



NOVEL SWEETENERS OR SUGAR SUBSTITUTE FOR DENTAL HEALTH: A REVIEW

Dental Science

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ABSTRACT

Nobel sweeteners can be used for caries protection, nutritional values and economic basis. A strong relation exists between diet and oral health across the life span. Dietary behaviour is determined by community, family and individual factors. Excessive sugar consumption is associated with increased risk of caries, cardiovascular disease, Diabetes mellitus, metabolic syndrome, nonalcoholic fatty liver disease and obesity etc. Clinicians and parents should encourage children in early experience with healthy food habits. Novel sweeteners can be used instead of sugar to the children for healthy eating behaviour development. This study aimed to search and collect scientific evidence to use novel sweeteners to live healthy life. It is essential to adopt a scientific attitude towards novel sweeteners to open a new knowledge.

KEYWORDS

Nobel Sweetener, Dental Health, Sugar

INTRODUCTION

Sweeteners can be classified as nutritive/calorie or nonnutritive/non calorie or natural/synthetic acknowledges a difference in the amount of energy provided as well as availability in nature of the sweetener. Sugar substitute can be used for caries protective, nutritional values, toxicological and economic basis. Vipeholm study¹ researched on nonacidogenic sugar substitutes (sweeteners) which do not cause pH falls in dental plaque thus lower the dental caries. The objective of the study was to understanding to choose a novel sugar or sweet danger sugar intake for healthy eating behaviour development which further lead to prevention of dental caries. Excessive added sugar consumption may lead to hurdle such as bingeing, desire to limit, cravings, risky use for future life style. Synthetic sweeteners are considered safe for teeth like Aspartame, saccharin, cyclamate, xylitol, and mannitol used for caries active patients. Starch is digested by salivary amylase to oligosaccharides, which is fermented by oral microflora sugars. The 2015 Dietary Guidelines for Americans² and the World Health Organization³ recommend limiting added sugar to less than 10% of total energy intake.⁴ This review article focussed on some novel sweetener available.

Scenario of Sugar consumption in US and dental caries

In US Sugar beets are responsible for 45% of sugar production (vs. 33% from sugar cane), remaining 22% of US sugar being imported. The price of sugar in US is approximately 50% higher than the world price. In US global sugar prices increased from 2007 to 2012 due to natural disasters, the price of high-fructose corn syrup has also risen due to higher production cost. The decreased sucrose consumption to the decline in caries prevalence is often discussed because, in many European countries, sucrose consumption did not decline but incidence of caries did. As they are using more preventive and therapeutic treatment through insurance. Rugg-Gunn et al⁵ reported an increase in caries of 5 carious tooth surfaces within 2 y in children (initially aged 11–12 y) who consumed >163 g sugar/d, whereas children who consumed less than half this amount (78 g) still developed 3.2 carious tooth surfaces. Szpunar et al⁶ found that each additional 5-g/d intake of sugars was associated with a 1% increase in the probability of developing caries during a 3-y interval.

A clean tooth will not decay,” stated J Leon Williams (1852–1931), first president of the American Dental Association. He suggested that oral hygiene is sufficiently effective to prevent dental caries. Stephan and Miller⁷ provided evidence for this statement and conducted the first pH measurements in dental plaque. Within 3 min after human teeth were rinsed with a sucrose solution, the pH of plaque dropped from 6.5 to 5.0 and remained such for 40 min. When teeth were cleaned, no decrease in pH was registered. It was assumed that simple brushing alone will not prevent dental caries^{8,9}

CLASSIFICATION³⁹

1. Nutritive/Calorie Sweeteners further classified as

1. Poly alcohols/sugar alcohols i.e. Xylitol, Sorbitol
2. Hydrogenated starch hydrolysates i.e. Lycasin, Palatinin
3. Coupling sugars i.e. Sorbose, Palatino

Non-Caloric/Non-nutritive sweetener

1. Cyclamate
2. Saccharin
3. Aspartame
4. Sucralose
5. Neotame

2. Natural sugar substitute Sweetener

1. Xylitol
2. Sorbitol
3. Mannitol
4. Trehalose
5. Stevia
6. Tagatose
7. Starch Hydrolysates
8. Honey
9. Jaggery
10. Glycirrhizine
11. Monellin
12. Thaumatin
13. Mirakulin

Artificial sugar substitute sweetener

1. Acesulfame K
2. Alitame
3. Neotame
4. Aspartame
5. Cyclamate
6. Saccharin
7. Sucralose
8. Neosporidine Dihydrochalone

Acesulfame-K is a white crystalline powder with high intensity sweetener about one twenty times sweeter than sucrose and has high water solubility. It has identical sweetness as aspartame, about half as sweet as sodium saccharin, and four to five times sweeter than sodium cyclamate. It is non toxic, low calorie and recommended daily intake 0 to 15 mg/kg¹⁰. It is metabolized by the human body but not metabolized by bacteria¹¹

Aspartame- It was discovered accidentally in 1965 by G. D. Searle and Co. chemist James Schlatter. It is an artificial, dipeptide, white crystalline, unscented intense sweetener, noncariogenic nearly 180-200 times sweeter than sucrose so maintains a stable blood glucose level. Dental plaque does not utilize aspartame so recommended widely in sugar free medicines¹⁰. It is hydrolyzed in intestinal lumen into aspartic acid, phenylalanine and methanol and absorbed into the blood and get metabolized.¹² It is synergistic to enhance flavour which

is evident in chewing when mixed with other sweeteners including sugar.¹⁰ Headaches, brain tumors, brain lesions, and lymphoma are side effects of Aspartame. High level of the naturally occurring essential amino acid phenylalanine is a health hazard to phenylketonuria (PKU) i.e. a rare inherited disease. So it must be labelled with the statement phenylketonurics: contains phenylalanine. Aspartame causes behavioural problems and during gestation prejudicial to fetal embryo.¹⁹

Cyclamates-It is used as the compounds cyclamic acid, sodium cyclamate, calcium cyclamate and used mostly in 10:1 cyclamate/saccharin mixture. It was synthesized in 1937 and produced commercially in the United States in 1950. It is produced in many countries including Japan, Germany, Spain, Taiwan, and Brazil.¹² Regulatory decisions declined the utilization of cyclamates in the 1960s but utilization has begun to increase again.¹³ It was first promoted as table top sweetener for diabetics.¹⁴ The mouth washes containing cyclamate, xylitol and sucrose sweeteners were evaluated by Paunia K et al. (1984). Less dental plaque was observed in cyclamate and xylitol groups in contrast to sucrose. Cyclamate is absorbed partially from the intestine, and is converted to cyclohexylamine by microorganisms in the large bowel.¹² Bladder cancer and testicular atrophy had been reported by cyclamate.¹⁵

Saccharin-It is commercially available in sodium and calcium salt forms, readily soluble in water. In dilute aqueous solutions they are three hundred times sweeter than a solution containing at same concentration by weight of sucrose. It is largely absorbed from the small intestine and excreted by the kidneys.¹⁶ It is neither metabolized in the gastrointestinal (GI) tract nor influence blood glucose levels¹⁷, so it is viable sugar substitute for diabetes person. The Adequate Dietary Intake (ADI) for saccharin is set at 5 mg/kg body weight per day for adults and children.¹⁸ But bladder cancer occurrence was found among rats devouring saccharin.¹⁹ J. M. Tanzer (1988), did an experiment to study the effect of bicarbonate based dental powder containing fluoride and saccharin on inhibition of dental caries associated with *S. mutans* in rats in contrast with use of topical fluoride and fluoride with de ionized water and outcome of study showed dental powder containing fluoride and saccharin showed maximum decrease in dental caries when contrasted to topical fluoride alone or when utilized with de ionized water.²⁰

Sucralose - It was discovered in 1976 by Tate & Lyle, working with scientists Leslie Hough and Shashikant Phadnis at Queen Elizabeth College. It was first approved for use in Canada (marketed as Splenda) in 1991 and endorsed in Australia, New Zealand, Europe, Mexico, Brazil, China, India and Japan. It is the most common sugar substitute for baking and cooking. It is calorie free and it also contains dextrose and maltodextrin. It is 400-700 times sweeter than sugar. The acceptable daily intake (ADI) for sucralose in US is 5mg/kg body weight/day but USFDA daily intake is 1.6mg/kg. But it can be triggering agent for migraine, weight gain and some hypersensitive reactions.²⁰

Polyols

Tooth-friendly polyols include sorbitol, xylitol, mannitol, erythritol, and isomalt.

Xylitol - It is a five-carbon polyol with sweetness similar to sucrose²¹. It is pleasant and give cooling sensation found in variety of fruits and vegetables. It is usually acquired from birch trees and other plant fibre called xylan. It play important role in prevention of dental caries, stimulate the saliva resulting in increased buffer activity and an increase in pH, and enhanced remineralization so suitable sugar substitute.²¹ and is not a compelling substrate for plaque bacteria. It is approximately fifty percent absorbed in small intestine and fifty to seventy five percent of its fermentation takes place in large bowel²².

Direct metabolism happens in the liver or indirect metabolism by fermentative degradation by intestinal flora²³. ADI mentioned intake by humans is about 100 g per day. It is responsible for growth inhibition of microorganism like *Streptococcus mutans* (cariogenic bacteria). Xylitol is changed over to xylitol-5-phosphate by means of phosphoenolpyruvate resulting in development of intracellular vacuoles and cell membrane degradation. Unwittingly contributing to its own death, then *S. mutans* dephosphorylates xylitol-5-phosphate. The dephosphorylated molecule is expelled from the cell leading to starvation of the bacteria such as *S. mutans*. Xylitol has shown to impact growth of nasopharyngeal bacteria such as *S. pneumonia* and *S.*

mitis, hence has a role to play in nasopharyngeal pneumonia. Daily fluoride brushing plus xylitol consumption was found more beneficial than daily fluoride brushing alone. Xylitol as a sucrose substitute becomes an extremely attractive as no acid is formed from xylitol by the dental plaque in oral cavity. In fact, during and after chewing of a xylitol sweetened gum, the plaque pH increases. In addition pH-mediated effect, xylitol appears to inhibit the growth and metabolism of *S. mutans* indirectly.²⁴ In dental plaque xylitol inhibits the formation of insoluble glucans and lipoteichoic acid, thus plays a crucial role in the adhesion and cohesion of bacteria in dental plaque²⁵. Xylitol intake can cause stomach discomfort and above 40 grams per day, might cause diarrhoea²⁰.

Field studies on xylitol such as, Turku chewing-gum study²⁶, the Ylivieska study²⁷, the Montreal study²⁸, and the Belize study²⁹ have shown that the use of xylitol helps in the prevention of dental caries. Beside studies there is also clinical evidence that xylitol candies are as effective as xylitol gum in caries prevention and is economically feasible to include xylitol in school-based caries control programs³⁰. The Belize study²⁹ is the first clinical trial of xylitol that enables the caries-preventive action of xylitol to be compared with sorbitol, and concluded that xylitol is superior in reducing caries. These findings are valid in randomized studies that account for dietary habits, oral hygiene practice, and socioeconomic status in other populations.

Sorbitol

It is a six-carbon polyol present in the berries of mountain ash, fruits and vegetables. Its sweetness is equivalent to sixty percent of the sweetness of sucrose. It is derived from the catalytic hydrogenation of glucose, sucrose, starch and absorbed and metabolized in the liver.²³ In mouth it is metabolized at a slower rate by all of the *mutans streptococci* including *S. mutans* than sucrose. It is impervious to digestion by oral microbes which break down sugars and starches to release acids leading to cavities or disintegrate tooth enamel thus effective anticariogenic properties. It can be widely used for people with diabetes. It add sweetness, bulk and texture to food, and help food to stay moist. Sorbitol-sweetened gums simulate saliva without causing a drop to the critical pH and have been shown to be equal to xylitol gum in terms of caries control⁴⁸. Higher amounts of sorbitol intake cause abdominal discomfort pain, and mild to severe diarrhoea, irritable bowel syndrome and fructose malabsorption.²³

Natural Sugar Substitutes

Stevia

Stevia rebaudiana Bertoni is a perennial shrub of family Asteraceae, native of Paraguay and Brazil, used as a food supplement in several countries such as Brazil, Japan, United States and European Union. FDA has approved this as novel sweetener. It has two primary glycosides that are stevioside, 110-270 times sweeter than sugar and rebaudioside, 180-400 times sweeter than sugar. Rebaudioside is widely used as having higher commercial value due to nice flavor unlike other artificial sweeteners that have metallic taste.²⁹ Its fresh leaves contain a high water content (eighty to eighty five percent), ascorbic acid, β -carotene, chromium, cobalt, magnesium, iron, potassium, phosphorus, riboflavin, thiamin, tin, zinc, and chemicals products found are apigenin, austroinilina, avicularin, β -sitosterol, caffeic acid, campesterol, caryophyllene, centaureidin, chloro-genic acid, chlorophyll, kaempferol, luteolin, quercetin, stigmaterol. About a quarter of a teaspoon of leaves is equivalent to one sugar tea spoon. It is produced by soaking leaves in warm water at 15:1 v/w for three hours followed by filtering and purified by using calcium hydroxide, the filtrate passes through the ion exchange column to remove unwanted pigments and then concentrate by rotary evaporator at a temperature of 45°C. In the digestive tract, rebaudiosides are metabolised into stevioside and is broken down into glucose and steviol. The glucose is used by bacteria in the colon but is not absorbed into the blood stream. Steviol is not further digested and is excreted.³¹ Das et al. did an in vivo study about rats to examine the cariogenic potential of stevioside and found low potential to development of dental caries³⁰. It has seen that *Streptococcus mutans* have low acidogenic potential when grown on medium that contain Stevioside in comparison with the sucrose, glucose or fructose. The phytochemicals present in Stevia are austroinilina, β -carotene, dulcoside, niacin, oxides rebaudi, riboflavin, steviol, stevioside and thiamine. These nutritious substances contents are tannin, xanthines (theobromine and caffeine) and flavonoids which have anti-plaque activity. Acceptable safety intake of stevioside in humans is 7.94 mg/kg/day.³⁰

Honey/Rebiana truvia

It is a super-saturated, delicious, naturally sweet nectar popular worldwide, collected by bees from a wide variety of plants. It contains sugars as fructose (18.4%), glucose (30.3%), sucrose (1.3%), other carbohydrates (12%), minerals (0.169%), proteins (169 mg/100 g) with a water content of about 17.2%.³² Mouth washes containing propolis (present in bee products) possessed antimicrobial activity against *Streptococcus mutans* and used as an alternative treatment in dental caries prevention, reduction of plaque accumulation and polysaccharide formation.³³ It cause less demineralization of tooth surface when compared to glucose and fructose.

Jaggery

It is a natural ancient sweetener prepared by concentrating the extracted sugarcane juice. It is a unrefined non-centrifugal sugar consumed in Asia, Africa, Latin America and Caribbean³⁴. It is a product of sugarcane, rich in vital minerals like Calcium, Magnesium, Potassium, Phosphorus, Na, Iron, Mn, Zinc, Cu, Cl, Vitamin A, B1, B2, B5, Vitamin B, C, D, E and protein. It form longer chains of sucrose. Hence, it provide energy for a extended time and isn't harmful for the body.³⁵ It is easily digestible, rich in minerals, less Sulphur, and enhances distinctive taste as sweetener.

Trehalose

It (α-Glc(1-4)α-Glc) is found in yeast, fungi (mushrooms) and in small amounts in bread and honey. It is used by the food industry as a replacement for sucrose where less sweet taste is desired but with similar technological properties.³⁶

Polyphenols

Polyphenols such as tannins in cocoa, coffee, tea, and many fruit juices may reduce the cariogenic potential of foods. In vitro experiments have shown that these polyphenolic compounds may interfere with glucosyltransferase activity of *mutans streptococci*, which may reduce plaque formation. In rat experiments, tea polyphenols reduced caries.^{37,38}

Tagatose

It is considered as novel as its chemical structure is low carbohydrates sweetener similar to fructose, occur naturally in dairy product.

Side effects of excessive cariogenic sugar consumption

As "prevention is better than cure", parents and family members play important role in development of healthy taste preference and eating behavior. Sugar substitute or novel sweeteners can be used for prevention of caries as well as also for nutritional, toxicological, economical and present dietary habits point of view of using more sugar. One of the disadvantages of the bulk sweeteners is that they are only partially absorbed in the small intestine which may induce osmotic diarrhea³⁹. For this reason food and drinks containing bulk sweeteners are not recommended for children under 3 years of age in whom they may also cause stomach problems when used in sugar-free medicine if the daily intake is high.

Some investigators claim that excessive sugar consumption is associated with increased risk of caries⁴⁰, obesity⁴¹, cardiovascular disease⁴², Type-2 diabetes mellitus, metabolic syndrome, non alcoholic fatty liver disease. In addition artificial sweeteners cause health hazards like obesity, is the primary risk factor for the development of SDB (sleep-disordered breathing). Inadequate sleep duration and quality in children and adolescents is associated with an increase in body weight and obesity, decreased insulin sensitivity, hyperglycemia, and prevalent cardiometabolic risk and brain tumours, bladder cancer etc. Thus, more research should be done to determine natural foods and components that shield against dental caries as well as facilitate dietary advice effective.

Benefit of novel sweeteners

These are generally safe contribute fewer calorie to food as compare to regular sugar. It can raise blood sugar level but our body does not completely absorb it.

CONCLUSION

The dental caries is a potential risk factor for children growth. To reduce dental caries along with oral hygiene measure frequent rinse mouth with water, chew sugarless gum, which stimulates remineralization of teeth and eat dairy product such as cheese after the consumption of fermentable carbohydrates. Drink, rather than

sip, sweetened and acidic beverages avoid putting an infant or child to bed with a bottle of milk, juice, or other sugar-containing beverage. Novel sweeteners are to be developed for food manufacturers marketing to significantly reduce dental caries in the population at large. Novel approach is needed for novel sweetener to be used for healthy dental health.

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