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Chemical Constituents of Food Additives and Their Effects

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ABSTRACT: Food additives are chemicals added to foods to keep them fresh or to enhance their colour, flavour or texture. They may include food colourings (such as tartrazine or cochineal), flavour enhancers (such as MSG) or a range of preservatives. From a food chemist's perspective, every additive in food (in fact, practically everything under the sun) regardless of its source or anticipated purpose, is composed of chemicals. That brings us face to face with the debate on natural vs synthetic chemicals. Majority of those chemicals synthesized in the chemical laboratory are also found naturally existing in foods. Chemicals are after all chemicals and the distinction between a "natural" and "synthetic" chemical is somewhat subjective. For example, the sugar in sugarcane (sucrose) is no different in chemical composition and function than the usual refined sugar added daily to our food. Similarly, the primary organic acid in a garden orange is vitamin c (ascorbic acid) which is the same vitamin c that is ″artificially″ added to canned beverages. Similarly, citric acid produced commercially in the lab by enzymatic action is the same naturally-occurring acid that gives lemons their natural tarty flavor. To say one chemical might be nutritionally safer than another because of its origin probably does not make much scientific sense.

KEYWORDS-food additives, chemical, constituents, synthetic, acids, organic

I. INTRODUCTION

E numbers are all prefixed by "E", but countries outside Europe use only the number, whether the additive is approved in Europe or not. For example, acetic acid is written as E260 on products sold in Europe, but is simply known as additive 260 in some countries. Additive 103, alkannin, is not approved for use in Europe so does not have an E number, although it is approved for use in Australia and New Zealand. Since 1987, Australia has had an approved system of labelling for additives in packaged foods. Each food additive has to be named or numbered. The numbers are the same as in Europe, but without the prefix "E".

The United States Food and Drug Administration (FDA) lists these items as "generally recognized as safe" (GRAS);[4] they are listed under both their Chemical Abstracts Service number and FDA regulation under the United States Code of Federal Regulations.
In 2012, the EFSA proposed the tier approach to evaluate the potential toxicity of food additives. It is based on four dimensions: toxicokinetics (absorption, distribution, metabolism and excretion); genotoxicity; subchronic (at least 90 data) and chronic toxicity and carcinogenity; reproductive and developmental toxicity.[21] Recent work has demonstrated that certain food additives such as carboxymethylcellulose may cause encroachment of microbes from the gastrointestinal tract into the protective mucus layer that lines the intestines.[22] Additional preclinical work suggests that emulsifiers may disrupt the gut microbiome, [1,2,3]cause or exacerbate inflammation, and increase intestinal permeability.[23] Other food additives in processed foods, such as xanthan gum, have also been shown to influence the ecology of human gut microbiomes and may play a role in the divergence of gut microbiomes in industrialized societies as compared to pre-industrialized societies.[24] Although still controversial, some scientists hypothesize that these changes to human gut microbiomes may be a contributing factor to the rise in chronic inflammatory diseases in industrialized populations.

Food additives can be divided into several groups, although there is some overlap because some additives exert more than one effect. For example, salt is both a preservative as well as a flavor.[5][1]

Acidulants

Acidulants confer sour or acid taste. Common acidulants include vinegar, citric acid, tartaric acid, malic acid, fumaric acid, and lactic acid.

Acidity regulators

Acidity regulators are used for controlling the pH of foods for stability or to affect activity of enzymes.

Anticaking agents

Anticaking agents keep powders such as milk powder from caking or sticking.

Antifoaming and foaming agents

Antifoaming agents reduce or prevent foaming in foods. Foaming agents do the reverse.

Antioxidants

Antioxidants such as vitamin C are preservatives by inhibiting the degradation of food by oxygen.

Bulking agents

Bulking agents such as starch are additives that increase the bulk of a food without affecting its taste.

Food coloring

Colorings are added to food to replace colors lost during preparation or to make food look more attractive.

Fortifying agents[4,5,6]

Vitamins, minerals, and dietary supplements to increase the nutritional value

Color retention agents

In contrast to colorings, color retention agents are used to preserve a food's existing color.

Emulsifiers

Emulsifiers allow water and oils to remain mixed together in an emulsion, as in mayonnaise, ice cream, and homogenized milk.

Flavorings*

Flavorings are additives that give food a particular taste or smell, and may be derived from natural ingredients or created artificially.

*In EU, flavorings do not have an E-code and they are not considered as food additives.

Flavor enhancers

Flavor enhancers enhance a food's existing flavors. A popular example is monosodium glutamate. Some flavor enhancers have their own flavors that are independent of the food.

Flour treatment agents

Flour treatment agents are added to flour to improve its color or its use in baking.

Glazing agents

Glazing agents provide a shiny appearance or protective coating to foods.

Humectants

Humectants prevent foods from drying out.

Tracer gas

Tracer gas allows for package integrity testing to prevent foods from being exposed to atmosphere, thus guaranteeing shelf life.

Preservatives

Preservatives prevent or inhibit spoilage of food due to fungi, bacteria and other microorganisms.

Stabilizers

Stabilizers, thickeners and gelling agents, like agar or pectin (used in jam for example) give foods a firmer texture. While they are not true emulsifiers, they help to stabilize emulsions.

Sweeteners

Sweeteners are added to foods for flavoring. Sweeteners other than sugar are added to keep the food energy (calories) low, or because they have beneficial effects regarding diabetes mellitus, tooth decay, or diarrhea.

Thickeners

Thickening agents are substances which, when added to the mixture, increase its viscosity without substantially modifying its other properties.

Packaging

Bisphenols, phthalates, and perfluoroalkyl chemicals (PFCs) are indirect additives used in manufacturing or packaging. In July 2018 the American Academy of Pediatrics called for more careful study of those three substances, along with nitrates and food coloring, as they might harm children during development.

Categories of food additives

Acids

As shown most of the food acids are tracked down to the fruits such as grapes, lemon, orange, berries, plums, etc. While the human metabolic system readily adjusts to most of the natural food acids, there are some acids that the human body does not naturally recognize and are unhealthy thus leading to irritation and inflammation.[7,8,9]

Acid	Source
Citric Acid	Citrus fruits – Lemon, Orange
Malic Acid	Apple
Tartaric Acid	Grapes, Pineapples
Acetic Acid	Vinegar
Oxalic Acid	Tea, Pepper
Tannic Acid	Tea
Caffeotannic Acid	Coffee
Benzoic Acid	Cranberries, Plums
Butyric Acid	Decomposition of Butter
Lactic Acid	Butter Digestion

Citric acid (IUPAC Name)

2-hydroxypropane-1, 2, 3-tricarboxylic acid): it is a weak organic acid with the chemical formula C6H8O7. Its position is well established in the food industry as a natural preservative and additionally it gives a characteristic acidic or sour taste to food and drinks. When heated above 175°C, it undergoes decarboxylation i.e. loss of carbon dioxide. The acid strength of citric acid is somewhat higher than typical carboxylic acids. Applications: (a) citric acid is the acid of choice in the beverage industry and is used widely in carbonated beverages for its flavoring and buffering (pH maintaining) properties while its solubility properties make it a supreme additive for syrup concentrates; (b) It also increases the efficacy of anti-microbial (bacterial, fungal, etc.) preservatives. Citric acid (sometimes used as its citrate salt) is also used in non-carbonated beverages such as juices, thirst-quenchers, etc. (c) it is used in dry powder beverages, as also inartificially sweetened beverages. Citric acid helps add bulk and mouth-feel typically attributed to sucrose. In a recent paper the addition of citric acid showed reduced levels of the carcinogen acrylamide in cooked food[17] (Figure 1).

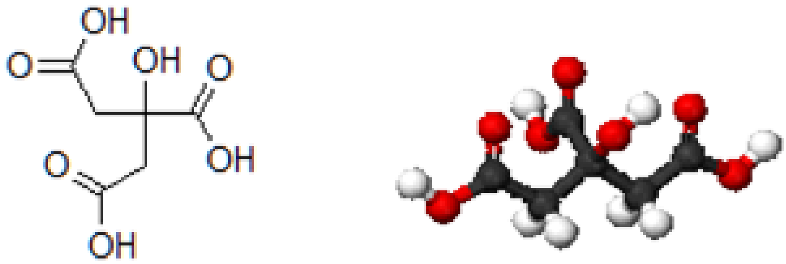


Figure 1 Structure of citric acid.

Tartaric acid (IUPAC Name)

2, 3-dihydroxybutanedioic acid): Tartaric acid is a white crystalline dicarboxylic aldaric acid with the formula C4H6O6. It occurs naturally in many plants, e.g. grapes, bananas, and tamarinds. It functions as a leavening agent when added together with baking soda; is also routinely added to wine as the principal acidulant; is used as an antioxidant which makes it a more healthy alternative acid. Occasionally, tartaric acid is replaced by its salt i.e. tartarate. Chemically, it is a dihydroxy derivative of succinic acid which is itself used as a buffering agent in foods (Figure 2).

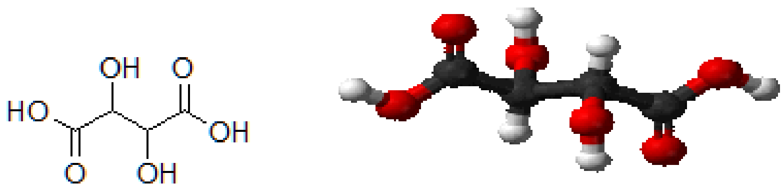


Figure 2 Structure of tartaric acid.

Malic acid (IUPAC Name)

2-hydroxybutanedioic acid): Malic acid is an organic compound with the formula HO2CCH2CHOHCO2H (C4H6O5) and exists in its two stereoisomeric forms (L- and D-enantiomers), though only the L-isomer is found in nature. The salts of malic acid are known as malates. Applications: (a) low calorie beverages -its biggest advantage is that as compared to citric acid, the amount of malic acid required to be added to achieve the same level of sourness, is significantly lower.[18] Malic acid has an extended sourness i.e. its sourness stays longer and hence results in a more balanced taste. (b) Hard candy-It melts sooner than other food acids and hence can be assimilated easily into the molten hard candy without adding any extra water thus leading to increased shelf-life. (c) Chewing gum-For good chewing gum, it is important that it lead to profuse secretion of saliva and to achieve it, a combination of saccharin and food acid is often used. Blends of malic acid with other food acids having different miscibilities results in a progressive release of the acid creating sustained juiciness and flavor during chewing. (d) Desserts - it enhances fruit flavor in sherbets and water ices. In gelled desserts, addition of controlled amounts of malic acid leads to enhanced fruit flavor and pH control (Figure 3).

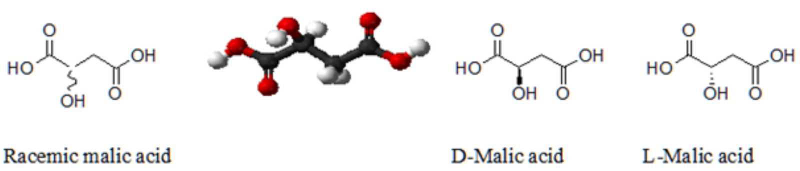


Figure 3 Structures of malic acids.

Fumaric acid (IUPAC Name)

(E)-butenedioic acid): Fumaric acid is the chemical compound with the formula HO2CCH=CHCO2H. Among all the food acids we have discussed up to now, this is the only acid having a double bond in its structure and it is therefore classified as an unsaturated acid. This white crystalline acid is one of the two isomeric unsaturated dicarboxylic acids, the other being maleic acid (the cis-isomer). Fumaric acid has a natural fruity taste and its salts and esters are called fumarates. Incidentally, dimethyl fumarate reduces disability progression in multiple sclerosis[19] (Figure 4).

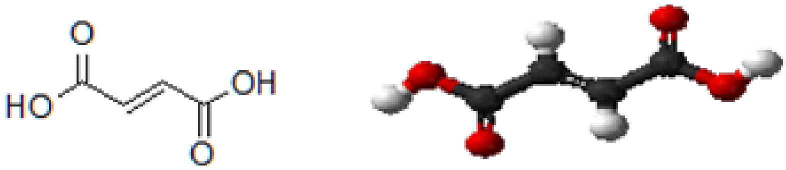


Figure 4 Structure of fumaric acid.

As a food additive, this acid is mainly used as an acidity regulator. Fumaric acid is a food acidulent[20] used since 1946. It is usually a good alternative acid for tartaric acid and sometimes of citric acid. When used as a replacement for citric acid, it is added at a rate of 1.36 g of citric acid to every 0.91 grams of fumaric acid. It is also the acid of choice as a coagulant in stovetop pudding mixes.

Lactic acid (IUPAC Name)

(2-hydroxypropanoic acid): lactic acid, (obtained from milk and hence termed as “milk acid”), is an important chemical compound that plays a crucial role in various biochemical processes. Lactic acid is a a-hydroxy carboxylic acid with the chemical formula C3H6O3. It exists in two enantiomeric forms: L (+)-lactic acid and D (-)-lactic acid, the former being the enantiomer that is primarily involved in human metabolism.[21] In early 1960’s, the presence of D-lactic acid in infant milk formulas was found to lead to infant acidosis.[22] Applications: Being widely prevalent in natural foods, it is extant in many foodstuffs. Natural fermentation of mainly milk-based products e.g. cheese, yogurt, soy sauce, , meat products, etc yields lactic acid and hence it is widely used in food applications such as confectionery, bakery products, meat products, beverages, dairy products, salads, dressings, ready to-eat meals, etc. Lactic acid when used as a food additive mainly serves as a pH regulator or a preservative. Sometimes, it is also used as a flavoring agent. Among its many uses[23] are: (a) Meat, Poultry and Fish: in the form of its salts sodium or potassium lactate, it is employed to extend shelf life, control disease-causing bacteria (thus improving the safety and nutritional value of food), enhance (and protect) meat flavor, and improve water binding/retention capacity. (b) Pickled Vegetables: here again the natural preservative action of lactic acid is employed in preventing the damage of olives, gherkins, pearl onions (pearl onions closely resemble leek and are sweeter than common onions), and other vegetables preserved in brine. (c) Salads and Dressings: addition of lactic acid provides a relatively milder flavor to food products while maintaining natural microbial stability and safety. (d) Baked Goods: Sourdough is a type of bread made by prolonged fermentation of dough with lactic acid[24] where the latter is used directly for acidification in the production process. (e) Savory Flavors: Lactic acid does not just enhance the usual flavors, but it also enhances a broad range of savory flavors (also called umami flavors)[25,26] (Figure 5 & 6).

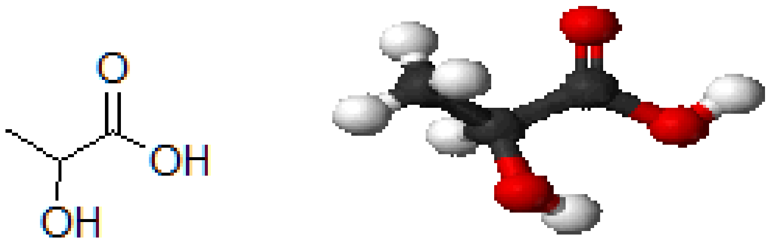
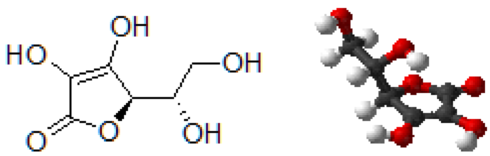


Figure 5 Structure of lactic acid.



II. DISCUSSION

Acidity regulators

Acidity regulators are required to maintain a balance between an extreme acid flavor and an extreme alkaline flavor. For instance, citrus fruits, juices, or yogurt are some commonly used acid foods while egg white and baking soda exemplify alkaline foods. Acidity regulators can be organic acids (e.g. acetic acid) or mineral acids (e.g. hydrochloric acid), bases (again organic or inorganic), neutralizing agents, or buffering agents (pH regulators). Of the most widely used acidity regulators are citric acid, acetic acid, and lactic acid. Notably in Europe, acidity regulators are controlled by strict EU (European Union) laws specifying authorisation, use, and labelling of all acidty rgulators.[27]

Anti caking agent[10,11,12]

Anti-caking agents inhibit lump formation in food items thereby facilitating food products′ transport. Examples of anticaking agents are starch, magnesium carbonate (MgCO3), and silica. These are added to fine-particle solid food products, like table salt, flours, coffee, and sugar. Anticaking agents may be water soluble (hydrophilic) or soluble in organic solvents like alcohol (hydrophobic) and consequently they function either by adsorbing excess moisture (hydrophilic property), or by creating a coating on the particles and making them water repellent (hydrophobic property). Calcium silicate (CaSiO3), a commonly used anti-caking agent generously added to table salt, tends to absorb both water and oil indicating its amphiphilic proclivities. Some common anti-caking agents are: Aluminium silicate (Al2 (SiO3)3), Bentonite (a type of clay like montmorillonite), Calcium aluminosilicates (mainly CaAl2Si2O8), Calcium ferrocyanide (Ca2[(Fe(CN)6]), Stearic acid (a long chain fatty acid of the formula CH3 (CH2)16CO2H, Talcum powder, Tricalcium Phosphate (also referred to as bone ash having formula Ca3 (PO4)2), etc. Anticaking additives are also used to prevent the humidification of vitamin C[28] (Figure 7).

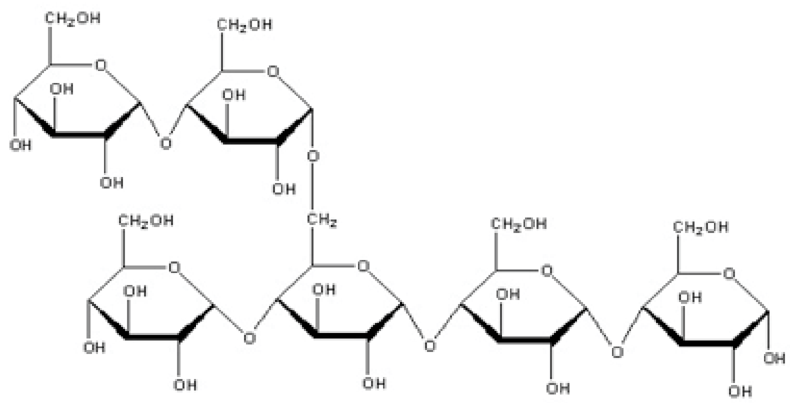


Figure 7 Structure of Starch.

Antifoaming agents

As a very general functional definition, an anti-foaming agent (also called a defoamer) is, as its name implies, a chemical additive that reduces and/or hinders the formation of foam (froth) in industrial process liquids. A variety of chemicals are available to prevent formation of foams[29] and these can be classified as: oil based, powder based, water based, silicone based, etc. When used as a food additive, antifoaming agents reduce outflow (effervescence) in a preparation or serving. These agents are found in various foods such as chicken nuggets in the form of polydimethylsiloxane which is a type of silicone polymer. Silicone oil is also added to commercial cooking oil to inhibit excessive frothing while deep-frying foods.

Antioxidants

An antioxidant is a molecule that inhibits or prevents the oxidation of other molecules. Traditionally, antioxidants are compounds that are believed to promote health by removing reactive chemical species that cause harmful effects when metabolized in the body.[30] Oxidation is a chemical reaction resulting in addition of oxygen to, or removal of hydrogen from, or removal of electrons from a substance. From a nutritional perspective, oxidations can result in the formation of free radicals which are chemical species having unpaired electrons that make them very unstable and therefore highly reactive. One of the common free radicals is the infamous reactive oxygen species (ROS). The latter can initiate uncontrolled chain reactions in the biological cells ultimately leading to damage or death of the cell. The function of antioxidants is to terminate these harmful chain reactions by taking out the dangerous free radical intermediates, hence resulting in the inhibition of further oxidations. Apart from their nutritional value, antioxidants also have varied industrial uses, such as their application as food and cosmetics preservative and to thwart the degradation of rubber and gasoline.[31] Antioxidants are subdivided based on their solubility in water (hydrophilicity) or their solubility in lipids (hydrophobicity). Applications: As detailed earlier, the use of antioxidants as food additives is primarily attributed to their ability to help guard against food deterioration. Now, it is well known that in refrigerated or even frozen foods, oxidation reactions do not stop and therefore food degradation keeps occurring. This degradation is surprising in that bacterial or fungal decomposition usually stops at subzero temperatures. Hence, the addition of antioxidants is virtually inadvertent in common foods that require shelf life. Some dietary additives e.g. vitamin C (ascorbic acid), tocopherols (vitamin E), carotenoids, polyphenolics, etc. can obliterate the danger of ROS free radicals. Such food products based on high antioxidant benefits include: whole foods and beverages (e.g. green tea, now much in vogue) or some chemically isolated substances available in the market as dietary supplements (e.g., vitamin C, lycopene, selenium, etc.).[32] Some synthetic (chemically prepared) compounds are also used as antioxidants such as tertiary butyl hydroquinone (TBHQ), propyl gallate (PG), butylated hydroxytoluene (BHT), and butylated hydroxyanisole (BHA) etc.[33] One of the reasons why fats (margarine or butter etc.) should not be wrapped in aluminum foil or stored in metal containers is that oxidation is often catalysed by metals. Antioxidant additives are also included in fat-based cosmetics such as lipstick (which sometimes gets into food), moisturizers, etc. to prevent their rancidity.

Bulking agents

Bulking agents increase the bulk or volume of a food without altering its taste or its available energy e.g. starch is a popular bulking agent. Starch or amylum is a member of the carbohydrate family (a chemical group of compounds made up of C, H, and O only and having the empirical formula CH2O) consisting of a number of glucose units. Since it contains large number of glucose units joined together it is classified as a polysaccharide and interestingly, it is synthesised by all green plants as an energy storage source. Majority of the staple foods consumed by humans today comprises of rice, wheat, potatoes, maize (corn), etc., all containing starch. Pure starch which is insoluble in cold water or alcohol is a white, tasteless and odourless powder. When dissolved in warm water, it gives wheat paste, which can be used as a thickening, stiffening, or gluing agent (remember those poster campaigns in colleges?). The industrial processing of starch is commercially important as it gives rise to many of the sugars found in processed foods. The bulk of the starchy food intake worldwide comprises of cereals or grains most prominent among them are: wheat, corn, paddy (rice), barley, and sorghum which is a type of grass. Many starchy foods are characteristically grown only in specific climates, including acorns, arrowroot, taro, bananas, millet, oats, sago, sweet potatoes, rye, chestnuts, yams, beans (of various types e.g. mung, peas, lentils, etc.).[34] Popular everyday foods and delicacies consisting of starchy food are e.g. noodles, breads, pancakes, pasta, etc. Starch as such is not that easy to digest but when cooked, its digestibility is increased. Consequently, for our prehistoric human ancestors eating grains would not have been a lucrative way to obtain energy.

Food coloring

Any additive which may be in the form of a dye, pigment, or a chemical compound, that imparts color to the food can be termed as a color additive.[35] Usually, addition of colors can make the food look more attractive and it can also influence the observed flavor e.g. launching of the green ketchup by Heinz in 2000.The reasons for adding color to food could be various; such as to compensate for the loss of color due to atmospheric exposure to light, air, extreme temperatures, etc. FDA authorizes colors to be classified as allowable either with certification or exempt from certification. In either case, stringent safety standards are applied before these colors are officially endorsed and allowed to be added.[36] Certified colors are man-made and used widely because of their versatility and cheapness. Color additives are broadly categorized in the following three types: straight colors i.e. pure pigments that are not mixed or modified by other chemicals; lakes which are formed by mixing or reacting straight colors with other substances and; mixtures which are usually formed by mixing two different color additives. In the US, the following nine color additives are permitted: FD&C Blue No. 1, FD&C Blue No. 2, FD&C Green No. 3, FD&C Red No. 3, FD&C Red No. 40, FD&C Yellow No. 5, FD&C Yellow No. 6, Citrus Red No. 2, and Orange B where FD&C stands for Food Drug And Cosmetic. Notably, the latter two colors are permitted only for coloring the skins of oranges and casings of frankfurters and sausages, respectively.[37] Colorants of natural origin such as from vegetables, minerals, or animals are generally exempt from certification but may be more expensive than certified colors. Some examples of exempt colors can be found in the list shown below. According to the Centre for Science in the Public Interest,[38] since addition of colors is widely prevalent in foods having low nutritional value e.g. candy, soda pop, gelatin desserts, etc., one is advised to avoid all artificially colored foods. Colorings have been reported to cause hyperactivity (which is a part of the larger group of diseases called Attention Deficit and Hyperactivity Disorder, ADHD) in some sensitive children. As a thumb-rule, if colors are used in food it usually is a good indicator that fruit or other natural ingredient has not been used for that preparation (CSPI). As a passing remark, the most common pigments of red, blue, and yellow colors obtained from natural sources as a general rule belong to the polyphenols and carotenoid family.[39] Some examples of natural food dyes[40] are:[13,14,15]

a. Caramel coloring - made from caramelized sugar i.e. by heating solid or dissolved sugar at high temperatures
b. Annatto (Bixa orellana) - a reddish-orange pigment obtained from the seed of the achiote plant.

c. Chlorophyllin - Chlorophyllin is a semi-synthetic mixture of water-soluble sodium copper salts derived from chlorophyll; a green dye made from chlorella algae
d. Cochineal (Dactylopius coccus)- the name of both crimson or carmine dye derived from the cochineal scaly insect
e. Betanin -a glycosidic red dye extracted from beets; generally used for short shelf-life food items
f. Turmeric.-. the active ingredient of which is curcumin, a phenolic compound, is often used as a much cheaper replacement of saffron
g. Saffron. (Crocus sativus) one of the most expensive natural spices; imparts rich golden-yellow hue
h. Paprika (Capsicum annum) obtained from a member of the capsicum family
i. Lycopene: red dye from tomatoes; is a type of carotenoid pigment
j. Elderberry juice: elderberry plant, also called Sambucus nigra, gives colors ranging from peach to strawberry to magenta
k. Pandan leaves (Pandanus odoratissimus) - imparts green coloration to food
l. Butterfly pea (Clitoria ternatea)-its blue flowers are used as a blue dye for foods e.g. in Malay cooking, the flowers are added to glutinous rice to give a tinge of blue color
m. An inventory of all allowed food colorants can be found at the FDA website.[41] The color additives are purified and then added as a formulation in solid or liquid form. The solvents present in these formulation could be hexane, acetone, ether, ethyl acetate, etc. that facilitate the extraction of the colorants. These solvent etc. residues may be found in the finished edible product but luckily these need not be declared as they form a group of chemicals called “carry-over ingredients”. The food colorants could sometimes be hazardous e.g. annatto (of plant origin, for providing orange or bright yellow color to food), cochineal (of insect origin, imparts crimson color to food), caramine (similar to cochineal, giving natural red color), etc.[42]

Emulsifiers

Food emulsifiers must be surface active, possess a capacity to create foam and of course, be edible. Sometimes the term HLB (hydrophilic/liphophilic balance)[43] is used to quantify an emulsifying agent. An emulsifier (sometimes referred to as an "emulgent") is a species that helps stabilize an emulsion by increasing its kinetic (as opposed to its thermodynamic) stability. Examples of food emulsifiers are: (a) lecithin: Lecithos, which in Greek means egg yolk, is the major emulgent in the form of lecithin, (b) Proteins: especially those containing both hydrophilic and hydrophobic functional groups, e.g. milk proteins, legume proteins, etc. (c) Mustard: the chemicals in its seed are mainly responsible for its emulsifying action, (d) Sodium Stearoyl Lactylate: it is an ester having a long hydrophobic chain in its structure, (e) DATEM (diacetyl tartaric acid ester of monoglycerides and diglycerides)): also an ester majorly used in baking. Uses of Emulsifiers: Chemically, emulsifiers are molecules usually having two ends: one of which is hydrophobic (water repelling) and the other hydrophilic (water loving). Emulsions where oil is dispersed in water are common in food, e.g.: (a) Crema (i.e. the foam) in espresso -coffee oil dispersed in water it is an unstable emulsion, (b) Mayonnaise and Hollandaise sauce -also oil-in-water emulsions (c) Homogenized milk-it is raw milk mechanically churned to give it a homogeneous and smooth texture where the proteins and fats are broken down to give a smooth feel.

Flavors

Flavor is mainly a sensory response to the stimulation of taste buds and olfactory organs when food strikes them and it is possible to alter the flavor of the food to affect the senses.[44] Interestingly, food, drinks, or other dietary objects are identified mainly by the senses of smell (olfactory) and sight (visual), not taste (Small 2008). Hence, the main element of a food item's flavor is its smell although we have to consider sympathetically the case of people suffering from anosmia i.e. odor blindness. It is commonly accepted that the main attributes of flavor are the following: sweet, sour, bitter, salty, and then there is the recently recognized fifth one ‘umami’ ("oo-mommy" or savory/pleasant), followed by pungent or piquant, and finally metallic, the seven basic tastes. Natural flavor extracts are not abundantly available and extracting flavorants from them requires heavy spending, hence most of the commercially employed flavorants are chemically synthesized and are branded as ″nature-identical″, i.e. they can be considered as chemically comparable to the original natural flavors. There are three major types of flavoring additive substances used in foods: (a) natural; obtained from plants or animals by physically, microbiologically, or enzymatically manipulating the ingredients present in the respective original source, (b) Nature-Identical; as aforementioned, these may be made by chemical synthesis or isolated by chemical means, and (c) Artificial; flavoring substances not found in any natural product and are obtained by chemical manipulation of say, crude oil, coal tar, etc.[45] The extraction of flavorants from their natural sources maybe accomplished by solvent extraction (i.e. by selectively dissolving one of them in a mixture of solvents), distillation (based on differential boiling points of the ingredients), or using force or pressure to squeeze it out. After further purification, the extracts are then added to the desired foods. Many flavor additives consist of esters (chemicals formed by the reaction of a carboxylic acid and an alcohol), which have a characteristic "fruity" odour. Some important chemicals and their characteristic odours have been tabulated in Table 3. Discussed below are two of the most important factors responsible for flavors: (a) Taste: when it comes to taste, the Umami or "savory" or ″pleasant″ flavorants are now fairly common flavor additives and are primarily based on amino acids and nucleotides (nucleotides consist of a base, a sugar, and a phosphate unit). Although, in a purely technical sense, sugar and salt also constitute taste flavorants but in gastronomy, it is those additives that lead to an enhancement of umami or other secondary flavors that are regarded as the taste flavorants. Artificial sweeteners though are all technically regarded as flavorants. Umami flavorants recognized and lawfully allowed by the European Union include the ones shown in Table 3.[46] (b) Color: as we have seen earlier the natural color of food coupled with the color additives can affect its overall flavor. It interesting to note that the color of the food served in front of you sets up an expectation of the flavor: e.g. greens from the green vegetables give a feeling of freshness; reds from the red fruits give a perception of ripeness; and purple of the meats sometimes give an impression of being perfectly cooked.[47] From: More recently, natural pigments and dyes for use in food are being sourced from e.g. plants, insects, and microorganisms.[48] It is pertinent to mention that the classic example of the influence of cooking on flavor as well color of the cooked food is the Maillard reaction which occurs between the amino acids and the reducing sugars that are present in the cooked food.

III. RESULTS

This non enzymatic reaction is mainly responsible for the browning of food when cooked at around 140°C or above. It has also been shown by research that the Maillard reaction products may be responsible for the inhibition of microbial growth in food[49]

Some umami flovorants recognized by EU[16,17,18]

Chemical	Odor
Diacetyl	Buttery
Isoamyl Acetate	Banana
Benzaldehyde	Bitter Almond
Cinnamic Aldehyde	Cinnamon
Ethyl Propionate	Fruity
Methyl Anthranilate	Grape
Limonene	Orange
Ethyl Decadienoate	Pear
Allyl Hexanoate	Pineapple
Ethyl Maltol	Sugar, Cotton Candy
Ethylvanilin	Vanilla
Methyl Salicylate	Whitegreen

Some chemicals and their characteristic odors

Acid	Description
Acetic acid	Gives vinegar its sour taste and distinctive smell.
Ascorbic acid	Found in oranges and green peppers and gives a crisp, slightly sour taste. Better known as vitamin C.
Citric acid	Found in citrus fruits and gives them their sour taste.
Fumaric acid	Not found in fruits, used as a substitute for citric and tartaric acid.
Lactic acid	Found in various milk or fermented products and give them a rich tartness.
Malic acid	Found in apples and gives them their sour/tart taste.
Phosphoric acid	Used in all Cola drinks to give an acid taste.
Tartaric acid	Found in grapes and wines and gives them a tart taste.

Flour treatment agents

Also called bread improvers or improving agents are food additives pooled with flour to develop their baking functionality. Hence, these are generally used to increase the rapidity of dough rising and to improve the strength and workability of the dough. These falls into the following four main categories: oxidizing and reducing agents, enzymes, bleaching agents, and emulsifiers. Usually the addition of a small amount of these flour treatment species is enough to bring about the desired effect and hence they are sold mixed with soy flour base. Since freshly milled flour is yellowish, flour bleaching agents are mixed with flour to make it appear whiter. Oxidizing agents are used as treatment agents added to flour to help with the development of gluten which gives the flour its elasticity and chewiness. Common oxidizing agents thus added are: (a) Azodicarbonamide (biurea, also known as an improving agent), (b) Urea (NH_2CONH_2), and (c) Potassium Bromate ($KBrO_3$). Potassium bromate is well known oxidizing agent, and is completely used up in the bread baking process. However, if proper precautions are not taken to keep the amount of potassium bromate concentration under control, then even a residual amount remaining unused may be harmful if consumed[50] (Figure 8).

Figure 8 structure of azodicarbonamide and urea.

Glazing agents

A glazing agent usually functions as a coating material to prevent water loss and provide other surface protection for the food some common galzing agents are beeswax (e.g. for coating of confectionary), lac: obtained from the lac insect from India (used in chocolates, candies, etc), mineral oil which is generally used to coat chewing gums, fresh vegetables, drug capsules, etc.

Preservatives

In a very general way, a preservative is a naturally or synthetically obtained substance that is added to products such as foods, pharmaceutical preparations, biological samples, etc. to prevent decomposition brought about by bacteriological growth, or by atmospheric degradation, or by adverse chemical changes.[51] Most preservatives can be categorized as: (a) those that help prevent bacterial or fungal growth, (b) those preventing oxidation, and (c) those that prevent the natural ripening of foods, vegetables, etc. Most preservatives that are added to food can be classified into class-I and class-II preservatives; the former are natural chemicals commonly found in the kitchen e.g. salt, sugar, alcohol, vinegar, etc. while the class-II preservatives are artificial compounds and are usually synthesised e.g. benzoates, sorbates, sulfites, etc. Lately, the benefit ensuing from these preservatives as against their safety issues is the subject of debate among academics and regulatory authorities.[52] The natural food preservatives and the natural ways of preserving foods are the traditional methods used for millenniums including grandma's recipes still used at home while making pickles, jams, and juices etc. Also included in this list are the established procedures of salting, freezing, boiling, smoking, etc.[53] For example, coffee powder and soups are dehydrated (i.e. all the moisture removed) and freeze-dried to preserve their quality and enhance shelf-life. The following is list of some commonly added chemical food preservatives[54] classified by their preservative action - antioxidant functionality: BHT, BHA, and citric acid; microorganism inhibitory: benzoates, sodium nitrate, and sodium nitrite; those that inhibit molds: calcium propionate and potassium sorbate; those that prevent discoloration: sulfur dioxide, etc.

Stabilizers

In chemistry, a stabilizer can be thought of as the antithesis of a catalyst. In food chemistry, the term can be applied to refer to a chemical or other additive that impedes separation of emulsions, suspensions, and foams. Food stabilizers are used to produce uniform texture of foods and to improve "mouth feel" especially in frozen desserts, jellies, etc. and may consist of gelatin, pectin, guar gum, carrageenan, xanthan gum, whey, etc (US FDA food ingredients). Some types of stabilizers are: (a) Sequestrants (metal chelators), (b) Antioxidants, (c) Ultraviolet stabilizers, and, (d) Emulsifiers and Surfactants.

Organic Vs synthetic food: the debate continues

Surprisingly, majority of people assume that organic foods taste better than those grown conventionally. However, there is not much real evidence to corroborate this statement. The term "natural" applies broadly to foods that are unprocessed or minimally processed and free of colors, artificial sweeteners, synthetic preservatives, other additives, and are even devoid of stabilizers, growth hormones, emulsifiers, etc.[55] Incidentally, the term "organic" when viewed from the standpoint of food science includes not just the food itself but also alludes to how the food was produced. Foods tagged as organic must be certified by the National Organic Program (NOP) of the United States Department of Agriculture. They must be grown and processed under strict laws using accepted organic farming methods that a) recycle the resources produced and b) promote biodiversity. The latter two are the vital elements of environmentally sustainable agriculture (US FDA Food Marketing Institute). Largely, one can find out whether the product is organic or natural by searching its PLU (price look up) code usually found on the sticky label[19]

IV. CONCLUSION

The business of food additives is thriving and to cite some recent data, Global Industry Analysts Inc. (GIA) released a global report in 2010 on food additives market that underlines exciting prospects for the world market for food additives as it is projected to exceed $33.9 billion by the year 2015[60] and possibly may reach $45 billion by 2020. Perhaps the most significant trend driving growth in additives is a general increase in processed foods consumption across the world. From a food business perspective, the emerging markets of Asia and Latin America are becoming increasingly attractive for food additive industries and suppliers as the processes food demand in these regions is growing by leaps and bounds[61] Research and Markets has announced the addition of the "Food Additives - Global Strategic Business Report" document to their offering and as expected, the United States and Europe once again continue to dominate the world food additives market.[62] Americans are particularly growing health conscious and cautiously counting calories such that low-calorie, low-fat foods are fast gaining popularity in the United States. More and more technology-driven research is now being undertaken that will allow the production of additives in newer and more sophisticated ways e.g. the increasing stress being laid on biotechnology as it uses simple organisms to produce additives that are the same as natural food constituents. In 1990, FDA approved the first bioengineered enzyme, rennin, extracted from calves' stomachs for use in cheese making industry.[63] It appears that some of the sectors likely to have better-performance may include segments such as colors and flavors that are naturally sourced, enzyme based foods, food hydrocolloids (which are foods similar to gums), and some of the functional food ingredients. As is evident from previous discussion, the inclination to spend more on naturally sourced and/or additive-free food and drinks is projected to continue in the short-term. This could be largely due to increasing end user concern over the safety of artificial ingredients. The role of food packaging in modern day food industry is also crucial and has huge economic impacts e.g.[64] have investigated the benefits of intelligent packaging systems to the quality and safety of food.

So, in looking toward the future, increases in overall population will definitely have a remarkable effect on the world's food supply. Statistically, although the level of food additives added to food vis-a-vis the total diet of an average customer is minor, the overall contribution does turn out be significant. Recently the FDA's Food Safety Modernization Act (FSMA), one of the boldest reforms of U.S. food security and health safety laws in more than 70 years, was made into law by President Obama on January 4, 2011. Its focus is to make sure the U.S. food supply is safe by aiming on prevention rather than response to food contamination. Ultimately, the responsibility of avoiding the risk of consuming unsafe food lies with us and herein the World Health Organization's rule-of-thumb guide says it all: keep the food clean; effort should be made to separate raw from cooked food; cook the food thoroughly; store the cooked/uncooked food at safe temperatures; and take precautions to use safe water and raw materials as far as possible.[65] With increasing public concern about food safety issues[66] eventually, there are four important players that will decide the future of food additives: law-makers, scientists, commercial enterprises, and finally the consumers themselves.[67] Hence, the use of food additives is vast; they are used from cold drinks to chips and as preservatives in pickles to coloring and sweetening agents in many food items. All these uses can be expanded with the help of further research. The report analyses the chemistry of food additives, their structures, and their chemical properties. The report can be used as a benchmark for further studies.[20]

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