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Dental aspects of the use of sweeteners

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Abstract: One of the chief advantages of alternative sweeteners replacing sugars in foods and drinks is the potential benefit to dental health. Interest formerly focused on the use of intense sweeteners mostly in drinks, but with recent improvements in the range and properties of bulk sweeteners that can be used as substitutes for sugars in solid foods, increasing attention is now being paid to the re-formulation of confectionery and other potentially cariogenic snack foods. More than 55 publications and reviews on developments in this field are cited.

Three main health benefits have been identified as reasons for replacing sugars in the diet by alternative sweeteners. These are

1. For calorie control. Obesity is the most serious nutritional disorder facing developed countries today. Intense or high-potency sweeteners allow consumption patterns to remain unchanged while calorie intake can be reduced.

2. For diabetics. The sweet taste of foods and drinks can be maintained while sugar intake is cut down.

3. For dental health. The incidence of dental caries is related to the frequency of sugar intake. The use of alternative sweeteners can help to limit sugar intake.

It is this third property that will form the subject of this paper. Much has been written about the harmful consequences of excessive sugar or sucrose consumption on health, but careful investigations of the allegations against it have concluded that its only proven adverse effect is its cariogenic (dental decay-causing) action (refs. 1 and 2).

This has led to the promotion of non-sugar sweeteners as replacements for fermentable sugars in the diet, efforts to re-formulate various types of high-sugar foods and drinks with alternative sweeteners, much research on the dental properties of the sweeteners, and investigation of the possible caries-inhibitory action of certain of the sweeteners.

TYPES OF SWEETENERS AND THEIR MAIN APPLICATIONS

The range of non-sugar sweeteners developed for specific purposes has been expanding over the last few years, in some cases with a view to achieving a particular objective such as curbing dental caries or demonstrating advantages in research on their dental effects (e.g. refs. 3 - 6). The sweeteners that have been examined in this way can be divided into two main classes with two distinct sets of properties:

A. Bulk sweeteners
All are carbohydrates or carbohydrate derivatives.
Can be metabolised to varying extents, usually providing energy.
Can contribute to the bulk and structure of foods.
Generally have a less strongly sweet taste than the intense sweeteners.

B. Intense or high-potency sweeteners
They are required in only minute amounts.
Provide very little or no energy.
Provide no bulk but are especially useful in drinks.
May be blended with bulk sweeteners for use in solid foods.

Both classes have potential applications in lessening the risk of dental caries, but they will be considered separately, reviewing their properties and research that has been carried out on their dental effects. The range of sweeteners available has increased greatly over the last few years, but only those that have shown promise in dental caries control will be reviewed here. The selection of sweeteners for this purpose is a demanding process in which many different factors have to be taken into account, including their taste profile and perception; safety; pathways of metabolism; toxicology; nutritional and dental effects compared with sugars; technological considerations such as stability and compatibility with other ingredients of foods and drinks; cost relative to sugar; acceptability to consumers; and last but by no means least, their fulfilment of regulatory / legislatory requirements in the different countries and parts of the world where they are to be used.

For many years interest focused chiefly on the the development of new intense sweeteners as replacements for sugar, but over the last ten years or so the emphasis seems to have shifted towards extending the range of bulk sweeteners that have potential applications in improving the dental properties of sugar-containing foods and confectionery.

BULK SWEETENERS

These can be classified into three main groups:

Polyols and related materials, in which the reducing groups of a carbohydrate have been hydrogenated, so that the product is metabolised in a different way from its parent carbohydrate. This group includes sorbitol, mannitol, lactitol, xylitol, erythritol, maltitol and Malbit(R), isomalt (Palatinit(R)) and hydrogenated starch hydrolysates, one of which is Lycasin.

Alternative sugars. Among those that have been suggested are sorbose, coupling sugar, neosugar, trehalulose, isomaltulose (palatinose) and certain L-sugars.

Starch derivatives, including glucose syrups, corn syrups, high-fructose syrups and certain of their hydrogenation products.

MAIN DENTAL EFFECTS -- BULK SWEETENERS

Polyols. Most attention has been given to sorbitol (6-carbon) and xylitol (5-C). One reason for the interest in sorbitol (at least 37 scientific papers referring to its dental effects published since 1980) may have been its ready availability, especially in products for diabetics. Dental research on it has been reviewed in refs. 7 - 12, among others. The consensus is that sorbitol has low or no cariogenicity. The question has been raised, however, of whether oral micro-organisms may adapt to metabolise it to cariogenic acids. The possibility of this is thought to be slight in normal individuals (ref. 13).

The low cariogenicity of xylitol (over 100 papers published on it since 1980) has been the subject of many reviews and monographs, e.g. refs. 14 - 21. It has been noted that xylitol is not metabolised to acids by oral micro-organisms, and that regular use of products containing xylitol can help to restrict dental caries levels. There has also been a suggestion that xylitol may possess some anti-caries activity.

Among other polyols shown to have dental properties superior to those of sucrose is lactitol (see ref. 22), which has aroused interest on account of its easy availability from the dairy industry. More recently the dental benefits of isomalt (ref. 23) and erythritol (ref. 24) have been summarised, and a case has been made for using maltitol as a sugar substitute (ref. 25). Sweets made with isomalt instead of sucrose showed an improvement in their dental properties (ref. 26).

One reason for caution in the use of certain of the polyols is the digestive disturbance which can follow excessive consumption. The maximum tolerable level is generally said to be in the region of 30g at a single time or 70g per day, but it would be lower for children. The metabolism of the polyols has been documented in detail (see refs. 27 & 28).

Alternative sugars. In comparison with the polyols, relatively little has been published on their dental prospects. Most of the work on the low cariogenicity of isomaltulose (palatinose) has been done in Japan (e.g. refs 29 - 31). α,α-Trehalose has been evaluated mainly as a cryoprotectant (ref. 32), but one report exists of the low cariogenicity of trehalulose in rats (ref. 33). L-sorbose was found to be non-cariogenic in rats (ref. 34) but in another study its advantages were not clear (ref. 35).

Starch derivatives. Interest in their dental properties has persisted over a period of 30-40 years, as some of them can be used as bulk sweeteners to replace sucrose in a variety of foods. Starch hydrolysates include glucose syrups (corn syrups) and maltodextrins, which can be classified according to their dextrose equivalent (DE). A glucose syrup (DE 41) dissolved in the drinking-water of caries-active rats was less cariogenic than the same concentration of sucrose (ref. 36), but in more recent studies certain glucose syrups and maltodextrins in solid form (11 to 36% sugars) were associated with significantly higher caries levels than some common dietary sugars (ref. 37). Other indications of the beneficial effects of foods containing glucose syrups were given in refs 38 - 40.

More attention has been paid to the dental advantages of hydrogenated starch hydrolysates and Lycasins. Reviewing all the evidence, it has been concluded that Lycasin is likely to be non-cariogenic or virtually so (ref. 41). This was supported by findings in laboratory rats (refs. 34 & 42) and *in vitro* (refs. 43 - 45). Several types of confectionery showed improved properties when formulated with Lycasin in place of sugar, but some of the products were hygroscopic (ref. 26).

DENTAL HEALTH IMPLICATIONS OF INTENSE SWEETENERS

The main health motive in developing new intense sweeteners has been to assist in calorie control, with their uses for diabetics and dental health subsidiary to this. As [1] the only property they have in common with sugars and sweet carbohydrates is the perception of a sweet taste by the taste buds on the tongue, [2] they cannot be fermented to cariogenic acids in any quantity by oral micro-organisms, and [3] they do not act as substrates for the production of the microbial polysaccharides that help to constitute the matrix of the dental plaque, the chief dental research interest in them has been to determine if any of them display any caries-inhibitory action.

Saccharin, acesulfam-K and cyclamate are three of the most widely used, and have certain similarities of structure. Apart from the absence of cariogenicity, the principal dental interest in saccharin is that it actually exhibits a degree of microbial inhibition and suppression, curbing the level of dental caries in rats when administered in the drinking fluid at levels similar to those in low-calorie drinks (ref. 46) and when incorporated into the solid diet (refs. 47 & 48). In a trial of a saccharin-containing table-top sweetener in man, dental plaque accumulation was reduced significantly compared with a sucrose control (ref. 40). It was later found that cultures of human dental plaque micro-organisms were inhibited in growth and the production of acid and polysaccharide by saccharin (refs. 49 & 50). Further investigation showed that saccharin, unlike other sweeteners, is actively taken up by oral microbial cells, leading to a 30- to 40-fold increase in concentration within the cells, and inhibiting cellular metabolism by an effect on the cytomembrane (ref. 51). No such *anti*-cariogenic effects have ever been ascribed to acesulfam-K or cyclamate.

Aspartame, a sweet dipeptide with a completely different structure, is also non-cariogenic, but there is some evidence of an inhibitory effect on the growth of dental plaque micro-organisms. When oral bacteria were grown on a nitrogen-free medium to which various nitrogenous compounds were added, aspartame proved to be a relatively poor nitrogen source for microbial growth and metabolism (ref. 52), and and it also showed some inhibitory action on mixed dental plaque cultures (ref. 49).

Other intense sweeteners. The cariogenic organism Streptococcus mutans formed less acid when grown on media containing stevioside than on sucrose, glucose or fructose media. Studies in Japan demonstrated variable levels of growth suppression of oral micro-organisms, and indicated that stevia was effective against some strains of streptococci and lactobacilli (ref. 53).

As with other high-intensity sweeteners, it has been confirmed that sucralose is non-cariogenic (ref. 54). Sucralose was not utilized by oral bacteria and appeared to inhibit the formation of glucose and fructose polymers that are present in the dental plaque (ref. 55).

More dental research has been carried out on glycyrrhizin than on most of the other intense sweeteners (ref. 56). Both the growth of oral bacteria and acid production by them were reduced in the presence of glycyrrhizin, with the suppression of carbohydrate metabolism. When a glycyrrhizin gel was applied to the teeth, plaque deposition tended to be diminished. Glycyrrhizin gel as a vehicle for applying either fluoride or triamcylolone to the teeth was also tested. This produced some benefit in the treatment of recurrent aphthous stomatitis. As the gels it forms are stable, glycyrrhizin has been accepted as a vehicle for supplying idoxuridine-1, which can inhibit the growth of certain Herpes viruses around the mouth.

CONCLUSIONS

Undoubtedly one of the chief incentives for formulating sugar-free or sugar-low products is to improve their dental properties and diminish their cariogenicity, which is known to be related to their sugar content and frequency of sugar intake. In evaluating their dental properties, a clear distinction has to be drawn between the bulk and intense sweeteners. Not only are the high-potency materials non-cariogenic, but in general their sweetening power is so great, and they are needed in such minute amounts, that circumstances in which they could exert any cariogenic action are highly unlikely. There has been some limited interest in their possible *anti*-cariogenic activity, but this has been confined mainly to saccharin and aspartame, with rather less data available on stevia, sucralose and glycyrrhizin.

In contrast, advances in the last few years seem to have focused more on developing and improving the properties of bulk sweeteners that may have applications for use in confectionery and other types of solid foods, rather than in drinks. This trend can be seen in recent publications in the field of sweeteners (e.g. ref. 5), and may reflect the fact that a particular need to improve the quality of sugar-free versions of these products has been identified.

The two main sources of attack on the dental hard tissues currently receiving close attention are [1] erosion, resulting from the consumption of acidic foods and drinks, and therefore not influenced by the presence of sweeteners, and [2] dental caries, in which sugar entering the mouth is fermented by dental plaque bacteria to acids that participate in the decay process. Caries is recognised by the dental profession as a particular problem in children, but there are reservations over whether sweet products re-formulated with non-sugar sweeteners should be provided for them, and some countries have regulations expressly prohibiting this. Toleration to polyols is certainly lower in children than in adults, and products aimed at young children are not usually formulated with alternative sweeteners, the manufacturers preferring to remain with 'natural' sweeteners.

The main opportunities for non-sugar sweeteners appear to lie in the expanding range of foods and especially drinks now on the market for adults, for whom the potential dental benefits are easy to discern.

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