Food Additives and Their Applications in Food Systems

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What Is an Additive?

A food additive is defined as any substance, natural or artificial, that is added to a food product either purposely or accidentally. However, for this discussion, food additives will refer to those chemical substances that are intentionally added to a food.

Intentional Versus Incidental Food Additives

Intentional food additives can be defined as those components that are knowingly incorporated into food products by the food manufacturers. Incidental food additives include those substances that gain access to food products indirectly via environmental contamination or during the manufacturing process.

Currently, over 2,800 different substances are intentionally added to the food supply, while as many as 10,000 other substances constitute the category of incidental food additives.

Regulations of Food Additives

Regulating and policing food additives is the responsibility of the Food and Drug Administration (FDA). Because food additives are policed by the FDA, certain requirements must be met in order for a food additive to be used in a food system.

Food additives are tested for safety on at least two animal species, usually mice and rats. Scientists determine the no-observable-effect level (NOEL) which corresponds to the highest dose of an additive that produces no unexpected adverse health problems in the laboratory animals.

If an additive exhibits the ability to cause cancer, this additive cannot be used because it would be in violation of the Delaney clause in the 1958 Food Additive Amendments. This clause prevents the intentional addition of a compound which has been shown to cause cancer in animals or humans.

Certain substances are considered "safe" according to experts. Approximately 600 "generally recognized as safe" (GRAS) substances are used in the food industry. Typical examples of GRAS substances include spices, natural seasonings, baking powder, citric acid, malic acid, mono- and diglycerides, and many others.

In the situation of non-GRAS substances, approval by the FDA is granted upon submission of scientific data showing that the substance is harmless in the intended food application at a specific level. The FDA sets limits on the type of foods in which the additive may be used and the maximum concentration of the additive. Therefore, a food additive may be permitted at a level of 100 p.p.m. in one food, 50 p.p.m. in another, and not allowed in the third.

Today, manufacturers must present information to the FDA in a petition for a new substance to be added to foods. A petitioner must establish that the new ingredient is necessary for producing a specific food product.

Major Uses for Food Additives

Because food additives are closely regulated by the FDA, they cannot be used to cover up or deceive the consumer. The food additive intended for use in a product must have a purpose. The major uses for food additives include preservation, enrichment, improvement in color and flavor, alteration of texture, and processing and/or preparation aid. Each of these uses will be described in more detail.

Preservation

One of the main functions of additives is to preserve food. Without the addition of these additives, products would spoil at a more accelerated rate than would be expected by the American consumer. The typical consumer is used to "fresh" products.

In order to achieve "freshness," additives are added to ensure that bread does not arrive at the grocery

store veiled in mold or that milk does not contain sour or off-flavors.

Because the nutrient content of food provides a supportive medium for microorganisms, preservatives are added to control microbial growth and propagation. Included in the vast array of preservatives that are used for the sole purpose of limiting microbial interactions are organic acids and their salts, sulfites, nitrites, parabens, and a host of other compounds. These compounds help to preserve the food supply as well as to reduce the risk of food-borne illnesses.

Enrichment

Enrichment is yet another function that food additives may perform. Enrichment with nutrients simply refers to the addition of certain nutrients in amounts that do not exceed those found in the food before processing. Various cereal-grain-based products utilize this process in order to restore the original amount of nutrients prior to processing.

A typical example of an enriched product is bread. Without the addition of thiamine (B_1), riboflavin (B_2), and niacin (B_3), bread would be extremely deficient in these B-complex vitamins as well as the mineral iron. Enriching helps to ensure that proper proportions of important nutrients are contained in the final product.

Improvement in color

Food products may attain their final color from several sources including natural or artificial sources. Naturally occurring plant pigments, such as carotene, chlorophyll, and lycopene, help impart hues of orange, green, and red, respectively. Without the addition of vegetable dye, Cheddar cheese would lack its familiar orange color.

In addition to plant pigments, animal pigments, including myoglobin and heme, exist and serve to incorporate color in products such as meat. Certain red colors, such as kermes and lac, are derived from insects. Certain algae and fungi also produce color and can be incorporated into specific foods.

Sources for naturally occurring colors are endless, however, economics may influence whether to use a natural or a synthetic food color. Although naturally occurring colors are often used in food products, artificial coloring can also be used as an alternative. The use of artificial colors may be more economical than natural colors, and synthetic colors generally excel in coloring power, color uniformity, and color stability.

Improvement in flavor

Flavoring agents include both natural and synthetic compounds that are used for incorporating flavor. Plant extracts, essential oils, herbs, spices, and other substances head the list of natural flavors used.

On the other hand, synthetic flavor additives are becoming more popular. Methyl salicylate and benzaldehyde are two commonly used synthetic flavors that impart wintergreen and cherry flavoring, respectively.

Alteration in texture

Recipe modification involves more than simply reducing or eliminating the amount of shortening in formulation.

The purpose of using gels, gums, and water-based shortening substitutes is to eliminate fat and caloric intake without sacrificing texture, mouth-feel, and other sensory characteristics of the food. Additives that fulfill the qualifications of texture manipulation contribute desirable characteristics to the food.

The food manufacturer utilizes countless approved ingredients and chemicals to help modify texture. A simple compound such as sucrose or table sugar can be used in varying concentrations to achieve a variety of results.

Sugar affects texture differently depending upon its concentration. In a dilute solution, it adds body and mouth-feel to soft drinks, while in higher concentrations it crystallizes and adds brittleness to hard candies.

Preparation aid

Certain food additives are used by the manufacturer for processing ease. Foam, a mass of bubbles created when certain types of gas are dispersed into a liquid, can be controlled by making processing changes or by using mechanical defoaming equipment.

Chemical defoamers have been proven to be the most effective and economical means of controlling this processing menace. These antifoaming agents may be used in cocoa or other foods high in fat content.

Important to remember is that additives can not be used to deceive or cover up. Furthermore, additives are not intended to replace Good Manufacturing Practices (GMPs) or sanitation measures. They are to be used in conjunction with these practices.

Also keep in mind that food additives may serve more than one purpose. Many are considered to be multifunctional in their application to food systems.

Categories of Common Food Additives

Food additives have been used to flavor, preserve, and perform various functions for thousands of years. However, additives are subject to misinformation and confusion.

Classification of additives is based on the function of the additive, however, many food additives perform multifunctional tasks. The following is a simple classification of food additives according to function.

Acidulants

Acids, buffers, and alkali fall into the category of pH-adjusting/controlling chemicals with acidulants being the most frequently used. Properties of food acidulants, such as melting point, solubility in water, taste characteristics, and physical form, help the processor make decisions as to which acidulant to incorporate into the process.

Typical acids utilized in the food industry include acetic, adipic,

ascorbic, citric, fumaric, lactic, malic, phosphoric, tartaric, and succinic. While many of these acidulants are derived from fruits and vegetables, fermentation and chemical synthesis are two additional means of generating acidulants.

Anticaking compounds

Compounds that are added to dry mixes to prevent clumping and to keep powders free-flowing fall into this category. Anticaking agents not only keep high-fat foods (especially boxed mixes) from caking together, but also serve as a processing aid. Examples of anticaking agents commonly used include calcium silicate, silicon dioxide, and silicon aluminate (a.k.a. "sand").

Antioxidants

Antioxidants, as the name implies, serve to prevent or minimize oxidation. Lecithin, vitamin E, and certain sulfur-containing amino acids are naturally present in foods. Lecithin is commonly found in soybeans and is obtained for commercial use by solvent extraction.

Although antioxidants can be traced to natural sources, synthetic chemicals approved by the FDA for addition to foods are much more effective. Without these antioxidants, potato chips, breakfast cereals, salted nuts, and many other fatty foods could not be stored without developing rancidity.

Examples of synthetic antioxidants used include butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tertiary butylated hydroquinone (TBHQ), and propyl gallate (PG).

Bases

Like acidulants, bases provide a means of adjusting or controlling the pH. Certain processes often incorporate adjusting the pH into the unit operation. The vegetable industry often submerges vegetables in a hot alkali solution to facilitate skin removal. An alternative can be the use of a 1 percent lye solution at 93°C to loosen the skins.

Because the cost of lye and of treating lye-containing waste waters can be appreciable, processors often use less expensive techniques such as hot-water scalding, steaming, or direct exposure to gases or flame.

Bases also play a key role in color development, alteration of texture, and removal of bitter compounds in certain products. Sodium hydroxide, a base commonly used in the food industry, is often added to ripe olives to assist in darker color development and removal of bitter compounds. When dipped in a 1.25 percent sodium hydroxide solution at 90°C prior to baking, pretzels display a more desirable brown color and a smoother texture than without dipping.

Bleaching agents

Bleaching agents have an important use in the bakery industry primarily in flour milling and bread making. Benzoyl peroxide is applied to wheat flour to remove plant pigments such as chlorophyll. The final product has a white color.

Another bleaching agent, hydrogen peroxide, has applications in the dairy industry, especially in milk. Note that the hydrogen peroxide is removed before the milk is packaged and transported.

Chelating agents (sequestrants)

The most problematic metal ions in foods are iron, copper, nickel, and zinc. These ions can produce undesirable effects in foods, such as discoloration, turbidity, and oxidation. Chelating agents are needed to form a complex with these unwanted trace metals and render them inactive.

Because chelating agents are used to control the reactions of trace metals in food systems, they are often termed "metal scavengers." They combine with trace minerals to prevent development of undesirable color reactions.

Without chelating agents, discoloration would occur in foods such as potatoes where the iron reacts with phenolic compounds in the presence of oxygen. Although citric acid and polyphosphates are commonly used in the food industry, the most effective sequestrant is ethylenediamine tetraacetic acid (EDTA).

Applications of chelating agents include adding phosphates in soft drinks to chelate heavy metal ions that interfere with carbonation and using EDTA in mayonnaise to protect flavor.

Clarifying agents

The beverage industry relies on clarifying agents to prevent cloudiness in the final product. Agents such as bentonite are used in processing juices, wines, vinegar, and other liquids.

Enzymes

Enzymes are ideal for use in certain food systems because they are very specific and only act on specific substrates. As biological catalysts, they lower the energy required in biochemical reactions and accelerate the rate of the reaction.

In the bakery industry, the enzyme amylase functions to accelerate the fermentation process. This type of enzyme is specific because it works only on amylose (starch).

Various enzymes are utilized extensively in the food industry for a variety of applications. Specific enzymes are used in such food commodity groups as cereal products, alcoholic and nonalcoholic beverages, fats and oils, fruits and vegetables, meat and other proteinaceous foods, and dairy products.

Flavoring agents

Flavoring agents can be broken down into food flavors and flavor enhancers. Food flavors include over 1,200 different flavoring materials and constitute the single largest category of food additives. Natural flavoring substances include herbs, spices, essential oils, and plant extracts. However, today there is more emphasis on the use of synthetic flavors because they are more economical compared to natural flavors.

Flavor enhancers or potentiators are also considered flavoring agents. Unlike food flavors which contribute

flavor, flavor enhancers do not have flavor in themselves. Flavor enhancers serve to intensify the flavor of other compounds present in foods.

Monosodium glutamate (MSG), the most commonly used potentiator in the food industry, is an example of a flavor enhancer. Baby food companies, however, discontinued the use of this compound in baby foods after an investigation by the National Academy of Sciences–National Research Council revealed that MSG may be linked to brain damage. The Chinese restaurant syndrome is associated with MSG and causes affected people to feel pressure in their chests, warmth, and tingling.

Food colors

Color is a strong visual tool used to evaluate food products. Food colors may be added to products for several reasons:

- To restore the original appearance of the food where the natural colors have been destroyed by processing.
- To ensure uniformity of color due to natural variations in color intensity.
- To intensify colors to the level which the consumer associates with that specific food type.
- To help protect flavor and light-sensitive vitamins during shelf storage.
- To give an attractive appearance to foods which would otherwise look unattractive or unappetizing.
- To help preserve the identity or character by which foods are recognized.
- To serve as visual indication of quality.

Two basic sources for food colors exist. Natural colors are pigments that are obtained from plant, animal, or mineral sources. Examples of natural colorants include chlorophyll, carotenoids, and other pigments.

The second category, artificial colors, are synthetically manufactured and are the primary sources of commercial colorants. These synthetic color additives, "certified" by the FDA, are designated as FD&C (Food, Drug, and Cosmetic). Physical and chemical properties of certified food colors include:

- hue range
- compatibility with food components
- stability to light, oxidation, and pH change

FD&C Blue #1 (brilliant blue), FD&C Green #3 (fast green), FD&C Red #40 (erythrosine), and FD&C Yellow #6 (sunset yellow) are examples of synthetic colors used in the food industry.

Food irradiation

Food irradiation, as an alternative to chemical substances, is another means of food preservation. Although food irradiation appears to be a type of processing method, it falls under the category of food additives because of an FDA regulation under terms of the 1958 Food Additive Amendment to the Food, Drug, and Cosmetic Act.

Sprout inhibition, insect disinfestation, sterilization, pasteurization, shelf-life extension, and elimination of parasites are several applications for irradiation. Although irradiation looks promising from a scientific standpoint, it has yet to gain approval from the general public.

Gases

Industrial gases have a variety of uses and functions in the food industry, with nitrogen and carbon dioxide being the two most widely used. The presence or absence of certain gases can directly influence the shelf stability, color, texture, and flavor of a product.

By controlling the amount or level of gases in a food's environment, the processor can increase the product's longevity. The combination of gas flushing and food preservation methods (freezing, irradiation, dehydration) yields a high quality product.

Humectants

The primary purpose of humectants is to bind water that may be present in a food system. Adding these chemicals helps food retain proper moisture, fresh flavor, and texture.

Humectants such as glycerol, propylene glycol, and sorbitol are often added to candies, shredded coconut, marshmallows, and others. The ingredients, sucrose (table sugar) and salt, also fall into this classification as additives.

Leavening agents

Leavening agents such as baking soda, baking powder, and yeast play an important role in the bakery industry. Without these common leavening agents that are necessary for carbon dioxide production, breads and cakes would lack a light texture.

Non-nutritive additives

Sugar substitutes and fat replacers that do not contribute calories to food fall into this category. Saccharin and acesulfame potassium (acesulfame-K) are non-nutritive sweeteners used in foods. Acesulfame potassium is approved for use in dry-food products and is relatively heat stable. Saccharin can be utilized in low-calorie products such as jams, beverages, and desserts. Drawbacks are that a warning label must accompany use of saccharin and that it has a bitter aftertaste.

Presently, there are three primary types of fat substitutes being extensively researched. These include carbohydrate-based replacers such as polydextrose, maltodextrin, and tapioca dextrin; protein-based substitutes which include Simplesse^{R} and Trailblazer^{R}; and synthetic compounds such as olestra and caprenin. Although many of these substitutes are only partially metabolized by the body yielding 1 to 4 calories per gram, they cannot be classified as non-nutritive food additives.

Nutrient supplements

Vitamins and mineral supplements are added to foods to improve nutritional quality or to replace nutrients lost during processing. In fact many food items, such as flour, have been enriched. Margarine, milk, and salt are additional examples of foods in which

vitamin A, vitamin D, or iodine has been added.

Adding nutrients has decreased the number of people suffering from vitamin and mineral deficiencies such as beriberi (thiamin deficiency), pellagra (niacin deficiency), scurvy (vitamin C deficiency), and goiter (iodine deficiency).

Preservatives

This class of food additives contains a variety of compounds. The compounds aid in the extension of shelf life by inhibiting microbial growth or by minimizing the destructive effects of oxygen, metals, and other factors that may lead to rancidity. A common example of a preservative used since the beginning of time is table salt. Salt's effectiveness to suppress microorganisms lies in the fact that only those microbes with a high tolerance for salt can survive.

The most important preservative utilized in the meat industry is nitrite. Nitrite inhibits the growth of the deadly bacterium *Clostridium botulinum* and is used extensively in cured meat products.

Sodium benzoate or potassium benzoate is typically added to soft drinks. Mold inhibitors such as calcium and sodium propionates and sorbates are used in bakery items such as breads and cakes, while sorbic acid is utilized by the dairy industry in cheese.

Fumigants such as ethylene oxide and ethyl formate are used to control microorganisms on spices, nuts, and dried fruits. Sulfur dioxide, which controls browning of fruits and vegetables caused by enzymes, is yet another example of a preservative.

Stabilizers and thickeners

These food additives provide uniform consistency as well as improve the color, texture, and flavor in candies, chocolate milk, artificially sweetened beverages, ice cream, and other frozen desserts.

Gravy is a common example of a food product that utilizes starch as a thickener. Other examples of thickeners and stabilizers include vegetable gums such as carrageenan and guar, pectins, agars, starches, and gelatins.

Without stabilizers and thickeners, ice crystals form in ice cream and other frozen desserts, particles of chocolate separate from chocolate milk, and volatile flavor oils evaporate in cakes, puddings, and gelatin mixes.

Surface active agents

This group of food additives includes emulsifiers, antifoaming compounds, and detergent chemicals. Emulsifiers are used to keep water and oil from separating in products such as margarine, salad dressing, ice cream, and other emulsions. Lecithin, which is a natural emulsifier obtained from soybeans, as well as mono- and diglycerides, head the list of emulsifiers used in the food industry. Emulsifiers, composed of chains of unsaturated fatty acids, are capable of depressing foam and serve as antifoaming agents in dairy products and egg processing. An example of an emulsifier that also falls into the detergent category is sodium lauryl sulfate. This compound functions as a whipping aid in marshmallows and angel food cake mixes.

Consumer Expectations and Demands

Consumption trends of the various food products have changed in the past several years because of growing concern for a healthier lifestyle. With the increasing demand for more healthy food products, processors have the responsibility for adjusting conventional products.

A conventional cookie formulation may contain 35 percent fat; however, the consumer may request a recipe tailored so the fat content is only 5 percent. Food additives play an important role in the reformulation of low-fat, low-calorie products.

Increasing or maintaining the shelf life of products encourages the processor to look for new and improved shelf-life extenders. The use of a surface spray containing potassium sorbate on flour tortillas may extend the shelf life of the product. This spray system utilizes potassium sorbate as a dough additive that functions as a preservative. Other additives are also used to extend shelf life.

The growing demand for shelf-stable products has led to increased use of packaging. Thermo-formed packaging, gas flushing (CO_2), vacuum packaging, and other materials and methods for prolongation of shelf life have been used with successful results on a variety of products.

Consumers fear the unfamiliar. One example is additives. In reality, the absence of additives would result in inferior food quality, limited shelf life and availability of certain food, and more danger of microbiological contamination. Proper use of food additives in food systems can ensure that food products meet governmental standards and, more importantly, consumer expectations.

For additional information or technical service on food additives, applications, and usage levels contact:

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