Zaslađivači u hrani
(Sweeteners for foodstuffs)

Marijan Katalenić 1, Massimo Giangaspero 2
1 Croatian Institute of Public Health, Zagreb
2 Faculty of Veterinary Medicine, University of Milan, Italy

The sweetening properties of the substances like saccharin, aspartame, acesulfame K and cyclamate are using to replace saccharose (white sugar), for the productions of energy-reduced food, non cariogenic foodstuffs or food without added sugars and for the production of other dietetic products. Intense sweeteners are present in few well identified categories of foods (sugar free products) but may also be ingested as table top.

According to the most recent scientific and toxicological information, these substances are to be permitted only for certain foodstuffs and under certain conditions of use. Authorizations for the use of a low-calorie sweetener in food and drinks in the EU is given on the recommendation of the European Food Safety Agency (EFSA), and on the basis of a proposal by the European Commission and a joint decision by the European Parliament and the European Council. The role of EFSA is that of a risk assessor and its independence is crucial, to regulators, decision makers, industry and consumers alike. Whereas the prime consideration for any rules on sweeteners and their conditions of use should be the need to protect and inform the consumers. Concerning sweeteners for use in foodstuffs, European Parliament and Council Directive 94/35/EC have been evaluated as well as the European Parliament and Council Directive 2003/115/EC amending European Parliament and Council Directive 94/35/EC.

Quantitative assessment of present and future risk of exceeding the Acceptable Daily Intake (ADI) for intense sweeteners is an important element that has to be obtained through consumer survey. Once a sweetener has been found safe by an independent scientific body it is given an Acceptable Daily Intake (ADI). The ADI is the amount of a food additive that can be consumed in the diet every day throughout life without health risks. It is in fact a safe intake level. The granting of an ADI and the approval of a substance signifies that a product is safe.

According to Joint FAO/WHO Expert Committee on Food Additives (JECFA) "the ADI relates to lifetime use and provides a safety margin large enough for toxicologists not to be particularly concerned about short-term use at exposure levels exceeding the ADI providing the average intake over long periods of time does not exceed it." The ADI is the most important practical tool for legislators in ensuring the appropriate and safe use of food additives. The amounts of food additives permitted in different foods and including beverages are established so that even the average daily intake by high consumers over prolonged periods of time would not exceed the ADI value. Different international scientific bodies such as JECFA and EFSA use the same method of deriving the ADI independently. This guarantees consistency of food safety worldwide. Dietary surveys have shown that intakes of low-calorie sweeteners are generally well below the ADI. Sugar free products may be consumed by high percentage of subjects. Especially teenagers are particular categories of interest due to their specific nutritional habits within European countries.

One of the recent food additive directives of the European Parliament include the general obligation for the Member States to monitor the usage and consumption of sweeteners used in foodstuff. The risk of exceeding the ADI in a population group likely to have an above average consumption of foods that are currently available in a sugar free version (soft drinks, candies and chewing gums) should not be neglected. The intake has to be assessed on the basis of two weeks dietary records. Mean daily intake among consumers is calculated in mg per kg of body weight. Projections, made in EU, suggest that approaching the ADI could be possible only if subjects with high intakes of both soft drinks and table top sugar substituted these items with respectively sugar free beverages and table top sweeteners containing either saccharin or cyclamate. It is a one of the reason to establish system for analyzing risk of exceeding the ADI for intense sweeteners in Croatia.

More in general, identify foods that are sources of individual variability in nutrients will be useful to determine food based dietary guidelines that should take into account the cultural context of the population for which they are developed in order to be attainable. Foods that actually determine the intake of nutrients for which desirable changes have been identified have to be evaluated through inter-individual variability of nutrient intakes which is determined by the variability in the consumption of its food sources among the population. Intake of each food source and the total nutrient intake allow quantification of the percentage of variability explained by each item and takes
into account the possibility of correlations between different food sources. Once a key food is identified, several strategies are available to modify its intake in the population: through changes in the percentage of consumers / in the mean portion size / in the frequency of intake.

The evaluation of food consumption patterns in Croatia will be of interest when comparing with other European countries and aiming to determine appropriate preventive or corrective measures to reach the final objective of a healthy lifestyles.

Table 1 – ADI for intense sweeteners

<table>
<thead>
<tr>
<th>E</th>
<th>Sweetener</th>
<th>ADI mg/kg bw</th>
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<tbody>
<tr>
<td>E95 0</td>
<td>Acesulfame K</td>
<td>0 – 9</td>
</tr>
<tr>
<td>E95 1</td>
<td>Aspartame</td>
<td>0 – 4</td>
</tr>
<tr>
<td>E96 2</td>
<td>Aspartame-acesulfame salt</td>
<td></td>
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</tbody>
</table>

the aspartame and acesulfame moieties in aspartame-acesulfame salt are covered by the acceptable daily intake (ADI) values previously established for aspartame and acesulfame-K (respectively 8 - 40 mg/kg body weight per day for aspartame and 6-9 mg/kg bodyweight per day for acesulfame-K).

| E95 2 | Cyclamate                        | 0 – 7        |
| E95 9 | Neohesperidine DC                | 0-5          |
| E95 4 | Saccharin                        | 0-5          |
| E95 5 | Sucralose                         | 0-15         |
| E95 7 | Thaumatin                         | acceptable no ADI |

Saccharin (E954) was the first low-calorie sweetener used, and has been in use for more than 100 years. It is low in cost, claims 200 times the sweetness of sucrose and is acaloric. Despite a bitter, metallic aftertaste, saccharin tabletop sweeteners remain popular with consumers. Saccharin currently is approved in more than 100 countries, but has been much maligned due to early studies showing bladder tumors in rats. After reviewing more than 30 human studies, the Joint Expert Committee on Food Additives (JECFA) doubled the Acceptable Daily Intake (ADI), stating, “adverse findings observed in male rats fed extremely high doses of sodium saccharin are not relevant to man.”

Cyclamate (E952), a calorie-free sweetener discovered in 1937, is 30 to 50 times sweeter than sucrose. It is metabolized to a limited extent in some individuals, but generally is excreted unchanged. It comes in two forms - sodium cyclamate or calcium cyclamate - both of which exhibit stability to both high and low temperatures and has a pleasant, sweet taste profile. Cyclamate is approved in more than 50 countries worldwide, including the EC.

Aspartame (E951) is approximately 200 times sweeter than sugar, and approved for general use in more than 100 countries, aspartame's main liability is that its stability is affected by moisture, pH and temperature. Its many forms, powder, granular, liquid and aspartame-acesulfame salt, meet most solubility and manufacturing requirements. Noncariogenic and well-tolerated by diabetics, it is widely used in sugar-reduced and sugar-free products as well as calorie-reduced and low-calorie ones. With its clean, sugar-like taste, after it was introduced in 1981 and for most food manufacturers became the gold standard for high-intensity sweeteners.

But, upon ingestion, aspartame breaks down into several constituent chemicals, including the naturally occurring essential amino acid phenylalanine which is a health hazard to the few people born with phenylketonuria, a congenital inability to process phenylalanine. Aspartame products generally include a warning label related to phenylketonuria to help protect these people. It is safer for those with the disease to monitor their diets and to attempt to avoid such products. Phenylketonuria (PKU) is a rare inherited disease that prevents the essential amino acid phenylalanine from being properly metabolized. Because of this, phenylalanine can accumulate in the body and cause health problems including mental retardation. People with PKU are placed on a special diet with a severe restriction of phenylalanine from birth to adolescence or after. Women with PKU must remain on the special diet throughout pregnancy. Since individuals with PKU must
consider aspartame as an additional source of phenylalanine, aspartame-containing foods must state "contains phenylalanine".

Some point to the rapid breakdown of aspartame causing spikes of phenylalanine and aspartic acid which can upset chemical balances and cross the blood-brain barrier, as well as unnatural spikes in levels of methanol in places the body does not normally encounter it (like within metabolic processes) raising concerns as to its safe containment and elimination.

Acesulfame-K (E950) is white, crystalline powder and approximately 200 times sweeter than sugar. It has an intense, sweet taste with early onset, but an off-taste at high levels that is easily overcome by blending with synergistic sweeteners, such as aspartame. It has excellent solubility and stability, and is approved in more than 100 countries. It is noncariogenic and suitable for use by diabetics.

Acesulfame-K alone, a sugar and caloric reduction of 30% can be achieved, but when combined with other high-intensity sweeteners, this can go to 70% to 80%. Recently, focus has shifted to blending high-intensity sweeteners with sugar or other sweeteners, such as high-fructose corn syrup.

Sucralose (E955) is made from cane sugar with three hydrogen-oxygen groups selectively replaced by three chlorine atoms. The molecule becomes 600 times sweeter than sugar, but the body no longer recognizes it as a carbohydrate. It cannot be digested and metabolized, so it yields no calories and is safe for diabetics. Its taste profile is similar to sugar, with no unpleasant aftertaste. After years of study and review, now has approval in more than 50 countries. Highly soluble, sucralose has excellent stability in high temperatures and across all pH ranges, so it works in all types of products and manufacturing conditions, and has a long shelf life. It is available as a clear, colorless, highly soluble liquid concentrate that is approximately 150 times sweeter than sugar; or as a white to off-white, practical odorless, crystalline powder that is approximately 600 times sweeter than sugar. Sucralose has been used in carbonated soft drinks, juices and other still beverages; gelatines, puddings and fillings; sauces, toppings and syrups; processed fruits; chewing gum; powdered mixes; baked goods; dairy products; confectionery; and nutritional products. It can replace all or part of a product’s nutritive sweetener. However, products that rely on sugar for volume require bulking agents.

Neohesperidine dihydrochalcone (E959) is a bitterness suppressor and flavour modifier which also gives a very intense sweet taste. It is 1500-1800 times sweeter than sucrose at threshold concentrations.

The intense sweetener Neohesperidine DC, made from a natural substance, is suitable for use in a wide range of food products, to round and balance their sensory profile. Particularly calorie-reduced products can be made more acceptable. Neohesperidine DC is also suitable for use in pharmaceuticals because of his high stability and flavour modifying properties. Neohesperidine DC has advantages over other sweeteners: “ due to its intense sweetness, only small amounts are required; ” synergy properties with other sweeteners, therefore requirements and costs are reduced; “ flavour modifying properties: reduction of bitterness and aftertastes associated with sweeteners; enhancement of pleasant flavours; ” high sensory stability to thermal processing and storage; can be used in a wide range of products; “ enhances taste and the mouthfeel of calorie- and fat-reduced products.

At high concentrations, neohesperidine DC exhibits a long –lasting sweetness associated with menthol or licorice-like aftertaste. Therefore, it is a reason that neohesperidine DC is typically used in mixture with other low-calorie or bulk sweeteners. Currently, Neohesperidin DC is authorised for human consumption, either as a sweetener or as a flavour modifier, in many areas including all the countries within the European Union, USA, Australia and New Zealand, and several countries in Africa, Asia, Europe and Latin America.

Thaumatin (E957) is a mixture of intensely sweet proteins (thaumatins) extracted with water from the arils of the fruit of the West Africa, perennial plant Thaumatococcus daniellii. The thaumatins have a normal complement of amino acids, except that histidine is not present. The molecular weights of the thaumatins are approximately 22,000. There are no unusual side-chains, atypical peptide linkages, or end-groups. Extensive disulfide cross-linking confers to thaumatin thermal stability, resistance to denaturation, and maintenance of the tertiary structure of the polypeptide chain. The maintenance of tertiary structure is critical to thaumatin’s technical function. Cleavage of just one disulfide bridge results in a loss of sweet taste. Thaumatin functions primarily as a flavour enhancer and as a high-intensity sweetener.

Aspartame and acesulfame K (E962) are approved additives in the EU. The aspartame-acesulfame salt is a real salt which, when added to foods (aqueous food and also in the mouth), dissociates into an anion (negatively charged acesulfame) and a cation (positively charged aspartame). These two ions are the same as those deriving from the two approved sweeteners. The difference is that the potassium cation of acesulfame K has been replaced by aspartame. The two molecules are combined in a fixed one to one ratio. The dissociation of the aspartame-acesulfame salt in an aqueous solution would be chemically expected but it is further confirmed by Nuclear Magnetic Resonance studies in simulated gastric juice. These studies demonstrate the release of the same ions as those deriving from an equimolar mechanical blend of aspartame and acesulfame K. Considering that a) the salt represents an alternative source of aspartame and acesulfame ions to the two
already permitted sources (E951 and E950), b) potential exposure is the same with an equivalent blend of aspartame and acesulfame K, c) the use of this substance raises no additional safety considerations the Committee regards as acceptable the use of aspartame-acesulfame salt as an additive. It should be ensured that consumption of this substance is taken into account when estimating intakes of aspartame and acesulfame K in relation to the ADIs for these substances.

New sweeteners are coming

Neotame is one of new, still coming sweeteners, is derived from a dipeptide composed of phenylalanine and aspartic acid. Its configuration does not allow dipeptidases to break the peptide bond and therefore, yields no calories or phenylalanine during metabolism. This off-white crystalline powder is more readily soluble than aspartame in some food-system solvents. Its stability is similar to aspartame — excellent in dry, finished products, but subject to degradation in the presence of moisture — the rate is pH-, temperature- and time-dependent. It does, nonetheless, overcome some of aspartame’s stability shortcomings in baked goods, fermented products like yogurts, and certain flavoring systems.

At 7,000 to 13,000 times sweeter than sugar, neotame is the most potent sweetener marketed today. Like aspartame, which can enhance certain fruit flavors, neotame functions as a flavor enhancer in some applications and certain flavor systems. Studies have shown that neotame modifies flavors at nonsweetening levels and that it works well to modify the taste of soy. In addition, it works well in combination with other sweeteners. There are a number of product applications for neotame, liquids, chewing gum, where it extends sweetness and flavor. Product developers can capitalize on neotame’s flavor-enhancing and masking properties to reduce ingredient costs and create unique taste profiles.

Trehalose, found naturally in honey, mushrooms, and other foods, is a nonreducing sugar with half of sugar’s sweetness. Commercially produced from cornstarch, using the Hayashibara-patented enzymatic conversion and crystallization method. Its functional classifications include coloring adjunct, flavor enhancer, humectant, nutritive sweetener, stabilizer, thickener and texturizer. Trehalose possesses a number of significant functional attributes. Its mild sweetness has a rapid onset and a slightly longer temporal profile than sucrose. This white crystalline powder produces clear solutions, has chemical, acid and thermal stability, plus exceptionally low hygroscopicity and a high glass-transition temperature. As a nonreducing sugar, it does not react with amino acids or proteins and, therefore, does not exhibit Maillard browning. These characteristics can improve stability of flavors, color and moisture in food products and extend shelf life. It can also protect and preserve food’s cell structure, which can help maintain desired texture during freezing and thawing. Trehalose applications include confectionery; processed foods, such as dried vegetables and fruits; dairy; fruit products; and chewing gum.

A disaccharide with two glucose molecules, trehalose is fully digested and metabolized so it doesn’t offer caloric savings. However, studies have shown it to be less cariogenic than sucrose without the potential for a laxation effect. And emerging studies indicate that consumption of trehalose-sweetened beverages result in a lower insulin response than glucose-sweetened beverages.

Tagatose, a monosaccharide derived from lactose, is present in dairy products and other natural sources in small quantities. Tagatose is an excellent low-calorie, full-bulk sweetener with a taste emulating that of table sugar, obtained patent protection on its use, and developed and patented a process for making tagatose from whey. Tagatose was self-affirmed as GRAS in 2001 and the Joint FAO/WHO Expert Committee on Food Additives (JECFA) has also recommended its use as a food additive. Approval processes in a number of other countries have been initiated. Tagatose, 92% as sweet as sucrose, provides the bulk of other carbohydrate sweeteners. It is highly soluble, about as hygroscopic as sucrose, stable at pHs from 3 to 7, Maillard reactive and caramelizes to fructose at low temperatures. Its melting point is relatively high, but its glass-transition temperature is low. It is synergistic with other sweeteners and can improve texture and mouthfeel in reduced and no sugar formulas. Potential applications for tagatose include confectionery, ready-to-eat cereal, ice cream and baked goods.

Tagatose is a ketohexose in which the fourth carbon array is chiral and a mirror image of that around the fourth carbon atom in fructose. Absorption of tagatose is incomplete, about 80% reaches the colon for fermentation by microflora. Tagatose has been approved for only 1.5 calories per gram, but there is evidence that it is considerably less. In addition to prebiotic properties, research has shown that it does not raise blood glucose or insulin levels and appears to blunt the rise in blood glucose after carbohydrate loading in diabetics.

Stevia (also called sweetleaf, sweet leaf or sugarleaf) is a genus of about 150 species of herbs and shrubs belonging to the Asteraceae (sunflower) family, native to subtropical and tropical South America and Central America (north to Mexico).

As a sweetener, stevia’s sweet taste has a slower onset and longer duration than that of sugar, although some of its extracts may have a bitter or liquorice-like aftertaste at high concentrations.
With its extracts having up to 300 times the sweetness of sugar, stevia has garnered attention with the rise in demand for low-carbohydrate, low-sugar food alternatives. Stevia also has shown promise in medical research for treating such conditions as obesity and high blood pressure. Stevia has negligible effect on blood glucose, therefore it is attractive as a natural sweetener to diabetics and others on carbohydrate-controlled diets. However, health controversies have limited stevia's availability in many countries; for example, the United States banned it in the early 1990s. Stevia is widely used as a sweetener in Japan, and it is now available in the US and Canada as a food supplement, although not as a food additive.

Something about polyols

Another group of nutritive sweeteners are referred to as sugar alcohols, or polyols. The polyols are excluded from the term "sugars" on a food's ingredient legend, and are instead labeled as "sugar alcohols" at about 70% to 75% solids. Sugar alcohols are slowly absorbed, primarily in the small intestine, resulting in a lowered caloric value as well as a lowered glycemic and insulimic response. The polyols include sorbitol, mannitol, xylitol, erythritol, lactitol, isomalt, maltitol and liquid hydrogenated starch hydrolysates (HSH) and maltitol syrups. Polyols are used extensively in the place of sucrose in sugar-free confectionery, chewing gum, baked goods, and dairy products.

HSH and maltitol syrups act as binders and humectants in many nutritional bars, and either maltitol and/or xylitol can be found in the chocolate coatings. Because they can be added to sugar-free products, the polyols are used in products for diabetics, but also have been recognized by athletes and physicians as a way to increase carbohydrate content with less of a caloric effect. Due to its slow absorption, excessive consumption can have laxative effect and often can cause gas and/or bloating. Thus those with extreme anal leakage problems should make sure not to consume sugar alcohols.

Maltitol (E965) is a sugar alcohol (polyol) used as a sugar substitute. It has 90% the sweetness of sugar and nearly identical properties, except for browning. It is used to very easily replace sugar and has less food energy, does not promote tooth decay and has a somewhat lower blood sugar response. Unfortunately, maltitol is well known to cause gastric distress, particularly if consumed in great quantities. Chemically, maltitol is also known as 4-O-α-Glucopyranosyl-D-sorbitol. Maltitol, like other sugar alcohols, does not brown or caramelize. It is not metabolized by oral bacteria, so it does not promote tooth decay. It is somewhat more slowly absorbed than sugar (sucrose) which makes it somewhat more suitable for people with diabetes than white sugar (sucrose). It is very important to be aware that its blood sugar impact is far from negligible and some traditional sugars, such as fructose, actually have a significantly lower impact on blood sugar. Its food energy value is 2.1 calories per gram (8.8 kJ/g); (sugar is 4.0 cal/g (16.7 kJ/g)).

Maltitol is particularly demonized regarding gastric side effects because it is so easy for food producers to use it in vast quantities (due to its amazingly sugar-like properties) so consumers often end up consuming far more than they could most other sugar alcohols. While this is a major problem with maltitol, many sugar alcohols are far more likely to cause gastric distress than maltitol when compared gram-for-gram.

Sorbitol (E420), a monosaccharide with 0.6 times the sweetness of sucrose, functions as a humectant, shelf-life extender and sweetener in sugar-free baked goods; inhibits crystalization and enhances the texture of frozen foods; and reduces caramelisation and stabilizes colour in sausage.

Lactitol (E966), a disaccharide derived from milk sugar, has a relative sweetness of 0.3 to 0.4 times that of sucrose and a low glycemic index (GI). This polyol is closest in functionality to sucrose and can be used to replace sugar and even decrease sweetness in oversweetened products, while maintaining other product attributes. For example, lactitol yields sugar-free and reduced-sugar baked items with good crispness, like cookies, and no-sugar-added ice cream with texture and scooping characteristics comparable to standard products.

Xylitol (E967) is as sweet as sucrose and is typically used in sugar-free confections and gums. It enhances flavor and provides a pleasant cooling effect that improves mint flavor and heightens the freshness of berry profiles. Not only is xylitol noncariogenic, research has shown that it might also exhibit cariostatic qualities.

Polyols that are not as sweet as sucrose are often used with high-intensity sweeteners to adjust sweetness. Some processors would like to take advantage of the health and functional benefits of polyols without using non-nutritive sweeteners.

Isomalt (E953) is an artificial sugar substitute, a type of sugar alcohol, which is primarily used for its sugar-like physical properties. It has only a small impact on blood sugar levels, does not promote tooth decay, and has one half the calories of sugar. Isomalt is typically blended with a high intensity sweetener such as sucralose, so that the mixture has approximately the sweetness of sugar.

Isomalt is an odourless, white, crystalline substance containing about 5% water of crystallisation. Isomalt has a minimal cooling effect (negative heat of solution), unlike many other sugar alcohols,
particularly xylitol and erythritol. Isomalt is unusual as it is a synthetic sugar alcohol that is produced from sugar.

Isomalt is manufactured in a two-stage process in which sugar is first transformed into Isomaltulose, a reducing disaccharide \(6\'-0\,-\text{D-glucopyranosido-D-fructose}\). The Isomaltulose is then hydrogenated, using a Raney metal catalytic converter. The final product – Isomalt – is an equimolar composition \(6\'-0\,-\text{D-glucopyranosido-D-sorbitol} (1,6\,-\text{GPS})\) and \(1\,-0\,-\text{D-glucopyranosido-D-mannitol-dihydrate} (1,1\,-\text{GPM-dihydrate})\).

Isomalt can be used in sugar sculpture and is preferred by some because of it will not crystalize as frequently as sugar.

Conclusion

Sugar and calorie reduction represents a growth opportunity for food including beverage manufacturers. But as everyone in the industry knows, taste trumps nutrition in the long run.

Different low-calorie sweeteners show differences in properties such as perceived sweetness, "mouth feel", duration of sweet taste, aftertaste, solubility and stability at various pH values and temperatures. Not only is a single low-calorie sweetener safe but also combined low-calorie sweeteners are safe. The scientific basis on which food ingredients, including low-calorie sweeteners, are approved includes a thorough understanding of how each ingredient is handled by the body. They have a different metabolic route, meaning that a low-calorie sweetener cannot have an effect on another low-calorie sweetener in the body. This also means there is no combined effect for low-calorie sweeteners.

The reader is therefore left with a choice between accepting the conclusions of internationally recognised scientific and regulatory bodies, or the conspiracy theories of those who seem to believe that it is in the interests of regulators to behave irresponsibly.