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The secret ingredients: Decoding food additives

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Abstract
The expansion of the food industry to meet consumer demand for processed foods has significantly increased the use of food additives. Although food manufacturers must list additives on product labels, the technical terms used often confuse or mislead consumers. Additives are sometimes called "secret ingredients" due to the perceived lack of transparency and the complexity of labelling practices. Additives are crucial for improving the quality, safety, and appeal of processed foods. They are substances, natural or synthetic, added to foods for technical purposes and are regulated to ensure consumer safety and health. Food additives can be categorized into nutritive additives, processing agents, preservatives, and sensory agents (Thakur *et al.*, 2022) [30, 31]. Nutritional additives, such as vitamins and minerals, replenish nutrients lost during processing or fortifying foods. Processing agents achieve specific technological effects. Preservatives, both antimicrobial and antioxidant, extend shelf life by preventing microbial growth. Mostafa *et al.* (2018) [23] demonstrated that plant-based preservatives like pomegranate and clove extracts show strong antimicrobial activity. Sensory agents include colourants, flavourings, and sweeteners, which enhance appearance and taste. Studies by Ahmed *et al*. (2021) [3] noted excessive artificial colour use in processed foods for children, surpassing permissible levels. Additionally, prolonged intake of aspartame, a synthetic sweetener, has shown adverse effects on liver health in animal studies (Abhilash *et al.*, 2011) [1]. Regulatory bodies like the FDA, EFSA, and FSSAI oversee the safety and permissible use of food additives, setting acceptable daily intake (ADI) levels. Systems such as E numbers and INS numbers standardize additive identification globally. However, excessive additive consumption can lead to allergies, liver damage, cancer, or hyperactivity in children (Baig and Kasim, 2018) [7]. While food additives improve safety and shelf life, consumer awareness is vital to ensure their responsible use for a safe, diverse food supply (Sun *et al.*, 2021) [28, 29]

Keywords: Food additives, secret ingredients, labelling, preservatives, E numbers

Introduction

Food additive means any substance not normally consumed as food by itself and not normally used as a typical ingredient of the food, the intentional addition of which to food for a technological purpose (FSSAI, 2015) [10]. In the modern food industry, the use of food additives has become ubiquitous, playing a significant role in food processing, preservation, and enhancement. Food additives are substances added to food products during processing or production to improve their overall quality and shelf life. They serve various functions, ranging from preserving freshness to enhancing flavours and colours, and they play a crucial role in meeting consumer demands for convenient, nutritious, and flavorful food options. The history of food additives dates back centuries, with humans using natural substances like salt, spices, and vinegar to preserve and flavour foods. However, with advancements in food technology and changes in consumer preferences, the spectrum of additives has expanded significantly. Today, food additives encompass a vast array of substances, including preservatives, antioxidants, emulsifiers, stabilizers, thickeners, colourants, flavour enhancers, and sweeteners, among others. While food additives offer numerous benefits, concerns about their safety and potential health effects have also arisen. Critics often highlight the need for thorough evaluation and regulation of additives to ensure they do not pose risks to consumers' health. Regulatory agencies around the world, such as the Food and Drug Administration (FDA) in the United States and the European Food Safety Authority (EFSA) in Europe, establish guidelines and safety standards for the use of food additives. These regulations aim to ensure that additives are safe for consumption at specified levels and undergo rigorous testing before approval.

Functions of food additives

According to Thakur *et al.*, (2022) [30, 31], food additives serve several main functions in food production and processing, including:

a. **Enhance flavour:** Food additives are often used to enhance or modify the flavour of food products. Flavour enhancers like monosodium glutamate (MSG) are added to intensify existing flavours, while artificial and natural flavours can be added to impart specific tastes.

b. **Extend shelf life:** Many food additives act as preservatives, extending the shelf life of food products by inhibiting the growth of bacteria, fungi, and other microorganisms. Common preservatives include antioxidants like vitamin C and vitamin E, as well as substances like sodium nitrite, which prevents bacterial growth in processed meats.

c. **Increase nutritional value:** Some food additives are used to fortify or enhance the nutritional content of food products. For instance, vitamins, minerals, and other nutrients can be added to foods to address specific nutritional deficiencies or to meet regulatory requirements. Examples include adding vitamin D to milk or iodine to salt.

d. **Improve overall quality:** Additives are sometimes used as processing aids to facilitate the manufacturing process or improve the overall quality of the final product. These additives may not necessarily remain in the final product but are used during processing. Examples include anti-caking agents to prevent clumping and enzymes to aid in dough conditioning.

Role of food additives in improving overall quality of final product

Food additives play a crucial role in improving the overall quality of food, explained here with an example of homemade bread and commercial bread. From the picture that is given below it is clear that commercial bread looks better. In the preparation of homemade bread yeast sugar and fat are added with basic ingredients where whereas in commercial bread other than these basic ingredients additives like oxidizing agents mainly hydrogen peroxide for improving the colour, vitamins as nutritional additives, sorbates or propionates as preservatives, and glycerol monostearate for making bread soft and palatable. The benefits of adding these additives to bread are physically evident in this picture, Consumers demand for appealing foods resulted in wide applications of additives in food processing industries. (Image 1)

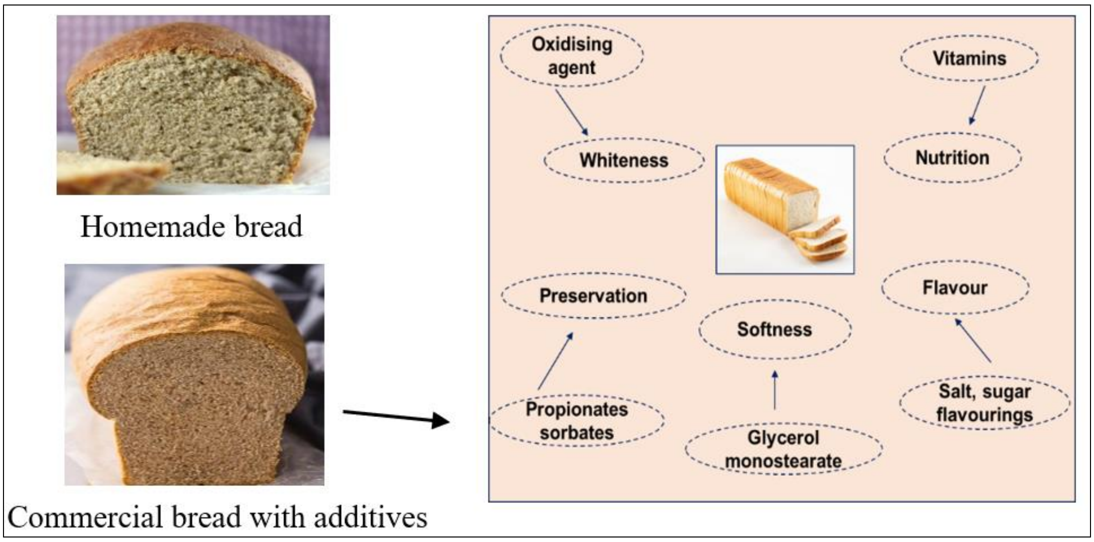


Fig 1: Commercial bread with additives

Classification of food additives

According to (FSSAI, 2011) [9] there are four general categories of food additives based on functions:

- Nutritional additives
- Processing agents
- Preservatives
- Sensory agents

Nutritional additives: They are added to foods either to restore or enrich the nutrients lost during processing or to fortify with nutrients to address nutritional deficiencies prevailing among the population. For this purpose, vitamins (Vitamin A, B complex and D) minerals (Iron, Iodine and Sodium chloride) and amino acids (Lysine and methionine) are mostly used. Some of the nutritional additives are given below in Table 1.

Table 1: Food application of nutritional additives

Food	Nutritional additives	Benefits	References
Rice flour	L- lysine	Protein synthesis and tissue repair	Goyal *et al.*, 2017 [15]
Dairy products	Vitamin A and D	Increase calcium absorption	Adinepour *et al.*, 2022 [2]
Passion fruit juice	Ferrous sulphate	Increases iron availability	Haro-Vicente 2006 [17]
Salt	Iodine (20 - 30 ppm) Iron (850 - 1100 ppm)	Reduces iron and Iodine deficiency	FSSAI, 2018 [11]
Oil	Vitamin A (6 - 9.9 µg RE/g) Vitamin D (0.11 - 0.16 µg/g)	Increases calcium absorption	FSSAI, 2018 [11]

2 Processing agents

Processing agents are added to achieve a desired property in the final product (Thakur *et al.*, 2022) [30, 31]. Various types of processing agents have a crucial role in improving the overall quality of food products some of them are given below;

a. **Anticaking agent:** Anticaking agent is an additive that is used while processing to prevent the formation of lump. They can absorb excess moisture in food and help them to remain in powdered form carbonates and silicates of Ca and Mg are mainly used as anticaking agents in salt, soup powders, milk powder etc. They can be used in food stuffs at a max of 2 per cent for e.g. Calcium Silicate is added to free-flowing salt.

b. **Leavening agents:** Leavening agents are used mainly in bakery products to create structure and texture, mainly by incorporating CO_2 gas into the foodstuffs and helping to impart soft and fluffy texture to baked goods. Examples -yeast baking powder and baking soda etc. They can be used at (Good Manufacturing Practices) GMP level.

c. **Emulsifiers:** Emulsifiers are used to stabilize oil-in-water emulsions uniformly in foods, mainly used in ice-creams. In ice-cream it helps to prevent large ice-crystal formation while freezing egg lecithin is a natural emulsifying agent used widely in bakery products at GMP level. Synthetic emulsifiers like polysorbates are also available for use in foods.

d. **Chelating agents:** Chelating agents are also known as sequestrants or metal scavengers because it inactivates the metal ions in foods that promote oxidation, these agents are mostly used in canned foods Foods rich in sulfur, such as garlic and broccoli, are used as the natural chelators in some foods. The most widely used artificial chelatings agent is Ethylenediaminetetraacetic acid (EDTA), and added to food at about 250mg.kg.

e. Stabilizing or thickening agents are used to produce a uniform texture and improve mouth-feel by forming a gel structure in combination with water, for ex - pectin, guar gum etc. these are mainly used in sauces.

f. **Stabilizing or thickening agents:** jams soups puddings, acrylic acid, methacrylic acid are the artificial thickening agents that are used in foods

g. **Acidity regulators, or pH control agents:** Acidity regulators, or pH control agents are used to change or maintain the pH of food products. They can be organic acids like lactic acid, acetic acid, formic acid, citric acid, citric and cam be added to foods at GMP level mostly used in beverages. Uncontrolled pH can result in the growth of undesirable bacteria (artificial acidity regulator can also be used for ex Sodium adipate.)

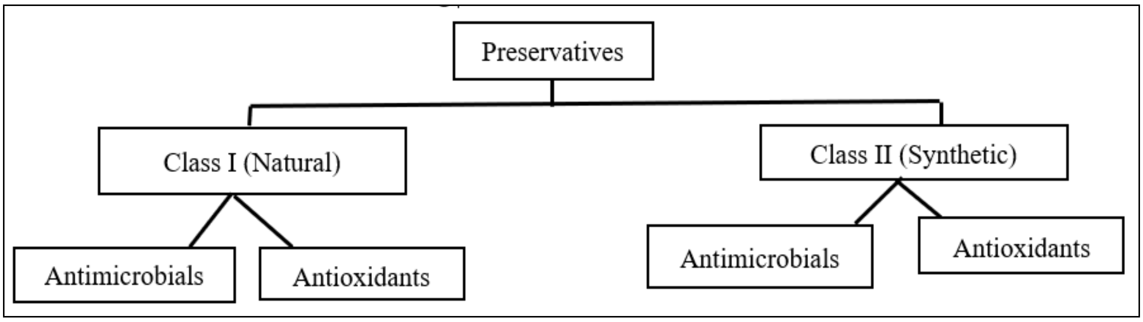
h. **Glazing agents:** Glazing agents are used to providing a protective coating or lustrous surfaces to foods, such as beeswax, candelilla wax, and oxidized polyethylene wax, etc.

i. **Bleaching agents:** Bleaching agents helps to bleach the flour making it whiter and widely used by flour milling and baking industries. Freshly milled flour has a yellowish colour, after adding bleaching agents such as benzoyl peroxide it will become whiter. A premix of 32 per cent benzoyl peroxide and 68 per cent cornstarch is used in bleaching flour. The maximum amount used as a flour bleaching agent is 50 mg/kg.

j. **Clarifying agents:** Clarifying agents are used to clarify liquid foods by removing particles or sediment from juices, beers wines to make them clear. For example – bentonite and gelatin etc. It can be used at the GMP level.

3. Preservatives

Preservatives are used to increase the shelf life of food by inhibiting the growth of yeast, moulds and bacteria and also to arrest other chemical changes in foods. According to (FSSAI, 2015) [10] preservatives are classified into class 1 and class 2, class 1 from natural sources and class 2 purely synthetic they are further classified into antimicrobials and antioxidants. Class 1 antimicrobials include natural food ingredients such as salt, sugar wood smoke and plant and animal-derived substances and bacteriocins. The common salt is 15 to 20 per cent and sugar is 65 per cent when added to foods and can act as a preservative. Class 2 antimicrobials include; Propionic acid and its sodium salt (sodium propionate) this is an antifungal preservative that is mainly used in baked and canned products it prevents microbial growth by affecting cell membrane permeability. Sulphur dioxide- it is used in the preservation of juices squash pulp or other products it mainly inhibits the growth of bacteria and moulds, It is used in the form of sulphite, metabisulphite and bisulphate, KMS is used as a stable source of SO2. Benzoic acid or its sodium salt (sodium benzoate) is effective against yeast and moulds and less effective against bacteria. It is used in fruit juices, syrups jams and pickles etc. And class 2 antioxidant BHA. BHT and TBHQ are mainly used to prevent the oxidation of fatty acids in food products.



3.1 Mechanism of action of preservatives

a. Antimicrobials

Antimicrobials and antioxidants work through different mechanisms to extend the shelf life of food products and prevent spoilage caused by microorganisms or oxidation. Some natural antimicrobials such as salt sugar and honey inhibit the growth of microorganisms at higher concentration levels, In hypertonic solution they exert an osmotic pressure that causes plasmolysis and destroys the cell membrane in bacteria. Antimicrobials interfere with the activation of proteolytic enzymes in microorganisms resulting in the protein synthesis of microorganisms stopping, and also by decreasing the water activity by reducing the solubility of oxygen in water leading to the death of aerobic microorganisms.

b. Antioxidants

Oxidation of unsaturated fatty acids involve reaction between C-C double bond and oxygen molecule and the product of this reaction is free radicals that are highly reactive and unpaired electron so antioxidants neutralises these radicals by donating one electron thus it prevents the oxidation and prevent rancidity and off flavour in food**.** Antioxidants are also preserving food by inhibiting the enzymatic reaction for example – when cut surface of fruits and vegetable expose to air phenol oxidase enzymes released at the surface and react with polyphenol compound present in fruits and vegetables and oxidising into orthoquionoe and then orthoquionoe rapidly polymerise into brown pigment. Antioxidants acts phenol oxidase enzyme and prevent browning (Garcia and Searle, 2016)

Class I Antimicrobials: These include natural food ingredients such as salt, sugar, wood smoke, plant- and animal-derived substances, and bacteriocins. Common salt, when used at a concentration of 15 to 20 percent, and sugar, at 65 percent, can act as effective preservatives.

- **Plant-derived antimicrobials:** These include spices like clove and cumin seeds, herbs like basil, essential vegetable oils, vinegar, etc. There are no permissible limits for these antimicrobials.
- **Animal-derived antimicrobials:** These are synthesized by animals, mostly in the form of peptides, polysaccharides, and fatty acid derivatives. Some of these compounds include: Lysozyme: Derived from hen eggs, it has antibacterial effects at concentrations of 40–500 mg/kg in cheese. Lactoferrin: Derived from bovine milk (bovine refers to cows that have not yet calved). It can be used at a concentration of 0.2 percent in dairy products. Chitosan: Derived from the shells of crustaceans (e.g., crabs, lobsters). It is effective against yeasts and can be used in beverages at 0.3 mg/ml. Chitosan effectively eliminates yeast.
- **Bacteriocins:** These are proteins produced by bacteria (lactic acid bacteria or LAB) that can kill other bacteria. They are antimicrobial peptides produced by various bacterial species, particularly LAB. Bacteriocins are used as preservatives in food because they are heat-stable and have a wide pH tolerance. A maximum level of 12 mg/kg of nisin is considered safe for use in cheese, while pediocin can be used at 2.9 mg/kg in meat.

Class II: preservatives are obtained through the chemical derivation of compounds. Sorbates, benzoates, propionates, and sulfites are widely used as preservatives in fruit processing. (Table 2)

Table 2: Class II preservatives and its level of addition in food products and ADI (Acceptable Daily Intake)

Preservatives	ADI (mg/kg bw)	Level of addition in foods (%)	Products
Sodium benzoate	2.5	0.03 - 0.2	Pickles, jam jellies etc.
Sodium propionate	10	0.1 - 0.2	Fruits, vegetable and bakery products
Potassium sorbate	25	0.05 - 0.2	Soft drinks and wines
Sodium nitrite	0.06	0.01 - 0.02	Meat products
Sulphur dioxide	0.7	0.005 - 0.2	Fruits juices, sqush, pulp vegetables, cereals, etc.

Class I Antioxidants: Natural antioxidants are widely distributed in foods and medicinal plants. These compounds, particularly polyphenols and carotenoids, exhibit a broad spectrum of biological effects, including anti-inflammatory, anti-aging, anti-atherosclerosis, and anticancer properties. In food systems, they play a crucial role in preventing oxidation reactions. Below are some common sources of natural antioxidants.

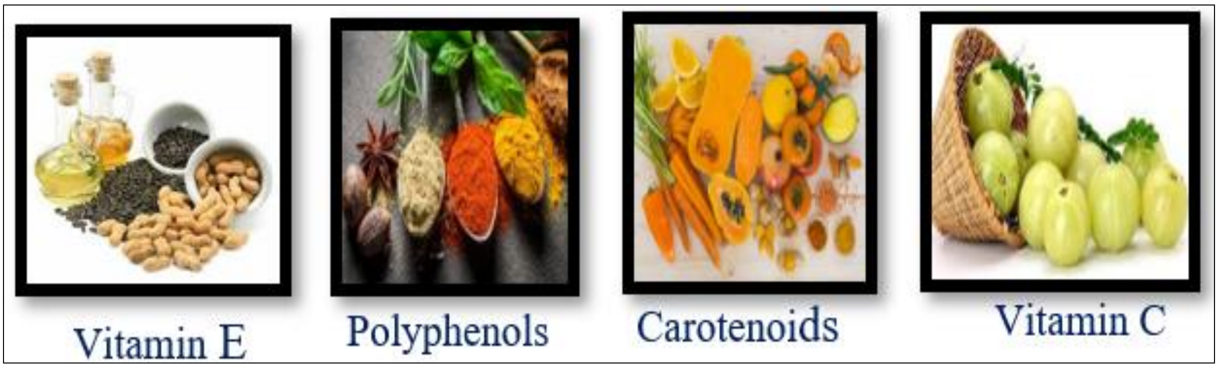


Fig 2: Sources of class I antioxidants

Table 3: Food applications of class I antioxidants

Antioxidants	Source	Applications	References
Polyphenols (Epicatechin, quercetin, catechin)	Kiwi fruits	Prevent the oxidation of meat	Jiao *et al*., 2020 [18]
Pigments (Carotenoids, chlorophylls, phycocyanin)	Micro algae	Enhances antioxidant capacities of fresh fish burgers	Atitallah *et al*., 2019 [6]
Vitamin E (Tocopherol)	Vegetable oil	Prevents the oxidation of fats processed food	Zahoor and Allai, 2020 [33]
Beta carotene	Spinach	Reduce oxidative stress	Anand *et al*., 2022 [5]
Vitamin C	Citrus fruit	Increases iron absorption	Oormila *et al*., 2023 [26]

4. Sensory agents

Sensory agents are used to improve or modify the organoleptic properties or visual characteristics of food. These include colorings, flavorings, and sweeteners

a. Colouring Agents: The processing of food can lead to the degradation or loss of natural pigments present in the raw materials. To address this, coloring agents are added to restore or enhance the color of food. These agents can be obtained from natural sources, such as turmeric for yellow color and carrots for orange color. Chemically synthesized colors include Ponceau 4R and Sunset Yellow, among others. The use of synthetic colors is limited to specific food products, such as bakery items and canned foods. The maximum permitted level of synthetic colors in confectionery is 100 ppm (Gan *et al.*, 2013) [12].

Fig 3: Sources of natural colour

b. Flavouring agents: Flavouring agents are substances added to foods and beverages to enhance or modify their taste and aroma. These agents can be either natural or artificial and are available in various forms, such as liquids, powders, extracts, and essential oils.

- **Herbs and Spices**: Herbs and Spices: Herbs such as clove, mint, basil, thyme, and rosemary, along with spices like cinnamon, cloves, and cumin, are used to impart complex and aromatic flavors to dishes.
- **Fruits and Vegetables:** Fresh or dried fruits and vegetables, such as citrus fruits, berries, and tomatoes, contribute natural sweetness, tanginess, and other distinctive flavors to food preparations.
- **Extracts and Essences**: Natural extracts derived from plants, fruits, and flowers, such as vanilla extract, almond extract, and peppermint oil, are concentrated sources of flavor compounds.
- **Artificial Flavourings:** Synthetic Flavour Compounds: These are chemically synthesized flavour compounds designed to mimic the taste and aroma of natural ingredients. They can provide consistent and intense flavours, often used in processed foods and beverages. Artificial flavoring agents are widely used in the food industry to replicate or enhance natural tastes. Allylpyrazine, for instance, imparts a roasted nut flavor and is used in accordance with Good Manufacturing Practices (GMP). Similarly, allyl hexanoate is known for its pineapple-like taste and is also applied under GMP guidelines. Ethylvanillin, along with ethyl esters, contributes both vanilla and fruity notes to various food products, with their use similarly regulated by GMP standards.
- **Natural flavors:** Substances extracted from natural sources such as plants, fruits, vegetables, herbs, spices, or animal products. They are used to enhance the taste and aroma of foods and beverages without introducing synthetic chemicals. Examples include vanilla extract from vanilla beans, citrus oil from orange peels, and almond flavor from bitter almonds. These flavors aim to replicate the natural taste of the source material.
- **Flavour Enhancers:** Substances such as monosodium glutamate (MSG) and ribonucleotides enhance the perception of savory taste (umami) and overall flavor intensity without adding their own distinct taste. MSG can be used at a concentration of 150 mg/kg in canned meat (FSSAI, 2018) [11].

c. Sweeteners

Sweeteners are substances added to food and beverages to impart sweetness. They are categorized into nutritive and non-nutritive sweeteners.

- **Natural Sweeteners:** These are nutritive sweeteners, such as fructose (fruit sugar), glucose, and sucrose.
- **Sugar:** Common table sugar, or sucrose, is extracted from sugarcane or sugar beets. It is widely used in cooking and baking, providing sweetness along with bulk and texture.
- **Honey:** Produced by bees from flower nectar, honey contains various sugars, including fructose and glucose, as well as small amounts of vitamins, minerals, and antioxidants.
- **Maple Syrup:** Derived from the sap of maple trees, maple syrup has a distinct flavor and provides sweetness along with trace nutrients like manganese and zinc.
- **Artificial Sweeteners:** These are low-calorie sweeteners, also known as non-nutritive sweeteners, which are chemically synthesized and commonly used in snacks and drinks.
- **Aspartame:** A low-calorie sweetener made from the amino acid's aspartic acid and phenylalanine. It is significantly sweeter than sucrose and is used in various sugar-free and low-calorie products.
- **Saccharin:** One of the oldest artificial sweeteners, saccharin is 200–700 times sweeter than sucrose. It has no calories and is frequently used in beverages, tabletop sweeteners, and processed foods.

- **Sucralose:** Made from sucrose by replacing three hydroxyl groups with chlorine atoms, sucralose is approximately 600 times sweeter than sucrose. It is heat-stable and widely used in baked goods, beverages, and dairy products (FSSAI, 2018) [11].

Table 4: Maximum permitted level of artificial sweeteners

Artificial sweeteners	Maximum permitted level (ppm)
Aspartame	2000 (chocolates)
Acesulphame K	600 (ready to drink beverages)
Saccharin	3000 (chewing gum and bubble gum)
Sucralose	750 (sweets and milk products)

Risks associated with consumption of additives

Long-term intake of food additives can have various effects on health, depending on factors such as the type of additive, the amount consumed, individual susceptibility, and dietary patterns (Thakur *et al.*, 2022 [30, 31]; Landrigan *et al.*, 2021) [20]. Artificial sweeteners are among the most widely used food additives worldwide. Due to their low or zero calorie content, affordability, and ability to provide significantly greater sweetness than natural table sugar, artificial sweeteners are increasingly used as sugar substitutes in products such as sugar-free desserts and sodas (Tandel, 2011). However, the health benefits of artificial sweeteners have been questioned in recent years. Studies have reported that their consumption may reduce gut microbiome diversity and impair glucose metabolism, potentially leading to glucose intolerance (Suez *et al.*, 2014). Common artificial sweeteners approved by the WHO/FAO for use in foods include acesulfame potassium, aspartame, saccharin, sucralose, cyclamate, and neotame.

- **Hematological Changes:** Synthetic additives such as nitrates and nitrites can bind to hemoglobin, the protein responsible for carrying oxygen in the blood. This reduces oxygen levels in the blood and tissues, leading to conditions like hypoxia, anemia, and other hematological abnormalities (Gokoglu, 2019).

- **Glucose Intolerance:** Non-caloric artificial sweeteners (NAS), including saccharin, sucralose, and aspartame, are commonly used as sugar substitutes. Studies suggest that NAS consumption may lead to glucose intolerance and intestinal inflammation by altering the composition of the intestinal microbiota.

- **Adverse Effects on Reproductive Functions:** Exposure to certain food additives during pregnancy or lactation can impact reproductive development and overall health in offspring. Some additives have been associated with impaired fetal growth, abnormalities in reproductive organ development, and disruptions in reproductive function, as evidenced in animal studies.

- **DNA Damage in Liver, Kidney, and Brain Cells:** Some food additives exhibit genotoxic and mutagenic properties, potentially leading to DNA damage and genetic abnormalities in offspring. Artificial colors such as tartrazine and sunset yellow, along with preservatives like nitrites and nitrates, have been reported to cause DNA damage and mutations in both cellular and animal studies.

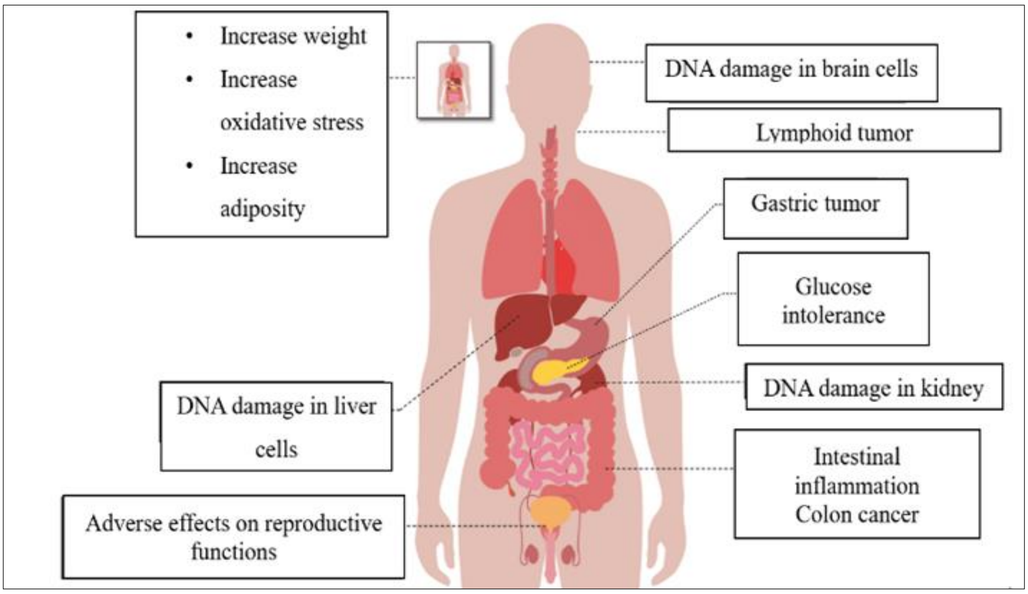


Fig 4: Risk associated with long term intake of food additives

Table 5: Studies related to effects of long-term intake of food additives

Food additives	Uses	Long term risk
Tartrazine (Food colour)	Used as colorants in food products and cosmetics	Genotoxic potential towards human lymphocytes and bind to DNA directly (Shakoor *et al.*, 2019) [27]
Boric acid (Preservative)	Used in meat and dairy products and also sometimes as a pesticide	Allergic reactions like skin rash, itching (Hadrup *et al.*, 2021) [16]
BHA and BHT	butter, meats, chewing gum, snack foods, dehydrated potatoes and beer	Child hyperactivity, damage of lungs, liver, kidneys and also cause cancer (Pande and Kumar, 2021)
Vinegar	Used as a flavouring and pickling	Hypokalemia and osteoporosis (Mirza *et al.*, 2017) [21, 22]
Chlorine dioxide	Bleach *maida* to white (Residual alloxan)	Induce diabetes mellitus (Rohilla and Ali, 2012) [25]

Regulations on food additives

Food additives undergo rigorous safety testing before they are approved for use. Regulatory agencies, such as the Food and Drug Administration (FDA) in the United States and the European Food Safety Authority (EFSA) in Europe, assess safety data at both national and international levels. They determine whether an additive can be used in foods and specify the acceptable levels. In India, the Food Safety and Standards Authority of India (FSSAI) is responsible for regulating food safety standards.

- **Labeling:** Food labeling regulations typically require manufacturers to list all ingredients, including food additives, on product labels. Additives must be identified using their common or scientific names, and their presence must be clearly indicated in the ingredient list or through specific labeling statements (e.g., "contains sulfites"). Additionally, labeling requirements may mandate the declaration of allergenic ingredients or substances known to cause adverse reactions in sensitive individuals, such as artificial colors or flavorings.

- **E Numbers:** E numbers are a system of codes used within the European Union (EU) to designate food additives that have been evaluated and approved for use in food products across EU member states. The "E" stands for "Europe" and is followed by a numerical code assigned to each approved additive. For example, E100 refers to curcumin, a natural yellow pigment derived from turmeric. Each E number corresponds to a specific additive with defined functions, such as preservatives, antioxidants, colorants, emulsifiers, and flavor enhancers. This system ensures transparency and consistency in labeling and safety standards within the EU.

- **INS Numbers:** The International Numbering System (INS) for Food Additives is a global classification system established by the Codex Alimentarius Commission, a joint initiative of the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). INS numbers provide a standardized method for identifying and categorizing food additives worldwide. Many countries outside the EU use INS numbers for regulation, facilitating international trade and harmonizing food standards. While some additives have both E numbers and INS numbers, differences in numbering and classification may occur due to varying regulatory requirements. In India, the FSSAI primarily uses the INS system to classify and regulate food additives (Wu *et al.*, 2022) [32].

Bio- synthesis of additives for future foods

Biosynthesis of food additives refers to the natural production of compounds used in food processing or preservation. These compounds are often derived from biological sources such as plants, microbes, or animals, providing a sustainable and eco-friendly alternative to chemical synthesis. Microbial fermentation is a common method for the biosynthesis of food additives, producing preservatives, sweeteners, flavorings, and colorants for foods. Notably, biosynthesized additives are often effective at low concentrations (Sun *et al.*, 2021) [28, 29].

Microbial Fermentation: Microbial fermentation is widely used for the production of food additives, including organic acids (e.g., citric acid, lactic acid), enzymes (e.g., rennet for cheese production), and flavor compounds (e.g., amino acids, vitamins). Bacteria, fungi, and yeast act as biocatalysts, fermenting substrates like sugars, alcohols, and organic acids to yield desired compounds. For instance, citric acid, a common food acidulant and flavor enhancer, is biosynthesized using *Aspergillus niger* through the fermentation of glucose or other carbohydrates**.**

Enzymatic Conversion: Enzymatic processes enable the conversion of precursor molecules into desired food additives through specific biochemical reactions. For example:

- **High-Fructose Corn Syrup (HFCS):** Produced through the enzymatic hydrolysis of starch using enzymes like α-amylase and glucoamylase, followed by the isomerization of glucose to fructose using glucose isomerase.

- **Protein Modification:** Enzymes hydrolyze proteins into amino acids or peptides, enhancing flavor or texture.

- **Fat Modification:** Lipase enzymes catalyze esterification or interesterification reactions to modify fats for desired properties.

- **Carbohydrate Conversion:** Sucrose can be enzymatically converted into invert sugar, commonly used in confectionery products.

Examples of Biosynthesized Food Additives

- **Xanthan Gum:** A thickening agent derived from the bacterium *Xanthomonas campestris*, used extensively in bakery products (Amanullah *et al*., 1998) [4].

- **Riboflavin (Vitamin B2):** Produced from the fungus *Ashbya gossypii*, serving as a nutritional additive in fortified foods.

- **Astaxanthin:** A natural antioxidant and pigment biosynthesized from the microalga *Haematococcus pluvialis*, often used in aquaculture and dietary supplements (Kallscheuer, 2018) [19]. Biosynthesis offers a sustainable and efficient means of producing food additives, reducing reliance on synthetic chemicals while enhancing food safety and quality.

Conclusion

Food additives play a significant role in the modern food industry, offering numerous benefits such as enhancing the flavor, appearance, and shelf life of products. They are essential for maintaining food quality and safety, making products more palatable and convenient for consumers. However, their use is not without concerns. Potential health risks associated with certain additives, including allergies and long-term effects, highlight the need for stringent regulatory oversight and continuous research. Consumers should be well-informed about the types of additives in their food and their potential impacts. Reading labels and choosing minimally processed foods can empower individuals to make healthier dietary choices. The balance between leveraging the benefits of food additives and ensuring consumer safety remains a key focus for food manufacturers, regulatory bodies, and health professionals. Ultimately, while food additives contribute positively to the global food supply, their use must be carefully managed and monitored to protect public health. Continued education and research are essential to understanding their full effects and developing safer alternatives where necessary. By paying attention to food labels and making conscious choices, consumers can improve their diets and overall well-being.

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