SWEETENERS

Contents

Intensive

A Bassoli and L Merlini, Università di Milano, Milan, Italy

Background

The sensation derived from tasting a sweet substance is a pleasant one for most of the contemporary mankind. It is debatable whether this is an innate character or built on the millenary use of honey and sugar as foods. Sugar plays an important role in the human diet, being widely distributed in nature and accounting for a large portion of total nutrient intake, at least in the developed countries. The necessity, or interest, in substituting the whole, or part of, sugar in foods while maintaining the sweet taste, derived first from the requirement of reduction of sucrose in the diet of diabetics, who comprise up to 2% of the world population. Later on, from the attempt to avoid risks connected with obesity or overweight caused by the excessive caloric intake in developed countries, and to prevent dental caries. Sweeteners can be used to produce foods that are sweet yet have no sugar.

A sweetener is a substance that can be added to foods to confer a sweet taste. Sweeteners belong to two main classes: intensive and bulk sweeteners. Intensive sweeteners are substances so sweet that minute amounts can substitute substantial amounts of sucrose, with a greatly reduced caloric intake. However, this change can create difficulties in the preparation of traditional sweet foods, such as cakes or confectionery, in which sugar, often used in large amounts, confers very important properties besides sweetness, such as structure and absorbance of water. This problem can be solved using so-called bulk sweeteners, which have a chemical structure, sweetening power, and mechanical and physical properties very similar to those of sucrose.

From a nutritional point of view, sweeteners are often classified as caloric, low-caloric, and noncaloric. However, there are no great differences in the amount of calories produced by the complete consumption of similar amounts of different sweeteners. Low-caloric sweeteners owe their definition to the fact that they are not absorbed as much as sugar, and therefore, while their sweetening potency is maintained, only a part of their caloric value is utilized by the consumer. Similarly, noncaloric sweeteners are so called because they are so much sweeter than sugar, that only a minute amount is required to impart the sweetness required, and the energy produced is negligible. It should be noted that these definitions are not strict and are used randomly by different authors.

Intensive Sweeteners

The first sweetener to be used was saccharin (q.v.), the production of which began in 1884, and in the first half of the last century, production was directed almost exclusively to diabetics. In the 1950s, the demand for sweeteners, mostly for soft drinks, led to the discovery of other sweet compounds, first of all cyclamates (q.v.). These were used mainly in nonalcoholic drinks, and in the USA, in 1968, production rose to 9500 tonnes corresponding to about 300 000 tonnes of sugar. In the meantime, concern about the possible dangerous consequences of the systematic use of food additives became increasingly widespread, with calls for more accurate toxicological tests. Indeed, the results of studies aiming to demonstrate the innocuity of cyclamates were used by the Food and Drug Administration (FDA) to ban cyclamates from soft drinks in the USA in the 1970s. However, the controversy surrounding the interpretation of such studies meant that their use has continued, with repeated applications to reapprove the use of cyclamates, and they are still being used in many other countries, albeit with restricted daily intake doses.

In the last two decades, the market has called for new sugar substitutes with sensorial properties as similar as possible to those of sugar, and with unquestionable safety. At present, the introduction of a new sweetener on to the market is regulated by laws or directives of the authorities (FDA, European Community), who require, among other data, a dossier with acute and long-term toxicity studies. As a consequence of the different regulatory laws or procedures in different countries, it is possible that the use of a sweetener may not be allowed in all countries, or that the procedures to put it into the market are much longer in one country than in others. For those approved for use, regulatory authorities, such as the FDA, Scientific Committee for Food of the European Commission (SCF), or Joint Expert Committee on Food Additives (JECFA) of the FAO/WHO, have established an acceptable daily intake (Table 1).

Design of a New Sweetener

Research on new sweet compounds for use as sugar substitutes has been constantly growing.

According to Hough, a new sweetener:

1. should be at least as sweet as sugar, colorless, odorless, with a pleasant sweet taste, and as similar to sugar as possible;
2. should be soluble in water, and chemically and thermally stable;
3. should have no toxic effect whatsoever, an expected metabolism, or be excreted unmodified;
4. should be easy to produce; if it is a synthetic compound, its purity must be guaranteed; if it is a natural compound, its sources of supply must be guaranteed;
5. should be compatible with production or application technologies; and
6. should be cheaper than those already in use, even if a better taste or other advantages can counterbalance a higher cost.

One of the major problems in the research of new sweet compounds is a lack of information on the mechanism of sweet-taste perception. Experimental evidence from biology, chemistry, physiology, psychology, and neurology supports the hypothesis of the existence of one or more receptor proteins on the taste buds that should mediate the chemoreception mechanism. The first results in cloning candidate genes for sweet taste receptors appeared in 2001, but the molecular details of the entire biological process are still unknown, and so the question of 'how to design a new intensive sweetener' is still open. The rational design of new molecules generally starts from known sweet natural compounds or synthetic sweet molecules. Most of the commercially successful intensive sweeteners (such as aspartame and saccharin) have been discovered by chance and/or designed from a rational and systematic modification of known molecules. In this case, the first step is the identification of those molecular fragments that are important in the receptor–sweetener interaction, the so-called glucophores. This aim is obtained *via* a systematic process of structural modification by synthesis and a critical comparison of the structure–activity relationships of the derivatives obtained. Successful examples of this procedure are sucralose and neotame.

Perceptual Characteristics of Sweeteners

Perceptual characteristics, which include sensory and hedonic, i.e., pleasant aspects of sweeteners, play a major role in food selection and intake. Beyond intensity of sweetness, other characteristics, such as the time–intensity profile, bitterness, other aftertastes (metallic, sour, etc.), fragrance, 'body' (viscosity), and freshness, influence the perception and therefore the acceptability and/or the preference for a sweet material. These characteristics are evaluated by sensory analysis (q.v.), performed by a trained panel of tasters, following established procedures, and with statistical treatment of data. In tasting a sweetener, the form in which it is presented, concentration, temperature, and pH of the solution, are important factors. Important characteristics are those related to mouth feel. A sweetener with a negative heat of solution gives a sensation of cool if tasted as a solid, that is not given by its aqueous solution. A diluted solution of an intensive sweetener has a low 'body,' which, on the contrary, is perceived when tasting a more concentrated (and more viscous) solution of a sugar alcohol, with a sweetness comparable with that of sucrose. The overall description of the taste quality of a sweetener is usually reported as a 'spider web' diagram (Figure 1), representing the mean scores for different attributes as determined by the sensory analysis.

The onset of the sweet taste and the change of its intensity over time, i.e., the temporary profile of a sweetener, is very important in determining the overall quality of the substance. The taste perception is a time-dependent phenomenon related to the time after which the sweetness is perceived (lag time), duration, and speed of the increase and decrease of the stimulus itself. These parameters are described in a time–intensity profile (Figure 2), which is characteristic and different for each sweet substance.

In the example, the time–intensity profile of sucrose and an intensive sweetener are compared. The two substances have similar lag times, and the sweet taste is immediately perceived; but in sucrose, the rate of increase and especially the decrease of the stimulus are higher than in the intensive sweetener. An intensive sweetener usually shows a longer duration of the stimulus, i.e., a prolonged onset of the sweet sensation (or lingering) that can sometimes be an undesirable side-effect. The maximum intensity of the sweet taste (I_{max}) is similar, but the overall effect on the taste of the two substances is quite different. Each sweetener has its own taste profile, which depends also on the presence of other sweeteners, taste modifiers, or flavors in the same mixture.

Table 1 Characteristics of various sweeteners

Sweetener	*RS*[a]	*Limitations*	*Status (updated to spring 2001)*	*ADI*[b] *(mg per kilogram of body weight)*	*Notes*
Acesulfame K	130–200	At high concentrations, may have a slight aftertaste	Approved by SCF[c] and JECFA[d]. Approved in more than 90 countries world-wide	15 (JECFA); 9 (SCF)	Flavor enhancer. Good shelf-life; thermal resistance. Synergistic with other sweeteners
Alitame	2000–3000	On long-term storage, can impart an off-taste	Approved in Australia, Chile, Colombia, Indonesia, New Zealand, Mexico, and the People's Republic of China. Approval is also being sought in the USA, Europe, and other countries	0.1–1	Clean sweet taste. Sweetness profile close to that of sugar. Heat stability; synergistic
Aspartame (q.v.)	200	Limited stability to acidic pH and high temperatures	Approved by SCF[c] and JECFA[d]. Approved by the US FDA	40	Produces phenylalanine during metabolism: consumption limited for people suffering from phenylketonuria. Synergistic, flavor enhancer for citrus and other fruits
Cyclamate (q.v.)	30–50		Approved by SCF[c] and JECFA. A petition for the reapproval of cyclamate is under review by the US FDA	11 (JECFA); 7 (SCF)	Good shelf-life; synergistic; economic
Neotane	7000–13 000	Slow degradation at very low pH	Approved by FDA and ANZA[e]	6	High quality sweetness, flavor enhancer, excellent stability
NHDC	400–600	At high concentrations, exhibits a long-lasting sweetness associated with a menthol- or licorice-like aftertaste	Approved by SCF[c]. Approval for food use in countries outside the European Union has been granted or is being sought	0–5 (SCF)	Obtained from bitter flavonoids in orange peels. Remarkable synergy with acesulfame and aspartame. Flavor enhancer, bitter taste inhibitor
Saccharin (q.v.)	300–500	Metallic aftertaste	Approved by SCF[c] and JECFA[d]. Approved in more than 90 countries world-wide	5 (JECFA, SCF)	The first calorie-free sweetener discovered in 1879
Stevioside	100–150	Licorice aftertaste	*Stevia* extracts are approved for food use in several South American and Asian countries, but lack approval in Europe and North America and at the international level	Not determined	Extracted from the leaves of the *Stevia rebaudiana* plant
Sucralose	600	Sucralose can hydrolyze slowly in solution, under extreme conditions of acidity and temperature	Sucralose is currently approved for use in foodstuffs in more than 35 countries, including the USA and Japan	0–15	High-quality sweetness, good water solubility and excellent stability in a wide range of processed foods and beverages
Thaumatin	2000–3000	Delayed perception of sweetness; perception lasts a long time leaving a licorice-like aftertaste at high usage levels	Approved as a sweetener by SCF[c] and JECFA[d]. Approved as a flavor enhancer in Europe. Classified as generally recognized as safe by the FDA in the USA	Not specified (JECFA)	A mixture of three proteins of molecular weight 22 000, extracted from the fruit of West African plant *Thaumatococcus daniellii*

[a]RS, relative sweetness with respect to sucrose. This value is determined by a sensory analysis of aqueous solutions of sucrose (usually at 3, 5, or 10% by weight) taken as standard references compared with solutions of the sweetener at different known concentrations.
[b]ADI, acceptable daily intake. The ADI is the amount of a food additive, expressed on a body-weight basis, that can be consumed in the diet every day throughout life without any appreciable health risks. It is in fact a safe intake level.
[c]SCF, the Scientific Committee for Food of the European Commission. Reference legislation is contained in the *European Parliament and Council Directive 94/35/EC of 30 June 1994 on sweeteners for use in foodstuffs*.
[d]JECFA, the Joint Expert Committee on Food Additives of the FAO/WHO.
[e]ANZA, Food Standards Australia New Zealand.

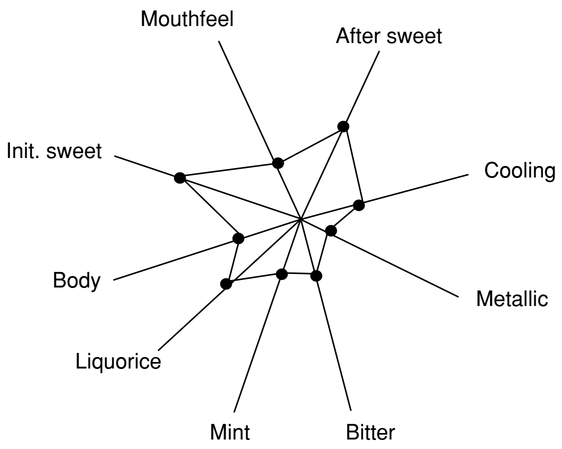

Figure 1 A 'spider web' representation of some perceptual characteristics of an intensive sweetener as determined by the sensory analysis.

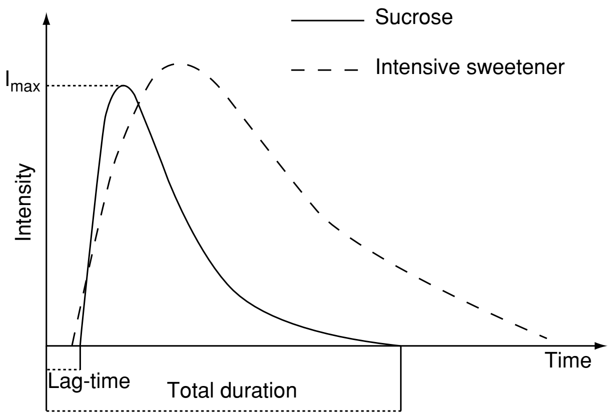

Figure 2 Schematic time–intensity profiles of sucrose and of an intensive sweetener.

Synergy

Many sweeteners show a synergistic effect when used in mixtures, i.e., the taste intensity of the mixture is higher than the sum of the intensities of the single components. This phenomenon is of practical importance, since it offers several advantages. First, the use of mixtures of intensive sweeteners helps in approaching the optimal sucrose taste, which can be mimicked by varying the components' concentrations in order to approach the desired time–intensity profile of the mixture. Sweetener mixtures can also have lower costs, especially if synergy is at play, resulting in a lower daily consumption of the individual additives in food. Manufacturers can overcome the limitations of individual sweeteners by using them in blends; mixtures of saccharin and cyclamate have been used in a number of commercial products.

Table 1 and Figure 3 provide details and structures, respectively, of the intensive sweeteners currently used in many countries.

Acesulfame K

Discovered in 1967 by Hoechst, acesulfame K is structurally related to saccharin. When used in high concentrations above normal use, it may have a slight aftertaste.

Applications Acesulfame K has a good shelf-life and is very stable with normal preparation and processing of foods; it is heat-resistant and therefore suitable for cooking and baking.

Safety Acesulfame K is not metabolized by the body and is excreted by the kidneys unchanged. A large number of safety studies have been conducted, and no adverse effects have been reported.

Status Acesulfame K has been approved for a variety of uses in more than 90 countries. In 1998, the FDA broadened the US approval of acesulfame K to allow its use in nonalcoholic beverages.

Alitame

Discovered by Pfizer Inc., alitame is a high-intensity sweetener formed from the amino acids L-aspartic acid and D-alanine, and an amine derived from thietane. The aspartic acid component is metabolized normally, and alanine amide is not hydrolyzed any further.

Applications Alitame has the potential to be used in almost all areas where sweeteners are presently used. It has an excellent stability at high temperatures, and so it can be used in cooking and baking. During long-term storage, some soft drinks sweetened with alitame can develop an off-taste.

Safety Extensive animal and human studies have supported the safety of alitame.

Status Alitame has been approved for use in a range of foods and beverages in Australia, Chile, Columbia, Indonesia, New Zealand, Mexico, and the People's Republic of China. Approval is also being sought (2000) in the USA, UK, Canada, Brazil, Europe, and other countries.

Aspartame (q.v.)

Aspartame, discovered by Nutrasweet in 1965, is the most commonly used intensive sweetener of the new generation. The compound is made by coupling two

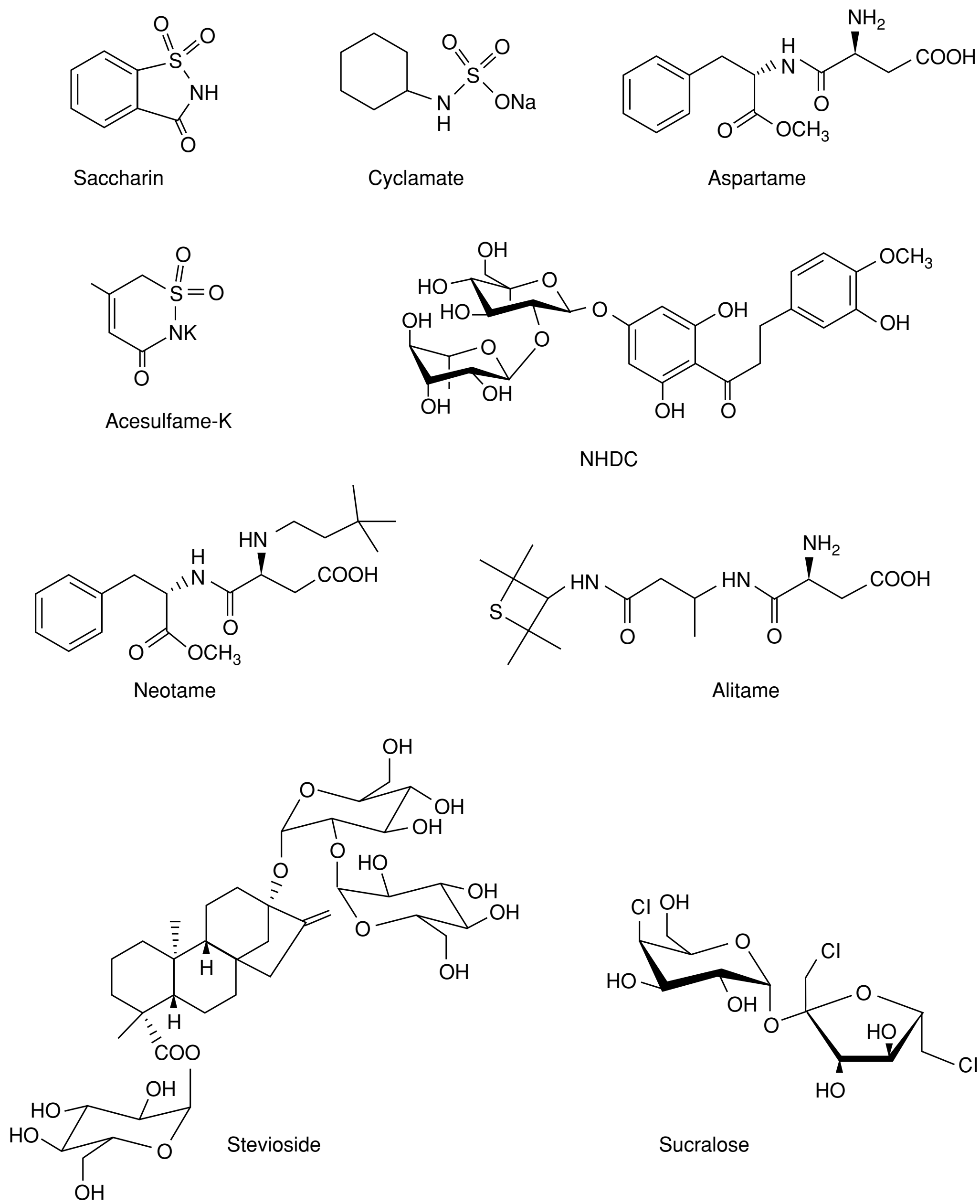

Figure 3 Structure of the most common sweeteners.

essential amino acids, aspartic acid and phenylalanine, found naturally in most protein-containing foods, including meats, dairy products, and vegetables. Upon digestion, aspartame breaks down to phenylalanine, aspartic acid, and a small amount of methanol, this last in levels that are insignificant compared with those of many natural foods. Aspartame enhances and intensifies flavors, particularly citrus and other fruits.

Applications Aspartame is used to sweeten a variety of foods and beverages, and as a table-top sweetener. It is currently used in well-known brands of a great variety of foods and drinks.

Safety Aspartame is one of the most thoroughly tested food ingredients. Aspartame is safe and approved for people with diabetes, pregnant and nursing women, and children.

Status Aspartame has been approved in more than 90 countries and is widely used throughout Eastern and Western Europe, the USA, Canada, South America, Australia, and Japan.

Cyclamate (q.v.)

Cyclamate was discovered in 1937. It is metabolized to a limited extent in the gut by some individuals, shows limited absorption by the body, is excreted unchanged by the kidneys, is stable at high and low temperatures, has a good shelf-life and pleasant taste profile, and is suitable for cooking and baking.

Applications Cyclamate, particularly in combination with one or more other low-calorie sweeteners, has a wide range of applications in foods and beverages.

Safety The SCF confirmed the safety of cyclamate in 1994, as did the Cancer Assessment Committee of the FDA in 1984 and the US National Academy of Sciences in 1985.

Status Cyclamate has been approved in more than 50 countries world-wide. A petition for the reapproval of cyclamate is still (as at July 2001) held in abeyance by the FDA.

Neohesperidinedihydrochalcone (NHDC)

NHDC is a low-calorie sweetener and flavor enhancer that can be produced by hydrogenation of neohesperidine, a flavonoid occurring naturally in bitter oranges. At high concentrations, NHDC exhibits a long-lasting sweetness associated with a menthol- or licorice-like aftertaste. NHDC is not absorbed to any significant extent, but it is metabolized by the intestinal flora, yielding the same or similar breakdown products to its naturally occurring analogs.

Applications NHDC is typically used in combination with other sweeteners, with remarkable synergistic effects. Even at very low concentrations (5 p.p.m.), NHDC can still improve the overall flavor profile and mouth feel of certain foods, acting as a flavor enhancer and modifier rather than as a sweetener. It also has bitterness-reducing properties. NHDC is stable in solid form and in aqueous solutions of pH 1–7. It is heat-stable and therefore can be used in foods requiring pasteurization or UHT processes.

Status NHDC is a permitted sweetener in Europe. Approval for food use outside the European Union has been granted, or is being sought.

Neotame

It is a derivative of a dipeptide, structurally related to aspartame. Its relative sweetness is much higher, being 7000–13 000 times that of sucrose and c.40 times that of aspartame. Neotame has been developed by Monsanto.

Applications Neotame can be used across many food categories, including beverages, dairy products, frozen desserts, baked goods, and gums. It also has flavor-enhancing properties, especially for mint.

Status In July, 2002, FDA approved neotame for use as a general-purpose sweetener. Its use is also permitted in Australia and New Zealand.

Saccharin (q.v.)

Discovered in 1879, saccharin has been used commercially to sweeten foods and beverages since the turn of the twentieth century. It is absorbed slowly, not metabolized, rapidly excreted unchanged by the kidneys, highly stable with a long shelf-life, suitable for cooking and baking, does not promote tooth decay, and is suitable for diabetics.

Applications Saccharin has the widest range of applications and is used in a great variety of foods.

Safety Saccharin has a history of a century of safe human use and is probably the most thoroughly researched of all food additives. Its safety was questioned in a 1977 Canadian study that found bladder tumors in male rats, albeit given unrealistically high doses. All scientific research conducted since then has shown that this effect is only seen in male rats at extremely high doses and has supported the safety of saccharin for human use at the levels currently consumed. Several human studies have shown no overall association between saccharin consumption and cancer incidence.

Status Saccharin has been approved in more than 90 countries. In the USA, the FDA proposed a ban on saccharin in 1977, on the basis of the aforementioned high-dose rat studies. The proposed ban was formally withdrawn in 1991, but saccharin and foods and drinks containing saccharin were still required to carry a warning label. In 2000, legislation gave saccharin a clean bill of health and removed the label.

Stevioside

Stevioside is extracted from the leaves of *Stevia rebaudiana* Bertoni, a plant growing in South America and several Asian countries. Stevioside is a glycoside consisting of the aglycone steviol (ent-13-hydroxykaur-16-en-19-oic acid) and three glucose molecules. The sweetness of stevioside is accompanied by a licorice-like aftertaste.

Applications Leaves of the stevia plant have been used for centuries in Brazil and Paraguay to sweeten foods and beverages. Stevioside can be used in soft drinks, Japanese-style vegetable products, table-top sweeteners, confectionery, fruit products and seafood, and in some countries as stevioside-rich *Stevia* extracts.

Safety and status Stevia extracts have been approved for food use in several South American and Asian countries but lack approval in Europe and North America and on an international level. Safety studies on stevioside and *Stevia rebaudiana* have not been accepted internationally, owing to the lack of generally accepted specifications. In 1999, the SCF reiterated the opinion that "stevioside is not acceptable as a sweetener on the presently available data." The JECFA reviewed stevioside in 1998 but could not quantify an acceptable daily intake (ADI) because of inadequate data on the composition and safety of stevioside. In 2000, the European Commission refused a request for marketing authorization for *Stevia rebaudiana* plants and dried leaves. Stevioside, as a sweetener, is not permitted in the USA and may not be used or marketed in Europe.

Sucralose

Sucralose is the common name for 4,1′,6′-trichlorogalactosucrose, a high-intensity sweetener derived from ordinary sugar, developed jointly by McNeil Specialty Products and Tate & Lyle. Sucralose is not metabolized.

Applications Sucralose has a high-quality sweetness, good water solubility, and excellent stability in a wide range of processed foods and beverages. Like sugar, sucralose hydrolyzes in solution, but only over an extended period of time under extreme conditions of acidity and temperature.

Safety Extensive studies have shown that it is safe for human consumption.

Status Sucralose is currently approved for use in foodstuffs in more than 35 countries.

Thaumatin

Thaumatin is a low-calorie protein sweetener and flavor modifier extracted from Katemfe, the fruit of the West African plant *Thaumatococcus daniellii*, and is totally natural with an intense sweetness. A limitation of thaumatin is its delayed perception of sweetness, but perception lasts a long time, leaving a licorice-like aftertaste at high usage levels. It is metabolized by the body like any other dietary protein.

Applications Thaumatin is stable in freeze-dried form and is soluble in water and aqueous alcohol. It is heat- and pH-stable and synergistic when combined with other low-calorie sweeteners. Thaumatin has a wide range of applications in food and drinks and is particularly effective for its flavoring properties and because it adds mouth feel.

Safety A large number of animal and human studies have been conducted, showing no adverse reactions. Thaumatin is classified as generally recognized as safe by the FDA. The JECFA gave thaumatin an ADI of 'not specified.'

Status Thaumatin is a permitted sweetener and has been approved in all applications in the European Community as a 'flavor preparation.' Similar approval exists in Switzerland, the USA, Canada, Israel, Mexico, Japan, Hong Kong, Korea, Taiwan, Vietnam, Australia, New Zealand, and South Africa, and further approval is being sought elsewhere.

Uses

Food Intensive sweeteners have several practical applications. Their main use is in food, where they are used as additives in several products: table-top sweeteners, carbonated beverages (soft drinks), noncarbonated beverages (e.g., coffee drinks, alcoholic drinks, cider, juices, fruit nectars, shakes, ice tea, instant beverages), dairy products (yogurt, icecream), desserts (puddings, jellies, gelatins, flans), marmalade and jams, chocolate, fruit preserves, fruit spreads, baked goods (confectionery, biscuits, breakfast cereals), chewing gum, pickled vegetables, marinated fish, savories, sauces, and salad dressings.

They are also used in the preparation of dietetic products or functional foods such as vitamin- and mineral-fortified products, sport drinks, and low-fat products.

Pharmaceuticals and dental decay prevention In pharmaceuticals, sweeteners are used as additives in drugs for oral administration, especially to mask the bitter or unpleasant taste of certain active ingredients. They are widely used in the preparation of toothpaste and mouthwash, for improving taste and preventing dental decay. In fact, dental caries is the result of the interaction of sucrose or other carbohydrates with oral bacteria, leading primarily to dental plaque formation and secondarily to tooth decay, as a result of the alterations of dentin caused by acidic fermentation end products and inflammatory processes induced by bacterial toxins.

The potentiality of alternative sweeteners to reduce dental caries has attracted much interest and many studies. All the intensive sweeteners and sugar alcohols (q.v.), such as xylitol, sorbitol, and mannitol, are noncariogenic, since they are not fermented by oral bacteria.

Economics

The world market for sweeteners has tended to increase broadly in line with the world economy. The average growth rate in the 1990s was around 2%. The world consumption of intensive sweeteners reached 12 million tonnes of sugar equivalents in 1997, with a share of the total sweeteners market of *c*. 9%. Asia accounts for 50–55% of the total, with the rest being shared almost equally between the Americas and Europe. More than 70% of the market by quantity (sugar equivalents) is represented by saccharin, aspartame having 18% and cyclamates 5%, whereas if the consumption is measured by value, aspartame accounts for 62%, saccharin 17%, cyclamates 5%, and others 16%. The high share of saccharin is due to its cheapness, making it suitable for use in many applications where only a generic sweetener is required, and for nonfood use, such as pharmaceuticals, animal feed, and toothpaste. Another reason is its stability under a wide variety of conditions, together with a high-quality sweetness. All this explains why it has a high share (90% or more) of the Asian market, whereas aspartame is mostly used in North America, followed by Europe. As for other, recently introduced, intensive sweeteners, the use of acesulfame-K is increasing, especially in blends for soft drinks, whereas the natural compound stevioside is mostly used in Asia.

Bulk Sweeteners

In sweet foods, sucrose provides not only sweetness but also, in many cases, structure, weight, and volume. This 'bulk' effect must be maintained in sugarless products to insure that those properties make the product acceptable to the consumer and to maximize the shelf-life. Moreover, the substitution of sugar must minimize the changes in the technological processes of production. In products where this bulk effect cannot be provided only by water (drinks) or partially by air (e.g., in icecreams), such as confectionery, chocolates, hard and soft candies, jellies, chewing gums, dragées, and jams, the so-called bulk sweeteners can be used. The most important of these are glucose, fructose, lactose, galactose, maltose (q.v.), and sugar alcohols (q.v.), these last obtained by hydrogenation of carbohydrates. They should have a relative sweetness and rheological properties at least as good as that of sugar. (*See* **Sugar Alcohols**.)

See also: **Acesulfame/Acesulphame**; **Aspartame**; **Cyclamates**; **Isomalt**; **Saccharin**; **Sensory Evaluation**: Sensory Characteristics of Human Foods; Taste; **Sucrose**: Properties and Determination; **Sugar**: Refining of Sugarbeet and Sugarcane; **Sugar Alcohols**

Further Reading

Corti A (ed.) (1999) *Low-calorie Sweeteners Present and Future: World Conference on Low-calorie Sweeteners*. Basel: Karger.

Gilbertson TA and Kinnamon SC (1996) Making sense of chemicals. *Chemistry and Biology* 3: 233.

Grenby TH (ed.) (1987) *Development in Sweeteners*, vols. 1–3. London: Elsevier Applied Science.

Grenby TH (ed.) (1989) *Progress in Sweeteners*. London: Elsevier Applied Science.

Guesry PR and Secrétin M (1991) *Sugars and non-nutritive sweeteners*. In: Gracey M, Kretchmer N and Rossi E (eds) *Sugar in Nutrition*. Nestlé Nutrition Workshop Series, vol. 25, pp. 33–53. New York: Raven Press.

Hough L (ed.) (1997) Plenary Lectures from the Jerusalem International Symposium on Sweeteners. *Pure & Applied Chemistry* 69: 655–727.

Laing GD and Jinks A (1996) Flavour perception mechanisms. *Trends in Food Science and Technology* 7: 387–388.

Mathlouthi M, Kanters A and Birch GG (eds) (1993) *Sweet Taste Chemoreception*. London: Elsevier Applied Science.

O'Brien L and Gelardi RC (eds) (1991) *Alternative Sweeteners*. New York: Marcel Dekker.

Schiffman SS (1991) *Receptors and transduction mechanisms for sweet taste: an overview.* In: Gracey M, Kretchmer N and Rossi E (eds) *Sugar in Nutrition*. Nestlé Nutrition Workshop Series, vol. 25, pp. 55–67. New York: Raven Press.

Shallenberger RS (1994) *Taste Chemistry.* London: Blackie & Hall.

Van der Wel H, Van der Heijden A and Peer HG (1997) Sweeteners. *Food Reviews International* 3: 193–268.

Walters DE, Orthoefer FT and DuBois G (eds) (1991) *Sweeteners: Discovery, Molecular Design and Chemoreception*. Washington, DC: American Chemical Society.

Others

M B A Glória, Federal University of Minas Gerais, Belo Horizonte, Minas Gerais, Brazil

Background

Sweetness is one of the most important taste sensations for humans. Sucrose has been widely used for its