CHAPTER

30

Food Additives

The great bulk of food is comprised of chemicals such as carbohydrates, fats, proteins, vitamins, minerals, water, etc. Besides the natural components of food stuffs, additional chemicals may be incorporated, either directly or indirectly, during the growing, storage or processing of food.

30.1 What are Food Additives?

A food additive is defined as a substance or mixture of substances, other than a base foodstuff, which is present in a food as a result of any aspect of production, processing, storage, or packing. This definition includes both intentional and unintentional additives. The unintentional additives, which are not added to achieve an effect in the food but which may accidentally enter into foods as a result of their use in agricultural production, raising animals, food processing or packing, are no additives in the technical sense of the term, but they are food contaminants.

An expert committee on "food additives," made up of representatives of FAO and WHO, has definec food additives as non-nutritive substances added intentionally to food, generally in small quantities to improve its appearance, flavour, texture, or storage properties. This definition excludes substance added primarily for their nutritive value, such as vitamins and minerals. The Codex Committee on Foo Additives and Contaminants (CCFAC) establishes and endorses permitted maximum or guideline level for individual food additives, contaminants, and naturally occurring toxicants, in food and animal fee

Regarding additives, the committee considers technological justification and the need for propose levels of use. It also develops and enables general risk analysis for all foods through General Standa for Food Additives (GSFA) and General Standard for Contaminants and Toxicants in Foods (GSTF).

The primary objective of establishing maximum–use levels for food additives in various food grou is to ensure that the intake of an additive from all its uses does not exceed its Acceptable Daily Intak

A broad definition of "food additive" is any substance the intended use of which results, directly indirectly, in its becoming a component of or otherwise affecting the characteristics of any food, and whi is safe under the condition of its use. Any substance present in food, either by intentional addition or an unintentional contaminant, has its effects on the safety of food. Some groups of intentional additi and unintentional contaminants (not covered in previous chapters) are discussed in this chapter.

30.2 Need for Food Additives

For centuries, man has recognized the effects of food additives and has used whatever was availab marigold for colour, wood ashes for leavening, the lining of calves, stomach for cheese making, They were used for effects without knowing the changes they brought about. As long as the ingredi did not make one sick immediately, it was all right to use it. Today, thousands of compounds are used as food additives, whose chemical identity and structure are known. They can be obtained in a very high state of purity and, when used, bring about the desired effect in foods.

The use of food additives is imperative in the complex and integrated society in which we live. The areas of food production are separated from the areas of consumption. Additives have provided protection against food spoilage during storage, transportation, distribution, or processing. Also, with the present degree of urbanization, it would be impossible to maintain food distribution without the processing and packing with which many additives are involved.

A number of factors have led to the demand for foods with built-in preparation—"convenience" foods. A can of vegetable soup is a convenient food, since various vegetables have been cut, blended, supplemented with spices, and so on. It just requires warming up before use. There is a great demand nowadays for "instant," "heat and serve," and "ready-to-cook" convenient foods. These foods make up about 60 per cent of the food that Americans buy. Such foods result in saving considerable amounts of time and effort in food preparation at home, restaurants, etc. The "convenience food revolution" would not have been possible without food additives.

Additives permit the variety of foods that we deem desirable and which certainly are objectively important in maintaining good nutrition. Vitamins and minerals are important, among other things, for good health. Many of these chemical additives can be manufactured so that foods can be "fortified" or "enriched". Potassium iodide, for instance, added to common salt, can eliminate goitre, enriched rice or bread with B-complex vitamins can eliminate pellagra, and adding vitamin D to cow milk prevents rickets.

Many foods, particularly those with high moisture contents, do not keep well. All foods are subject to microbial attack. Fats or oily foods become rancid, particularly when exposed to humid air. The conservation of the quality of foods against agents causing such deterioration of foods requires the addition of preservatives. Additives are also used to colour foods, add flavour, impart firmness, and retard or hasten chemical reaction in food.

There is then the need for the use of food additives to maintain the nutritional quality of food, to enhance stability with resulting reduction in waste, to make food more attractive, and to provide efficient aids in processing, packing and transport. The amount of additives used should be kept to a minimum; it should conform to a standard of purity and be safe. On the other hand, food additives must not be used to disguise faulty processing and handling techniques, to deceive the customers, or if it reduces the food's nutritive value, or when the desired effect can be achieved by good manufacturing practices that are economically feasible.

Over 3,000 different chemical compounds are used as food additives. They are categorized into different groups. A few types of additives are indicated below.

30.3 Antioxidants

An antioxidant is a substance added to fats and fat-containing substances to retard oxidation and thereby prolong their wholesomeness, palatability, and, sometimes, keeping time. An antioxidant should not contribute an objectionable odour, flavour, or colour, to the fat or to the food in which it is present. It should be effective in low concentrations and be fat soluble. Also, it should not have a harmful physiological effect.

Vegetables contain several antioxidants besides vitamins C and E, especially the flavonoids, of which quercetin in onions and apples and epigallocatechin in tea are typical examples. In one study, increasing vegetable intake by at least 400 g per day resulted in a 42% reduction in the risk of coronary heart disease. Flavonoids have become the subject of intensive research in recent years for their strong antioxidant properties. Oxidative reactions are also implicated in the development of diabetes, and Vitamin E has been found to have a preventative role here too.

Antioxidants thus have wide-ranging life-protective properties. Vitamins C and E are the two antioxidants present in living creatures, including ourselves, which fulfill the antioxidant role, and which are also widely used as supplementary additives. These are among the safest chemicals known. A recent survey concluded vitamin C inhibits the formation of carcinogenic nitrosamines, stimulates the immune system, protects against chromosome breakage, and regenerates vitamin E as part of the antioxidant defence system.

Some antioxidants used in foods are butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG), and tertiary butyl hydroquinone (TBHQ), which are all phenolic substances. Thiodipropionic acid and dilauryl thiodipropionate are also used as food antioxidants. The Joint FAO/WHO Expert Committee on Food Additives has recently considered the Acceptable Daily Intakes (ADIs) of BHA and BHT and set them at 0-0.5 mg/kg body weight for BHA and 0-0.3 mg/kg body weight for BHT. Naturally occurring substances that act as antioxidants are tocopherols. The tocopherols act as biological antioxidants in plant and animal tissues, but they are rarely used as additives because they are more expensive than synthetic antioxidants.

Antioxidants function by interrupting the free radical chain mechanism involved in lipid oxidation. They are effective in small concentrations (0.01–0.02 per cent). Mixed antioxidants sometimes act synergistically. The presence of metallic ions, particularly copper and iron, promotes lipid oxidation through a catalytic action. Acidic compounds, like citric acid, complex with iron and thus, when present along with phenolic antioxidants, enhance the latter's activity.

Browning of cut fruits and vegetables is due to enzymic oxidation of phenolic substances. Antioxidants prevent this discolouration. Ascorbic acid is used as an antioxidant in this case. Acids, such as citric and phosphoric, increase the effectiveness of ascorbic acid in preventing browning.

30.4 Chelating Agents

Chelating agents or sequestrants. are compounds that form complexes with metal ions. Many metals exist in food in a naturally chelated form, such as, magnesium in chlorophylls, iron in ferritin and haemoglobin, and copper, zinc and magnesium in enzymes. When metallic ions are released due to hydrolytic or other degradative reactions, they are free to participate in reactions that lead to discolouration, oxidative rancidity, turbidity, and flavour changes in foods. Addition of chelating agents results in the complexing of these metal ions and thereby the stabilization of foods.

Compounds containing two or more functional groups, such as hydroxyl, sulphydryl, carboxyl, phosphate, etc., chelate with metals under favourable conditions. Chelators used in the food industry include sorbic acid, polycarboxylic acids (citric, malic, tartaric, oxalic, and succinic acids), polyphosphates (ATP and pyrophosphates), macromolecules (porphyrins, proteins), and EDTA. Other chelating agents, which are capable of inhibiting polyphenol oxidase, include cyanide, diethyldithiocarbomate, sodium azide and 2-mercaptobenzothiazole, carbon monoxide, mercaptobenzthiazole, dimercaptopropanol, and potassium methyl xanthate. Citric acid and its derivatives, phosphates and salts of ethylene-diamine tetra-acetic acid (EDTA) are the most popular chelating agents used in foods.

Chelating agents are not antioxidants; they serve as scavengers of metals that catalyze oxidation. They, however, are antioxidant synergists. Citric acid and its esters in propylene glycol solution are effective synergists in lipid systems. It is often used in combination with other antibrowning agents such as ascorbic or erythorbic acids and their neutral salts, for the chelation of pro-oxidants and for the inactivation of polyphenol oxidase. Recommended usage levels for citric acid typically vary between 0.1 and 0.3 per cent with the appropriate antioxidant at levels ranging between 100 and 200 ppm. Citric acid exerts its inhibitory effect on polyphenol oxidase by lowering the pH as well as by chelating the copper at the active site of the enzyme.

Polyphosphates and EDTA are used as chelating agents in canned seafoods. Seafoods contain substantial amounts of magnesium ions which sometimes react with ammonium phosphate, with the formation of glossy crystals (struvite). Iron, copper, and zinc containing seafoods react with sulphides that lead to product discolouration. These reactions are prevented by the addition of chelating agents.

EDTA is a chelating agent permitted for use in the food industry as a chemical preservative. Calcium disodium EDTA and disodium EDTA have been approved for use as food additives by the United States Food and Drug Administration.

Polyphosphates, sodium acid pyrophosphate, and metaphosphate, are chelating agents of limited cold water solubility. They have been used as antibrowning agents for fresh-peeled fruits and vegetables at concentrations as low as 0.5 to 2 per cent (final concentration in the dip solution). Sporix™, an acidic polyphosphate mixture (sodium acid pyrophosphate, citric acid, ascorbic acid, and calcium chloride), has been observed to delay the onset of oxidation and enzymatic browning in fruits and vegetables.

Various sulfated polysaccharides, including carrageenans, amylose sulfate, and xylan sulfate, were determined to be effective browning inhibitors in both apple juice and diced apples. Pectin, a naturally occurring anionic polysaccharide at a concentration of 0.5 per cent, gave between 5 and 10 per cent inhibition of apple juice browning. Carboxyl groups present in pectin are believed to be capable of chelating the copper moiety of polyphenol oxidase, thus preventing browning.

Citric and phosphoric acids are used as acidulants in soft drink beverages. These chelate with metals which otherwise promote the oxidation of flavour compounds and catalyze discolouration reactions. Chelating agents also stabilize fermented malt beverages by complexing with copper, which otherwise catalyzes the oxidation of phenolic substances, which subsequently interact with proteins to form haziness or turbidity.

30.5 Colouring Agents

These include colour stabilizers, colour fixatives, colour retention agents, etc. They consist of synthetic colours, synthesized colours that also occur naturally, and other colours from natural sources. Even though colours add nothing to the nutritive value of foods, without certain colours most consumers will not buy or eat some foods. Thus, colours are frequently added to restore the natural ones lost in food processing or to give the preparations the natural colour we expect.

Originally, many colour additives were natural pigments or dyes. For example, spinach juice or grass, marigold flower, and cochineal, were used to obtain green, yellow and red colour, respectively. This gave place to synthetic dyes obtained from coal tar. Synthetic colours generally excel in colouring power, colour uniformity, colour stability, and cost. Further, in many cases, natural colouring materials do not exist for a desired hue. Carbonated beverages, gelatin dessert, candies, and bakery goods, are some foods that are coloured with coal tar dyes. As several coal tar compounds have been shown to be potent carcinogens, the use of coal tar dyes as food additives is restricted. Many countries have severely restricted the number of coal tar dyes for use in foods, while some other countries have completely banned their use. Food colours used also include some inorganic materials, such as iron oxide to give redness, and titanium dioxide to intensify whiteness.

Several natural food colours extracted from seeds, flowers, insects, and foods, are also used as food additives. One of the best known and most widespread red pigment is bixin, derived from the seed coat of *Bixa orellana*, the lipstick pod plant of South American origin. Bixin is not considered to be carcinogenic. The major use of this plant on a world wide basis, however, is for the annatto dye, a yellow to red colouring material extracted from the orange-red pulp of the seeds. Annatto has been used as colouring matter in butter, cheese, margarine and other foods. Another yellow colour, a carotene derived from carrot, is used in margarine. Saffron has both flavouring and colouring properties and has been used for colouring foods. Turmeric is a spice that gives the characteristic colour of curries and some meat products and salad dressings. A natural red colour, cochineal (or carnum) obtained by extraction from the female insect (*Coccus cacti*), grape skin extract, and caramel, the brown colour obtained from burnt sugar, are some natural colours that are used as food additives.

Further information on colours can be found in Chapter 8.

30.6 Curing Agents

These are additives to preserve (cure) meats, give them desirable colour and flavour, discourage growth of micro-organisms, and prevent toxin formation.

Sodium nitrite has been used for centuries as a preservative and colour stabilizer in meat and fish products. The nitrite, when added to meat, gets converted to nitric oxide, which combines with myoglobin to form nitric oxide myoglobin (nitrosyl-myoglobin), which is a heat-stable pigment. The curing also contributes flavour to the meat. In addition, nitrite curing inhibits the growth of *Clostridium* and *Streptococcus* and also lowers the temperature required to kill *C. botulinum*.

It has been discovered that cooking nitrite cured meat products results in the formation of small amounts of N-nitrosamines, which are potent carcinogens. The nitrosamines are formed by the reaction of secondary and tertiary amines, through the following type of reaction.

$$\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!\!>NH + NO_2 \longrightarrow \begin{matrix} CH_3 \\ CH_3 \end{matrix}\!\!>N\text{-}N=O$$

Dimethylamine — N-nitrosodimethylamine

Nitrosation may also take place in foods during storage or processing, and nitrosamines may be ingested as such. There is some evidence that nitrosamines are formed under the strong acid conditions in the human stomach when nitrite cured meats are ingested.

In recent years, use of nitrite for curing has become controversial. Although the levels are low, the production of carcinogens during food manufacture or preparation cannot be ignored. As the derivation of nitrosamines is due to NO_2^- in meat, a reduction in the concentration of the curing agent used helps alleviate the problem. However, the reduction in the concentration of NO_2^- enhances the risk of food poisoning due to *Clostridium botulinum*. Recent results have shown diminished concentrations of nitrite can be used in the presence of another preservative that acts synergistically. In the presence of isoascorbate, even very dilute concentrations of nitrite significantly decrease spoilage and toxin production.

Other agents used for curing meat are ascorbates and several phosphates. Ascorbate and isoascorbate react with nitrite to give nitric oxide and thereby accelerate the rate of formation of nitrosylmyoglobin. They also stabilize colour and flavour. They inhibit the formation of nitrosamines. Through chelating iron, they may contribute also to the anti-microbial stability of cured meats.

Polyphosphates, such as sodium tripolyphosphate ($Na_5P_3O_{10}$) and sodium hexametaphosphate $(NaPO_3)_n$, where; n = 10 to 15, are used in meat curing. These compounds, through enhancing water retention, aid tenderness, juiciness and flavour of cured meats. They also influence texture and, by chelating metal ions, act as antioxidants. The latter property also contributes to the anti-microbial properties of cured meats.

30.7 Emulsions

Emulsifiers are a group of substances used to obtain a stable mixture of liquids that otherwise would not mix or would separate quickly. They also stabilize gas-in-liquid and gas-in-solid mixtures. They are widely used in dairy and confectionery products to disperse tiny globules of an oil or fatty liquid in water. Emulsifying agents are also added to margarine, salad dressings, and shortenings. Peanut butter contains up to 10 per cent emulsifiers.

One of the most widely used emulsifiers is lecithin which is found in milk, egg, and soyabean. Lecithin keeps, in milk, the butterfat and water phases more or less uniform. Commercial vegetable lecithin is obtained principally from soyabean. Lecithin is employed in the preparation of cocoa butter and chocolate candy. The texture and keeping qualities of bread and other fermented baking products are improved by the use of lecithin. Lecithin is a more effective emulsifying agent in combination with monoglyceryl stearate and ascorbic acid. Several mono and diglycerides and their derivatives are good emulsifying agents. In these cases, the ester groups make the molecule fat-soluble, while the alcohol group lends water solubility to another portion of the molecule. As a result, the molecule can serve as a bridge to keep fat molecules suspended in water.

In addition to these natural emulsifiers, there are many synthetic ones. These include calcium stearoyl lactylate, diglycerides, dioctyl sodium sulfosuccinate, hydroxypropyl cellulose, lecithin, monoglycerides, polysorbate 60, 65, and 80, propylene glycol, sodium hexametaphosphate, sodium lauryl sulfate, sodium stearoyl lactylate, and sorbitan monostearate.

For more information on emulsions, and their formation, properties and stability see Subsection 11.4.3.

30.8 Flavours and Flavour Enhancers

Flavouring additives are the ingredients, both naturally occurring and added, which give the characteristic flavour to almost all the foods in our diet. Flavour enhancers are not flavours themselves but they amplify the flavours of other substances through a synergistic effect. Flavour and flavour enhancers constitute the largest class of food additives. These are about 2,100 approved natural and synthetic flavours, of which more than 1,600 are synthetic ones.

Natural flavour substances, such as spices, herbs, roots, essences, and essential oils, have been used in the past as flavour additives. The flavours of such materials are not uniform. They vary with the season and area of production. In addition, natural flavours are in short supply and the amount of flavour substances in them is very tiny. It would take about a tonne of many spices to produce 1 g of the flavour substances, and in some cases only 0.1 g can be extracted. Natural food flavours are thus being replaced by synthetic flavour materials.

The agents responsible for flavour are esters, aldehydes, ketones, alcohols, and ethers. These substances are easily synthesized and can be easily substituted for natural ones. Typical of the synthetic flavour additives are amyl acetate for banana, methyl anthranilate for grapes, ethyl butyrate for pineapple, etc. Generally, most synthetic flavours are mixtures of several different substances. For example, one imitation cherry flavour contains fifteen different esters, alcohols, and aldehydes.

One of the best known, most widely used and somewhat controversial flavour enhancers is monosodium glutamate (MSG), the sodium salt of the naturally occurring amino acid glutamic acid (see also Section 9.13). This is added to over 10,000 different processed foods. This has been in use in Chinese and Japanese cooking for centuries, and was extracted from seaweeds and soyabean. About 65 years ago, a Japanese named Ikeda discovered that the flavouring from these is MSG and that it has an attractive meat-like flavour. MSG is now manufactured on a large scale all over the world, and especially in Japan.

MSG is generally recognized as safe. However, it was reported some time back that MSG injected to young mice resulted in brain damage. Also, some individuals experience symptoms often comparable to those of heart attack, when served with food containing large amounts of MSG. The matter has now been thoroughly investigated, and it has been concluded that there is no risk in its use. However, MSG which was being added to baby foods is now discontinued, as its benefits to babies are dubious.

Yeast extract has the same flavour enhancing property as MSG. It is found that, in this case, the flavour enhancing substances are the ribonucleotides. These are ten times more powerful than MSG.

30.9 Flour Improvers

These are bleaching and maturing agents; usually, they both bleach and "mature" the flour. These are important in the flour milling and bread-baking industries. Freshly milled flour has a yellowish tint and yields a weak dough that produces poor bread. Both the colour and baking properties improve by storing the flour for several months before making bread.

During storage, atmospheric oxygen oxidizes the carotenoid pigments responsible for the colour of the flour, converting them to colourless compounds. They also oxidize some of the proteins which form dough to give the latter increased strength and elasticity. These improvements can be obtained more rapidly with the use of chemical agents.

Chemical agents used as flour improvers are oxidizing agents, which may participate in bleaching only, in both bleaching and dough improvement, or dough improvement only. The agent that is used only for flour bleaching is benzoyl peroxide ($C_6H_5CO_2O_2$). This does not influence the quality of the dough. Materials used both for bleaching and improving are chlorine gas, (Cl_2); chlorine dioxide, (ClO_2); nitrosyl chloride, ($NOCl$); and nitrogen di- and tetroxides, (NO_2 and N_2O_4). Oxidizing agents used only for dough improvement are potassium bromate, ($KBrO_3$); potassium iodate, (KIO_3); calcium iodate, [$Ca(IO_3)_2$]; and calcium peroxide, (CaO_2).

Benzoyl peroxide oxidation takes several hours. The gaseous agents used for bleaching and improvement act immediately upon contact with flour. Oxidizing agents used for dough improvement only remain inactive until yeast fermentation lowers the pH of the dough sufficiently to activate them. As a result of late action, they cause increase in loaf volume, improved loaf symmetry, and improved crumb and texture characteristics. The dough improving oxidizing agents oxidize sulphydryl groups (-SH) in the proteins of gluten to yield an increased number of intermolecular disulphide bonds (-S-S-), resulting in a tougher, drier, more extensible dough that gives rise to improved characteristics in finished products.

30.10 Humectants and Anticaking Agents

Humectants are moisture retention agents. Their functions in foods include control of viscosity and texture, bulking, retention of moisture, reduction of water activity, control of crystallization, and improvement or retention of softness. They also help improve the rehydration of dehydrated food and solubilization of flavour compounds.

Polyhydroxy alcohols are water soluble, hygroscopic materials that exhibit moderate viscosities at high concentrations in water and are used as humectants in foods. Some of them are propylene glycol ($CH_3 \cdot CHOH \cdot CH_2\ OH$), glycerol, and sorbitol and mannitol [$CH_2OH\ (CHOH)_4\ CH_2OH$]. Polyhydric alcohols are sugar derivatives and most of them, except propylene glycol, occur naturally.

Anticaking agents help prevent particles from adhering to each other and turning into a solid chunk during damp weather. They help free flowing of salts and other powders. These materials function by readily absorbing excess moisture, by coating particles to impart a degree of water repellency, and/or by imparting an insoluble particulate diluent to the mixture. Calcium silicate ($Ca\ SiO_3$, $X\ H_2O$) can absorb liquids in amounts two and a half times its weight and remain free flowing. In addition to absorbing water, some anticaking agents effectively absorb oils and other non-polar organic compounds.

Calcium silicate is used to prevent caking in baking powder, table salt, and other foods and food ingredients. Because it can absorb oils, calcium silicate is a useful anticaking agent in complex powdered mixes and certain spices, which contain free essential oils. Calcium and magnesium salts of long-chain fatty acids (e.g., calcium stearate) are used as conditioning agents for dehydrated vegetable products, salt, and other food ingredients in powdered form. Other anticaking agents used in food industry are sodium silicoaluminate, tricalcium phosphate magnesium silicate, and magnesium carbonate.

30.11 Leavening Agents

Leavening agents produce light fluffy baked goods. Originally, yeast was used almost exclusively to leaven baked products. It is still an important leavening agent in bread making. When yeast is used, ammonium salts are added to dough to provide a ready source of nitrogen for yeast growth. Phosphate salts (sodium phosphate, calcium phosphate) are added to aid in control of pH.

To make light cakes, biscuits, waffles, muffins, and many other baked products, chemical leavening agents are used. Baking powders generate carbon dioxide for leavening purposes. For a further account of leavening agents *see* Chapter 16.

30.12 Nutrient Supplements

Nutrient supplements restore values lost in processing or storage, or ensure higher nutritional value than what nature may have provided. When foods are processed, there may be loss of some nutrients and additives may be added to restore the original value. For example, to produce white flour, wheat is milled in such a way as to remove the brown coloured part of the grain, which is rich in vitamins and minerals. To restore the nutritive value, thiamine, nicotinic acid, iron and calcium, are added to the flour. Similarly, vitamin C is added to canned citrus fruits to make up the loss of the vitamin during processing.

When manufactured foods are used as substitutes for natural ones, nutrients are to be added to the former to ensure that their nutritional value is at least equal to the natural product. For example, margarine is used as a substitute for butter on account of its cheapness. To ensure that the nutritional status of those who use margarine does not suffer, addition of vitamins A and D to it, at least equal to that of the natural product, is necessary,

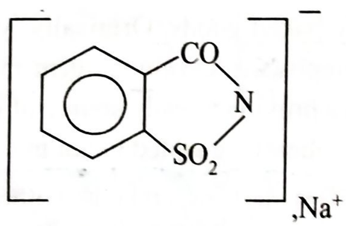
Some foods are to be fortified by adding specified nutrients in excess of what nature provides. Milk, for instance, which is a nutritious food is low in vitamin D content. Addition of this vitamin to milk has helped some countries to reduce the incidence of rickets. Similarly, cereals, baby foods, and fruit juices, are fortified with vitamins to improve the nutritional benefits. Some proteins of foods are deficient in essential amino acids and such foods are fortified with lysine and methionine. Similarly, foods are fortified with essential fatty acids, if they are deficient in them.

Iodine deficiency causes goitre. Seafoods are a source of iodine and where these do not form part of the diet, goitre may be endemic. Iodine in the form of potassium iodide added to common salt in a controlled amount (iodized salt) is a safeguard against this disease. Similarly, fluorine in small quantities in food and water is required for normal tooth development. When there is this deficiency, controlled addition of fluoride to drinking water ensures effective protection against dental decay.

30.13 Non-nutritive Sweeteners

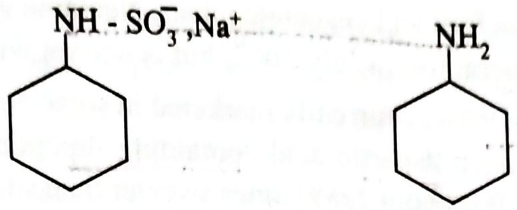
In many ways, sucrose is an ideal sweetener; it is colourless, soluble in water, and has a "pure" taste, not mixed with overtones of bitterness or saltiness. But it is rich in calories. Diabetics and overweights, who must restrict their intake of sugar, must have an alternative to sucrose. Thus, synthetic non-nutritive sweeteners, having less than two per cent of the calorific value of sucrose, for an equivalent unit of sweetening capacity came into use.

The first synthetic sweetening agent used was saccharin (sodium ortho benzene sulphonamide or the calcium salt), which is about 300 times sweeter than sucrose in concentrations up to the equivalent of a 10 per cent sucrose solution.



Sodium saccharin

Use of saccharin often leaves a bitter and unpleasant after-taste. Attempts to find better substitutes resulted in the accidental discovery of cyclamates (sodium and calcium salts of cyclamic acid—cyclohexane sulphamate), which are about 30 times sweeter than sucrose but have little of the after-taste of saccharin. So, cyclamates were widely used as sweetening agents in the manufacture of soft drinks, other low-calorie liquid foods, and dietetic forms of foods. However, the use of cyclamates has been banned after high dosages were found to produce bladder cancer in rats, probably from the formation of cyclohexylamine, a known carcinogen.



Sodium cyclamate Cyclohexylamine

Newer non-nutritive sweetening agents, ranging in sweetness from 10 to 3,000 times of sucrose have been discovered. Among them is glycyrrhizic acid, obtained from the roots of a European leguminous plant *Glycyrrhiza glabra* (licorice). The sweet taste of glycyrrhizic acid is detectable at one-fiftieth the threshold taste level of sucrose. It is used in tobacco products, confectioneries and beverages.

Acesulfame K is used in baked goods, chewing gum, gelatin desserts, and soft drinks. It is about 200 times sweeter than sugar. In 1998, the FDA allowed this chemical to be used in soft drinks, thereby greatly increasing consumer exposure. Acesulfame K is not digested, so it contributes no calories to the diet. Some animal studies suggest a possible cancer-promoting effect.

Aspartame is used in "Diet" foods, including soft drinks, drink mixes, gelatin desserts, and low-calorie frozen desserts. Aspartame is produced from two amino acids—aspartic acid and phenylalanine—and is 180 times sweeter than sucrose. Although FDA points to more than 100 scientific experiments that purportedly document the safety of aspartame, many consumers and scientists are not convinced that long-term daily intake of aspartame is completely safe, and are concerned about the growing number of foods that contain this ingredient. Aspartame intake is known to be dangerous for persons with phenylketonuria, a metabolic disorder that results in dangerously high blood levels of phenylalanine. In addition, aspartame is not recommended for use by pregnant or lactating women.

Sucralose is derived from table sugar (sucrose). It closely resembles table sugar in taste, is highly water-soluble, and is exceptionally stable at high temperatures. In 1998, the FDA approved it as a tabletop sweetener and for use in baked goods, beverages, gelatin, and frozen dairy desserts. In 1999, the FDA expanded the approved uses for sucralose, allowing it as a general-purpose sweetener for all foods. Sucralose is not absorbed from the digestive tract, so it adds no calories to consumed food. In addition, sucralose does not increase blood sugar levels.

Cyclamate was synthesized in 1937 at the University of Illinois by a student who accidentally discovered its sweet taste. Cyclamate was initially marketed as tablets that were recommended for use as a tabletop sweetener for people with diabetes and others who had to restrict their intake of sugar. In the United States, FDA banned the sale of cyclamate in 1970 after lab tests indicated that large amounts of cyclamates caused bladder cancer in rats, a disease which rats are particularly susceptible to, also caused by drinking sugar water. The findings of these studies have been challenged and some companies are petitioning to have cyclamates reapproved. Cyclamates are still used as sweeteners in many parts of the world. They are used with official approval in over 55 countries.

Neotame is the latest FDA approved non-nutritive sweetener that is between 8,000 and 13,000 times sweeter than sucrose. It is chemically similar to the popular artificial sweetener aspartame. Neotame is moderately heat stable and extremely potent and is considered to be of no danger to those suffering from phenylketonuria, as it does not metabolize into phenylalanine. The product is rapidly metabolized, completely eliminated, and does not accumulate in the body. Because only very small amounts of neotame are needed to sweeten foods, the amount of methanol derived from neotame is very small relative to that derived from common foods, such as fruit and vegetable juices. Neotame was approved by the Food and Drug Administration (FDA) for general use in July 2002, but is not yet widely used in food products.

Alitame developed in the early 1980s is currently marketed in some countries under the brand name Aclame. Like aspartame, alitame is an aspartic acid-containing dipeptide Alitame has been several distinct advantages over aspartame. It is about 2,000 times sweeter than sucrose, about 10 times sweeter than aspartame, and has no aftertaste, its half-life under hot or acidic conditions is about twice as long as aspartame's, although some other artificial sweeteners, including saccharin and acesulfame potassium, are more stable yet. Unlike aspartame, alitame does not contain phenylalanine, and can therefore be used by people with phenylketonuria. Alitame has approved for use in Mexico, Australia, New Zealand and China. Petition to permit alitame's use in the United States in 1986 by the Food and Drug Administration, but is still pending in 2006.

Dulan is about 250 times sweeter than sugar. It was an important sweetener of the early 20th century and had an advantage over saccharin in that it did not possess a bitter after-taste. Early medical tests marked the substance as safe for human consumption, and it was considered ideal for diabetics. However, an FDA study in 1951 raised many questions about its safety, resulting in its removal from the market in 1954 after animal testing revealed unspecified carcinogenic properties.

Neohesperidin dihydrochalcone sometimes abbreviated to Neohesperidin DC or simply NHDC, is derived from citrus. It is roughly 1,500–1,800 times sweeter than sugar at threshold concentrations; around 340 times sweeter than sugar weight-for-weight, NHDC is stable to elevated temperatures and to acidic or basic conditions, and so can be used in applications that require a long shelf-life. NHDC itself can stay food safe for up to five years when stored in optimal conditions. Generally recognized as a safe "flavour enhancer," it is particularly effective in masking the bitter tastes of other compounds found in citrus, including limonin and naringin. In food it is used as a flavour enhancer in concentrations of around 4–5 parts per million (ppm), and as an artificial sweetener at around 15–20 ppm. Research has shown that at strengths of around and above 20 ppm, NHDC can produce side-effects such as nausea and migraine.

5-Nitro-2-propoxyaniline, also known as P-4000 and Ultrasuss, is one of the strongest sweet-tasting substances known, about 4,000 times the intensity of sucrose. It is an orange solid that is only slightly soluble in water. It is stable in boiling water and dilute acids. Because of its possible toxicity, it is banned in the United States, although it is used in some European countries as an artificial sweetener.

The tropical African fruits, kutemfe and serendipity berry contain low-calorie sweeteners. Kutemfe contains two proteins, thaumatin I and II. On a molar basis, these substances are about 10^5 times as sweet as sucrose. The protein substance, monellin, obtained from serendipity berries, is as sweet as the sweeteners from kutemfe. But these substances are unstable to heat and lose their sweetness at pH, room temperature.

30.14 pH Control Agents

These include acids, alkalis and buffers. They not only control the pH of foods but also affect a number of food properties such as flavour, texture, cooking qualities, etc. For an account of the use of these agents in foods, see Subsections 11.2.1 and 11.2.3.

30.15 Preservatives

A preservative is defined as any substance which is capable of inhibiting, retarding, or arresting, growth of micro-organisms, of any deterioration of food due to micro-organisms, or of masking evidence of any such deterioration. It is estimated that nearly 1/5 of the world's food is lost by microbial spoilage. Chemical preservatives interfere with the cell membrane of micro-organisms, their enzymes, or their genetic mechanisms. The compounds used as preservatives include natural preservatives, such as sugar, salt, acids, etc., as well as synthetic preservatives. Chemical preservatives are generally added after the foods are processed. The role of some preservatives is considered in this section.

30.15.1 Sodium Chloride

This has been used as a food preservative from early times. Salt stops the growth of micro-organisms and interferes with the action of proteolytic enzymes. Salt also causes food dehydration by drawing out water from the tissue cells. Salt is employed to control microbial population in foods, such as butter, cheese, cabbage, olives, cucumbers, meats, fish and bread. The amount of salt added determines the extent of protection afforded to the food. The term "brine" is used to denote the percentage of NaCl in the water phase of a food. In the preservative action of NaCl, there is synergistic action with other intrinsic factors such as pH, or extrinsic factors such as temperature, partial pressure of oxygen, etc.

30.15.2 Sugar

Sugar aids in the preservation of products in which it is used. The high osmotic pressure of sugar creates conditions that are unfavourable for the growth and reproduction of most species of bacteria, yeasts and moulds. The preservative action of moderate strength of sugars can be improved if invertase is used to increase the concentration of glucose relative to sucrose. Foods in which sugars aid preservation include syrups and confectionery products, fondant fillings in chocolate, honey, jams, jellies, marmalades, conserves, and fruits such as dates, sultanas and currants.

30.15.3 Sulphur Dioxide

Sulphur dioxide has been used in foods for long as a general preservative. It is used in the treatment of fruits and vegetables before and after dehydration to extend the storage life of fresh grapes, prevent the growth of undesirable micro-organisms during wine making, and in the manufacture of fruit juices. Sulphur dioxide is also the most useful agent for the prevention of browning reactions in dried fruits. Most cut fruits are treated with sulphur dioxide to prevent enzymic browning.

Forms in which sulphur dioxide is employed as a preservative include the gas (SO_2), the sodium or potassium bisulphites ($NaHSO_3$, or $KHSO_3$), sulphites (Na_2SO_3 or K_2SO_3,), and metabisulphite ($Na_2S_2O_5$ or K_2,S_2O_5). In aqueous solutions, sulphur dioxide and the sulphite salts form sulphurous acid (H_2SO_3) and ions of bisulphite (HSO_3^-) and sulphite (SO_3^{2-}). At low pH values (lower than 4.5), the undissociated sulphurous acid predominates and inhibits the growth of yeasts and moulds. At high values, the ion is effective against bacteria but not against yeast. The sulphurous acid anti-microbial activity may be due to the reaction of bisulphite with acetaldehyde in the cell, the reduction of essential disulphide linkages in enzymes, and the formation of bisulphite addition compounds that interfere with respiration.

One of the defects of use of sulphur dioxide is it leaves an unmistakable taste in the mouth. It also causes the breakdown of vitamin B-1, so that foods containing sulphur dioxide may not be good sources of this vitamin.

30.15.4 Nitrate and Nitrite

The role of these compounds as anti-microbial agents has already been discussed in Section 30.6.