

# Nutritive and Non-Nutritive Sweeteners: A Review

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## ABSTRACT

The importance of sugar as the principal dietary substrate that drives the caries process has led to growing interest in sugar substitutes. Dynamic relation exists between sugars and oral health. Dental profession shares an interest in the search for safe, palatable sugar substitutes to prevent dental caries and have attempted to persuade their patients to adopt special dietary programs to limit the frequency with which sugar containing foods are ingested. Hence, this paper reviews the role of various nutritive and non-nutritive sweeteners and its role in prevention of dental caries which provides a framework for consumers and health professional in maintaining the intake of sugar.

**KEYWORDS:** Cariogenicity, Dental Caries, Sugars, Sugar Substitutes.

## INTRODUCTION

Dental caries is a infectious disease, in which sugar present in plaque together with cariogenic bacteria can produce the disease under certain environmental conditions.<sup>1</sup> The importance of sugar as dietary substrate that drives the caries process has led to a growing interest in sugar substitutes.<sup>2</sup> These sugar substitutes, also called as polyols, are hydrogenated carbohydrates in which the aldehyde group at one end, has been reduced to a hydroxyl or alcohol group.<sup>3</sup>

These can be broadly classified as high-intensity sweeteners (noncaloric) and bulk sweeteners (caloric). Most of the sugar substitutes are considered as non-cariogenic.<sup>3</sup>

Hence, here an attempt is being made to review the various nutritive and non-nutritive sweeteners and their role in prevention of dental caries which provides a framework for consumers and health professional to use in maintaining the intake of sugar.

## SUGAR AND SUGAR CONTAINING SUBSTANCES

The etymo-logy of the word “sugar” has been traced to the Chinese term *shache*, literally, “sand sugar plant”, then to Sanskrit, *Rarkara*, meaning sand or gravel, and more directly from Arabic, *sukkar*. Various forms of sugar and sugar containing substances are described in Table -1.

Sucrose is found in all green plants, where it is an early product of photosynthesis and is the main agent for translocating carbon to the rest of the plant. Sugar cane

and sugar beet are major industrial sources of sugar.<sup>4</sup> Sucrose is a non-reducing disaccharide and can be readily hydrolyzed. The resulting mixture of glucose and fructose has negative optical rotation and is known as “invert sugar”, which is slightly sweeter than sucrose. Sucrose is fermentable and are major concern for the cause of dental caries but resists bacterial decomposition when in high concentration.<sup>4</sup>

Sugar and Sugar Containing substances
Sucrose, Glucose, Glucose syrup, Fructose, Sorbose, Lactose, Maltose, Dextrose, Honey, Corn syrup, Invert sugar syrup, Molasses, Treacle, Galactose Agave nector

Table -1

## SUGAR SUBSTITUTES

The major health benefits of sucrose substitutes in foods and drinks are their contribution to controlling body weight, diabetes and in promoting oral health.<sup>4</sup> Table – 2 describes various forms of sugar substitutes.

Various forms of Sugar Substitutes <sup>4,5,6</sup>	
A. Nutritive Sweeteners	B. Non-Nutritive Sweeteners
I. <b>Monosaccharide Polyols</b>	a. Saccharin
a. Sorbitol	b. Acesulfame – K
b. Xylitol	c. Aspartame
c. Mannitol	d. Thaumatin
d. Erythritol	e. Cyclamate
II. <b>Disaccharide Polyols</b>	f. Dulcin
a. Isomalt (Palatinit)	g. Aldoximes
b. Maltitol	h. Neotame
c. Isomaltulose	i. Stevia
d. Trehalose	j. Sucralose
III. <b>Polysaccharide Polyols</b>	
a. Hydrogenated glucose syrup (Lycasin)	

Table - 2

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Most of us enjoy eating sweet tasting foods, and some might almost have a psychological need for them and are described as a “universal human weakness.” The association between the frequency of sugar consumption and dental caries have been well documented. Dental profession are interested to find a safe, palatable sugar substitutes to prevent dental caries and have attempted to persuade their patients to adopt special dietary programs to limit the frequency with which sugar containing foods are ingested.<sup>4</sup> Hence, there is increasing interest in the use of sweetening agents which confer sweetness but are safer for teeth.

### A. Nutritive Sweeteners

Nutritive sweeteners are also called as carbohydrate sweeteners (caloric). It provides a high-quality sweet taste and has an acceptable texture and shape and thus remains the most popular sweetener.<sup>5</sup>

#### I. Monosaccharide Polyols

Monosaccharide alcohol is the general term for the chain – like polyalcohol obtained by reducing the carboxyl group of sugars.

**a. Sorbitol (D-glucitol):** Sorbitol occurs naturally in cherries, plums, apples, many berries, seaweeds and algae. It is moderately sweet, relatively inexpensive and has less shelf life because of hygroscopic property.

#### Dental Aspect

**Fermentation by oral microorganisms:** Practically all strains isolated from caries inducing mutans group of *Streptococci* will ferment sorbitol to give a final pH of below 5.0. Although *Streptococcus mutans* ferment sorbitol, the rate of acid production is much slower compared to other fermentable hexoses and disaccharide. This permits salivary buffers to neutralize acid end products as they are formed.<sup>4</sup> Sorbitol should be considered a low cariogenic sweetener rather than a non-cariogenic one because consumption of larger amount increases the acid producing microorganism in plaque. Cariogenic microorganisms can “learn” to metabolize sorbitol when their sugar supply is restricted. Firestone and Navia (1986) suggested that chewing sorbitol-sweetened gums for five minutes after receiving a sucrose rinse has shown to substantially reduce demineralization.<sup>6</sup>

**Side effect of Sorbitol:** Sorbitol in large dose may cause osmotic transfer of water into the bowel leading to diarrhoea.<sup>7</sup>

**b. Xylitol:** Xylitol is a pentose alcohol with sweetness similar to sucrose, found naturally in a variety of fruits, vegetables and also are available in various other processed forms such as gums, lozenges, syrups and snack foods. It is directly absorbed by the small intestine and subsequently metabolised.<sup>4</sup>

**How xylitol in chewing gum works to inhibit caries development.**

- Xylitol is not fermented by cariogenic salivary *mutans streptococcus* as it replaces sucrose with xylitol and “starves” the cariogenic microorganisms. Therefore consistent use of xylitol-sweetened gum reduces plaque

accumulation. Hence, enamel demineralization is prevented, and plaque bacteria cannot undergo proliferation.

- Xylitol prevents the accumulation of plaque on the tooth surfaces.
- Plaque pH does not drop when xylitol-sweetened gum is chewed, but remineralization is enhanced.
- Chewing any gum stimulates the flow of saliva, which enhances the buffering effect.<sup>8</sup>

**Xylitol and maternal transmission of cariogenic bacteria:** A study in Finland by Isokangas *et al.* (2000) recruited 195 mother and infant pairs in which all of the women had high levels of salivary *mutans streptococci*. A statistically significant reduction in colonization of *mutans streptococci* was observed in the teeth of the children whose mothers regularly chewed xylitol sweetened gum compared with children whose mothers received fluoride or chlorhexidine varnish treatment.<sup>8</sup>

#### Use of xylitol-sweetened gum in dental practice

Xylitol sweetened gum offers more benefit in terms of reducing caries risk than does sorbitol-sweetened gum. Patients who chew gum regularly should be encouraged to chew gums sweetened with sorbitol or xylitol. Dentists should stress that chewing xylitol-sweetened gum as a supplemental practice, not a substitution for preventive dental program that includes the use of fluoride, consciously applied oral hygiene practices and regular professional visits.<sup>8</sup>

Age	Xylitol products	Dosage
< 4 years old	Xylitol syrup	3 or 8 gram/ day in divided doses
> 4 years old	Chewing gums, mints, lozenges, snack foods such as gummy bears.	3 or 8 gram/ day in divided doses

Recommendation for children at moderate or high caries risk<sup>9</sup>

**Side effect of Xylitol:** High dosage of xylitol may cause diarrhoea in humans. Like sorbitol, it is only absorbed from the gastrointestinal tract and, therefore, draws water into the bowel by osmotic effect. Ingesting diet with highest xylitol content showed an increase in urinary bladder calculi, epithelial hyperplasia and neoplasia of bladder.<sup>7</sup>

**c. Mannitol:** Mannitol is a polyol made by hydrogenation of fructose. It was first isolated from the sap of a flowering ash tree found in Southern Europe and Asia. It does not absorb moisture into products (non-hygroscopic) and is therefore often used as a dusting powder for chewing gum to prevent the gum from sticking to manufacturing equipment and wrappers. It is also included in chocolate-flavoured coating agents for ice cream and sweets due to its high melting point and does not discolour at high temperatures, which makes it ideal for use in pharmaceuticals and nutritional tablets.<sup>10</sup>

**Dental Aspect:** Edwardsson (1970) obtained spontaneous mutants of *Streptococcus mutans* which had lost their ability to ferment mannitol and sorbitol but which

retained their caries inducing ability when tested in hamster.<sup>10</sup>

**d. Erythritol:** Erythritol exists widely in nature, including in lichens, mushrooms, fruits, fermented foods and body fluids of mammals. It is also obtained from the fermentation of glucose by yeast. The sweetness of erythritol is 70-80% that of sucrose. Erythritol is predominantly absorbed from the small intestine and most of the absorbed sugar are excreted in urine without being metabolised therefore it does not cause diarrhoea.<sup>7</sup>

**Dental Aspect:** Erythritol can be classified as a non – cariogenic sweetener. As seen in the study conducted by Kawanabe *et al.* (1992) *streptococcus mutans* and *streptococcus sorbinus* did not attach to glass in the presence of erythritol, indicating that it does not appear to be used by *mutans streptococci* for synthesis of water – insoluble glucans. A significantly lower caries score were observed in the rats infected with *streptococcus sorbinus* and fed with erythritol.<sup>12</sup>

## II. Disaccharide polyols

Disaccharide polyols are those sugar substitutes which contain more than one hydroxyl groups. Various forms of disaccharides polyols are described as follows:<sup>11</sup>

**a) Isomalt (Palatinit):** Palatinit is obtained by the dehydrogenation of palatinose. The sweetness of palatinit is 45% that of sucrose. The majority of ingested palatinit reaches large intestine, where it is fermented to organic acid by *enterobacteria* and subsequently absorbed.

**Dental Aspect:** Karl (1978) conducted a study on rat model and suggested that palatinit are non-cariogenic in nature, where caries scores were found to be significantly lower in those rats fed palatinit compared with rats fed sucrose and lactose. Moreover, *Streptococcus mutans* strains were unable to produce notable amounts of acid from palatinit.<sup>11</sup>

**b) Maltitol:** Maltitol, also termed as reducing maltose, is a disaccharide alcohol of glucose and sorbitol. The sweetness of maltitol is 75-80% that of sucrose and its quality of taste resembles that of sucrose.<sup>11</sup>

**Dental Aspect:** Ooshima (1992) have shown that maltitol is non-cariogenic in nature as it does not lower plaque pH and a significantly lower caries score was reported for rats fed with maltitol compared with those fed with sucrose.<sup>13</sup>

**c) Isomaltulose (Palatinose):** Palatinose is a disaccharide of glucose and fructose. It is obtained from sucrose using a transferase produced by *Protamino bacterium*. The sweetness of palatinose is 42% that of sucrose.<sup>7</sup> It does not induce diarrhoea. For this reason, it is considered as an excellent sweetener for infants, children and diabetic patients.<sup>11</sup>

**Dental Aspect:** According to Takazoe (1985), Palatinose is considered as non – cariogenic because little or no acid was produced by a number of serotypes of *mutans streptococci* and other oral *streptococci* following fermentation of palatinose as compared with glucose.<sup>11</sup>

## III. Polysaccharide polyols :

Polysaccharide are sugar substitutes which contains more than one hydroxyl group and are described as below:

**Hydrogenated glucose syrup (Lycasin):** Most commonly used type being Lycasin (8055) containing 6-8% sorbitol, 50-55% maltitol, 20-25% maltotritol and 10-20% polysaccharide alcohols. Rugg – Gunn, (1989) found that human plaque pH measurement rank Lycasin as hypoacidogenic. Mixed cultures of oral microorganisms incubated with Lycasin produced less polysaccharide and acid with less demineralizing action on dental enamel and hydroxyapatite than the sugar incubated controls. Overall Lycasin (8055) has a very low cariogenic potential but no active cariostatic properties.<sup>14</sup>

## J. Non-Nutritive Sweeteners

Low-calorie sweeteners (referred to as non-nutritive sweeteners, artificial sweeteners or sugar calories) are ingredients added to foods, yogurt, medicinal preparation, dentifrices, mouthwash and beverages to provide sweetness without adding a calorie. The non-caloric sweeteners are generally much sweeter than sucrose and can, therefore, be used in small amounts.<sup>15</sup>

**i) Saccharin:** Saccharin was first developed in 1878; oldest approved artificial sweetener. It is 300 times as sweet as sucrose by weight, non-cariogenic and non-caloric but can have a slightly bitter or metallic taste.<sup>15</sup>

**Dental Aspect:** Saccharin, when used as a supplement to a cariogenic diet significantly, reduced both fissure and smooth surface caries in rats, apparently interfering with the growth of *Streptococcus mutans*.<sup>4</sup>

Cases of photosensitization and allergic reaction such as urticaria have been reported. Oral dose of 5 – 25gm daily may cause anorexia, nausea and vomiting. In 1972, the FDA set limits on the use of saccharin, citing the evidence that rats develop bladder tumours.<sup>4</sup>

**ii) Acesulfame – K:** Hoechst (1967), found that compounds with the dihydro – oxtiazinone dioxide ring system had a sweet taste. In terms of sweetness, Acesulfame – K is about 130 times as sweet as sucrose. It is stable in high temperature, low pH and storage range that is likely to be encountered in foods and beverages.<sup>4</sup>

**Dental Aspect:** It is not cariogenic, but no active cariostatic properties have been reported aside from a positive synergistic effect on inhibition of acid production by oral microorganisms when combined with cyclamate and saccharine (Ziesenitz and Siebert, 1988).<sup>15</sup> Safety studies have found no evidence of carcinogenicity, mutagenicity, cytotoxicity or teratogenicity.<sup>4</sup>

**iii) Aspartame:** Aspartame was accidentally discovered in 1965 by Searle Research Laboratories to have a pronounced sweet taste, being about 180 times sweeter than sucrose in aqueous solution, known under the brand name “NutraSweet”. It is an odourless white crystalline powder with a refreshing sweet taste, but it is extremely unstable at extreme pH range. It is used in noncarbonated

fruit juices, fruit drinks, frozen stick type confections, breath mints and sweetening agents in drug products.<sup>4</sup> Concerns about the safety of aspartame relate to its phenylalanine and aspartate contents, may cause Phenylketonuria (PKU), a genetic defect of phenylalanine metabolism and other reason for caution in approving aspartame is based on neurotoxic properties of aspartate and glutamate on the developing brain.<sup>16</sup>

**Dental Aspect:** *In vitro* studies by Greenby (1991) have brought some evidence of an inhibitory action on bacterial growth and adherent plaque formation. Also according to Richard (1992) the lower level of aspartame may be more effective in reducing cariogenicity in the presence of a lower level of sucrose.<sup>16</sup>

**iv) Thaumatin:** In West Africa the inhabitants used an extract “thaumatin” derived from fruits of a shrub, *Thaumatococcus daniellii* to sweeten foods such as bread and palm wine. It is 100,000 times sweeter than sucrose on molar basis and 3,000 times sweeter on weight basis.<sup>4</sup>

**Dental Aspect:** According to Ikeda (1982), anticariogenic property of thaumatin is due to inability of *mutans streptococci* to liberate acid or insoluble glucan.<sup>11</sup>

**v) Cyclamate:** Cyclamate are 30 times sweeter than sucrose and is freely soluble in water. It is not fermented by oral microorganisms, consequently non – acidogenic in plaque pH measurements *in vivo* and thus possesses no cariogenicity.<sup>4</sup> Cyclamates as 1% dietary levels produce a minimal laxative effect and are tumour promoters rather than true carcinogens.<sup>4</sup>

**vi) Neotame:** Neotame is a derivative of aspartic acid and phenylalanine. It is approximately 7,000 – 8,000 times sweeter than sugar, although some report a sweetening power of up to 13,000 times that of sugar. Neotame was approved by FDI in July 2002 as a general purpose sweetener. Because of extraordinary sweetness, neotame is consumed in small amounts and produces reduced level of phenylalanine in bloodstream which is clinically insignificant. It is not fermentable by oral microbiota and possesses a crisp and sweet taste.<sup>17</sup>

**vii) Stevia:** Stevia is calorie free, non-cariogenic and intensely sweet naturally occurring compound found in the leaves of a small shrub, *Stevia rebaudiana Bertoni*, also called *Yerbaa Dulce*, which grows wild in Paraguay. It is 300 times sweeter than sucrose and heat stable with little or no metallic taste. In 2008, FDA responded favourably to chemically refined derivative of stevia, the extract Rebaudioside A, to be used as a general purpose sweetener. Stevia has been shown to be safe for diabetic patient and has no mutagenic property.<sup>11</sup>

**viii) Sucralose:** Sucralose is a non-nutritive, non-caloric trichlorinated derivative of sucrose. It is 600 times sweeter than sucrose but is not metabolized by the body. It is heat stable thus widely used in carbonated and non-carbonated beverages, tea and coffee sweetener, baked goods, chewing gums and frozen desserts. The sweetener is marketed for home use under the brand name SLENDA® (Granular Low Calorie Sweetener) is a

blend of sucralose and malt dextrin. *In vitro* and animal studies done by Mandel & Grotz (2002) have clearly shown that plaque bacteria are unable to metabolise sucralose.<sup>18</sup>

## CONCLUSION

Effective caries prevention largely relies on the regular use of fluoride and oral hygiene. The potential efficacy of nutritional modifications on caries prevention has been suggested in the past. Sugar substitutes play an important role in shifting the caries process in favour of maintaining dental health, a greater variety of sweets containing sucrose substitutes of nutritional value should also be developed.

The use of non-cariogenic sweets can be recommended by professionals in the clinical settings as an important adjunct to reducing dental caries risk in individuals. To ensure success, a greater variety of sweets is required and new sucrose substitutes of nutritional value should also be developed. Industrialised countries commonly use a labelling system for listing the ingredients of processed food to enable the consumer to select foods in keeping with their personal health concerns. In the case of dental caries, labels such as ‘these sweets do not cause dental decay’ and ‘these sweets promote remineralisation of dental enamel’ could be displayed. These labels can play a significant role in informing the consumer about dental caries prevention and will certainly become more widespread in the future.

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