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Food additives from classification to their use in the food industry: A review

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ABSTRACT

The use of food additives in food production is inevitable in this modern world. Although only a safe amount of food additives is approved, their safety has always been questioned. At present, artificial synthetic food additives have gradually replaced natural food additives and many problems related to food additives, involve the abuse of food additives, excessive additives, or even toxic additives. Obviously, food additives can bring people great sensory enjoyment and commercial convenience, but they may also cause potential risks to human health. So, it is of high significance to conduct quantitative analysis on the content of food additives. According to their functions and the regulatory requirements of food additives, this review started with the classification, and functions of various food additives involving preservatives, sweeteners, emulsifiers, stabilizers, thickeners, and gelling agents and the advantages and disadvantages of food additives usage.

Introduction

Food additives are substances that are included in food in order to meet specific technological or sensory objectives. These components may be synthetic or natural (Abdel Ghany, 2015), and preserve flavor or enhance its taste, appearance, or other qualities (Wu *et al*., 2022). The United States Food and Drug Administration defines food additives as any substance whose intended use results in, or may reasonably be expected to result, directly or indirectly, in its becoming a component, or otherwise affects the properties of any food (Alemu, 2022). Moreover, it is defined as any substance or combination of ingredients that are added to a food at any time during its production, processing, storage, or packaging is considered a food additive (Mirza *et al*., 2017).

Food additives are an important part of the modern food industry since they are used in food to preserve or improve its flavor, safety, freshness, appearance, and nutritional value. More than 2000 distinct types of authorized additives in 22 categories are available in China (CFDA and NHC, 2014), comparatively, this number is over 1500 and 4,000 in the US and the EU, respectively (Zhang *et al*., 2019; Commission Regulation, 2022). On the French market, food goods contained at least one additive in 53.8% (N = 126, 556) of cases, and at least five additives in 11.3% of cases (Chazelas *et al*., 2020).

Food additives are utilized in the food processing industry to improve the nutritional value, color, flavor, aroma, and shelf life of food products. Food has seen significant changes in how people consume it, as a result of the fact that everyone needs it to survive, making it the most essential good for their health (Gultekin *et al*., 2019).

Today's food sector places a high priority on using food additives properly. First off, food additives play a dual purpose in food preservation and nutritional value improvement by boosting the food's color, flavor, and flexibility. For example, the right food nutrition enhancers may be added to make up for nutrition lost during meal preparation. They provide a balanced diet while successfully preventing malnutrition and nutritional deficiencies (Elsheri *et al*., 2023). Second, adding food additives such coagulants, stabilizers, and defoaming agents makes food processing procedures easier. For instance, the mechanization and automation of tofu manufacturing can be easily achieved when gluconate lactone is utilized as a tofu coagulant. Food additives also enhance convenience for businesses by prolonging shelf life and assisting with manufacturing, packaging, storage, and transportation (Wu *et al*., 2022).

Meat and meat products have a unique capacity to deliver essential nutrients like high-quality proteins, as well as a number of minerals and fat-soluble vitamins due to their high bioavailability in the human diet (Geiker *et al*., 2021). Furthermore, it has been shown that the processing of meat and meat products results in the production of a variety of substances that are advantageous to human health. Despite the fact that processed meat products normally have a longer shelf life than fresh meats, a number of factors, such as microbiological degradation and loss of sensory quality, limit the shelf stability of such processed products (Aminzare *et al*., 2019).

The majority of studies, however, concentrate on the safety aspects of artificial food additives, and there are fewer that examine how gut microbiota traits are affected by food additives used in processed foods (Shi *et al*., 2017; Ghosh *et al*., 2021; Silveira *et al*., 2022). Meanwhile, as the human and microbial genomes merge and become intertwined due to the co-development of their metabolisms and sustainability. Bacteria, viruses,

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and a few unicellular eukaryotes all contribute to the development of the microbiota. The dysbiosis and dysregulation of gut homeostasis that results from exposure to dietary additives may also change the gut barrier and activate the immune system. Visceral pain, low-grade inflammation, and altered bowel habits are just a few of the gut symptoms of IBS that these microbial changes may make worse. Diets for IBS patients that are low in fermentable oligo-, di-, and monosaccharides (FODMAPs) and polyols (polyols) eliminate several additions. Numerous artificial sweeteners, emulsifiers, and food colors may have hidden drivers that aren't fully understood because the majority of studies have been conducted on animals, and human studies are still needed (Rinninella *et al*., 2020).

Food additives, such as Firmicutes, Bacteroidetes, Barnesiella, Prevotella, Ruminococcaceae, Bifidobacterium, etc., might have an impact on the gut microbiota (Liu *et al*., 2022), and those microbiomes were linked to obesity and diabetes, the maintenance of the gut barrier, short chain fatty acid (SCFA) metabolism, and the breakdown of fiber and sugar (Zhou *et al*., 2023). It is unclear if artificial food additives regulate the gut microbiota in a way that has an impact on the host's health and diseases. This review focused on the types and uses of artificial food additives as well as their effects on the gut microbiota.

Food additives classification and functions

Till now, there are more than 25,000 compounds of food additives being used all around the world (Anderson, 1986). According to the compositions, food additives are generally divided into two major categories of natural additives and synthetic additives. Wherein, the majority of natural food additives are created by separating substances from animal or plant sources. When compared to chemically produced additives, which can be used to extract and purify either organic or inorganic content, chemical raw materials provide the basis for these substances. Food additives can also be categorized into several classes according to their purposes, such as antioxidants, bleach, sweeteners, preservatives, colorants, thickeners, etc. Due to their numerous impacts, food additives from different groups may overlap (Wu *et al*., 2022).

Additives are categorized in a number of ways, including according to their occurrence, source, and function in food (Elsherif *et al*., 2023). Based on their frequency of occurrence, they are divided into intentional (deliberately added to the food, serve useful function(s)-beneficial, e.g. stabilizers, emulsifiers, preservatives, etc.) and unintentional food additives (contaminants), which find their way into food accidentally, cause health hazard and may also spoil the food, e.g. pesticides, toxins, heavy metals, etc.

a. Source, Natural, synthetic, and natural identical. They come from organic sources like plants, animals, microorganisms, etc. in the first place. b. Synthetic, They are made through chemical synthesis. c. Chemically similar to those obtained from Natural Sources, They are artificially produced but chemically comparable to those obtained from natural Sources. According to other studies, food additives might be classed as natural or synthetic depending on their chemical makeup (Wu *et al*., 2021; Elsherif *et al*., 2023).

Natural additives, Consumers and food producers are becoming increasingly interested in natural food additives. Purifying the components from plant or animal sources is one way to get them. Customers frequently choose products without additives. But if they are not supplied if at all feasible, they will favor foods with natural additives over those with synthetic ones (Carocho *et al*., 2015). As natural additives, olive leaf extracts (OLE) are regarded as a natural source of phytochemical components, particularly phenolics (Saleh *et al*., 2020).There are no particular categories for natural additives; instead, they all fall under the same "E" classification in the EU (EC, 2011). Synthetic additives, It is created from chemical raw materials through the separation and purification of either organic or inorganic components.According to recent studies, food additives are categorized into the following categories according to their function, preservatives, sweeteners, antioxidants, colorants, glazing agents and taste enhancers, emulsifiers, stabilizers, thickeners, and gelling agents (Carocho *et al*., 2018; Khorshidian *et al*., 2018; Sezgin *et al*., 2021).

Depending on how they are used in food, food additives in the European Union (EU) are categorized into a variety of functional classes, including sweeteners, colorants, preservatives, antioxidants, carriers, acids, acidity regulators, anticaking agents, antifoaming agents, bulking agents, emulsifiers, emulsifying salts, firming agents, flavor enhancers, foaming agents, gelling agents, glazing agents, humectants (Commission Regulation (EC)1333/2008).

Preservatives

Preservatives are food additives that, in accordance with EU law, prevent the growth of microorganisms (fungi and/or germs), extending the shelf life of the food (Silva and Lidon, 2016). Correspondingly, Carocho *et al*. (2018) stated that Preservatives are used to extend the shelf life of food by preventing or inhibiting food decomposition caused by contamination with fungi, bacteria, and other microorganisms. Similar to food colors, there are two primary categories of preservatives, artificial and natural. Sorbic acid, which is utilized in dairy, soybean, processed vegetables, cooked meat, and aquatic products, is one of the most widely used artificial preservatives. It is the most successful long-term preservation technique (Pongsavee, 2015). In food processing, sorbic acid can be used in doses ranging from 0.075 to 2.0 g/kg. In order to preserve condiments, pickled goods, drinking goods, and fruit wine, benzoic acid, and its salts are frequently added in amounts ranging from 0.2 to 2.0 g/kg (Elafify *et al*., 2022).

Nisin is a natural preservative that is added to foods like meat, dairy, and products with vegetable protein, canned goods, coffee, tea, and soy sauce (Tang *et al*., 2020). Nisin can be added in quantities ranging from 0.15 to 0.5 g/kg. Additionally, when preparing food, the maximum natamycin dosage should be kept to less than 0.1 g/kg (Javanmardi *et al*., 2019; Nair *et al*., 2020). One of the most extensively used meat decontaminants is lactic acid (LA). Extensive study has been done on the use of lactic acid to inhibit both spoilage and pathogenic microorganisms (Morshdy and Sallam, 2009). Garlic (Allium sativum) essential oil (GEO) is a member of the Alliaceae family, and its biological benefits are linked to sulfur-containing substances like allicin and other functionally active components. Additionally, a number of aromatic bioactive components, such as thymol and carvacrol, are crucial antibacterial and antioxidant compounds (Morshdy *et al*., 2022).

According to recent toxicological studies, synthetic preservatives may be considerably mutagenic at certain doses and/or when used for an extended period of time (Di Sotto *et al*., 2014). In order to replace the typical artificial preservatives used in food and reduce their quantity in foods and associated health risks, natural compounds with antibacterial and antioxidant action are being studied (Ramalho and Jorge, 2006).

Sweeteners

Sweetener, often known as a sugar substitute, is an ingredient in food that imparts a sweet flavor similar to that of sugar but has zero or very few calories (Martyn *et al*. 2018). Sweeteners are indispensable in daily life and are present in a wide variety of dietary items. However, excessive or irrational consumption of sweeteners as food additives results in negative issues because of the accumulation in the body (Chen *et al*., 2023).

According to recent studies, sweeteners can enhance taste perception and boost the enjoyment of food. These sweeteners can be found in a variety of food products, such as carbonated beverages, baked goods, alcoholic beverages, sweets, preserves, and confectionary (Wilk *et al*., 2022; Chen *et al*., 2023). According to their sources, sweeteners can be categorized as natural or artificial sweeteners (ASs); they can also be categorized as nutritive or non-nutritive sweeteners (NNS) based on whether

they include carbohydrates and provide energy or not (Whitehouse *et al*., 2008). NNS are preferred over nutritive sweeteners because they result in higher energy intake and poorer dietary quality. Examples of NNS include acesulfame (ACE), aspartame (ASP), neotame (NEO), saccharin (SAC), and sucralose (SUC). (Mora *et al*., 2021; Singh *et al*., 2023).

Natural sweeteners like sorbitol, xylitol, and mannitol are made from sugar, which is a common ingredient in processed fruits and vegetables, alcoholic beverages, sweets, dairy products, tea products, seasonings, and candy. Whereas sorbitol can only be used in doses up to 3.0 g/kg and mannitol should only be added in amounts no greater than 0.2 g/kg. Fruits, jams, beverages, desserts, and dairy products are the key food categories where artificial sweeteners, such as aspartame, cyclamate, saccharin sodium, acesulfame K (ACE K), and sucralose, are utilized. Aspartame has a maximum dosage range of 0.3 to 4.0 g/kg, cyclamate ranges from 0.65 to 8.0 g/kg, and saccharin sodium ranges from 0.15 to 5.0 g/kg.

Artificial sweeteners were once regarded to be a successful treatment for diabetes and obesity. Artificial sweeteners have no impact on body weight or glycemic management, according to human meta-analyses. However, recent research has revealed that artificial sweeteners have an impact on both human and animal insulin and incretion release as well as glucose absorption in the intestinal tract. Furthermore, due to changes in the gut microbiota, artificial sweeteners affect the microbiome's makeup and decrease glycemic control. It has also been demonstrated that early ACE K ingestion reduces the taste response to sugar (Iizuka, 2022). Data from both animal models and people indicate that artificial sweeteners may have negative effects that may contribute to metabolic syndrome and the obesity pandemic, despite the fact that they were first designed as a sugar alternative to help reduce insulin resistance and obesity. Artificial sweeteners are linked to increased calorie intake and weight gain because they seem to modify the host microbiome, diminish satiety, and disrupt glucose homeostasis. Artificial sweeteners are touted as a weight reduction aid and a healthy substitute for sugar (Pearlman *et al*., 2017; Gardener and Elkind, 2019).

Stabilizers, thickeners, gelling agents

Given that many of the uses of food additives are similar, and thickeners and gelling agents serve similar purposes (Abid *et al*., 2018). Polymers are frequently employed in cosmetic formulations for a variety of functions, such as thickening, emulsifying, and stabilizing agents that help improve the textural attributes of the finished product. The well-known polymers, which are adaptable and effective materials, are of the polyacrylate type and are created synthetically for these purposes. However, due to environmental concerns and the need for sustainability, natural polymers are now highly popular (Medina-Torres *et al*., 2014; Terescenco *et al*., 2021).

Stabilizers

Stabilizers are substances or chemicals that help poorly mixing food ingredients stay homogeneous after combining (Tekin Pulats€u *et al*., 2018). Agar, alginic acid, and its sodium, potassium, ammonium, and calcium salts are all components of the popular food stabilizer. Alginates are useful hydrocolloids that can be used to thicken and stabilize emulsions. They are polysaccharides that are extracted from brown algae and bacteria (Wang *et al*., 2015; Valentine *et al*., 2020). Alginates have been utilized in the food business as gel-forming agents, stabilizers, thickeners, and fillers. They also shown great biocompatibility and non-toxicity, making them popular choices for biomaterials in uses such protein delivery, tissue engineering, and cell encapsulation (Rodríguez-Abreu and Lazzari, 2008).

In order to increase the viscosity of food preparations without altering other characteristics like taste, thickeners or thickening agents are added. Pectin, for example, has a maximum dosage of less than 3.0 g/kg. Precision and individualization are needed when customizing liquid viscosities for patients with dysphagia. The viscosity of gum-based thickeners grows linearly with water concentration but does not approach pudding texture, whereas the starch-based thickeners' (alone or combined with gums) viscosity quickly achieves very thick textures (Calmarza-Chueca *et al*., 2022). Using commercial thickeners to change the viscosity of liquids can help patients with dysphagia and lower their risk of aspiration (Newman *et al*., 2016). These thickeners for medical application can be broadly divided into two groups, those based on starch and those based on gum. Initially, thickeners were solely based on starch; then, thickeners based on starch and a gum-starch combination were developed; and ultimately, thickeners based on gums with maltodextrins became available (de O. S. Schmidt *et al*., 2021). These gum-based thickeners have advantages over starch-based thickeners in terms of stability, amylase resistance, textural smoothness, adherence, and safety (Giura *et al*., 2021). To produce the necessary viscosity, the preparation of thickeners must be done at specific concentrations. The caregivers and medical professionals must regulate the preparation of thickened liquids carefully in order to lessen or eliminate the effects of liquid dysphagia (Sánchez-Sánchez *et al*., 2021).

Foods are infused with gelling ingredients such konjac, karaya, and gellan gum to create certain structure, flow, stability, and palatable attributes that customers like (Wu *et al*., 2022). Certain proteins and polysaccharides' capacity to create continuous three-dimensional molecular networks is the cause of the distinctive physical characteristics of food gels. Understanding the intermolecular interactions that create and maintain network cross-linkages is essential for the creation of new gel-based products and the improvement of existing ones (Oakenfull, 1987).

Thickeners

Thickeners or thickening agents are substances added to food preparations for increasing their viscosity without changing other properties like taste, for example, pectin has the maximum dosage of lower than 3.0 g/kg. The adaptation of liquids for patients with dysphagia requires precision and individualization in the viscosities used. We describe the variations of viscosity in water at different concentrations and evolution over time of the three compositions of commercial thickeners that are on the market (starch, starch with gums, and gum). By increasing the concentration in water, the viscosity of gum-based thickeners increases linearly, but it did not reach pudding texture, whereas the viscosity of the starch-based thickeners (alone or mixed with gums) rapidly reaches very thick textures (Calmarza-Chueca *et al*., 2022). One of the main treatments for patients with dysphagia is modifying the viscosity of liquids using commercial thickeners, thereby reducing the risk of aspiration (Newman *et al*., 2016). These thickeners for clinical use can be basically classified into two categories, starch-based thickeners and gum-based thickeners. At first, the thickeners were based exclusively on starch, later thickeners based on starch and a gum-starch mixture were formulated, and finally, thickeners based on gums with maltodextrins appeared (de O. S. Schmidt *et al*., 2021). These gum-based thickeners have stability, amylase resistance, texture smoothness, adherence, and safety advantages over starch-based thickeners (Giura *et al*., 2021). The preparation of thickeners must be carried out at defined concentrations to achieve the required viscosity. Proper management of the preparation of thickened liquids by caregivers and health professionals is very important to reduce or eliminate the consequences of liquid dysphagia (Sánchez-Sánchez *et al*., 2021).

Gelling agents

Gelling agents like konjac, karaya gum, and gellan gum are incorporated into foods to produce specific structure, flow, stability and eating qualities desirable for consumers (Wu *et al*., 2022). The characteristic physical properties of food gels result from the ability of certain proteins and polysaccharides to form continuous three-dimensional molecular

networks. Development of new products based on gels, and improvements to existing ones, require a basic understanding of the intermolecular forces by which network cross-linkages are formed and stabilized (Oakenfull, 1987).

Colorants

Food additives known as colorants replace colors lost during food preparation, enhance flavor perception, or improve the appearance of food (Coultate and Blackburn, 2018). Food is colored to either restore colors lost during preparation or to improve the appearance of the food. They are made up of both artificial and natural colors. Even though most colors don't contribute any nutritional benefit to food, most people won't buy or eat particular meals without certain colors (Alemu, 2022).

Colorants are present in two forms, natural food colors are hues that are generated from minerals, plants, or other living things (Darwish *et al*., 2016). For instance, curcumin is mostly used to tint dishes like beverages and sauces (Wu *et al*., 2021). Quinoline yellow is a synthetic food color that is used to tint beverages, ice cream, sweets, and cold fruits. It is sometimes referred to as phony food color made artificially.

Advantages of Food Additives

The food industry commonly employs food additives to extend product shelf life and improve foods' specific properties (Bruna *et al*., 2018). In addition to serving as a means of food preservation, food additives also aid in improving the nutritional value of food by enhancing its color, flavor, and flexibility (Wu *et al*., 2021). Assist in preventing contamination that might result in foodborne illnesses, such as lethal botulism (IFIC & FDA, 2010). Healthy food Nutrient enhancers may be added to compensate for nutrition lost during food preparation, preventing malnutrition and nutrient deficit and improving nutrition balance. Many foods have added vitamins, minerals, and fibers to compensate for those missing in a particular food or lost during manufacturing or to improve the nutritional value of a product (Wu *et al*., 2021). Preservatives suppress the development of molds, yeasts, and bacteria in sauces, beverages, and juices, among other goods (Türkoğlu, 2007). Antioxidants may avoid or reduce the deterioration of food caused by unstable particles and free radicals (Wu *et al*., 2021). Antioxidants inhibit rancidity and off-flavor development in fats, oils, and meals containing them. Additionally, they keep fresh foods like apples from browning if exposed to the air (FAO/WHO Expert Committee on Food Additives, 2016). Foods' expected texture and consistency are provided by emulsifiers, stabilizers, and thickeners (Silva and Lidon, (2016). During baking, leavening chemicals cause produced goods to FAO/WHO Expert Committee on Food Additives, 2016). While some substances assist in preserving the flavor and attractiveness of meals with low-fat content, certain additives help regulate the acidity and alkalinity of foods (Pongsavee, 2015).

Disadvantages of Food Additives

Despite their widespread usage, they are compounds that, like any other medicine, may cause adverse effects such as allergic reactions, behavioral abnormalities, and carcinogenic effects. Abnormal responses in the gastrointestinal, respiratory, dermatologic, and neurological systems may result from excessive doses of synthetic food additives (Wuthrich, 1993). When taken over the ADI, some preservatives, notably antimicrobial compounds, may be toxic and genotoxic as well as induce urticaria and behavioral disorders such as hyperactivity and Attention-deficit/hyperactivity disorder (ADHD) (Gören *et al*., 2015). Children who consumed too much sodium benzoate were hyperactive, had urticaria, and their Deoxyribonucleic Acid (DNA) was also severely harmed (DNA) (Zhang & Ma., 2013). Potential health risks from high dosages of propyl gallate include apoptosis and DNA breakage (Vikraman *et al*., 2013).

Conclusion

Despite the fact that food additives have been used since the Neanderthal era, they have become much more widely used and popular in recent years. Working women in particular have benefited from the scientific use of pre-made mixtures, flavouring and colouring agents, and essences to juggle the demands on their time. Additionally, food additives aid in the production of quick-and-easy to prepare convenience foods. According to World Health organization (WHO), food safety monitoring authorities should continuously monitor and guide the control and regulation of national and international health authorities to prevent adverse effects. A lasting solution has been to turn to organic foods to stop or reverse these effects, where feasible.

Conflict of interest

The authors have no conflict of interest to declare.

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