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Natural and synthetic colours in food. Impact on consumer health.

Koycho Koev[1], Mariya Hristova[2],

[1]*Department of Veterinary Microbiology, Infectious and Parasitic Diseases, Faculty of Veterinary Medicine, Trakia University, Stara Zagora, Bulgaria*

[2]*Risk Assessment Center on Food Chain, Sofia*

Corresponding author: MVHristova@mzh.government.bg

Summary

The colour of food is one of the leading organoleptic characteristics. It is one of the determining factors in the choice of food by consumers. The addition of colours to food is intended both at preserving the natural colour, which is lost in processing, and to restore uniformity of colour in the product. The addition of colours to food is permitted in the European Union (EU), but only with approved food colours. Legislation in this area regulates food additives, including colours, their use and the permitted amount of their incorporation into food. Food colours can be natural (derived from plants or animals) and artificial/synthetic (obtained artificially). The use of synthetic colours is associated with a number of adverse effects for the consumer's health, but no harm for the corresponding colour has been fully proven yet. Very often in production artificial colours are preferred, due to their lower cost in comparison to natural ones, as well as their light resistance. In order to understand more about food additives and in particular colours, this review provides information found in scientific literature on food colours permitted at European level, their use and side effects on human health.

Key words – *food colours, consumer health, safety*

Introduction

Colours, both in the environment and in food, are an important characteristic that very often determines the choice of food. For example, children often choose their food by colour. The brighter the colour, the more attractive and tasty it will be. The natural colour of food is often lost in the processing, and this requires colour to be added to restore the basic appearance or to add colour to colourless food. For example, when choosing a pink food, the consumer expects it to be sweet, as the pink colour in food is often associated with strawberries. And if we could do an experiment to choose food with the same content and nutritional value, but of a different colour, we would see that the choice is likely to be towards the brighter colour, as consumers often choose the product that is more appealing in appearance.

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Food colours are additives that are allowed for use in food, after authorization by the European Commission and their entry in the relevant legislation, as an authorized food additive. Any additive authorized for use in food has received approval after safety testing. Allowed food colours are naturally derived from plants, animals or ores, whereas synthetic are artificially developed and cannot be found in nature. For some synthetic food colours, there are studies that have reported adverse health effects, such as attention deficit and hyperactivity in children, allergies, and even carcinogenic properties. Colours are used in the production of various desserts, bakery products, decorations, sauces, confectionery, soft drinks and alcoholic beverages and more.

Materials and methods

The aim of the present analysis is to identify and characterize the natural and synthetic colours used in food production and how they affect consumer health. The analysis covers an overview of the available scientific literature as well as European legislation regarding the approval of the use of food colours.

Results

1. Approval of food colours and evaluation of their safety

A single food market could not exist without harmonized rules for the authorization and conditions of use of food additives. The criteria by which food additives, including colours, are evaluated and approved for use are defined in Regulation (EC) № 1333/2008 of the European Parliament and of the Council of December 16, 2008 on food additives. In according to Regulation (EC) № 1333/2008, a food additive may be included in a functional class „ colours " in the Community list in Annex II to the Regulation, if used for any of the following purposes:

- restoring the original appearance of food, the colour of which has been affected during processing, storage, packaging and distribution, thus disrupting the good appearance;
- giving a more attractive look to food;
- colouring of otherwise colourless food.

Any food colour authorized for use in the EU shall be subject to a rigorous scientific safety assessment by the European Food Safety Authority (EFSA). The EFSA Expert Scientific Panel which deals with food additives (ANS Panel) state that the safety assessment involves a review of all available, relevant scientific studies as well as data on toxicity and exposure of human, from which conclusions are drawn regarding the safety of the substance. The authorization procedure starts with an application to the European Commission (EC), consisting of a dossier containing scientific data on the substance and its proposed uses and levels of use. The EC then sends the dossier to EFSA and requires it to assess the safety of the substance for its use. The European Commission decides whether to authorize the substance on the basis of the EFSA safety assessment. As part of the safety assessment of food additives, EFSA shall establish, where there is sufficient information, an acceptable daily intake (ADI) for each substance. ADI is the amount of substance that people can consume every day throughout their lives without a significant health

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risk. It is derived by considering the highest level of intake, at which substances do not cause adverse effects in animal experiments and a safety factor (usually 100) is applied, to take into account differences between humans and animals. This means that even if people exceed ADI for a particular substance, the substance does not necessarily cause adverse health effects (ANS Panel).

Once authorised, these substances are included in the EU list of authorized food additives established in Regulation (EC) 1333/2008, which also lays down the conditions for their use. Each food additive after a marketing authorization is granted an individual E number. The name or E number of the additive must be indicated on the food label.

2. Types of food colours

2.1. Natural colours in food

Colours are substances that change the perceived colour of objects or give colour to colourless objects. The term "natural" is associated with not altered/unchanged, not created by human, but produced by nature. A natural colour is a substance that is produced from a plant, animal or mineral (Mohamad et al., 2019). The colours do not add any nutritional value to the foods. They are frequently added to restore colours that are lost during food processing. Natural colours added to food can be extracted from seeds, flowers and insects. Bixin is a natural colour extracted from the orange-red pulp of the seeds of the *Bixa Orellana* plant. It is mainly used as an annatto dye in butter, cheese, margarine and other foods. Other natural colours are carotene derived from carrot, and saffron, which has both flavouring and colouring properties. Turmeric, known as a spice, is a natural colour for meat products, curries and salad dressings. Cochineal or carmine is a colour that is obtained from the *Coccus cacti* insect and is used to produce red colour. Other examples are grape shell extract, caramel, etc. They are all designed to give certain foods a colour that people associate with a particular flavour (egg red for cherry, green for lime) (Inetianbor *et al.*, 2015)

Table 1: *Natural colours in food*

Curcumin (E 100)	*Lycopene (E 160d)*
Riboflavins (E 101)	*Beta-apo-8'-carotenal (E 160e)*
Carminic acid, Carmine (E 120)	*Lutein (E 161b)*
Chlorophylls and chlorophyllins (E 140)	*Canthaxanthin (E 161g)*
Copper complexes of chlorophylls, chlorophyllins (E 141)	*Beetroot Red, betanin (E 162)*
Caramels (E 150a, E 150b, E 150c E 150d)	*Anthocyanins (E 163)*
Vegetable carbon(E 153)	*Calcium carbonate (E 170)*
Carotenes (E l60a)	*Iron oxides and hydroxides (E 172)*
Annatto bixin E 160b(i)	*Aluminium (E 173)*
Annatto norbixin E 160b(ii)	*Silver (E 174)*
Paprika extract, capsanthin, capsorubin (E 160c)	*Gold (E 175)*

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Natural food colours used in the food industry are a wide range. Some of the most commonly used are carotenoids, anthocyanin's, betalains and chlorophylls.

2.1.1. Carotenoids

Carotenoids are widely distributed in nature. They can be red, pink, orange or yellow colour (Mohamad *et al*., 2019). Compared to animals, which can absorb carotenoids into their tissues, plants synthesize them. Plant sources include squash, carrots, spinach, broccoli, sweet potatoes, papaya and apricots. Carotenoids are grouped into carotenes and xanthophylls. Carotenites contain only carbon and hydrogen in their structure, while xanthophylls present carbon, hydrogen and oxygen. The difference between both groups is in their molecular structure as well as their functionality. According to their functionality, they are divided into primary (β-carotene, lutein and zeaxanthin) and secondary carotenoids (α-carotene, lycopene and astaxanthin) (Bocker & Silva, 2022). Along with the technological properties they provide to food carotenoids that are also thought to have positive health properties. For example, lycopene, which is a red pigment found in red fruits, has antioxidant properties. Vitamin A is required for many metabolic processes in the human body, such as immunity, growth development and vision. Lutein and zeaxanthin provide ocular benefits (Luzardo-Ocampo *et al*., 2021). Fucoxanthins are carotenoids found in marine algae. (Mohamad *et al*., 2019). They are believed to have various positive properties, such as photoprotective, anti-inflammatory, neuroprotective, antioxidant, etc. Carotenoids are mainly used in meat products, vegetable oils and butter (Luzardo-Ocampo *et al*., 2021). Sources of carotenoids are green leaves with an approximate content of β-carotene (~25-30%), lutein (~45%), violaxanthin (~15%), neoxanthin (~15%) and a small amount of α-carotene. α- and β-cryptoxanthin, zeaxanthin and antheraxanthin (Mohamad *et al*., 2019). Carotenoids have high pH stability and heat stability, but are sensitive to oxygen and light (Bocker & Silva, 2022). They are insoluble in water and instable , which is a challenge for their use (Luzardo-Ocampo *et al*., 2021).

2.1.2. Anthocyanins

Anthocyanins are group of pigments used in the food as natural colours with red, violet, and blue colour (Bocker & Silva, 2022). Anthocyanin comes from Greek word *anthos*, a flower and *kyanos*, dark blue. The structure of anthocyanins is based on the following anthocyanidins: pelargodin (plg), cyanidin (cyd), delphinidin (dpd), peonidin (pnd), petunidin (ptd) and malvidin (mvd) (Mohamad *et al*., 2019). Depending on the pH value, the anthocyanin molecule has a different colour. For example, a red colour predominates at pH 1 to 2, blue colour from pH 2 to 4, colourless at pH values from 4 to 6, pale yellow at values above 6. (Luzardo-Ocampo *et al*., 2021). The stability of anthocyanin molecules is affected by light, temperature, oxygen, presence of solvents, etc. Their instability can alter the sensory characteristics of the food. Thereby, anthocyanins have limited use as food colourant (Bocker & Silva, 2022). Anthocyanins are natural food colours used in foods, such as beverages, desserts, ice cream, and dairy products. They are believed to have antioxidant and anti-inflammatory properties (Luzardo-Ocampo *et al*., 2021).

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2.1.3. Betalains

Betalains are water-soluble pigments, such as red violet betacyanins and yellow betaxanthins. (Luzardo-Ocampo *et al.*, 2021). They are found in various plant parts and they are accumulated in cell vacuoles, for example in the underground parts of red beets (Mohamad *et al.*, 2019). Betalains are highly sensitive to light and high temperature, but they have higher water solubility, increased colouring potential and better pH-stability compared to anthocyanins. Betalains are used in confectionery , ice cream, yogurt, ready-to-use frostings, cake mixes, and beverages, etc. (Luzardo-Ocampo *et al.*, 2021).

2.1.4. Chlorophylls

Chlorophylls are pigments in green fruits and vegetables. Depending on the high temperature, oxygen availability and pH changes, they have different derivatives, such as chlorophyllides, pheophytins, etc. (Luzardo-Ocampo *et al.*, 2021). Chlorophyll is sensitive to pH variations and heat (Bocker & Silva, 2022). They are believed to have antioxidant, antimutagenic and anticarcinogenic activities. One of the most used chlorophyll sources is the *Spirulina* extract for used to desserts, beverage, yogurts, puddings, etc. (Luzardo-Ocampo *et al.*, 2021).

3. Synthetic colours in food

Very often, to achieve high colour intensity, more stable and uniform colour, synthetic colours are used in food. They have some advantages for use in food, such as light and pH stability, at the same time with low cost. These properties often make them preferred in food production. Most of the synthetic colours contain an azo group (Dey & Nagababu, 2022).

Table 2: Synthetic colours in food

Tartrazine (E 102)	*Patent blue V (E 131)*
Quinoline yellow (E 104)	*Indigotine, indigo carmine (E 132)*
Sunset Yellow FCF/Yellow-Orange S (E 110)	*Brilliant Blue FCF (E 133)*
Azorubin, carmoisine (E 122)	*Green S (E 142)*
Amaranth (E 123)	*Brilliant Black PN (E 151)*
Ponceau 4R, cochineal red A (E 124)	*Brown HT (E 155)*
Erythrosine (E 127)	*Litolrubin VK (E 180)*
Allura Red AC (E 129)	

In food production, during processing and storage, foods tend to lose their natural colours and require the addition of colour, which is seen as a technological necessity.

Tartrazine is a synthetic lemon-yellow food colour containing an azo group. It is used together with blue colours to produce a green colour in food. Tartrazine is used in food products, such as confectionery, bakery products, soft drinks, etc. Tartrazin has been reported to cause allergic reactions, likelihood hyperactivity in children, and carcinogenic effects in rats that are

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practically unproven. (Silva *et al*., 2022). Tartrazine is evaluated by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) in 1966 and the EU Scientific Committee on Food (SCF) in 1975 and 1984. Both committees established an acceptable daily intake (ADI) of 0-7.5 mg/kg body weight/day. The European Food Safety Authority re-evaluated Tartrazine and found that at the maximum reported levels of use, intake estimates were below the ADI. It concluded that Tartrazine may cause intolerance reactions in a small fraction of the exposed population and that sensitive individuals may react to Tartrazine at dose levels within the ADI (ANS Panel, 2009).

Quinoline Yellow is another colour used in a number of foods, such as confectionery and bakery products, beverages, condiments, desserts, ice cream, etc. No adverse effects such as toxicity, genotoxicity and carcinogenicity have been reported for it (Silva et al., 2022).

Sunset Yellow FCF is a yellow-orange food colorant soluble in water and ethanol. It is used in flavoured beverages, condiments, confectionery, chewing gum, marmalades, jams, desserts, etc. Various adverse effects have been reported for the use of Sunset Yellow FCF, such as allergic reactions in humans with an intolerance to acetylsalicylic acid, effects on the lipid profile of rats, growth retardation and weight loss (Silva et al., 2022). In 2009, the EFSA performed a safety assessment of Sunset Yellow FCF and established a provisional acceptable daily intake (ADI) of 1 mg/kg bw/day. The ANS panel was asked to evaluate newly submitted data from studies reporting adverse effects and to perform exposure assessment of Sunset Yellow FCF. Exposure estimates are well below the new ADI of 4 mg/kg bw/day for all population groups. The ANS panel concluded that using data provided by the food industry and Member States, the reported uses and levels of use of Sunset Yellow FCF (E 110) would not be a safety concern (ANS Panel, 2014).

Ponceau 4R - red synthetic food colour, soluble in water and sparingly soluble in ethanol. It is used in foods such as desserts, jams and marmalades, confectionery, condiments, sauces, alcoholic beverages, etc. At the permissible levels for use, there is no evidence of carcinogenicity, genotoxicity, neurotoxicity or reproductive toxicity. With surpassing this limit, allergic reactions are possible, especially in persons showing intolerance to acetylsalicylic acid (Silva et al., 2022).

Erythrosine - red synthetic food colour, soluble in water and slightly soluble in ethanol. It has limited use in foods, such as cocktail cherries, syrups, etc. The use of this colour is associated with allergic reactions. Studies with erythrosine report that only a small portion of erythrosine is absorbed and it is excreted almost entirely in the faeces. Some *in vitro* studies have shown positive genotoxicity results, but there are also negative *in vivo* genotoxicity studies (Silva et al., 2022).

Allura Red is also a red synthetic food colour used in desserts, bakery products, sauces, alcoholic beverages, etc. It is also reported to have an allergenic effect (Silva et al., 2022).

Azorubin (carmoisine) gives red colour to foods. It is soluble in water and slightly soluble in ethanol. It is used in foods such as confectionery, fine bakery products, condiments, seafood, appetizers and alcoholic beverages, etc. There is no evidence of adverse effects in terms of mutagenicity and carcinogenicity, but skin and respiratory allergic reactions are likely (Silva et al., 2022).

The most alarming data reported on adverse effects of artificial colours are in terms of their carcinogenicity. The evidence for these claims is still weak. Based on currently available research,

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consumption of food colours is unlikely to have carcinogenic effects. Another worrying link being made with synthetic colours is that they may have an effect on activity and attention in certain groups of children. There is no complete evidence for such a relationship, therefore research in this area needs to continue (Dey & Nagababu, 2022).

Discussion

The search for new natural colours in food industry is increasing with the technological progress. Given consumer's greater awareness of the health benefits of natural colours, as well as the perception that natural is safer, the demand for natural colours continues today. Anthocyanins, carotenoids and chlorophyll are natural colorants that can be found in the daily menu of people, as they occur in nature in fruits, vegetables and other foods (Mohamad et al., 2019). More research is needed on natural colours to understand better their composition, how to maintain their colour stability in foods under different conditions, such as temperature and pH (Luzardo-Ocampo et al., 2021). Dey & Nagababu, 2022 reviewed the adverse effects of food colouring in humans in their study. Most of the food colours tested conventionally in toxicity experiments show toxic effects at very high levels of intake, but reported illnesses are often due to the consumption of unauthorized textile colours. Dey & Nagababu's study mentioned hyperactivity in sensitive children. A large percentage of children with attention deficit hyperactivity disorder (ADHD) showed a reduction in symptoms when artificial colours and preservatives were removed from the menu. Another study they reviewed reported that food colour and sodium benzoate increased hyperactivity in groups of 3-year-old and 8/9-year-old children. The cause of their hyperactivity cannot be proven because the children ingested a mixture of ingredients and it is debatable which of them is causing the hyperactivity. Tartrazine is thought to cause behavioural changes in children, such as irritability, anxiety, depression, and difficulty sleeping but not all children's behaviour is the same after ingestion (Dey & Nagababu, 2022).

EFSA's expert (ANS Panel) reports that in 2007, the UK's Food Standards Agency (FSA) commissioned a study by researchers at the University of Southampton which showed that some mixtures of six azo dyes [Tartrazine (E102), Quinoline Yellow (E104), Sunset Yellow FCF (E110), Ponceau 4R (E124), Allura red (E129), Carmosin (E122)], and the preservative sodium benzoate (E211), may have a small effect on activity and attention in certain groups of children. They evaluated the so-called "Southampton study" in 2008 and concluded that the findings could not be used as a basis for changing the ADI for the individual additives. One reason for this is that the study evaluated mixtures rather than individual additives – therefore it is not possible to attribute the effects to any of the individual substances (ANS Panel).

Other studies, reviewed by Dey & Nagababu, reported that Tartrazine caused urticaria and asthma symptoms. Most allergic reactions are not life-threatening, but in case of allergy symptoms, it is advisable not to take oral synthetic dyes. The most commonly consumed and prone to causing an allergic response colorants are Tartrazine, Allura Red and Sunset Yellow (Dey & Nagababu, 2022).

Conclusions

People's eating habits and the ever-expanding variety of foods increase the technological progress in the food industry. Given the demand for natural foods or food ingredients, as well as the consumer's trust in them for wholesomeness and safety, the food sector is looking for natural sources of colours that could replace artificial ones. However, challenges for natural colours need to be overcome as they are affected by environmental conditions such as temperature, pH, light, etc. To address these limitations, new colour sources with properties capable of overcoming the challenges in production are sought. Given the reported adverse effects in some studies regarding artificial colours, individuals prone to allergic reactions and hyperactivity should avoid the consumption of products with colouring agents reported to be associated with adverse effects.

References

[1] European Food Safety Authority. EFSA Panel on Food Additives and Nutrient Sources added to Food (ANS). Food colours. https://www.efsa.europa.eu/en/topics/topic/food-colours

[2] European Food Safety Authority (EFSA). EFSA Panel on Food Additives and Nutrient Sources added to Food (ANS). Reconsideration of the temporary ADI and refined exposure assessment for Sunset Yellow FCF (E 110). EFSA Journal 2014;12(7):3765

[3] European Food Safety Authority (EFSA). EFSA Panel on Food Additives and Nutrient Sources added to Food (ANS). Scientific Opinion on the re-evaluation Tartrazine (E 102). EFSA Journal 2009; 7(11):1331

[4] Inetianbor, J. E., Yakubu, J. M. and Ezeonu, S. C. Effects of food additives and preservatives on man – a review. Asian Journal of Science and Technology. 2015, Vol. 6, Issue 02, pp. 1118-1135.

[5] Luzardo-Ocampo, I.; Ramírez-Jiménez, A.K.; Yañez, J.; Mojica, L.; Luna-Vital, D.A. 2021.Technological Applications of Natural Colorants in Food Systems: A Review. Foods., Vol. 10, Issue 634. **doi.org/10.3390/foods10030634**

[6] Maria Manuela Silva, Fernando Henrique Reboredo and Fernando Cebola Lidon. Food colour additives: A synoptical overview on their chemical properties, applications in food products, and health side effects. Foods. 2022, Vol. 11, Issue 379. **https://doi.org/10.3390/foods11030379**

[7] Mohamad M., Dailin D.,Gomaa S., Nurjayadi M., Enshasy H. Natural Colorant for Food: A Healthy Alternative. International Journal of Scientific & Technology research. 2019, Vol. 8, Issue 11

[8] Ramon Bocker and Eric Keven Silva. Pulsed electric field assisted extraction of natural food pigments and colorings from plant matrices. Food Chemistry: X. 2022, Vol. 15, Issue 100398. Regulation (EC) No 1333/2008 of the European parliament and of the Council of 16 December 2008 on food additives (*OJ L 354, 31.12.2008, p. 16–33)*

[9] Subhashish Dey, Bommu Hema Nagababu. Applications of food color and bio-preservatives in the food and its effect on the human health. Food Chemistry Advances. 2022, Vol. 1, Issue 100019