REVIEW ON BULK AND INTENSE SWEETINERS: CHEMISTRY AND APPLICATION IN FOOD MANUFACTURE.

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Abstract

The paper discourses the result of a literature review to identify alternative sweeteners and their application in food industries. The paper highlights that sweeteners has continued to attract consumers as sugar replacer in food, beverages and other application as flavor enhancer. It has been proven beneficial in weight loss and diabetes management. Sweeteners are food additives that are used to improve the taste of everyday foods. Natural sweeteners are sweet-tasting compounds with some nutritional value; the major ingredient of natural sweeteners is either mono- or disaccharides. Artificial sweeteners, on the other hand, are compounds that have very little or no nutritional value. This is possible because artificial sweeteners are synthesized compounds that have high-intensities of sweetness, meaning less of the compound is necessary to achieve the same amount of sweetness. Artificial sweeteners are used in products to prevent dental cavities. They do not release energy and provide an option as sugar replacer while sugar alcohols release energy, but are metabolized more slowly in body, allowing blood sugar levels to remain more stable over time. Many products viz; bread, cake pudding, biscuits, assorted drinks, kulfi e.t.c. has been prepared for diabetic's patients using different brand of artificial sweeteners and concluded artificial sweeteners as good option for providing sweet taste with less calories. Homemade cookies were also prepared using xylitol as sugar replacer in beverages and other confectionaries.

Keywords: Sweetners, Food Chemistry, Food, Food industry, Xylitol

Introduction

Sugars are inseparable part of our life as these add sweetness in our food, but it cannot be consumed in large amount as it can be one of the potent reasons of many degenerative diseases. So, artificial sugar is the option which provides us sweetness with less or no calories. Due to potently sweetness, sweeteners have continued to attract consumers as sugar replacer in food, beverages and other applications as flavour enhancer as sited by Kapadiya *et*,al 2019. It has been proven beneficial in weight loss and diabetes management. They are hypoglycaemic, non-mutagenic and non-carcinogenic in nature. The US Food and Drug Administration regulate artificial sweeteners as food additives (Grotz, et al. 2019).

Sweeteners

Sweeteners or sugar alternatives are sugar substitutes that duplicate the effect of sugar in taste with less food energy. Some sugar substitutes are natural and some are synthetic. Those, not natural are called artificial sweeteners. They are also called nonnutritive sweeteners (NNS) and non-caloric sweeteners. Classification of Alternative sweeteners has been presented in figure 1 which shows the following categories:(Monique, et al. 2019).

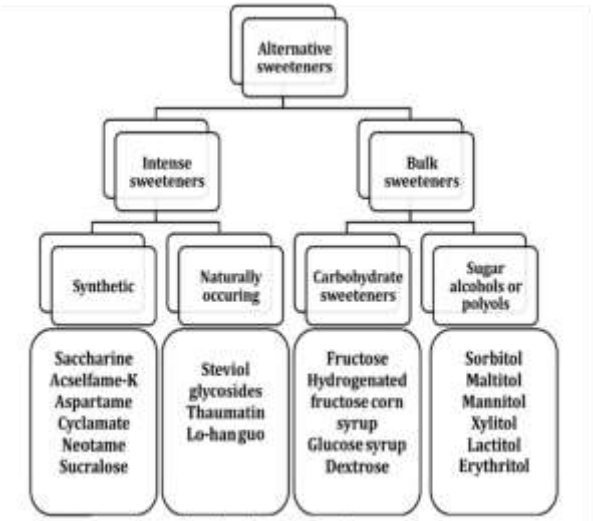

Fig 1: Classification of alternative sweeteners

High potency intense sweeteners-

These are the substances that taste hundreds or thousands times sweeter than sugar and provide no calories. It allows for much smaller quantities to be used. These are called artificial sweeteners, non-nutritive sweeteners or synthetic sugar substitutes because it is derived from either naturally occurring substances, including herbs or sugar itself or manufactured chemically. Saccharine, cyclamate, aspartame, neotame, sucralose, acesulfame K etc. fall in this category.

Natural high potency sweeteners- These are plant-derived substances that have high sweetness potency. They are also non-nutritive in nature. It includes stevia, Lo han, thaumatin, brazzein, monatin etc.

Carbohydrate sweeteners- These are nutritive sweeteners which supply calories in form of carbohydrate but other

nutrients like fructose, hydrogenated fructose corn syrup, dextrose, glucose syrup etc.

Reduced calorie bulk sweeteners- These are the substances that provide sweet taste without calories or with very few calories. Erythritol, maltitol, sorbitol, mannitol, xylitol are some examples of bulk sweeteners.

Why do they all taste sweet: Mechanism

Mechanism depends upon the neuroscience of the sweet taste. The gustatory system recognizes chemical stimuli *viz.* sweetness, sour, salty, bitter and umami which occurs through specialized taste cells, clustered together in small groups called taste buds. Activation of these cells releases neurotransmitters which transmit the taste information to brain and brain further processes taste information. Sweet receptors in mouth function in perception of sweet taste. Sweet taste signaling is mediated by T1R2 and T1R3 receptors.

Acesulfame K- Acesulfame K was accidently discovered in 1967 by Karl Claub and Jensen, who was a chemist in Hoechst AG and working in a lab when he noticed an intensely sweet taste on a piece of paper he had touched. The compound was Acesulfame K. It belongs to the class of dihydro-oxathiazinone dioxides. It is approximately 200 times sweeter than sucrose when used at moderate sweetness levels. Sweetness of Acesulfame K is perceived quickly and without any unpleasant delay like aspartame and sucralose, but Ott et al, (1991) reported that it has slight delayed bitter aftertaste.

Aspartame- It is also an intense nutritive sweetener, which is produced by combining the two amino acids L-phenylalanine and L- aspartic acid by a methyl- ester link. It is discovered by accident in 1965 by a Chemist named James Schlatter. He was working on an anti ulcer drug, when he accidently ingested the substance and noticed the sweet taste. It has a clean sweet taste and 180-200 times sweeter than sucrose. Unlike Acesulfame K, Aspartame can be metabolized by the digestive system. Being produced with amino acids, it provides 4 calories per gram.

Saccharine- Saccharin is the oldest chemical sugar substitute. The discovery of the saccharine was reported in 1879 by Remsen and Fahlberg who discovered it by accident, in the research department of John Hopkins University. They were researching toluene derivatives. One of the scientists, Constantin Fahlberg, accidentally spilled some of the compound on his hands and noticed the intense sweet taste. That compound was named saccharin. It has slight bitter aftertaste. Application of saccharine are in beverage like carbonated soft drinks, toothpaste, medicine. Saccharin is not used for baking because it is unstable when heated. It is commonly sold in pink packets under the brand name "Sweet' N Low".

Cyclamate- Sveda and Audrieth in 1937 discovered that that salts of cyclohexylsulfamic acids are sweet. Again he spilled some of the substance and noticed the sweet taste. It is not as sweet as Saccharin, but it has less of a bitter aftertaste and for some reason mixes well with it. These cyclohexylsulfamic acids were prepared by using chlorosulfonic acid as a sulfamating agent. These cyclohexylsulfamates are commonly referred as cyclamic acid salts or cyclamates.

Sucralose- It is high potency sweetener, made up from sucrose by a process of chemical modification that results in the enhancement of the sweetness intensity, retention of a pleasure sugar like taste and creation of a very stable molecule. He tasted the compound and reported sweet taste of sucralose. It is manufactured by the selective replacement of three hydroxyl groups on the sucrose molecule by three chlorine atoms to produce 1, 6-dichloro-1, 6-dideoxy-beta-D-fructofuranosyl-4-chloro-4-deoxy-alpha-Dgalactopyranoside. It is approximately 750 times sweeter than sucrose. Pure sucralose is white, free flowing powder, intensely sweet, practically odourless and freely soluble in water. It is most commonly sold under brand "Splenda". Tanu Jain and Kiran Grover (2015). The names of these sweeteners vary as their chemical and structural structure varies which shows sucrose having the highest potency and intense as shown below in fig 2. While in contrast to fig 3. Which has low potency and reduced calorie bulk sweetener. The names and chemical structure are having hydroxyl group (OH).

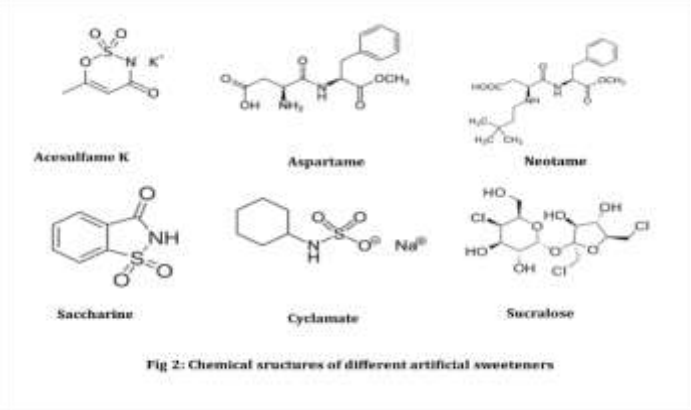

Fig 2: Chemical structures of different artificial sweeteners

Reduced calorie bulk sweetener-

Sorbitol and mannitol- These are the only polyols which is found in nature in appreciable quantity. Sorbitol was discovered in 1872 in the berries of mountain ash. Mannitol was found in marine algae and mushroom. They are produced when reducing sugar reacts with hydrogen. Both are sold in liquid (syrup) and solid (powder) form. Mannitol is a white crysatalline compound and shares same formula as sorbitol. Both can exist in different polymeric forms. For mannitol, most stable form is beta form. Sorbitol reported to have four forms (alpha, beta, gamma, delta). Different forms have different physical properties. Sorbitol is used in foods for diabetics since it does not cause an increase in blood glucose on ingestion. It includes hard candy, tabletting, cooked sausages, baked goods, panning, over the counter products, chocolate etc. (Rewicks,2016)

Erythritol- It is the only non-caloric bulk sweetener, which is found naturally in many fruits and vegetable. It was first isolated from algae protococcus vulgaris in 1852 by Lamy who named the substance Phycit. Later erythritol was also isolated from algae Trentepohlia jolithus. Erythritol is a white anhydrous, non-hygroscopic, crystalline substance, available in powdered or granular form with a mild sweeteners and similar appearance to sucrose. It is 60-70% as sweet as sucrose. Due to small molecular size, it is not metabolized in body. It is excreted unchanged in urine as well as in faeces. It is not fermented like other polyols. and does not give any glycaemic/ insulinaemic response. Since it is produced by fermentation process rather than chemical

reaction at commercial level, it is considered as natural sweetener. Erythritol can be consumed at relatively high level without side effects, since it is well absorbed and not fermented. It is very stable, does not decompose in acid/ alkaline environment. It is heat stable above 180°C. Application includes beverages, chocolates, chewing, candies etc. Tanu Jain and Kiran Grover (2015).

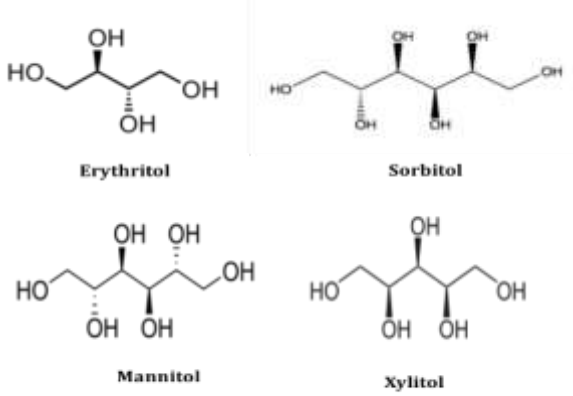

Fig 3: Chemical sructures of different artificial sweeteners

Xylitol **-** Xylitol is a sugar alcohol that has been used as a food additive and sweetening agent since 1960s. It is a natural constituent of many fruit and vegetables. and found in very minute amount (<1%). It is a five carbon polyol (pentitol). It was first discovered and reported in 1891 by Emil Fischer. He named the new compound xylit. Xylitol is the sweetest of all of the polyols being the only to exhibit a sweetest intensity equivalent to that sucrose. Xylitol can be combined with all polyols to produce significant sweetness synergy like high intensity sweetener. As it contains no reducing group, it does not take part in Maillard reaction. Applications that require caramelization or non enzymatic browning, the addition of small quantity of reducing sugars or colour may be required. Tanu Jain and Kiran Grover (2015).

Natural high potency sweeteners- Thaumatin- Thaumatin is a common name for a mixture of potently sweet proteins that can be extracted from West African perennial plant *Thaumatococcus daniellii* (Bennett). This plant produces fruit, arils of which contain the sweet proteins. The "Katemfe" fruit contains mixture of intensely proteins thaumatinI and thaumatinII which have similar amino acid sequence differing only in five residues. It is not a synthetic sweetener and is extracted from source using only aqueous extraction process followed by physical separation processes to remove unwanted material. The resulting product is a light tan coloured powder. The sweetness potency of thaumatin is normally described as being approximately 2000 times the sweetness of sucrose. (Grotz, 2018).

Steviol glycosides- Stevia leaves were used by indigenous peoples in Paraguay and Brazil since before recorded history. In the 1887, M. S. Bertoni, a Botanist was the first European to document stevia and later on in 1931, French chemists extracted stevioside, the main sweet component in the form of an extremely sweet, white crystalline compound. *Stevia rebaudiana* Bertoni is a plant name which is the source of the potently sweet stevioside, rebaudioside A and several other steviol glycosides. It belongs to compositae family. It is a perennial shrub. It is often referred to as "the sweet herb of Paraguay". It is also known as "honey yerba" and "hiney leaf". International The mature plant grows up to 65-centimetres (26 inches) to as tall as 180 cm (72 inches). It is a short day plant. The plant also has medicinal value. It has also been reported that *S. rebaudiana*, as a non-calorie first natural sweetener used in medicinal green teas for treating heart burn and other ailments, even though there are more than 200 species of the genus. (Grotz, 2018).

Metabolism

Acesulfame K is a chemical and in human body, it is absorbed and similarly excreted rapidly and completely unchanged in the urine. Therefore, it is non- caloric. No metabolism is observed in human and other species. Aspartame is broken down to aspartic acid, phenylalanine and methanol. Amino acids are digested, following the same pattern of as they would if generated from food, giving glucose and fumarate from aspartic acid and phenylalanine respectively as end products and utilized in the body in this form. The end product of methanol is formic acid and in this form it is eliminated out of the body. Neotame also contains phenylalanine in its molecule but it does not produce phenylalanine after hydrolysis. It is broken down into de-esterified neotame and methanol in equimolar quantities.

Health benefits- Blood glucose regulation Artificial sweeteners limit the use of sugars. They do not release energy and provide an option as sugar replacer while sugar alcohols release energy, but are metabolized more slowly in body, allowing blood sugar levels to remain more stable over time.

John C de Ruyter (2011) reported the effect of sugar sweetened beverages on body weight of children of 4-11 years. Mixture of sucralose and Acesulfame K in cane beverage is given against sugar for 18 months and found that there was more weight gain and increased body mass index in sugar group than artificial sweetener group. Same result was reported by Reid et al (2002) who saw the effect of artificial sweetener on 20-50years male and females. Other studies supported the above studies, concluding that artificial sweeteners decreased body weight, fat mass, body mass index and waist circumference of different individuals. Foods containing sorbitol and mannitol can be used by diabetics to manage their blood glucose levels since it does not require insulin for metabolism. The GI of both sorbitol and mannitol are very low at about 10 and 0 respectively. It exhibits a very low relative glycemic response (RGR) of 8 to glucose with a value of 100. It also provides fewer calories and a number of additional health related benefits without any reported negative impact on metabolic condition. Effect of chronic consumption of steviol glycosides was seen in diabetics and found that it did not alter glucose homeostasis.

Industrial applications

The definition of flavor enhancer is laid down in point 14 of Annex Iof Regulation (EC) No 1333/2008 on food additives: "[…] flavor enhancers are substances which enhance the existing taste and/or odor of a foodstuff […]" (European Flavour Association, 2015). According to the European Commission's Directorate General for Health and Consumers Guidance notes on the classification of flavoring substances with modifying properties and a flavor enhancer: "Substances that mainly enhance sweetness of food through intensifying the taste of added sugars or sweeteners should

be considered as flavor enhancers. The intended function of the added substance is to enhance sweet flavor, thus leading to the possibility of reducing the amount of added sweet ingredients. The same approach would apply if the substance is added mainly to enhance the saltiness or sourness of food […]" (European Union, 2014)

Many products *viz Besan laddu*, cake pudding, *halwa*, *kulfi* etc has been prepared for diabetics patients using different brand of artificial sweeteners and concluded artificial sweeteners as good option for providing sweet taste with less calories. Homemade cookies were also prepared using xylitol as sugar replacer. In other study stevia powder was used to replace sucrose in preparation of sweet products viz custard, *pinni*, sandesh for diabetics. Some more products, including chenna kheer and sweet bread were also developed using artificial sweeteners.

Table 1. Potency, technological properties and beverage and food applications of synthetic sweeteners.

Sweetener	Potency*	Technological properties	Beverage and food applications
Acesulfame-K	100-200 (1, 3, 8)	Good water solubility; very stable in solid forms, sweetness synergy in blends with improved taste profile; bitter and metallic off-tastes in high concentrations (3); not decomposed with digestion (9).	Carbonated and uncarbonated beverages (3, 5), confectionery, baked goods, fruit-flavored dairy products, delicatessen products and tabletop preparations (6).
Advantame	20,000-40,000 (3, 8)	Very stable in the solid form; pH dependent stability in solution; clean sweetness without off-tastes; slow sweetness onset and sweetness linger (3).	As an artificial flavor (3).
Alitame	2,000 (5, 8, 9)	Very stable to pH and temperature variation (9, 10); non-cariogenic (10) clean, sweet taste with no metallic bitter notes; sweet taste that lingers (9).	Food (*e.g.* baked goods) (5, 8, 9) and beverages (*e.g.* carbonated) (9) and as a sweetener (5).
Aspartame	100-200 (1, 3, 8)	Stable in its crystalline form; clean sweet taste without off-tastes; enhances citrus flavors; unstable in neutral pH and at high temperatures (3, 5, 9); moderate sweetness linger (3, 9); degraded into phenylalanine (3, 7, 10).	Sweetener, blends, carbonated and uncarbonated beverages (3, 5), yogurt, confectionery (2) and pasteurized and sterilized flavored milk (7).
Cyclamate	~30 (1, 3, 8)	Very stable in the solid form (3, 5, 9); weak bitter and salty tastes; no significant off-tastes; fast sweetener onset with no sweetness linger (3), enhances fruity flavors (9).	Sweetener blends, food (*e.g.* baked goods, confectionery) (3) and beverages (3, 5).
Neohesperidin dihydrochalchone	250-2,000 (3, 8, 10)	Very stable in solution and pH variation (3, 4); bitter, cooling and licorice like off-tastes; slow sweetness onset and long lingering taste (3).	Sweeteners blends, artificial flavor (3) and flavor modifier (5).
Neotame	7,000-13,000 (1, 3, 8)	Very stable in the solid form; clean sweetness with no off-tastes; strong sweetness linger (3).	Sweetener, sweetener blends (3), food and beverages (5).
Saccharin	300-500 (1, 3, 8)	Very stable in the solid form and in solution (3); bitter and metallic off-tastes, fast sweetness onset without significant lingering (3, 9).	Sweetener blends, food (*e.g.* cooking) and beverages (3).
Sucralose	~600 (1, 3, 8)	Freely soluble in water; stable in solution; unstable at high temperatures (3, 4, 9); no bitter aftertaste (4, 9); sweetness with a slight delay in onset with moderate linger (3).	Sweetener, blends, food (*e.g.* cooking and baking), beverages (5) and as an artificial flavor (3).

*Potency is expressed as times sweeter than sucrose. (1) Bellisle & Drewnowski (2007); (2) Butchko et al. (2001); (3) DuBois & Prakash (2012); (4) Grenby (1991); (5) Kroger et al.

Recommendation

It has been very helpful in people suffering from diabetics and those at predispose situation to be diabetics. It reduces the tasteless properties of some food to the patient suffering from diabetics. The proper food habits is enhance through the use of sweeteners.

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