative to artificial sugars, and the demand for these compounds has increased significantly (Priya et al., 2011).

Figures 1 and **2** show the chemical structures of artificial and natural sweeteners, respectively. Their sweetening power and physical properties are summarized in **Table 2.** The following is a detailed description of some artificial and natural sweeteners and their effects on human health.

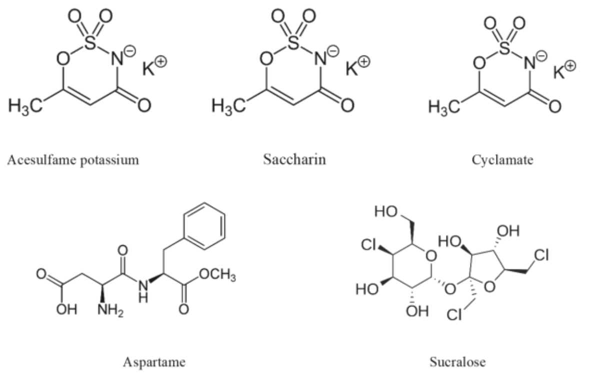

Figure 1: Chemical structure of some artificial sweeteners (Mortensen 2006; Carocho et al. 2017).

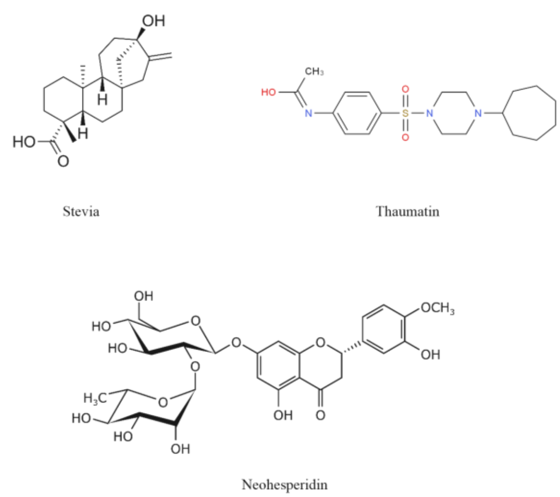

Figure 2: Chemical structure of some natural sweeteners (Garcia-Almeida et al. 2013).

Artificial sweeteners

Acesulfame potassium (E950)

Acesulfame potassium (Acesulfame K) is an artificial sweetener discovered in 1967 and is 200 times sweeter than sugar. Its solubility in water and stability in foods, especially its resistance to heat, make it a suitable sweetener for foods and beverages. Unlike other sweeteners, it does not leave any bitter taste; hence, it is used with other sweeteners such as Aspartame, Cyclamates, and Sucralose to increase and improve taste. Until 2000, researchers believed that this compound could have toxic side effects, but later, such claims were rejected, and many studies have recently described it as harmless. However, its high consumption can lead to increased accumulation of acetoacetamide in the body, a toxic compound, and results in side effects such as cancer and headaches. In addition, a new problem related to acesulfame potassium and other artificial sweeteners is their alarming increase in the environment, which is dependent on excessive consumption by the human population and its disposal in sewage. These compounds are not metabolized in the human body, and large amounts are excreted unchanged in the urine and feces before entering the sewage system. A more critical issue is that the residue is more harmful to the environment than acesulfame potassium, which can be a big challenge for the food industry and the environment. Therefore, researchers have attempted to identify new techniques to inactivate these environmental pollutants (Ali et al., 2021; Carocho et al., 2017; Whitehouse et al., 2008).

Aspartame (E951)

Aspartame, a dipeptide-synthesis sweetener, was accidentally discovered in 1969 and was the first FDA-approved sweetener (Castro-Muñoz et al., 2022; Choudhary & Pretorius, 2017). It is composed of l-aspartic acid and l-phenylalanine methyl ester. Because of its bitter taste, acesulfame potassium is often used. Because of its low-calorie content and intense sweetness, 200-300 times higher than that of sucrose, it has received much attention in the industry. Thus, it is used in food products as a substitute for sugar to prevent diseases such as obesity and diabetes. Owing to its decomposition at high temperatures, it is most commonly used in cold drinks and desserts. Some studies have indicated that overconsumption of aspartame may disrupt the oxidant/antioxidant balance, cause oxidative stress, and destroy cell membrane integrity. It potentially affects cell and tissue types, destroys cellular function, and leads to systemic inflammation (Choudhary and Pretorius, 2017; Griebsch et al., 2023; Jahanbani et al., 2019). Recently, researchers also observed the accumulation of fat droplets through an increase in triacyl glycerides and phospholipids in human neuroblastoma cells (SH-SY5Y Cells) treated with aspartame or its metabolites (Griebsch et al., 2023). However, the effect of this sweetener on the brain metabolism of people who receive it should be evaluated in vivo, and in case of confirming the occurrence of nerve cell dysfunction, decisions about its use as a sugar substitute should be revised (Griebsch et al., 2023). In general, by studying the studies conducted so far, it can be concluded that the safety of this sweetener composition is still controversial.

Cyclamate (E952)

Cyclamate, an artificial sweetener, was discovered in 1937. Three combinations of cyclamate acid, sodium cyclamate, and calcium cyclamate are known cyclamates. Cyclamates have suitable durability and are highly resistant to cold and heat conditions. The high solubility of these sweeteners in water can facilitate their use in foods and beverages. In addition, they can be used as flavor enhancers in many medicines. Cyclamate is 30 times sweeter than sucrose; consequently, it is used with other sweeteners (such as saccharin) in the food and beverage industry (Ali et al., 2021; Mortensen, 2006; Wang & Lin, 2025). This sweetener has very little toxicity, but is more toxic when metabolized to cyclohexylamine in the human body. Therefore, exposure to this sweetener over time can be fatal in humans. Therefore, it was banned by the Food and Drug Administration (FDA) in 1970 but re-evaluated in later years (Ali et al., 2021; Cao et al., 2020). However, scientific studies on cyclamates are still in progress. Studies performed in recent years have concluded that 1) most people cannot metabolize cyclamate, and most of it is absorbed and excreted unchanged in the urine; 2) only the unabsorbed form is available to the intestinal flora for metabolism, and a small amount of cyclamate, which is received per day in the body, is metabolized to cyclohexylamine; 3) using it in the allowable range has no adverse effects (Mortensen, 2006; Renwick et al., 2004).

Saccharin (E954)

Saccharin was one of the first artificial sweeteners to be discovered in 1878. Its sweetening power is 240-300 folds sugar, but due to its bitter and metallic taste, it is combined with cyclamate and aspartame. This sweetener is stable at low pH and high temperature; therefore, it is widely used in foods and beverages. In addition, it is recommended as a sugar substitute to combat overweight and obesity in humans. Some researchers have also recently shown its anti-glycemic benefits in patients with diabetes (Cao et al., 2020; Carocho et al., 2017; Gong et al., 2016). However, some studies have indicated that excessive consumption may contribute to being overweight and increase the risk of premature birth (Englund-Ögge et al., 2012; Pereira, 2014). Although 66-88% of saccharin is excreted in the urine and 10-40% in the feces 24 h after its consumption, the effects of saccharin radioactivity in many tissues, including the heart, liver, pancreas, adrenal gland, thymus, and testicles, remain for 72 h. Such data increases the likelihood that saccharin may have a specific biological function when it enters these tissues (Gong et al., 2016).

Sucralose (E955)

Sucralose, extracted from sucrose by replacing three hydroxyl groups with chlorine atoms, was accidentally discovered in 1976 and is 600 times sweeter than sucrose. Its use in beverages, food products, and medicine has increased because of its high stability to ethanol, heat, and acidic conditions and lack of hydrolysis during digestion (due to the presence of stable carbon-chlorine bonds and hydrophilicity). Other valuable properties of sucralose include no interference with glucose uptake, carbohydrate metabolism, and insulin secretion, making it safe and suitable for diabetic patients. Clinical studies have indicated that sucralose does not cause tooth decay. Owing to its hydrophilic properties and small size, 85% of it passes unchanged through the gastrointestinal tract and only 15% is absorbed. As with other discussed artificial sweeteners, excessive consumption of this sweetener can affect different organs and cause complications such as unusual pimples, migraine headaches and ischemic attack (Magnuson et al., 2017).

Table 1: A list of some artificial and natural sweeteners, with their Acceptable Daily Intake and their commercial uses.

Sweetener	ADI (mg/kg/day)	Commercial uses	References
Acesulfame K	9	Baked products, cereals, sweets, confectionary products, marmalades, canned food and fruit.	(Carocho et al., 2017)
Aspartame	40	Drinks, yogurts, lactic beverages, desserts and baked products.	(Carocho et al., 2014; Jahanbani et al., 2019; Griebsch et al., 2023)
Cyclamates	11	Desserts, baked and processed food, soft drinks, canned fruits and gelatins.	(Carocho et al., 2014; Carocho et al., 2017)
Saccharin	5	Fruit juices, processed fruit, gelatins, marmalades, sauces and desserts.	(Carocho et al., 2014; Carocho et al., 2017)
Sucralose	15	Jams, syrups, breads, dairy desserts, canned vegetables and pasteurized products.	(Rodero et al., 2009; Carocho et al., 2014)
Thaumatin	50	Soups, sauces, processed vegetables and egg derived products.	(Carocho et al., 2017)
Neohesperidin	35	Water-based flavored drinks, milk and derivatives, snacks and confectionary foodstuffs.	(Carocho et al., 2017)
Stevia	4	Ice creams, yogurts, cakes, sauces, drinks and bread.	(Carocho et al., 2017)

Table 2. Sweetness strength (relative sucrose) and physical properties of some sweeteners.

Sweeteners	Sweetness strength (relative sucrose) and physical properties and	References
Acesulfame K	≥200-Folds; solubility in water; Resistance to heat	(Whitehouse et al., 2008)
Aspartame	≥200-300 Fold; decomposition at high temperatures	(Choudhary and Pretorius, 2017)
Cyclamate	>30-Folds; solubility in water; highly resistant to cold/heat	(Mortensen, 2006; Ali et al., 2021)
Saccharin	>240-300 Folds; stable at low pH/ high temperatures	(Gong et al., 2016; Carocho et al., 2017; Cao et al., 2020)
Sucralose	600-Folds; high stability to ethanol, heat, and acidic condition	(Magnuson et al., 2017)
Thaumatin	2000-Folds; water-soluble and heat-resistant	(Carocho et al., 2014; Wölnerhanssen et al., 2020)
Neohesperidin	1500-Folds; high heat resistance; insoluble in cold water, high solubility in hot water	(Borrego and Montijano, 2001; Carocho et al., 2017)
Stevia	300-Folds; high heat resistance (up to 200 ° C); highly stable in acidic/alkaline condition	(Carocho et al., 2014; Grembecka, 2015; Carocho et al., 2017)

Natural sweeteners

Thaumatin (E957)

Thaumatin is a natural sweetener first extracted in 1972 by *Thaumatococcus daniellii*. This sweetener is 2000 times sweeter than sucrose, water-soluble, and heat-resistant, and contains two protein components (thaumatin I and thaumatin II). As thaumatin is a protein compound similar to other proteins, it is digested in the human body and produces approximately 4 kcal of energy. However, because of its high sweetness, it is added to food in small quantities; therefore, it produces few calories and is suitable for patients with diabetes. In addition to sweetening, thaumatin is used as a flavor enhancer. It is noteworthy that in studies conducted on this compound, no toxic effects or allergic reactions have been reported in humans. However, it is not approved as a sweetener in the USA and is only used as a flavor enhancer (Carocho et al., 2014; Wölnerhanssen et al., 2020).

Neohesperidin (E959)

Neohesperidin dihydrochalcone is another natural sweetener that is 1500 times sweeter than glucose. It is extracted from the skin of unripe fruits of *Citrus aurantium L*. More precisely, it is the flavon neohesperidin produced during extraction, which turns into dihydrochalcone after hydrolysis. Neohesperidin has a high heat resistance, and while it is insoluble in cold water, it has a high solubility in hot water. As it does not accumulate in tissues and is excreted quickly, it has been suggested as a non-carcinogenic sweetener (Borrego & Montijano, 2001; Carocho et al., 2017).

Stevia (E960)

Steviol glycosides and stevia are molecules extracted from the leaves of *Stevia rebaudiana Berton.* It is a natural sweetener that is 300 times sweeter than sucrose. Steviol glycosides are stable at high temperatures (up to 200 ° C); thus, they can be used in cooked or heated products. In addition, they are highly stable in acidic and alkaline environments (pH: 2-10), they are suitable for sweetening sour foods. Intestinal bacteria metabolize these molecules and convert them to steviol glucuronides, which are excreted in the urine. According to published data, stevia has anti-inflammatory and diuretic effects, and regulates sugar and blood pressure. Furthermore, no carcinogenicity has been reported for this compound, and it does not hurt reproduction and growth (Carocho et al., 2014, 2017; Grembecka, 2015).

Colorants

Food colorants have been added to food and beverages for a long time, dating back to ancient Egypt (1500 BC) (de Boer, 2014; Oplatowska-Stachowiak & Elliott, 2017). A colorant additive is any color, pigment, or chemical substance that reacts with another substance to create colorant compounds in food, beverages, and hygienic products (Amchova et al., 2015). The purpose of using colors in foods is 1) recovering destroyed colors, 2) enhancing natural colors, 3) coloring colorless substances, 4) identifying products through color, especially drugs, and 5) making foods more attractive to consumers. Food colors are classified into two categories based on their origin: natural and synthetic (Amchova et al., 2015; Heydarzade et al., 2021; Sciuto et al., 2017).

Tables 3 and **4** present lists of artificial and natural colorants, respectively, with their Acceptable Daily Intake, status worldwide, and commercial uses. Natural food colors are derived from different sources, such as vegetables, fruits, insects, and microorganisms, and not from chemical interventions. However, synthetic food colors are produced by chemical processes and commonly contain oils (Bakthavachalu et al., 2020; Sadar et al., 2017). While artificial colors are used more than natural colors because of their high resistance to heat, cheapness, variety, stability, and availability (Khosravi Mashizi et al., 2012), health concerns about the effects of these substances on consumers' health have increased. Most of these concerns arise from the decomposition of these substances in the body and the production of toxic substances. It has been reported that colorants can sometimes have toxic effects on organs such as the liver and kidneys. In addition, the consumption of artificial colors, even at low doses, can cause allergies in some people (Heydarzade et al., 2021; Khosravi Mashizi et al., 2012; Sadar et al., 2017). Today, increasing awareness of the side effects of synthetic compounds has increased the demand for natural food colors, and these natural substances are safe and have many benefits for human health (Habibi Najafi et al., 2018; Okafor et al., 2016).

The chemical structures of artificial and natural colorants are shown in **Figures 3** and **4**, respectively.

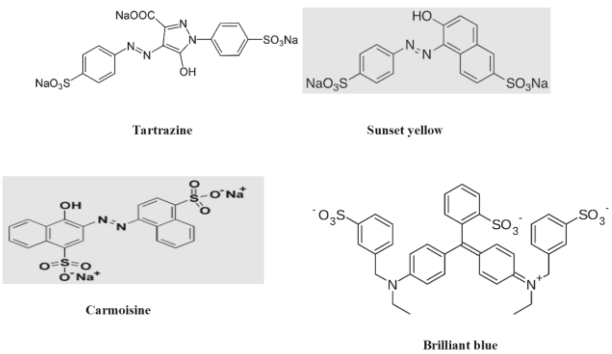

Figure 3: The chemical structure of some artificial colors.

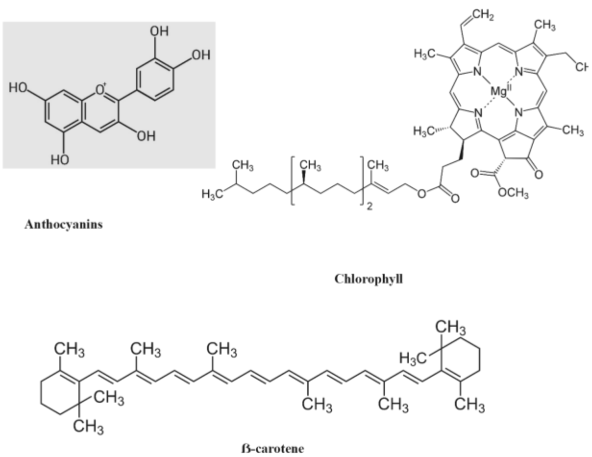

Figure 4: The chemical structure of some natural colors.

Artificial colors

Tartrazine (E102)

Tartrazine is one of the most widely used artificial colors and is extensively used in the food, beverage, and cosmetics industries. It is water-soluble and is composed of coal bitumen. Its color is lemon yellow and it is used as a low-cost substitute for saffron in cooking (Amin & Al-Shehri, 2018; Floriano et al., 2018; Moutinho et al., 2007). Recently, tartrazine consumption has increased in different age groups, especially children, which is why the assessment of the risks caused by tartrazine has received much attention. It is converted into aromatic amines after consumption by the intestinal microbial flora, which can finally be converted into nitrosamines. These compounds release active oxygen free radicals, which are responsible for various disorders, such as allergic reactions, anemia, tumor, cancer, and lesions in the liver, kidney, spleen, and brain. Furthermore, studies have indicated that high consumption of tartrazine in children results in complications such as thyroid cancer, chromosomal damage, asthma attacks, and hyperactivity. In addition, immunological reactions, such as fatigue, migraine, sleep disturbance, and depression, have been observed in different individuals owing to their high use. Therefore, owing to its many side effects on people exposed, its consumption should be limited, especially in sensitive groups (Amin & Al-Shehri, 2018).

Sunset yellow (E110)

Sunset yellow is an artificial azo color, equivalent to the natural color of carminic acid, and is recognized as a food additive by the FAO/WHO Committee in 1982. It is a polar and water-soluble color and forms an orange-yellow color after dissolving in water or acidic solutions and a red-brown color after dissolving in alkaline solutions. Although a large amount of this food coloring is excreted from the human body through urine and feces, its high consumption can pose potential risks to human health. The toxicity of Sunset Yellow may be due to its interaction with healthy cytosolic receptor molecules or the formation of reactive oxygen radicals, such as hydroxyl radicals (OH), superoxide anion (O_2), and hydrogen peroxide (H_2O_2) radicals, which cause complications such as the suppression of the immune system, migraine, asthma, weight loss of the thymus gland, chromosomal abnormalities, reduced percentage of monocytes, cancer, and eczema. Hence, determining this color in food using different methods is highly important for human health and food safety (Rovina et al., 2016, 2017).

Carmoisine (E122)

Carmoisine is a water-soluble artificial red-brown color that is widely used as a disodium salt in food, cosmetics, chemicals, pharmaceuticals, textiles, and paper. This color has an azo group (-N = N-), similar to tartrazine, and a yellow color. Saccharomyces cerevisiae, a part of the intestinal microbial flora, breaks down the azo group and turns it into toxic aromatic amines. Sulfanilic acid, the major metabolite of carmoisine, has potential effects on human health, such as allergic reactions, rashes and skin swelling, and hyperactivity; Furthermore, people with asthma can react severely to it. Studies have indicated that carmoisine changes biochemical markers in vital organs as well as the secondary structure of hemoglobin, even at low doses. In addition, it disrupts the secondary structure of DNA after binding to it, leading to the formation of toxic component (s). Thus, carmoisine can cause potential toxicity during its transfer and metabolism in the human body, which is why the toxicity of synthetic organic carcinogens that enter the bloodstream through food and other devices is concerning in modern times (Alshehrei, 2020; Basu & Kumar, 2014; Reza et al., 2019; Rus et al., 2010).

Brilliant blue (E133)

Brilliant Blue is a water-soluble organic compound known as blue triphenylmethane. Interestingly, when combined with yellow, it can be used as a green color in food and beverages. This color has low oxidative stability, but is highly stable when exposed to heat, light, and acidic conditions. In addition, brilliant blue has low digestive absorption, and the absorbed portion is excreted through the bile and the urinary tract. It is also absorbed by the damaged skin, which is 3600 times less than the accepted daily intake. Individual responses to this color vary not only in terms of age, dose, nutritional status, sex, and genetic factors, but also on long-term exposure to low doses. Studies have indicated that high consumption of this color is associated with skin irritation and bronchoconstriction, especially when combined with other colors, and has a high genotoxic potential due to DNA damage in humans. Recent in vitro studies have indicated the cytotoxic potential of this color in cell cultures of human blood lymphocytes, and a dose-dependent decrease in mitotic frequency was observed (Carocho et al., 2014; Ferreira et al., 2016).

Natural colorants

Anthocyanin (E163)

Anthocyanins, phenolic compounds belonging to the flavonoid family, are one of the main groups of plant compounds. To date, more than 300 anthocyanins with distinctive structures have been identified in nature, causing blue, red, orange, and purple colors in flowers, vegetables, fruits, and some grains (Imran et al., 2025; Mazza, 2007; Yousuf et al., 2016). Anthocyanin-rich extracts are highly effective in the food industry because of their dyeing properties as natural alternatives to artificial colors (Bueno et al., 2012). These colors are nontoxic and water-soluble; thus, they can be easily used in food and beverage systems (Mazza, 2007; Pazmiño-Durán et al., 2001). Interestingly, it has high antioxidant activity in addition to its coloring properties. The ability of anthocyanins to deal with oxidants helps fight atherosclerosis, relax blood vessels, and protect the integrity of endothelial cells that coat the walls of blood vessels. Generally, it helps prevent cardiovascular diseases, neurosis, diabetes, cancer, inflammation, and many other diseases. Additionally, it leads to allergy relief, wound healing, and improved eyesight. Owing to their coloring and therapeutic properties, researchers are always involved in studying the natural potential of anthocyanins (Mazza, 2007; Yousuf et al., 2016).

Chlorophyll (E140)

Chlorophyll, a natural pigment, plays a principal role in the appearance of green color in green plants. This pigment is fat-soluble and has become one of the most popular natural dyes in various fields of science and technology because of its unique properties. It has low toxicity, high antioxidant properties, and prevents chronic diseases, such as cancer, by eliminating free radicals. Chlorophylls are called green blood because of their similarity to the hemoglobin molecules in human blood cells. Many positive effects of this color have been reported in the human body. For instance, it increases smoky movements in the intestines, relieves constipation and inflammation, and reduces excess pepsin secretion associated with gastric ulcers. Furthermore, it removes heavy metals accumulated in the body owing to the consumption of contaminated food. The critical issue about Chlorophyll is highly sensitive to heat, light, oxygen, acids, and enzymes, leading to its rapid degradation and discoloration; hence, its use in the food industry is limited (Ahmadi et al., 2022; Hsiao et al., 2020; Jadhav et al., 2020; Okafor et al., 2016; Özkan & Bilek, 2015; Rajagopal et al., 2016).

Table 3: Specifications of some artificial colorants (Acceptable Daily Intake, status worldwide and their commercial uses)

Colorant	ADI (mg/kg/day)	Status worldwide	Commercial uses	References
Tartrazin	7.5	Banned in Norway and Austria	Candy, ice cream, noodles, shampoos, soaps	(Carocho et al. 2014; Okafor et al. 2016; Amin and Al-Shehri 2018)
Sunset yellow	2.5	Banned in Norway, Sweden and Finland	Jellies, soft drinks, nutritional supplements, pills, ointments	(Moutinho et al. 2007; Carocho et al. 2014; Okafor et al. 2016; Floriano et al. 2018)
Carmoisine	4	Banned in Canada, Japan, Norway, Austria, Sweden	Chocolate, jams, preserves, yogurts, mouthwash	(Carocho et al. 2014; Okafor et al. 2016; Alshehrei 2020)
Brilliant blue	10	Banned in Austria, Belgium, France, Norway, Sweden, Switzerland and Germany.	Cheese, jellies, soft drinks, shampoos, nail polish	(Carocho et al. 2014; Okafor et al. 2016; Reza et al. 2019)

Table 4: Specifications of some natural colorants (nutrients and their sources).

Colorant	Nutrients	Plant sources	Reference
Anthocyanins	Lutein, zeaxanthin, vitamin C, flavonoids, quercetin and ellagic acid	Eggplant, blackberry, purple, cabbage, plum, blueberry, raisins, prunes, purple grapes and figs	(Chaitanya Lakshmi, 2014)
Chlorophyll	Lutein, zeaxanthin, vitamin C, calcium, folate and β-carotene	Avocado, cucumber, spinach, kale, broccoli, artichoke, lettuce and kiwi	(Chaitanya Lakshmi, 2014)
Carotenoids	ß-carotene, zeaxanthin, flavonoids, vitamin C and Potassium	Pineapple, apricot, pumpkin, peach, carrot, orange and corn	(Chaitanya Lakshmi, 2014)

Carotenoids (E160)

Carotenoids are one of the most important natural pigments, with more than 700 compounds. They are fat-soluble pigments that cause red, orange, and yellow to appear and are found in all plants and a few animals. More precisely, the presence of these compounds in animals is due to their diet, as they cannot break down carotenoids. Carotenoids are currently used for various purposes in various industries. For example, owing to their coloring properties, they are mainly used in the food, cosmetics, and animal feed industries (Mezzomo & Ferreira, 2016; Rymbai et al., 2011). They are also used as vitamin supplements because beta-carotene is a precursor of vitamin A. Accordingly, its regular consumption can prevent night blindness through the supply of vitamin A.

On the other hand, carotenoids act as biological antioxidants, protecting cells and tissues from the damaging effects of free radicals and single oxygen, and are a valuable source of antitumor agents (Okafor et al., 2016). Currently, carotenoids used in industries are synthesized chemically because only an insignificant part of them can be obtained by extraction from plants or algae (Mezzomo & Ferreira, 2016).

Summary and perspectives

Sweeteners and colorants are probably the most controversial food additives, because their addition to food is not as necessary as preservatives. Generally, it can be stated that the application of sweeteners is a little more understandable than food colorants for two main reasons: first, food colors have more benefits for the producer than consumers, since it is easier to sell visually appealing foods and, therefore, more profitable; however, artificially sweetened foods have outstanding benefits, such as reduced calorie content or non-cariogenic properties for consumers. Second, avoiding sweeteners is more comfortable because, unlike colorants, they are only found in foods labeled as artificially sweetened, diet, or light products (Bearth et al., 2014).

Conclusion

To the best of our knowledge, due to the emergence of modern life and the increasing desire to consume processed foods in recent decades, the application of additives has been significantly increased in the food industry. Without food additives, maintaining high safety standards and simple production, transportation, and distribution of food are impossible. Sweeteners and colorants are widely used additives in the food industry. Unfortunately, the use of artificial types has been significantly increased because of their low prices, which can cause certain health risks. Therefore, their use should be limited so that the health of consumers is not threatened. Generally, with the increase in people's knowledge of food additives and awareness of the safety and benefits of natural additives, the demand for natural additives is increasing.

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Conflicts of Interest

Authors have no conflict of interest.

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