POTENTIAL HARMFUL EFFECTS OF ARTIFICIAL FOOD COLORS ON CHILDREN'S HEALTH - REVIEW OF LITERATURE

Tanja Marković[1*], Benjamin Muhamedbegović[2], Drago Šubarić[3], Đurđica Ačkar[3]

[1]Teaching Institute of Public Health Osijek-Baranja County, Franje Krežme 1, 31000 Osijek, Croatia
[2]University of Tuzla, Faculty of Technology, Univerzitetska 8, Tuzla, Bosnia and Herzegovina
[3]Josip Juraj Strossmayer of Osijek, Faculty of Food Technology Osijek, Franje Kuhača 18, 31000 Osijek, Croatia

review paper

Summary

The choice of food by modern consumers is highly affected by its visual appearance, with color as a key constituent making it more attractive to consumers. The emergence of food technology has brought about a wide range of artificial food colors and the possibilities of their use. Colors are additives used to provide or enhance characteristic colors in food products. They are routinely added to foods and beverages to improve their appearance, compensate color loss during processing, and give color to otherwise colorless food products. Food additives marked with E-numbers, the use of which is approved in the European Union, are also allowed in Croatia according to the national legislation, with defined maximum permitted amounts of certain colors in foodstuffs. Artificial food colorings have been the subject of controversy for many years and have been scrutinized for possible links to cancer, allergies, and hyperactivity. The negative impact on children's attention and activity is most often mentioned. The aim of this review is to give an overview of current knowledge on the toxicity issues and possible detrimental effects of food colorants on children's health.

Keywords: additives, artificial colors, children, health, negative impacts

ABBREVIATIONS:
WHO – World Health Organization
FDA – Food and Drug Administration
EFSA - The European Food Safety Agency
NOAEL - No Observed Adverse Effect Level
ADI - acceptable daily intake
AFC – artificial food colors
NHANES - National Health and Nutrition Examination Survey
ADHD - attention deficit/hyperactivity disorder

Introduction

Food scientists and producers know that, alongside flavor and texture, color plays a crucial role in taste and food perception (Burrows, 2009). The visual aspect is one of the main decision factors for food consumers. In this context, food colors are added to increase the visual attractiveness or to compensate for natural color variations in food (Oplatowska-Stachowiak and Elliott, 2017). Historically, ancient Egyptians added colorants to wine and confectionaries (Oplatowska-Stachowiak and Elliot, 2017). Food coloring could only be obtained from natural sources (saffron, pepper, turmeric, beet extract, and various flowers) (Sigurdson et al., 2017). For example, wheat starch, egg whites, or crushed almonds were used for white, one of the world's most expensive spices, saffron was used as a yellow or golden colorant, and mint, spinach, and parsley for green (Spence, 2022). In the 17th and 18th centuries, tea was colored with copper carbonate, and whiteness of a bread was enhanced with chalk (Sharma et al., 2011). The first synthetic color was developed by William Henry Perkin in 1856 while working with anillines (petroleum products). It was a purple pigment called „mauveine" (Mota et al., 2021), which led to synthesis of thousands of new coloring compounds for industrial applications (Oplatowska-Stachowiak and Elliott, 2017).
Food coloring can be artificial, created in the same way as natural coloring, or naturally derived. Natural colors are extracted from natural sources by more or less complicated processes. They have many positive features, such as reliability, functionality, biological potential, and health benefits, but they also have certain drawbacks, including sensitivity toward other food ingredients or in the presence of scents or odors, as well as instability in water, light and/or heat (Silva et al., 2022).
In contrast to natural colors that are extracted from natural sources, artificial colors are produced by the chemical synthesis or modification of several

*Corresponding author: tanja.markovic@zzjzosijek.hr

precursors (König, 2015). Nowadays, the food industry prefers artificial colors for their ease of production, low cost, high stability, and better coloring properties (Oplatowska-Stachowiak and Elliott, 2017). Additionally, they give the product a strong color without adding any unwelcome flavors (Barciela et al., 2023).

Foods on the market may contain excessive amounts of artificial colors. They have been linked to health issues including allergenicity, behavioral issues such as childhood hyperactivity syndrome, neurotoxicity, genotoxicity, and carcinogenicity, and are a major cause of food intoxication, according to a number of studies (Dey and Nagabubu, 2022; Corradini, 2019).

Since many synthetic compounds have been shown to be toxic and harmful to humans, the use of colors as food additives in the developed world is strictly controlled by legislation, which varies from country to country (Oplatowska-Stachowiak and Elliott, 2017). The European Food Safety Agency (EFSA) of the European Union (EU) and the Food and Drug Administration (FDA) of the United States of America are the two primary regulatory bodies in the world for food additives. These institutions carry out safety regulations, review scientific data, assess potential toxicity, and estimate human dietary exposure to food additives. Beyond just naming them, the EFSA gives each food additive a special identification code made up of the letter "E" and a number. Colorants range from E100 (Curcumin) to E180 (Litholrubine BK). Artificial food colors are restricted by Regulation (EC) 1333/2008. Only those colors listed in Annex II (European Commission, 2011) are authorized for foods. A list of the currently authorized artificial food colors is shown in Table 1.

Table 1. Artificial food colours authorized in the EU according to Regulation (EC) 1333/2008

ARTIFICIAL FOOD COLORS	
E-NUMBER	**NAME**
E 102	Tartrazine*
E 104	Quinoline Yellow
E 110	Sunset Yellow FCF/Orange Yellow S
E 122	Azorubine, Carmoisine*
E 123	Amaranth*
E 124	Ponceau 4R, Cochineal Red A*
E 127	Erythrosine
E 129	Allura Red AC*
E 131	Patent Blue V
E 133	Brilliant Blue FCF
E 142	Green S
E 151	Brilliant Blac BN, Black PN*
E 154	Brown FK*
E 155	Brown HT*
E 160e	Beta-apo-8'-carotenal (C30)
E 180	Litholrubin BK*

*azo-color

Since all chemicals have the potential to be harmful, the minimal exposure level at which adverse health consequences might manifest is estimated to establish the quantities that should be utilized in meals. This limit, known as the No Observed Adverse Effect Level (NOAEL), is mostly established through research conducted on animals. In order to account for interspecies differences between test animals and humans and intraspecies variability among humans, sensitive populations are taken into consideration when safety factors are added to the NOAEL. This results in the chemical's acceptable daily intake (ADI) value. The ADI is defined as ‘the amount of a substance that people can consume on a daily basis during their whole life without any appreciable risk to health”. ADIs are usually expressed in mg per kg of body weight per day (mg/kg body weight/day), (Martyn et al., 2013).

The level of exposure and individual sensitivity have direct influence in assessing toxic potential od substances, including additives. Since the acceptable daily intake (ADI) is calculated per kilogram of weight, children may be more sensitive to additive toxicity.

Compared to adults, children consume more food, drink more water, and breathe more air per unit of body weight. Additionally, since children may live longer than adults in the future, they have more time to develop chronic diseases brought on by early exposure to environmental toxins like food additives (Kraemer et al., 2022).

Methods

A review of the literature was carried out between June and September 2023, with a bibliographic search in the databases ScienceDirect, PubMed, and Google Scholar. Official documents and studies published since 2000 were selected (Figures 1 and 2). Keywords related to food additives, children, artificial colors, and health effects were used for the search.

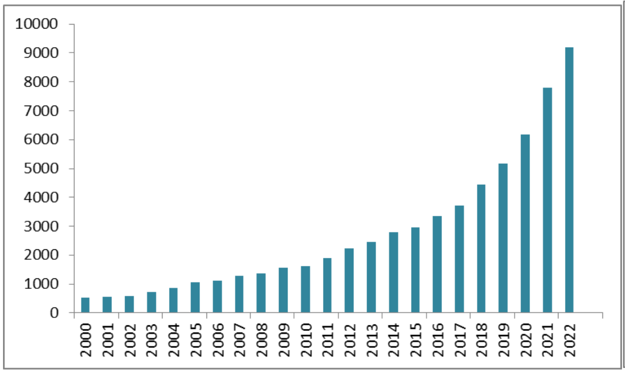

Figure 1. Dynamics of publication (2000 – 2022) of searches for food colors and health relationships (Based on data retrieved from Science direct) – visited 05.09.2023.

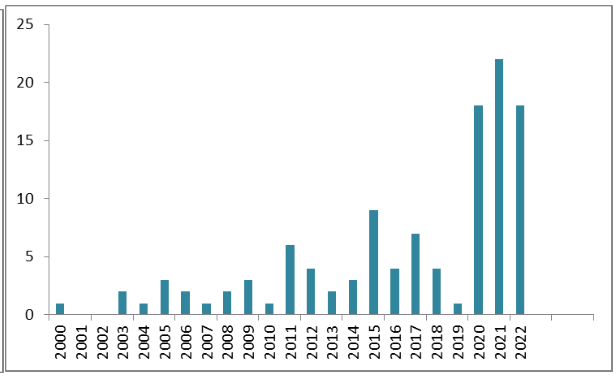

Figure 2. Dynamics of publication (2000 – 2022) of searches for food colors and health relationships (Based on data retrieved from PubMed) – visited 05.09.2023.

Results and discussion

Researches

A survey on the percentage of goods containing artificial colors (AFC) at one supermarket shop was done in North Carolina in 2014. For 810 goods in 19 categories, the research team gathered data on the products and food colorings. 350 goods overall (43.2%) contained AFC. Allura Red (29.8% of items), Brilliant Blue (24.2%), Tartrazine (20.5%), and Sunset Yellow (19.5%) were the most prevalent AFCs (Figure 3). Candy accounted for 96.3% of all products in this category, followed by fruit-flavored snacks (94.7%), drink mixes and powders (89.7%), and frozen breakfast (85.7%). The AFC most frequently used, found in 29.8% of items geared at children, was Allura Red. Categories with a high proportion of products containing Allura Red included candies (77.8%), drink mixes and powders (71.8%), and toaster cakes (66.7%), which were present in products in all 19 categories with products that contained AFC. Fast green, erythrosine, and other AFCs were found in less than 5% of items or not at all (Batada and Jacobson, 2016).

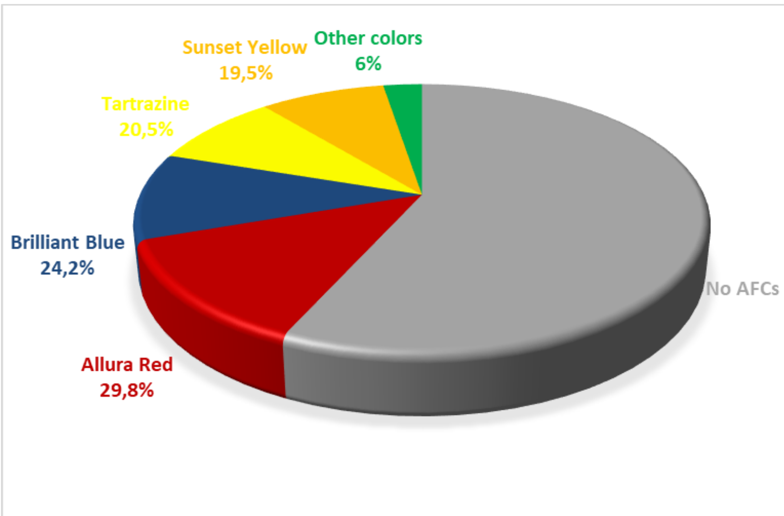

Figure 1. An illustration of the findings from a survey on the proportion of products containing artificial colors in one supermarket conducted in North Carolina in 2014 (adapted from Batada and Jacobson, 2014)

In the Netherlands, a study was carried out between September 2012 and December 2013 to determine the acceptable daily intake (ADI) of artificial food colors among schoolchildren using a prospective three-day food diary (two weekdays and one weekend day). It was found that the colors Brilliant Blue (E133), Patent Blue (E131), and Indigotine (E132) predominantly appear in their products in supermarkets (mainly sweets and carbonated drinks). None of the children consumed yellow, orange or red artificial food color. Only Brilliant Blue (E133), Patent Blue (E131), Indigotine (E132), and Green S (E142) were found to be used by children in Amsterdam as artificial food colorings, and their intake was shown to be much lower than the ADI (Kist-van Holthe et al., 2015).

A German database on the prevalence of food additives was built in order to obtain a more accurate estimate of toddlers' and kids' intake of food additives. It combines qualitative data on the presence of food additives in the consumed food with consumption data from two recent national nutrition surveys for toddlers and kids. Two dietary surveys from 2001–2002 and 2006, respectively, were utilized to collect data on consumption. The information regarding the presence of food additives is based on food labeling. Children in Germany ingest a variety of red hues (E110, E124, and E129), and their mean intake is 0.16-0.50 mg/kg/day, which is comparable to findings from the Netherlands (Diouf et al., 2014).

A 24-hour dietary recall was carried out twice in 58 schools to evaluate the use of artificial food color additives by children aged 5 to 14 in the State of Kuwait. To assess the potential risk connected to children in Kuwait consuming artificial color additives, a comparison with the recommended daily intakes (ADIs) was made. The findings showed that four of the nine approved colors: Tartrazine, Sunset Yellow, Carmoisine, and Allura Red exceed their ADIs by factors of 2–8. Further research is required to shed light on any potential negative health effects linked to the excessive use of these artificial color additives in the test population (Husain et al., 2006).

For Australian children, food exposure assessments to added colors were conducted in 2006. To ascertain whether food intake on a daily basis was likely to result in a significant health issue, the estimated dietary exposure to each particular color was compared to the pertinent, internationally accepted Acceptable Daily Intake (ADI). Even for high consumers, dietary exposure to certain added colors was below the ADI (Stevens et al., 2014).

Utilizing data on food and beverage dietary intake gathered from individuals in the 2015–2016 NHANES, researchers in the USA estimated AFC exposure in women of reproductive age, pregnant women, and children. The NHANES program polls a sample of roughly 5,000 people from across the country to determine the health and nutritional status of children and adults living in the United States. They compared them to the acceptable daily intakes (ADIs) recommended by the FDA and the WHO. Currently, there are seven FD&C (Federal Food, Drug, and Cosmetic Act, FDA) color additives approved for general use in food in the United States: Brilliant Blue, Indigo Carmine, Fast Green, Erythrosine, Allura Red, Tartrazine, and Sunset Yellow. The highest projected exposures for AFC consumers to the seven regularly used food colors were Allura Red, followed by Sunset Yellow and Tartrazine. The lowest exposures were found for Fast Green. Overall, children's estimated exposure to Allura Red and Erythrosine, as well as the other five food colors, tended to be higher compared with adult women (Bradman et al., 2022).

As they are the biggest consumers of artificial colors, research was also done in Saudi Arabia among school-aged children between the ages of 6 and 17. In order to acquire the data necessary to evaluate how much and what kind of food the children consume, individual interviews with the kids were done in their schools. Data from the 24-hour field survey of dietary recall were entered into the database and statistically processed. The questionnaire was used to identify the colors Sunset Yellow (E110), Tartrazine (E102), Carmoisine (E122), Brilliant Blue (E133), Allura Red (E129), Black PN (E151), Indigo Carmine (E132), and Fast Green (E143). According to the findings, schoolchildren consumed Carmoisine (32.3%) and Sunset Yellow (30.1%) of artificial food colors the most frequently, while Erythrosine (0.05%) was the least popular. In both sexes, the ADI of AFC declines with age to varying degrees. Most permitted colors surpassed their ADIs in the 6- to 11-year old group and most permitted colors were within the recommended ADIs in the 12- to 17-year-old age group when compared to the Food and Agriculture Organization and World Health Organization acceptable daily intakes, which indicates age-related decreases in schoolchildren's average daily consumption of AFC (Ahmed et al., 2023).

Utilizing information from 142 primary school students in three districts of Hong Kong, China, ages 8 to 9, who completed food-frequency questionnaires, it was possible to calculate the dietary exposure to artificial colors. The average amount of colored foods ingested was multiplied by the average levels of the color additives in those meals, and the result was divided by the average body weight for each group to get the ADI of authorized artificial food colors. With the exception of Sunset Yellow, an average primary school student's dietary exposure to artificial colors was significantly lower than the ADI for their ages. According to the data, 9-year-old boys had an average daily intake of Sunset Yellow (E110) that was 51% higher than the ADI threshold. The increasing consumption of soft drinks and treats like jellies, which contain high levels of this artificial color additive, was primarily to blame for the higher intakes of Sunset Yellow (Lok et al., 2011).

Based on research on food consumption and the concentration of food additives in accordance with WHO guidelines, a risk assessment study of six different types of food additives (including benzoates, sorbates, cyclamates, saccharin, Tartrazine and Sunset Yellow) in Vietnamese diets was carried out. Surveys on food consumption and food sampling were conducted in six provinces. According to the survey findings, different food product categories are consumed in varied amounts by people of various ages. The amount of coloring chemicals was significantly smaller and was mostly found in chili sauce. Total intake for Tartrazine and Sunset Yellow was substantially lower than their ADIs (Long et al., 2019).

The Brazilian Institute of Geography and Statistics' Household Budget Survey (HBS) data on food consumption were used in this study to calculate the theoretical maximum daily intake of the synthetic food color Sunset Yellow by the Brazilian population. In order to determine whether it was possible to surpass the ADI, the study included people from all age groups and urban and rural populations in the five regions of the nation. This was determined by comparing food items from Brazil's main retail chains that contain this color. These findings indicated that none of the aforementioned population groups' average Sunset Yellow consumption per capita exceeded the ADI (Feitosa et al., 2017).

Table 2 provides a summary of all these studies that evaluated the consumption of food colors by children.

Table 2. Studies that evaluated the consumption of food colors by children (dos Santos Kraemer et al., 2022)

Country	Population (age)	Period	Type of research	Analyzed type of synthetic colors	Intake estimations compared with the Acceptable Daily Intake (ADI)	Reference
Netherland	Median age 7.0, range 5–12 years	between September 2012 and December 2013	three-day prospective food diary and compared to the acceptable daily intake (ADI)	E102 Tartrazine E104 Chinoline Yellow E110 Sunset Yellow E122 Azorubine E124 Ponceau 4R E129 Allura Red E131 Patent Blue E132 Indigotine E133 Brilliant Blue E142 Green S	Intake of artificial food colourings is well below the acceptable daily intake (ADI) and is limited to Brilliant Blue (E133), Patent Blue (E131), Indigotine (E132) and Green S (E142)	Kist-van Holthe et al., 2015
Germany	Infants and toddlers aged 6 months to <5 years	in 2001/02 and 2006	It uses consumption data of two recent national nutrition surveys for children in combination with qualitative information of food additive occurrence in the consumed food	E110 Sunset Yellow E124 Ponceau 4R E129 Allura Red	Exposure for high-level consumers exceeded the ADI for two of the food additives; E120 Carmine acid (natural), E129 Allura Red	Diouf et al., 2014
State of Kuwait	5–14-year-old children	Not defined	24-h dietary recall field survey	E102 Tartrazine E110 Sunset yellow F E122 Carmoisine. E127 Erythrosine E129 Allura red E143 Fast green E132 Indigotine E133 Brilliant blue E151 Brilliant black E155 Brown HT	The results indicated that out of nine permitted colours, four exceeded their ADIs by factors of 2–8: tartrazine, sunset yellow, carmoisine and allura red	Husain et al., 2006
Australia	The Australian population aged 2 years and above, children aged 2-5 years, children aged 6-12 years,	three month period between June and August 2006	Dietary modelling as a tool used to estimate exposure to food chemicals from the diet as part of the risk assessment process.	E129 Allura red E122 Amarant E122 Azorubine E151 Brilliant Black E133 Brilliant Blue	For the Australian population and all population sub-groups assessed, dietary exposure to individual added colours was below the ADI even for high (90th percentile) consumers.	Stevens et al., 2014

	adolescents aged 13-18 years, adults aged 19-24 years, adults aged 25 years and above			E155 Brown HT E127 Erythrosine E143 Fast Green E142 Green S E132 Indigotine E124 Ponceau 4R E104 Quinoline Yellow E110 Sunset Yellow E102 Tartrazine		
USA	women of reproductive age, pregnant women, and children	2015-2016	NHANES (National Health and Nutrition Examination Survey)	E133 Brilliant Blue E132 Indigotine E127 Erythrosine E102 Tartrazine E129 Allura red E143 Fast green E110 Sunset Yellow	The highest projected exposures for AFC consumers to the seven regularly used FD&C food colors were Allura Red, followed by Sunset Yellow and Tartrazine. The lowest exposures were found for Fast Green	Bradman et al., 2022
Saudi Arabia	school-aged children from 6 to 17 years	Not defined	Individual interviews, 24-hour field survey of dietary recall	E132 Indigotine E127 Erythrosine E102 Tartrazine E122 Carmoisine. E129 Allura red E143 Fast green E110 Sunset Yellow E151 Brilliant Black E133 Brilliant Blue	Carmoisine (32.3 %) and Sunset Yellow (30.1 %) were the most frequently consumed, while Erythrosine (0.05 %) was the least consumed	Ahmed et al., 2023
Vietnam	Young children (≤5 years), elementary students (6–10 years) high school students (11-18 years) adults (19–40 age) and middle/elderly people (> 40 years)	Not defined	24-h dietary recall	E102 Tartrazine E110 Sunset Yellow	Average food additive intakes of consumer in Vietnam were within the recommendation of Codex Alimentarius.	Long et al., 2019
Brazil	Adolescents (10–18 years old) Adults (19–54 years old) Seniors (over 55 years old)	2008/2009	Official government dana	E110 Sunset Yellow	Consumption of Sunset Yellow per capita did not exceed the ADI	Feitosa et al., 2017
Hong Kong, China	Primary school children aged 8–9 years	Not defined	Food frequency questionnaire	E102 Tartrazine E104 Quinoline Yellow E110 Sunset Yellow E122 Carmoisine E123 Amaranth E124 Ponceau 4R E127 Erythrosine B E129 Allura Red AC E132 Indigo Carmine E133 Erioglaucine Disodium E142 Lissamine Green B	Dietary exposure was considerably lower than the threshold for acceptable daily intake (ADI) for their ages, except for sunset yellow FCF. Data obtained showed that the average daily intake of sunset yellow FCF (E110) was 51% over the ADI threshold in 9-year-old boys.	Lok et al, 2011

The idea that food allergies or sensitivities lead to behavioral and learning problems dates back to the 1920s, but it wasn't until 1973 that Dr. Benjamin Feingold proposed that artificial food colors were common causes of hyperactivity (Arnold et al., 2012). More than 3,000 distinct food additive effects were tested on 1,200 people, but his research was not only refuted but also made fun of. Feingold claimed that a diet devoid of these additives significantly reduced hyperactive symptoms, and more than 50% of the population benefited. Numerous studies were conducted to determine the validity of this claim, three of which, carried out at Southampton University, provided the first conclusive and scientific evidence of the negative effects of these colors (Mittal, 2020).

Food colors and ADHD

By 1980, the terminology "hyperactivity" was changed to "attention-deficit disorder" (ADD) to describe children who were inattentive but not hyperactive and "attention deficit/hyperactivity disorder" (ADHD) to describe children who were hyperactive, impulsive, and inattentive (Stevens et al., 2013). ADHD, commonly known as attention deficit hyperactivity disorder, is a neurological condition that affects children. It is often first diagnosed in infancy and frequently continues into adulthood. Although the actual etiology of ADHD is unknown, environmental variables such as pollutants and food may have an impact on symptom severity in addition to genetics. The Food and Drug Administration (FDA) has allowed artificial food coloring (AFC); however, according to Rambler et al. (2022), research suggested that it might had been linked to symptoms of ADHD.
Bateman et al. (2004) conducted research on whether artificial colors in food affect hyperactivity in children. 1873 of four-year-olds underwent tests for the presence of hyperactivity. The children underwent a baseline assessment and were then put on a diet that excluded artificial colors and benzoate preservatives for one week. Over the course of the following three weeks, they participated in a double-blind cross-over study where they were given, in a random order, periods of dietary challenge with either a drink containing artificial colors (20 mg per day) and sodium benzoate (45 mg per day) (active period) or a placebo mixture. Behavior was assessed by an examiner who was blind to nutritional status and parent ratings. During the weaning phase, hyperactive behavior significantly decreased. Additionally, according to parent reports, hyperactive behavior increased during the active phase far more than it did during the placebo period. According to the study's findings, parents could had notice an overall unfavorable impact of artificial food colors and benzoate preservatives on their children's behavior at the age of 3, but not by straightforward clinical evaluation. Bateman at al. (2004) believe that research suggests that all children would benefit if artificial food colors and benzoate preservatives were removed from their diets.
Some conclusions have been drawn from research on the effects of blue food coloring on children's health. The study was conducted on Brilliant Blue (Blue No. 1) and Indigotine (Blue No. 2), two of the most widely used synthetic blues. While concerns regarding the safety of AFCs continue to emerge, the toxicity of artificial blue food coloring has been evaluated in mice and rats in a lab setting (Rambler et al., 2022). Brilliant Blue and Indigotine have not been shown to be harmful or carcinogenic in rats or mice. On the other hand, Brilliant Blue showed potential for neurotoxicity in an in vitro study by inhibiting neurite development and cooperating with L-glutamic acid. The blood-brain barrier is still developing in fetuses and infants younger than 6 months, so this is especially concerning. To assess the safety of this color with more certainty, more research is required. Regarding Indigotine, it was shown that rats exposed to high concentrations of the color developed tumors (brain gliomas) at substantial rates. Despite this fact, the FDA found reasons to excuse that evidence and approved the continued use of the dye (Kobylewski and Jacobson, 2012; Olas et al., 2021).

Food colors and allergies

Since the usage of food additives has increased significantly over the past 20 years around the globe, numerous allergies and other immune reactivities have been documented (Vojdani, 2015). Dietary allergies include allergic responses to dietary additives. The cause of food allergy (hypersensitivity) is an immunologic reaction brought on by eating a food. The biggest foreign antigenic load that the human immune system encounters comes from eating. Food antigens, which frequently enter the body proper in most people, cause tolerance to develop. However, the immune system responds with some type of hypersensitive reaction if tolerance building is unsuccessful (Gultekin and Doguc, 2012). Food coloring and other additives are made of very small molecules, to which we have not developed a tolerance yet. These food additives become the main cause of the breakdown of immunological tolerance if they are able to attach to body proteins after metabolization or to food proteins during food production. They are thought to contribute significantly yet covertly to these immunological reactivities (Vojdani, 2015). Additionally, Tartrazine in particular has been mentioned as a potential asthma and urticaria trigger, especially in aspirin-intolerant patients. These reactions have happened after consuming meals or items that include Tartrazine and other food colors (Elhkim, 2007). Children with severe atopic dermatitis had an even higher percentage of reactions to Tartrazine. There have been reports of Tartrazine and other colorants being involved in numerous chemical sensitivity disorders that are not IgE-mediated (Inomata et al., 2006). Other research and case reports have linked the use of many food additives, including Tartrazine, to allergic, immunologic abnormalities like chronic urticaria, angioedema, and rhinitis, which are typically linked to food allergies. These other studies and case reports include Allura Red and Erythrosine. This study and numerous others pertaining to immunological reactions to food coloring were evaluated in great detail in a review paper, which came to the conclusion that allergic and immune reactions to food additives can be thought of as triggers or aggravating factors in sensitive people. Deleting these triggers can significantly alleviate a patient's symptomatologies, hence clinicians and sensitive consumers in particular should be aware of the allergic qualities of food additives (Vojdani, 2015).

Food colors and carcinogenicity

Highly processed foods have become a part of our daily diet. Such meals are frequently colored with food colors, particularly synthetic ones, which might have genotoxic or carcinogenic qualities. This poses a risk to the public's health. Children are the main consumers of artificial food color, which has multiplied over the past 50 years. Some colors could have carcinogens in them. The main factors causing liver cancer are food colors such as Erythrosine, Carmoisine, and Tartrazine (Malabadi et al, 2022). Research by Reza et al. (2019) was done to ascertain the relationship between carcinogenicity and the toxicities of the azo color Carmoisine on mice. The animals were placed into 4 groups when the trial began and were around 6 weeks old. For mice, Carmoisine was added to a standard diet at a variety of doses. Every day, the animal's overall health, mortality, and any signs of sickness were examined, and once a week, each animal's body weight was recorded separately. According to this study, treatment with large doses of Carmoisine can cause hepatotoxicity and renal failure. It might also be thought to be the cause of liver cancer development (Reza et al, 2019). There are nine colors that are now permitted in the US, and each of them has been linked to a range of health issues. Animal studies have shown carcinogenic effect of erythrosine, and there is evidence that numerous other colors have similar effect. It was discovered that three colors (Allura Red, Tartrazine and Sunset Yellow) contained benzidine or other carcinogens. There is no evidence that ingesting Erythrosine or any other artificial food colors causes cancer on humans. Scientists, however, tend to use the results of animal studies to understand possible effects in people. Although there are no FDA-approved artificial food colors that are categorized as carcinogenic, current research suggests possible health hazards that may be alarming (Kobylewski and Jacobson, 2012).

Conclusion

An essential component of a significant amount of the food sold nowadays is artificial food coloring. They do not increase the nutritional value or safety of food, in contrast to some other additives. They were just introduced to enhance the food's aesthetic identity and appeal to consumers, particularly children. The use of artificial food colors is still controversial. Some studies clearly indicate that the use of artificial colors can have toxic and harmful effects. Children are the most vulnerable group because of how quickly their bodies grow and change as well as how much more exposure to toxins they receive per kilogram of body weight. Since the FDA concluded that artificial food colors are not harmful to health, many scientists try to make the public aware of the fact that artificial food colors are not so harmless through their research and presentation of results in their scientific works. An additive consumption limit, or ADI, is established by taking into account the effects found in toxicological research conducted, mostly, on animal models. Since the early stages of life are not taken into account when setting safety limits, the context of consumption restrictions and the assessment of the toxicity of additives are more complicated when applied to children. Food color exposure is associated with negative behavioral outcomes in children, both with and without pre-existing behavioral abnormalities, according to recent human investigations, most notably controlled exposure studies in children. To further understand the relationship between consumption and harmful health effects, additional exposure analyses of legal artificial colors, particularly in youngsters, are urgently needed. Without this information, it would be very difficult to protect customers, especially the most helpless ones (children). It is advised that regulatory agencies demand better and independent toxicity testing, use more caution when approving certain hues moving forward, and only approve well-researched, secure colors. Also, due to concerns that artificial colors can affect children's behavior, in recent years, California's Office of Environmental Health Hazard Assessment (OEHHA) has been conducting the most rigorous assessment undertaken to date of the relationship between synthetic colors and their effects on child behavior. Based on multiple evidence, they conclude that the neurobehavioral effects of synthetic food colors in children should be acknowledged and steps taken to reduce exposure (Miller et al., 2022).

References

Ahmed, M.A., Al-Khalifa, A.S., Al-Nouri, D.M., El-din, M.F.S. (2023): Average Daily Intake of Artificially Food Color Additives by School Children in Saudi Arabia, *J King Saud Univ Sci* 35(4), 102596. https://doi.org/10.1016/j.jksus.2023.102596.

Arnold, L.E., Lofthouse, N., Hurt, E. (2012): Artificial Food Colors and Attention-Deficit/Hyperactivity Symptoms: Conclusions to Dye For, *Neurotherapeutics* 9(3), 599–609. https://doi.org/10.1007/s13311-012-0133-x.

Barciela, P., Perez-Vazquez, A., Prieto, M.A. (2023): Azo Dyes in the Food Industry: Features, Classification, Toxicity, Alternatives, and Regulation, *Food Chem Toxicol* 178, 113935. https://doi.org/10.1016/j.fct.2023.113935.

Batada, A., Jacobson, M.F. (2016): Prevalence of Artificial Food Colors in Grocery Store Products Marketed to Children, *Clin Pediatr* 55(12), 1113–19. https://doi.org/10.1177/0009922816651621.

Bateman, B., Warner, J.O., Hutchinson, E., Dean, T., Rowlandson, P., Gant, C., Grundy, J., Fitzgerald, C., Stevenson, J. (2004): The Effects of a Double Blind, Placebo Controlled, Artificial Food Colourings and Benzoate Preservative Challenge on Hyperactivity in a General Population Sample of Preschool Children, *Arch Dis Child* 89(6), 506–11. https://doi.org/10.1136/adc.2003.031435.

Bradman, A., Castorina, R., Thilakaratne, R., Gillan, M., Pattabhiraman, T., Nirula, A., Marty, M., Miller, M.D. (2022): Dietary Exposure to United States Food and Drug Administration-Approved Synthetic Food Colors in Children, Pregnant Women, and Women of Childbearing Age Living in the United States, *Int J Environ Res Pub Health* 19(15), 9661. https://doi.org/10.3390/ijerph19159661.

Burrows, A.J.D. (2009): Palette of Our Palates: A Brief History of Food Coloring and Its Regulation, *Compr Rev Food Sci Food Saf* 8(4), 394–408. https://doi.org/10.1111/j.1541-4337.2009.00089.x.

Chung, K.-T. (2016): Azo Dyes and Human Health: A Review, *J Environ Sci Health* Part C 34(4), 233–61. https://doi.org/10.1080/10590501.2016.1236602.

Corradini, M.G. (2019): Synthetic Food Colors, In *Encyclopedia of Food Chemistry* 291–96. Elsevier. https://doi.org/10.1016/B978-0-08-100596-5.21606-5.

Dey, S., Nagababu, B.H. (2022): Applications of Food Color and Bio-Preservatives in the Food and Its Effect on the Human Health, *Food Chem Adv* 1, 100019. https://doi.org/10.1016/j.focha.2022.100019.

Diouf, F., Berg, K., Ptok, S., Lindtner, O., Heinemeyer, G., Heseker, H. (2014): German Database on the Occurrence of Food Additives: Application for Intake Estimation of Five Food Colours for Toddlers and Children, *Food Addit Contam: Part A* 31(2), 197–206. https://doi.org/10.1080/19440049.2013.865146.

Durazzo, A., Carocho, M., Heleno, S., Barros, L., Souto, E.B., Santini, A., Lucarini, M. (2022): Food Dyes and Health: Literature Quantitative Research Analysis, *Measurement: Food* 7, 100050. https://doi.org/10.1016/j.meafoo.2022.100050.

Elhkim, M.O., Héraud, F., Bemrah, N., Gauchard, F., Lorino, T., Lambré, C., Frémy, J.M., Poul, J.M. (2007): New Considerations Regarding the Risk Assessment on Tartrazine, *Regul Toxicol Pharmacol* 47(3), 308–16. https://doi.org/10.1016/j.yrtph.2006.11.004.

Feitosa, L.C.A., Da Silva Rodrigues, P., Da Silva, A.S., De Oliveira Rios, A., Cladera-Olivera, F. (2017): Estimate of the Theoretical Maximum Daily Intake of Sunset Yellow FCF by the Brazilian Population, *Food Addit Contam: Part A* 20, 1–8. https://doi.org/10.1080/19440049.2017.1290829.

Feketea, G., Tsabouri, S. (2017): Common Food Colorants and Allergic Reactions in Children: Myth or Reality?, *Food Chem* 230, 578–88. https://doi.org/10.1016/j.foodchem.2017.03.043.

Gultekin, F., Doguc, D.K. (2013): Allergic and Immunologic Reactions to Food Additives, *Clin Rev Allergy Immunol* 45(1), 6–29. https://doi.org/10.1007/s12016-012-8300-8.

Husain, A., Sawaya, W., Al-Omair, A., Al-Zenki, S., Al-Amiri, H., Ahmed, N., Al-Sinan, M. Estimates of Dietary Exposure of Children to Artificial Food Colours in Kuwait, *Food Addit Contam* 23(3), https://doi.org/10.1080/02652030500429125.

Inomata, N., Hiroyuki O., Hiroyuki F., Toru O., Zenro I. (2006): Multiple Chemical Sensitivities Following Intolerance to Azo Dye in Sweets in a 5-Year-Old Girl, *Allergol Int* 55(2), 203–5. https://doi.org/10.2332/allergolint.55.203.

Kist-van Holthe, J., Altenburg, T., Bolakhrif, S., El Hamdi, L., Man, M.W., Tu, J., Chin, M.J., Paw, M.C.A. (2015): Consumption of Artificial Food Colourings by School Children in the Netherlands, *Adv Pediatr Res* 2, 5. https://doi.org/10.12715/apr.2015.2.5.

Kobylewski, S., Jacobson, M.F. (2012): Toxicology of Food Dyes, *Int J Occupat Environ Health* 18(3), 220–46. https://doi.org/10.1179/1077352512Z.00000000034.

König, J. (2015): Food Colour Additives of Synthetic Origin, In *Colour Additives for Foods and Beverages* 35–60. Elsevier. https://doi.org/10.1016/B978-1-78242-011-8.00002-7.

Kraemer, M. V. dos S., Fernandes, A. C., Chaddad, M. C. C., Uggioni, P. L., Rodrigues, V. M., Bernardo, G. L., Proença, R. P. da C. (2022): Aditivos Alimentares Na Infância: Uma Revisão Sobre Consumo e Consequências à Saúde, *Rev Saúde Pública* 56, 32. https://doi.org/10.11606/s1518-8787.2022056004060.

Lok, K.Y.W., Chung, Y.W., Benzie, I.F.F., Woo. J. (2011): Synthetic Colourings of Some Snack Foods Consumed by Primary School Children Aged 8–9 Years in Hong Kong, *Food Addit Contam: Part B* 4(3), 162–67. https://doi.org/10.1080/19393210.2011.585246.

Malabadi, R.B., Kolkar, K.P., Chalannavar, R.K. (2022): Plant Natural Pigment Colorants-Health Benefits: Toxicity Of Synthetic Or Artificial Food Colorants, *Int J Innov Sci Res Rev* 04(10), 3418-3429.

Martyn, D.M., McNulty, B.A., Nugent, A.P., Gibney, M.J. (2013): Food Additives and Preschool Children, *Proceedings of the Nutrition Society* 72(1), 109–116. https://doi.org/10.1017/S0029665112002935.

Miller, M.D., Steinmaus, C., Golub, M.S., Castorina, R., Thilakartne, R., Bradman, A., Marty, M.A. (2022): Potential Impacts of Synthetic Food Dyes on Activity and Attention in Children: A Review of the Human and Animal Evidence, *Environ Health* 21(1), 45. https://doi.org/10.1186/s12940-022-00849-9.

Mittal, J. (2020): Permissible Synthetic Food Dyes in India,*Resonance* 25(4), 567–577. https://doi.org/10.1007/s12045-020-0970-6.

Mota, I.G.C., Das Neves, R.A.M., Da Cruz Nascimento, S.S., Maciel, B.L.L., De Araújo Morais, A.H., Passos, T.S. (2023): Artificial Dyes: Health Risks and the Need for Revision of International Regulations, *Food Rev Int* 39(3), 1578–1593. https://doi.org/10.1080/87559129.2021.1934694.

Nguyen H.L., Hao, L.T.H., Trang, V.T., Son, C., Hung, L.Q. (2019): Assessing Dietary Risks Caused by Food Additives: A Case Study of Total Diet in Vietnam, *Health Risk Analysis* 2, 74–82. https://doi.org/10.21668/health.risk/2019.2.08.eng.

Olas, B., Białecki, J., Urbańska, K., Bryś, M. (2021): The Effects of Natural and Synthetic Blue Dyes on Human Health: A Review of Current Knowledge and Therapeutic Perspectives, *Adv Nutr* 12(6), 2301–11. https://doi.org/10.1093/advances/nmab081.

Oplatowska-Stachowiak, M., Elliott, C.T. (2017): Food Colors: Existing and Emerging Food Safety Concerns, *Crit Rev Food Sci Nutr* 57(3), 524–548. https://doi.org/10.1080/10408398.2014.889652.

Rambler, R.M., Rinehart, E., Boehmler, W., Gait, P., Moore, J., Schlenker, M., Kashyap, R. (2022): A Review of the Association of Blue Food Coloring With Attention Deficit Hyperactivity Disorder Symptoms in Children, *Cureus* 14(9), e29241. https://doi.org/10.7759/cureus.29241.

Regulation (EC), 2008. Of the European Parliament and of the Council of 16 December 2008 on Food Additives. No 1333/2008. *Official Journal of the European Union* 1. Pub. L. No. 1333/2008, 51.

Reza, S. A., Hasan, M., Hossain, K.I., Zubair, A., Bari, L., Abedin, Z., Khandaker, K.B.F., Haque, K.F., Islam, K., Ahmed, M.U., Hossain, K. (2019): Study of a Common Azo Food Dye in Mice Model: Toxicity Reports and Its Relation to Carcinogenicity, *Food Sci Nutr* 7(2), 667–77. https://doi.org/10.1002/fsn3.906.

Sharma, V., McKone, H.T., Markow, P.G. (2011): A Global Perspective on the History, Use, and Identification of Synthetic Food Dyes, *J Chem Edu* 88(1), 24–28. https://doi.org/10.1021/ed100545v.

Sigurdson, G.T., Tang, P.,Giusti, M.M (2017): Natural Colorants: Food Colorants from Natural Sources, *Annu Rev Food Sci Technol* 8(1), 261–80. https://doi.org/10.1146/annurev-food-030216-025923.

Silva, M.M., Reboredo, F.H., Lidon, F.C. (2022): Food Colour Additives: A Synoptical Overview on Their Chemical Properties, Applications in Food Products, and Health Side Effects, *Foods* 11(3), 379. https://doi.org/10.3390/foods11030379.

Spence, C. (2023): On the Manipulation, and Meaning(s), of Color in Food: A Historical Perspective, *J Food Sci* 88(S1), A5-A20. https://doi.org/10.1111/1750-3841.16439.

Stevens, L.J., Kuczek, T., Burgess, J.R., Stochelski, M.A., Arnold, L.E., Galland, L. (2013): Mechanisms of Behavioral, Atopic, and Other Reactions to Artificial Food Colors in Children, *Nutr Rev* 71(5), 268–281. https://doi.org/10.1111/nure.12023.

Stevens, L.J., Burgess, J.R., Stochelski, M.A. (2014): Amounts of Artificial Food Colors in Commonly Consumed Beverages and Potential Behavioral Implications for Consumption in Children, *Clin Pediatr* 53(2), 133-140.

Vojdani, A., Vojdani, C. (2015): Immune reactivity to food coloring, *Altern Ther Health Med* 21, 52-62.