

A REVIEW ON ARTIFICIAL SWEETENERS AND FOOD COLORANTS THEIR IMPACT ON HUMAN HEALTH

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ABSTRACT

This review article comprehensively explores the overview of artificial sweeteners and food colorants, examining their safety, regulatory status, and potential health effects. It explores the historical background of artificial sweeteners, covering key compounds like saccharin, aspartame and cyclamate, while also highlighting emerging alternatives such as rare sugars. The discussion extends to the physiological impacts of artificial sweeteners including their potential ill effects on blood glucose levels, obesity, gut microbiome, cardiovascular health, and cancer risk. Additionally, the review evaluates the safety and adverse effects of food colorants, emphasizing regulatory frameworks and potential health risks associated with synthetic food colorants like tartrazine and rhodamine B. It concludes by underlining the importance of cautious consumption, particularly among vulnerable populations like children and pregnant women, and advocates for ongoing research to inform evidence-based dietary guidelines and regulatory policies.

Key words: Artificial Sweeteners, Food Colorants, Rare Sugar, Diabetes, Obesity, Cancer.

1. INTRODUCTION

Introduction to artificial sweeteners and food colorants:

In the recent and current years people are very much conscious about their health and showing a great concern on quality of life. Imbalanced consumption of excess calories and saturated fats is leading most of the population to obesity. Obesity became a notable subject all over the world. Studies show that most of the individuals are disturbed by overweight and well-being associated consequences (type II diabetes).

The frighten prevalence of obesity has been impute to diversification of social-economic components like food habits and lifestyle. Responsibility on sugar consumption have taken into consideration from 1970s where obesity outbreak has started. Nutritive sweeteners are further classified into sugars, modified sugars, sugar alcohols and natural caloric sweeteners.¹

Artificial sweeteners degrade at varying rates under different environmental conditions. Incubated in aerobic soils for a period of 1-3 months, acesulfame and sucralose showed signs of slow degradation, suggesting even the most persistent sweeteners are not necessarily inert to microbial actions. In addition, positive observation of photoinduced decomposition and initial by-product identification in sucralose.



The legacy of food colorants stretches back to the ancient Roman Civilization when people colored their meals with saffron, different flowers, pomegranates, beetroots, and other natural ingredients. They even employed specific ores and minerals, like copper or silver, to beautify the cuisine with vibrant, brilliant hues. Meal coloring was primarily used to provide a pop of color to bland food or to cover up any cooking flaws. Humans started using synthetic colors for this purpose in the mid-19th century in place of natural colors. Since then, despite their legal ban, widespread usage of synthetic food colors has grown quite frequent due to the rise of packaged and food cultures.²

Naturally occurring color additives that were sourced from vegetables and minerals were used in ancient times, while the first artificially colored food was wine, back in 300 BCE. In 1856, William Perkin discovered mauve, the first synthetic dye, sourced from coal, creating a trend of coal-tar-colors. In the United States (US), the federal government started regulating food dyes back in the 1880s, and allowed dyes that were quite harmful to human health, although at the time, technology was not enough to understand this harm. In 1927, when the control and regulation of food dyes, as well as all food additives was handed over to the Food and Drug Administration of the United States of America, which until today enforces control over food related issues.³

In India, sweets are an integral part of everyday meals for most communities. Indians are the largest consumers of sugar in the world. However, with the rising prevalence of diabetes and obesity, many Indians are becoming aware of the dangers of refined carbohydrates. In such a scenario, the demand for artificial sweeteners is rising rapidly. The current market for this ingredient is estimated at 150 crores and is expected to have a double digit growth in the coming years³. For example, Saccharin, a commonly used sweetener in India, had a market volume of more than 4,600 tons in 2018 and is expected to reach 5,300 tons by 4,600. Since sweet dishes are an integral part of all religious rituals and family programmes in India, the demand for sweeteners will always be there. This is different from Western societies, where sweetened beverages and candy form the main route of intake of sugar.⁴

2. TYPES OF ARTIFICIAL SWEETENERS

Saccharin:

Saccharin is an artificial sweetener with zero food energy and no calories. This is the earliest and one of the oldest sugar used for about a century in processed food and beverages industries. Saccharin is 300 times more sweetener than Sucrose.

Acesulfame potassium (Ace-k) Acesulfame potassium is used as general sweetener. This is a white crystalline material which is stable up to high temperatures (250 °C). Because of its high stability under high temperature it is used in many bakery products.

Aspartame

Aspartame is the most discussed sugar substitute which tastes like sugar. This is highly stable to hot temperatures and has modest solubility in water. This rate of solubility of aspartame is directly proportional temperature.

Sucralose

Sucralose is one of the largely consumed sugar substitute. Sucralose is highly stable, safe and even used at higher temperatures (baked food products). Sucralose is up to 1000 times more sweeter than sucrose, thrice sweet as aspartame and acesulfame potassium and sucralose is twice sweet as saccharin.

The use of ASs has been constantly increasing in recent years. In the United States, it has been reported that almost 25% of children and more than 41% of adults have used ASs between 2009 and in addition, the cost of ASs reached approximately \$2.2 billion in 2020 and is continuously expected to increase worldwide.¹⁰

Table:1 Characteristic features of artificial sweeteners

General name or common name	Most popular Brand names	Intensity of sweetness compared to table suga	Kilo calories per gram (kcal/g)	Uses
Saccharin	Sweet' N Low, Sweet Twin	300	0	Soft drinks, beverages, fruit drinks, powdered dessert mixes, Tabletop sweetener, Jams, Chewing gum, Baked goods, canned fruits
Acesulfame K	Sunett, Sweet One	180-200	0	Tabletop sweeteners (in packets), carbonated beverages, desserts which are frozen, Candies, Chewing gum, Dairy products, syrups and sauces
Aspartame	NutraSweet, Natrataste, sugar twin, Equal	200	4	Tabletop sweetener (in packets), chewing gums, instant coffee and tea, gelatins, puddings, soft drinks, Yoghurt, Pharmaceuticals

Neotame	Same as common name (neotame)	10000	0	Baked goods, soft drinks, Chewing gum, Jams, Jellies, Puddings, Processed fruit and fruit juices
Sucralose	Splenda	600	0	Tabletop sweetener (in packets), baked foods, Frozen desserts and dairy products, Fruit juices, Chewing gum, gelatins, gelatins

Therapeutic use:

Replacement of common table sugar with less or no calorie sugar in food products allows less calories intake into the body which in turn helps in reducing weight. High sucrose containing foods may cause dental decay, in order to reduce this problem. prescribe to use sugar substitutes. People suffering from diabetes have fluctuations in blood sugar use of sugar substitutes or artificial sweeteners in diet instead of table sugar allows more stability in blood sugar levels.

Non therapeutic use

Aspartame taste same as common sugar which is used as sugar substitute in various processed foods. In few beverage and food industries aspartame is used as a sugar substitute which not only gives sugar taste but also enhances and even intensifies the flavors.

Health benefits:

Artificial sweeteners do not increase the sugar levels in blood which is responsible for diabetes. These sugar substitutes have no calories. As these artificial sweeteners do not increase calories, they help people to control their weight. They provide good oral health.

Toxic effects of artificial sweeteners:

Artificial sweeteners like saccharin, ace-k and aspartame involves in genetic change, especially in DNA of lymphatic cells. Few by-products produced from sugar substitutes cause breakage in DNA strands. These can change the metabolic properties of human body.

Table-2: Toxic effects of artificial sweeteners:

Name of artificial sweetener	Metabolites	Annual Daily Intake (mg/kg)	Acute problems	Chronic problems
Saccharin	Ortho sulfamoylbenzoic acid	5	Nausea, vomiting, diarrhea	Low birth weight, bladder cancer, hepatotoxicity
Acesulfame- K or acek	Acetoacetamide	15	Headache	Thyroid tumors in rats, clastogenic, high doses cause genotoxicity
Aspartame	Methanol, aspartic acid & phenylalanin	50	Headache, dry mouth, dizziness, nausea, vomiting, thrombocytopenia, mood swings	Lymphomas and leukemia in case of rodents
Neotame	Methanol and deesterified neotame	2	Headache, hepatotoxic at high doses	Lower birth rate, weight loss, cancer in offspring, hepatotoxicity
Sucralose		5	Diarrhea, dizziness, stomach pain	Thymus shrinkage, enlargement of cecal in rodents

Potential effects of artificial sweeteners:

The major physiological impacts of artificial sweeteners include which affects blood glucose levels, obesity, gut microbiome, cardiovascular health, and cancer.

Blood Glucose Concentration and Diabetes Mellitus

Consuming artificial sweeteners led to a rise in blood glucose levels but the rising level is lesser when compared to the glucose consumption. However, there is no noticeable change in the values between the four artificial sweeteners such

as aspartame, saccharine, sucralose, and stevia.¹⁸ Furthermore, an animal study demonstrated the development of glucose intolerance following saccharin consumption. In humans, when saccharin consumed above the upper limit recommended by the ADI, also induced glucose intolerance and altered gut microbiota in four out of seven healthy individuals. Other intervention studies experimented on healthy individuals and diabetic individuals have shown no significant impact of artificial sweeteners on glucose homeostasis.

Obesity

Increased body weight and adiposity arise from a positive energy balance. Artificial sweeteners will impact energy balance and body weight differently when compared to natural sugar through physiological processes. In a meta-analysis including six prospective cohort studies of 26,551 subjects, established that the risk of obesity increased by 21% for every 250 mL/day rise in artificial sweetener-containing soft drink consumption.²⁴ Several proposed mechanisms, both in vitro and in vivo, may elucidate the association between artificial sweetener intake and obesity.

Cardiovascular Disease

The negative consequences of added sugars on numerous health outcomes, including cardiometabolic disorders, have been extensively investigated and analysed in meta-analyses and are now widely acknowledged as major risk factors by public health authorities. The total artificial sweetener consumption was accompanied by a greater risk of cardiovascular system dysfunction. ACEK and sucralose were linked to an increased risk of coronary artery disease, whereas aspartame was not associated with such risk. The WHO's 2022 report on artificial sweeteners highlighted connections between the intake of beverages containing artificial sweeteners (used as a proxy) and certain intermediate indicators of CVD.

Cancer

The banning of cyclamate in 1970 due to suspicions of its carcinogenicity damaged the artificial sweetener market. However, these concerns regarding carcinogenicity have not been shown in human epidemiological studies. The diketopiperazine compound formed when aspartame decomposes has also been proposed as a potential cause of cancer. Another important discovery was the generation of nitrosated compounds through the interaction of aspartame or its diketopiperazine breakdown product with nitrates in the diet.⁵

Alteration in Gut microbiome and Gastro-intestine

The microbiome is a diverse mix of bacteria that has a huge dimensional spread throughout the gastrointestinal tract covering a surface area of around 300 to 400 m². The gut microbe is primarily populated by strictly anaerobic bacteria, with fewer facultative anaerobes and aerobes present. In both humans and rodents, the majority of this bacteria is found in the colon, where Bacteroidetes and firmicutes are the predominant groups. Earlier research indicates that obese rodents tend to have fewer Bacteroidetes and higher levels of firmicutes when correlated with their lean counterparts.²⁸ A study proposes that variations in the human microbiome may render certain individuals more susceptible to glucose intolerance following exposure to AS than others.²⁹ Artificial sweeteners might change the composition of the gut microbiota, as indicated by increased dysbiosis and a higher ratio of firmicutes: Bacteroidetes, observed in a cross-sectional study consisting the morbidly obese individuals.

Pregnancy and Lactating Mother

A Danish study involving 59,334 pregnant women discovered that consuming artificially sweetened beverages was linked to a higher risk of preterm delivery.³⁹ Englund-Ogge and colleagues investigated the association between sweetened beverage consumption during pregnancy and preterm delivery in a cohort of 60,000 women from Norway. Their findings revealed that the risk of preterm delivery increased by 25% with the consumption of just one daily serving of sugar-sweetened beverages.⁴⁰ A study utilizing data from the National Health and Nutrition Examination Survey to examine the dietary habits of pregnant women and their risk of gestational diabetes revealed that a diet high in added sugar and organ meat, while low in fruits, vegetables, and seafood, is associated with the highest risk of developing gestational diabetes mellitus.

Childrens:

The World Health Organization advises against marketing beverages with artificial sweeteners to children. Guidelines and recommendations tailored for children tend to be more conservative and cautious regarding artificial sweetener intake. Children consume a relatively high number of beverages containing artificial sweeteners compared to their body weight per day.³⁶ The majority of observational studies suggest that artificial sweetener intake in children correlates with heightened weight gain over time. According to a recent systematic review, approximately 4-18% of children carbonated beverage consumption comprises artificially sweetened drinks.³⁷ The ADA's position statement regarding children specifically emphasizes that artificial sweeteners are considered safe when used within the acceptable daily intake range, which will differ among each of the five FDA-approved artificial sweeteners.

Food Colors

According to the Federal Food, Drug and Cosmetic Act, color additives, with the exception of coal tar hair dyes, must receive approval from the FDA before they can be used in food, drugs, cosmetics, or medical devices that have prolonged contact with the bodies of humans or animals. Black and brown eyes are banned for use in developed nations due to their harmful ingredients, which can have severe adverse effects on human health. For the sake of human health, it's crucial to set limits on the concentration of dyes used. The maximum allowable limit for permitted color in any food product is set at 0.1 g per kg to ensure safety after consumption.

Food and drug regulatory agencies establish permissible levels of synthetic dyes for inclusion in food products. According to FSSAI regulations, the total concentration in synthetic food, the colorants must not fall above 100 ppm in food and beverage. Currently, it's estimated that the average Indian citizen consumes around 220 mg of food colorants per year.⁴⁸ FSSAI-approved synthetic colorants such as Red (Ponceau 4R, Carmoisine, Erythrosine), Yellow (Tartrazine, Sunset Yellow FCF), Green (Fast green FCF), Blue (Indigo Carmine, Brilliant Blue FCF). FSSAI approved natural colours are Carotenes and carotenoids, Chlorophyll, Caramel, Riboflavin, Annatto, Curcumin, Saffron.

Natural Colors:

Color is an important factor increasing consumer's acceptability to food products. This is due to consumers always links food color with other qualities such as ripeness, freshness, and food safety. Thus, many food products have added food colorants to make the food products more desirable and acceptable. The synthetic food colors are available in different color shades. There are many reports on the toxicity of synthetic colors. Approved synthetic colors are proved to be toxic and carcinogenic. This need has come from legislative action and consumer orientation against synthetic food colors. The usage of large synthetic colors causes pollution, disturbs the ecological balance and causes health hazards to human. Natural colors are obtained from naturally occurring sources such as plants, animals, insects, and minerals. Amongst the colors, plant-based pigments have wide range of medicinal benefits.

Plant natural colors:

The natural colorants in natural plants have been the source of the traditional colorants of raw as well as the processed food.⁶

Table:3 plant natural colors

Class	Color	E-number
Chlorophyll	Olive green	E 140
Anthocyanins	Red, purple, blue, pink, magenta	E 163
Carotenoids	Red, orange, yellow	E 160
Betalains	Red, yellow	E 162

Natural color Versus Synthetic color

- If the color comes from plants, microbes, or minerals, it is considered natural. Contrarily, synthetic colors are produced in a laboratory by biologists.
- Consumers prefer the use of natural colors rather than synthetic ones since it is generally acknowledged that they are healthier for your health.

Artificial food colors such as Tartrazine (19140), Sunset Yellow (15985), and Ponceau 4R (16255), have been related to rise in children's hyperactivity. Tartrazine is one of the synthetic food dyes that might trigger an intolerant reaction in those who are vulnerable. The evaluations of natural colors, however, are dependent on a variety of assumptions and have only been evaluated to a limited extent.

Health benefits of Natural Food colorants

- The colors are extracted from vegetables, fruits and elements
- Natural food colorants are good for health.
- Doesn't contain harmful elements that effects humans and animals

Purpose of Food coloring

- Enhancing the appearance of food
- For artistic or decorative uses, like cake frosting
- Giving food its own individuality
- Enhances flavor

➤ Used to alter the color of food or drink

Permissible limit of Synthetic Food colors

The range of synthetic colors is maximal. Typically, this represents 100 ppm of the finished product intended for ingestion. However, the maximum limit of approved synthetic food colors in various foods and beverages, as noted in regulations, could be up to but not exceed 200 ppm of the finished food or beverage intended for human consumption.

This review paper's objective is to provide the most recent information on the numerous issues raised by the usage of food coloring additives. The most important food health and safety concerns in the area of food colors are the lack of global regulation on legal food colors, the replacement of synthetic colors with natural ones, and the presence of harmful illegal colorants - both well-known and new, developing ones - in food.

Table:4 Artificial food colors are classified: As per PFA

S.No.	color	Common Name	Color shade	Color index
1	Red	Carmoisine	Red	14720
		Erythrosine	Bright pink/Red	45430
		Ponceau 4R	Strawberry Red	16225
2	Yellow	Tartrazine	Lemon yellow	19140
		Sunset yellow	Orange	15985
3	Blue	Indigo carmine	Royal Blue	73015
		Brilliant blue FCF	Turquoise Blue	42090
4	Green	Fast green FCF	Sea Green	42053

Adverse Effects of Food Colorants:

The Food Advisory Committee under the Food and Drug Administration held a hearing on certified color additives and their potential link to hyperactivity in children.⁴⁹ A research has indicated that young children exhibit strong responses to synthetic colorants, manifesting symptoms such as irritability, sleep problems, lack of attention, impulsivity, hyperactivity, and a clinical condition known as attention deficit hyperactivity disorder. Tartrazine appears to trigger the most allergic and intolerant reactions in all azo dyes, especially among asthmatics and individuals with aspirin intolerance.

Research on Brilliant Blue FCF has reported potential side effects on human health, noting that high doses could lead to settlement in the kidneys and lymphatic vessels.⁵¹ Azo dyes containing Benzedrine rings, when metabolized by anaerobic intestinal microflora in the body, can produce aromatic amines, which are known to be carcinogenic and may contribute to the development of intestinal cancer. Exposure to auramine, a dye known for producing a yellow color, and rhodamine can cause damage and dysfunction to the liver and kidneys in humans, significantly impeding their growth and function. Sunset Yellow and Tartrazine are synthetic colorants commonly used in food and beverages; excessive consumption of these additives has been linked to increased estrogen levels in the human body. Elevated estrogen levels can lead to various health issues in both males and females. In common carcinogenicity, hypersensitivity that induces the exacerbation of asthma, hyperkinesia and skin allergies can occur.¹¹

Rhodamine B

Rhodamine B, also known as an artificial red dye belonging to the xanthine dye group, imparts a vibrant red and finds extensive use in various industries, including cosmetics, textiles, medical applications, and paper production. This low-cost colorant is occasionally employed to impart vibrant color to popular street food items like gobi manchurian and cotton candy. Recently the Department of Health and Family Welfare under the Government of Karnataka, has imposed a ban on Rhodamine B. This dye is deemed carcinogenic to both animals and humans and has been associated with adverse effects such as skin pigmentation, respiratory inflammation, degenerative changes in the liver and kidneys etc., It's concerning that some of the synthetic food colorants banned to use in developed countries are still being used as food ingredients in various parts of India. Considering the significance of regulatory and societal factors concerning food colorants in India, there is a necessity for a revised catalog of authorized and prohibited food colorants to safeguard food safety and the well-being of consumers.⁵

Toxicity evaluation of synthetic food dyes

Increasing attention has been recently paid to the toxicity of additives used in food, namely to azo-dyes. This group of colorants typically consists of bright colours. However, the main concern often limiting their use is potential carcinogenicity occurring after their azoreduction to carcinogenic metabolites by intestinal microbiota. These

metabolites are known to be produced in the human body; however, the clinical importance of this phenomena depends on the ingested amount of the colorant. Furthermore, given the low rate of absorption, harm to human health is unlikely. However, in light of new findings, is it necessary to regularly assess potential toxicity of food colorants by regulatory authorities and consequently revise guidelines for their use.⁹

3. CONCLUSION

The increasing prevalence of chronic diseases like diabetes mellitus and cardiovascular diseases has brought attention to the role of dietary factors including added sugars and artificial sweeteners, as well as food colorants. While artificial sweeteners offer a low-calorie alternative to sugar, their potential health effects including impacts on blood glucose levels, obesity, gut microbiome and even cancer raise concerns. Similarly, food colorants both synthetic and natural, have been associated with adverse health effects including allergic reactions and potential carcinogenicity. In light of these concerns, there's a need for more research to better understand the long-term health implications of artificial sweeteners and food colorants. Meanwhile, emphasizing the importance of reducing added sugars in the diet, in search of healthier alternatives like rare sugars and stevia and advocating for stricter regulations on the use of food colorants could help mitigate potential risks. Additionally, caution should be exercised especially among vulnerable populations such as pregnant women, children and individuals with specific health conditions. Overall, a balanced approach that prioritizes consumer safety and public health is essential in navigating the complex landscape of dietary additives and their potential impacts on health. Hence, we conclude that our diet should not be influenced by the campaign's food marketing company.

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