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Review Article

Understanding Artificial Sweeteners and Food Colorants-their Impact on Human Health: A Review

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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.

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

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INTRODUCTION

In recent trends, it has been observed that increase in the incidence of diabetes mellitus and cardiovascular diseases. Intake of added sugars is directly related to higher energy consumption and is thought important contributor to the rise in obesity worldwide.[1] In 2016, the number of overweight adults exceeded 1.9 billion while over 650 million were classified as obese, reflecting a global prevalence of 13%.[2] As part of globalization and economic growth advancement, there has been a noticeable transition in dietary habits since 1970.[3] The current literature proposes that obesity and Cardiovascular Disease (CVD) are intentionally and unintentionally promoted by a high-sugar diet. The same effects of a high-sugar diet are also seen in incidence of cancer rates.[4] Because of the promotional marketing campaigns from the food industry, transforms these artificial sweeteners have emerged from sugar substitutes to projected health substitutes.

Artificial Sweeteners (ASs) also called high-intensity sweeteners are sugar substitutes that provide high sweetening properties associated with low or no added calories. Back in the 1970s, the FDA approved six sweeteners as food additives such as Aspartame, Acesulfame potassium (Ace-K), Advantame, Sucralose, Neotame and Saccharin. Fruit- and plant-based Sweeteners besides the six that have been authorized for use as food additives include specific steviol glycosides, which are pure extracts derived from the stevia plant, extracts from the monk fruit, Thaumatin, are widely acknowledged to be safe.[5] The World Health Organization advises aiming for a free sugar intake of less than 10% of total energy intake, preferably below 5%, as a conditional recommendation.[6]

Food colorants, often known as color additives, are any kind of dye, pigment or material which gives color to food or beverages. Extensive research emphasizes that the color of the food plays a significant role in shaping the flavor expectation, influencing our brain's anticipation of taste even before intake of food.[7] There are nine certified food colorants authorized by the FDA for use in food and the European Union (EU) permits the use of sixteen. In India, the FSSAI has released lists detailing both natural and synthetic colorants along with their approved thresholds in two sets of Food Safety and Standards regulations from 2009 and 2011.

Artificial Sweetener

Saccharin was the first artificial sweetener synthesized in 1879, it is a derivative of petroleum and is approximately 200-700 times sweeter than sucrose. Artificial sweeteners, also known as non-nutritive sweeteners are alternatives to traditional sweeteners like sucrose and they have low-calorie content. They

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were normally used in beverages and nutritional products. The FDA assesses the safety of artificial sweeteners by examining potential intake, cumulative effects from all sources and toxicological data from animal studies. The European Food Safety Authority reviews and verifies that artificial sweeteners consumed within the Acceptable Daily Intake (ADI) limits are not responsible for cancer or other health risks, ensuring they are safe for human utilization.[8] The FDA will establish Acceptable Daily Intake (ADI) levels for each sweetener, measured in mg per kg of body weight per day which is mentioned in Table 1. These levels indicate the quantity deemed safe for daily consumption throughout an individual's lifetime. The Acceptable Daily Intake (ADI) is usually 100 times less than the dosage of the sweetener that induced toxicity in animal trials. In order to approve a sweetener for use, the FDA must ensure that the Estimated Daily Intake (EDI) of the sweetener remains below the established ADI. If the EDI is lower than ADI, the sweetener is deemed safe for human consumption.[9]

Aspartame

Aspartame was first approved for use in 1974 and it is about 200 times sweeter than sucrose. Aspartame produces 4 calories per g.[3] The FDA concluded that aspartame is safe for the general public when manufactured using good manufacturing techniques and used under permitted circumstances of use, and this decision has been supported by scientific data ever since. However, individuals with phenylketonuria, a rare genetic disorder that affects phenylalanine metabolism, should avoid or limit their consumption of aspartame.[10] The Joint Expert Committee on Food Additives (JECFA) of the Food and Agriculture Organization (FAO), the World Health Organization (WHO), and the International Agency for Research on Cancer (IARC) have produced assessments on the health effects of aspartame, a non-sugar sweetener. IARC categorized aspartame as probably carcinogenic to humans (IARC Group 2B) citing "limited evidence" for carcinogenicity in humans, while JECFA confirmed the tolerable daily dose of 40 mg/kg body weight.[11] The two organizations conducted separate yet complementary evaluations to analyze the potential carcinogenic hazards and other health risks linked to consuming aspartame.

Cyclamate

The discovery of cyclamate dates back to 1937. It functioned as a low-calorie sweetener within the United States during the 1950s and 1960s. In the United States, the FDA has banned the use of cyclamates and its many salts including calcium, sodium, magnesium, and potassium salts.[10] Since 1970, following the outcomes of animal experiments, the FDA has harbored suspicions that cyclamate, also known as sodium cyclohexyl sulfamate, could potentially cause cancer. Consequently, its usage in all dietary foods and beverages was banned in the United States.[12]

Advantame

The most recent artificial sweetener approved by the FDA in 2014, Advantame is authorized to be used as a broad-purpose sweetener and flavor enhancer except in meat and poultry products. Advantame consists of chemical components Aspartame and vanillin.[13] It provides a heat-stable, chemically analogous environment that produces lower levels of phenylalanine, thus lacking a warning label for individuals with phenylketonuria, unlike Aspartame.[14]

Rare Sugars

According to the International Society of Rare Sugars, "monosaccharides and their derivatives are scarcely present in nature". These sugars have gained heightened attention due to recent progress in their large-scale biosynthesis for commercial purposes. Rare sugars such as L-glucose, D-allose, D-Psicose, D-tagatose, xylitol, and L-ribose. D-Psicose (PSI) and D-Tagatose (TAG), two rare sugars, have been granted Generally Recognized as Safe (GRAS) status. Rare sugars, valued for their ability to sweeten with few calories and in large quantities, deliver appealing sweetness without being metabolized in the human body, resulting in no calorie intake and rare sugars do not have ADI value. Hence rare sugars are a favourable option for diabetic patients due to these qualities.[15] Human trials provide evidence that both PSI and TAG, when consumed alongside a carbohydrate load, can decrease the subsequent rise in blood glucose levels in individuals with hyperglycemia. Research with animals has indicated that specific rare sugars might enhance lipid profiles, modulate the gut microbiome, and decrease the expression of pro-inflammatory cytokines.[16] Recent studies have initiated investigations into the impact of rare sugars on gastrointestinal tract health. Animal studies show that consuming PSI may increase the abundance of species such as Lactobacillus, which are believed secure against fructose-induced Non-Alcoholic Fatty liver Disease.[17] Rare sugars could provide an alternative to other sweetener because of these features.

Potential Ill 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.[19] 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.[20] Other intervention studies experimented on healthy individuals and diabetic individuals have shown no significant impact of artificial sweeteners on glucose homeostasis.[21] In contrast, a systemic review and meta-analysis of prospective cohort studies in healthy individuals found a connection between the intake of artificial sweeteners and the development of type 2 diabetes mellitus, independent of adiposity.[21] In a huge meta-analysis of prospective studies (17 cohorts with 38 253 cases) it was revealed that artificial sweeteners intake is associated with the risk of Type 2 Diabetes Mellitus (T2DM), and it implies that it may not be a healthy alternative to sugar-sweetened beverages as projected.[22] In another systematic review, four relevant studies from three observational studies were included, examining the positive relationship between artificial sweetener consumption in the form of soft drinks and the risk of type 2 diabetes mellitus and the review has concluded the presence of elevated risk of type 2 diabetes mellitus associated with daily consumption of 330 mL of artificially sweetened soft drinks.[23]

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. One possible explanation stem from the hypothesis that the perception of sweetness without calorie intake could disrupt the brain's metabolic signalling and appetite regulation.[25] The absence of satiety signals may lead to increased food consumption. Consuming a food lesser in energy could leads to the increase in overall food consumption. This phenomenon has been most thoroughly elucidated in the context of low-fat foods, where individuals tend to overeat after seeing items labeled as low-fat.[26] Several large-scale cohort studies have documented a positive, dose-dependent correlation between artificial sweetener consumption and elevated body mass index.[27]

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 m^2. 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.[27] 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.[30] A study involving, administering the ADI dosage for human utilization (15 mg per kg per day), found no impact on microbiota composition in mice after 8 weeks. However, another study using a dosage more than the ADI by more than two times (37.5 mg per kg per day), observed a rise in bacteroidetes and firmicutes after just 4 weeks of consumption in mice.[3]

Research on the effects of rare sugars on the gut microbiome is relatively new, but findings from animal studies suggest that PSI intake can elevate the presence of species like Lactobacillus, which are believed to secure against fructose-induced non-alcoholic fatty liver disease. TAG, as it is weekly absorbed, may function as a prebiotic and it has been shown to work in combination with probiotics in decreasing the susceptibility to chemically induced colitis in mice.[31]

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.[32] 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.[32] 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. These included a slight rise in the unfavourable ratio of total cholesterol to HDL cholesterol and a heightened likelihood of hypertension.[33] A longitudinal research conducted in the UK over a period of 11 to 12 years demonstrated that those who consumed two or more servings of non-nutritive sweeteners, such as those often found in diet soft drinks, had an elevated risk of developing coronary heart disease.[14]

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

Table 1: Safe level, toxicity symptoms and regulatory status of Artificial sweeteners.[35]

Artificial sweetener	FDA approval	FDA Status*	Safe level ADI (mg/kg/day)	Clinical symptoms of toxicity in humans		Sweetness (compared to sucrose)
				Acute	Chronic	
Acesulfame -K	1988	NNS, REG	15	Headache, nausea, impairment of liver, eye sight problem, hypoglycaemia	Clastogenic, genotoxic at high doses	200 time
Aspartame	1974	NUTRS, REG, GMP	50	Dry mouth, dizziness, mood changes, reduced seizure threshold, thrombocytopenia	Lymphomas	180-200 times
Advantame	2014	-	32.8	Gastrointestinal disturbances	-	20000 times
Neotame	2002	NNS, REG, GMP	2	Headache, hepatotoxic at high doses	Lower birth rate, weight loss	8000 times
Saccharin	1977	NNS, REG	5	Nausea, vomiting, diarrhea, sulfa allergy	Low birth weight, bladder cancer, hepatotoxicity	300 times
Sucralose	1998	NNS, REG, GMP	5	Diarrhea, headache, muscle cramp, stomach cramp, skin irritation, dizziness.	Thymus shrinkage (animal studies)	600 times

*__NNS__- Non-nutritive sweeteners, __GMP__- Good manufacturing practice, __NUTRS__- Nutritive sweeteners, __REG__- Food additives for which a petition has been filed and regulation issued.

its diketopiperazine breakdown product with nitrates in the diet. These compounds have been linked to cancer development.[18] Additionally, research has found that only prolonged, high intake of non-nutritive sweeteners, exceeding 1680 mg per day, is associated with an elevated risk of human bladder cancer.[12] There were 25 observational studies included in the analysis, with a total of 3,739,775 participants. While the consumption of artificial sweeteners does not demonstrate a definitive connection to cancer rates and mortality, there may be a heightened risk of cancer incidence connected with the intake of artificial sweeteners in Europe.[4] The NutriNet-Sante population-based cohort study, use of artificial sweeteners, notably aspartame and ACE K, correlates with a higher cancer risk. A study suggests that frequent consumption of artificially sweetened beverages defined as more than one drink per day, in postmenopausal women, may be linked to an increased risk of kidney cancer.[34] Research has extensively examined the connection between cancer and various identified factors, such as the correlation between aspartame can cause lymphoma in animal studies, cyclamate can develop bladder cancer, acesulfame K can develop thyroid cancer.[35] The other potential side effects of AS are mentioned in Table 1.

Susceptible Populations-Pregnancy and Children

Eliminating the daily use of artificial sweeteners, which are prevalent in food, cosmetic, and dietary products, is practically challenging. Nonetheless, caution should be exercised when using them, especially among high-risk individuals like pregnant and breast-feeding mother, diabetics and children.

Children

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. Nowadays, children's consumption of artificial sweeteners is thought to be significantly lower than the acceptable daily intake, ranging from approximately 10% of the acceptable daily intake for existing levels of aspartame consumption to as far as 60% of the ADI for acesulfame k.[36] The Institute of Medicine (IoM) does not advocate for the use of artificial sweeteners in children due to concerns that artificially sweetened beverages may

replace milk and 100% of the juice during mealtime.[9] The Pan American Health Organization Nutrient Profile Model advises against marketing any ultra-processed food or beverage, that may contain artificial sweeteners, to children, especially within school environments. This recommendation is based on the belief that regular consumption of sweet food and beverage products during childhood can influence lifelong utilization patterns.[38] The American Academy of Pediatrics has said that artificial sweeteners have not been sufficiently studied for usage in pediatrics and therefore should not play a major role in their diet.

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.[41] Research conducted on rats regarding early-life exposure to a sucrose-rich diet evaluated that offspring exhibit higher levels of adiposity and higher liver triglycerides.[42] Azad *et al*. found that infants whose mothers consumed AS daily during pregnancy experienced an increase in infant BMI and were twice the risk as likely to be obese at age one.[43] The study discovered that lactating mothers' breast milk contained saccharin, sucralose, and acesulfame potassium, all of which were clearly consumed by infants. Recent evidence indicated that pregnant women who consume artificial sweeteners may have bigger babies, and this weight tends to persist into childhood. Additionally, Studies on animals have demonstrated that when exposed to artificial sweeteners prenatally, offspring tend to consume more sweetened food in advanced stages of life.[44] The American Dietetic Association recommends avoiding non-nutritive sweeteners in children under 2 years of age and minimizing or completely avoiding their use during pregnancy and lactation, despite the FDA suggesting the use is safe.[36]

Better Alternative for Artificial Sweeteners

The Dietary Guidelines Advisory Committee emphasizes the importance of reducing added sugars in the diet but does not recommend replacing them with artificial sweeteners.[45] The recommended threshold for added sugar consumption is a maximum of 100 calories for women each day and 150 calories for each day. Rare sugars have been demonstrated to enhance glucose control and decrease body fat in human clinical trials and animal studies. Lowering postprandial glucose levels could result in various health advantages.[16] Since stevia is a natural product will have fewer side effects compared to other artificial sweeteners, it can be recommended as a sugar substitute for use in food dietary products.[18] Stevia will prominently enhance the nutritional level of diabetes mellitus patients.[46]

Food Colour Additives

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.[47] 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.

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.[50]

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.

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.[52] 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.[53] 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.

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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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

ACE K: Acesulfame Potassium; **ADA:** American Dietetic Association; **ADI:** Acceptable Daily Intake; **AS:** Artificial sweeteners; **EDI:** Estimated Daily Intake; **EU:** European Union; **FAO:** Food and Agriculture Organization; **FDA:** Food and Drug Administration; **FSSAI:** Food Safety and Standards Authority of India; **GRAS:** Generally Recognized as Safe; **IARC:** International Agency for Research on Cancer; **IOM:** Institute of Medicine; **JECFA:** Joint Expert Committee on Food Additives; **PSI:** D-Psicose; **TAG:** D-tagatose; **T2DM:** Type 2 Diabetes Mellitus; **WHO:** World Health Organization.

ETHICS APPROVAL

This study does not contain any studies with human or animal subjects performed by any of the authors.

AVAILABILITY OF DATA AND MATERIAL

The authors confirm that the data supporting the findings of this study are available within the article.

AUTHORS' CONTRIBUTIONS

The manuscript was written through equal contributions of all authors. All authors have given approval to the final version of the manuscript.

SUMMARY

FDA approved six sweeteners as food additives such as Aspartame, Ace-K, Advantame, Sucralose, Neotame and Saccharin. Fruit and plant-based sweeteners are also authorized to use as food additives. In the United States, the FDA has banned the use of cyclamates. Rare sugars such as L-glucose, D-allose, PSI, TAG, xylitol, and L-ribose. PSI and TAG have been granted GRAS status. Rare sugars have been demonstrated to enhance glucose control and decrease body fat in human clinical trials and animal studies. Stevia is a natural product has fewer side effects compared to other AS, it can be recommended as a sugar substitute for use in food dietary products. There are nine certified food colorants authorized by the FDA for use in food and the EU permits the

use of sixteen. In India, FSSAI has released lists detailing both natural and synthetic colorants. Synthetic colorants such as Red (Ponceau 4R, Carmoisine), Yellow (Tartrazine), Green (Fast green FCF), Blue (Indigo Carmine). Natural colours are Carotenes, Chlorophyll, Caramel, Riboflavin, Curcumin etc., Food Advisory Committee under the FDA held a hearing on certified color additives and their potential link to hyperactivity. The Department of Health and Family Welfare under the Government of Karnataka, has imposed a ban on Rhodamine B.

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