



SCIENTIFIC BACKGROUND

# Diet and teeth

How carbohydrates and food acids affect our teeth





## Healthy food, healthy teeth?

*Dr. Albert Bär explains why sugar is not the only culprit and why sugar-free product labels can sometimes be misleading.*

Despite declining trends in levels of dental caries in developed countries, dental caries remains prevalent and is increasing in some developing countries undergoing nutrition transition. There is convincing evidence for an association between the amount and frequency of free sugars intake and dental caries.

Dental caries occurs due to demineralisation of enamel and dentine by acids formed by bacteria in dental plaque through the anaerobic metabolism of sugars derived from the diet. When sugars or other fermentable carbohydrates are ingested, the resulting fall in dental plaque pH caused by organic acids

increases the solubility of calcium hydroxyapatite in the dental hard tissues and demineralisation occurs as calcium is lost from the tooth surface. The pH at which demineralisation occurs is often referred to as the critical pH and is approximately 5.5. In order to be on the safe side, Toothfriendly International applies a more conservative value, i.e. 5.7.

### Carbohydrates

Most food carbohydrates can be fermented by the microorganisms of the dental plaque to organic acids (e.g., lactic, acetic, propionic and butyric acid). The resulting acidification of the dental plaque promotes the demineralization of the underlying tooth surface. If periods with such demineralization occur

frequently, caries (tooth decay) may develop. Sites at which dental plaque accumulates and is not removed with the toothbrush, are particularly at risk for developing caries (e.g., occlusal surfaces of molar teeth, interproximal sites).

Many sugars (glucose, fructose, sucrose) as well as starch and starch hydrolysates (maltodextrin), which are widely used in foods, are fermentable and may promote tooth decay. Sucrose is, in this regard, particularly critical because it is not only fermented but in addition can be converted by certain plaque microorganisms to extracellular polysaccharides (glucans, fructans) which facilitate the adhesion of

# Diet and teeth

the plaque to the tooth surface and serve as reserve substrate from which acid may be formed even during periods with low availability of carbohydrates.

However, not all carbohydrates are fermentable by plaque microorganisms. Two sugars, namely D-tagatose and isomaltulose, are not fermented to a relevant extent and thus do not lead to plaque acidification. Similarly most sugar alcohols are not fermented to a significant extent. Pure resistant (i.e., non-digestible) maltodextrin and polydextrose are not fermented either. These non-fermentable carbohydrates are, therefore, suitable for the formulation of toothfriendly confectionery. However, it must be noted that certain brands of such complex carbohydrates may contain fermentable by-products and/or may be degraded to fermentable breakdown products during the food production process which makes them unsuitable for the production of dentally safe confectionery.

In other words, the fermentability of a food ingredient (sugar, oligosaccharide, polysaccharide, sugar alcohol) cannot be predicted with certainty from its chemical structure. Each of these carbohydrate categories contains products which may be fermentable and products which are not fermentable.

Accordingly, the presence of fermentable components cannot always be seen from the ingredient declaration of a food product. Hence, the cariogenic potential of a foods (candy, chocolate, beverage, etc.) cannot always be predicted with certainty from its composition. Therefore, it is not possible to conclude that sugarfree foods generally and by definition are ‚Toothfriendly‘, as it is often believed erroneously.

## Food acids

Food acids, such as citric, tartaric and ascorbic acid are usually added to fruit-based beverages, fruit- and berry-flavored candies, and other foodstuffs.

Such food acids have an adverse effect on dental health in different ways. Upon frequent and prolonged

contact with the teeth, they may directly lead to erosion (demineralization) of the tooth surface (Lussi et al., 2004). Furthermore, food acids may acidify the dental plaque for an extended period of time depending upon the mode of consumption (for example: sipping of a beverage in small but

plaque. Foods which contain excessive amounts of added or naturally present food acids, may have, in addition, an indirect cariogenic potential because frequent acidification of the dental plaque promotes the growth of acid-tolerant microorganisms, which often are also the most aciduric (i.e.

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frequent portions for a considerable length of time), thereby promoting not only demineralization of the tooth surface underneath the plaque but also the growth of acid-tolerant and thus particularly cariogenic plaque bacteria, such as *Streptococcus mutans* (Svanberg, 1980).

Foodstuffs which contain excessive amounts of added or naturally present food acids have, therefore, a damaging effect on dental health and are not Toothfriendly, even if they do not contain any fermentable carbohydrates.

## Measuring the cariogenic potential of foods

The cariogenic potential of a food, i.e. its ability to promote tooth decay, depends directly upon its content of substances, mainly carbohydrates, which may be fermented to acids by the microorganisms of the dental

acid producing) and thus cariogenic ones (such as *S. mutans*) (Svanberg, 1980).

The acidification of dental plaque due to the presence of fermentable carbohydrates can be measured by different methods using a pH-electrode. The method, which determines plaque-pH under the most realistic conditions, is the so-called plaque-pH telemetry. In this method, the pH is measured in human volunteers, i.e., *in-vivo*, with a so-called „indwelling“ electrode, an electrode which is inserted in the artificial tooth of a partial prosthesis. This electrode is facing an interproximal site (i.e., a predilection site of caries) and is covered by normal dental plaque that has accumulated on the electrode during a period of at least three but not more than seven days. With this method, the plaque-pH is measured on the tooth surface, i.e. under the dental plaque, or – in other words – at exactly the site where caries often occurs.

The method and its application have been described in detail (Imfeld, 1983), but it has also been referred to in numerous scientific publications (Lingström et al., 1993). At present, plaque-pH telemetry is routinely applied at three university institutes (in Switzerland, Germany, China and soon in Thailand) for the determination of the cariogenic and erosive potential of foods. Since these institutes follow exactly the same study protocol, which is laid down in TI's Standard Operation Procedure (SOP), the same test results will be obtained for a given foodstuff, regardless of where it is tested. Any other institute which would follow the same SOP, could also perform such tests after



# Diet and teeth



*The 'Toothfriendly' standard - each product must be non-cariogenic and non-erosive under normal conditions of use - meets the toughest guidelines set by the dental profession.*

the quality of its performance has been confirmed by interlaboratory comparative tests.

If non-acidogenic (and thus non-cariogenic) food is to be distinguished from acidogenic (and thus potentially cariogenic) food on basis of a plaque-pH test, it is necessary to define a critical plaque-pH.

Since different methods of plaque-pH measurement yield somewhat different results, this critical pH is not an absolute value but is method-dependent (Lingström et al., 1993). For the in-vivo method with measurement of the plaque-pH by an indwelling, interproximal electrode, a pH of 5.7 is considered to represent the critical level. This value has been derived from studies on dental enamel demineralization by acids and it contains a safety margin (Imfeld, 1983 (at p. 4)). A comparison of plaque-pH tests and rat caries experiments with several sugars and sugar substitutes supports the adequacy of this threshold value (Imfeld, 1983 (at p. 85/86)).

It follows from this data that a food, which during consumption and for 30 minutes after consumption does not depress the plaque-pH below 5.7, as measured by in-vivo plaque-pH telemetry, lacks a significant acidogenic potential and does, therefore, not expose the teeth to a significant risk of caries.

## Measuring the erosive potential of foods

The erosive potential of a food, i.e., its ability to demineralize the tooth surface directly (i.e., in the absence of plaque microorganisms), depends

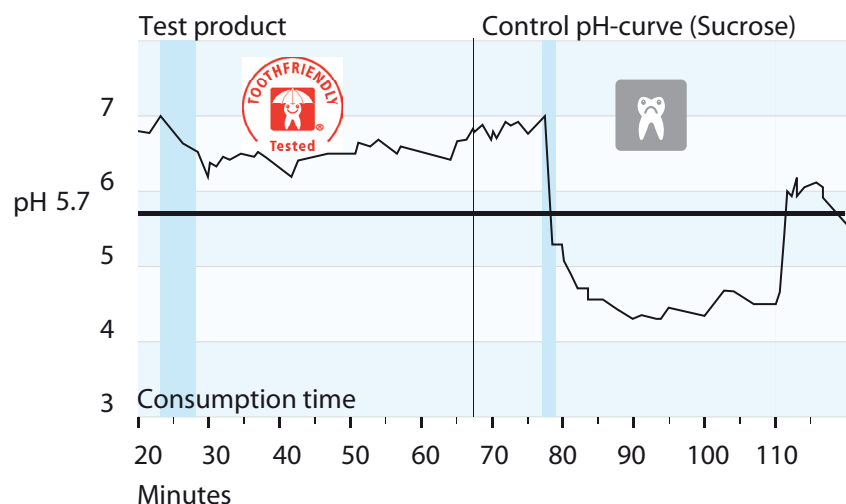
upon its content of organic or inorganic, added or naturally present acids. However, the magnitude of the erosive potential is determined not only by the quantity of acid present in the food, but also by the type of acid in terms of its buffering capacity in the relevant pH range and its ability to complex calcium ions.

The erosive potential of food can only be determined in-vivo because factors such as the dissolution time of a food (in the case of candies), contact time with the teeth (e.g., size of a candy) and neutralization of the acid(s) by saliva influence the magnitude of the erosive potential. For the determination of the erosive potential, the same instrumentation is used as for the measurement of

the cariogenic potential. However, the pH measurement is performed in this case with a plaque-free indwelling electrode in-vivo.

Measured by this method, an acid exposure of  $40 \mu\text{mol H}^+ \times \text{min}$  is considered to be the critical level. This value has been derived from in-vivo studies on regular foods which are generally recognized as not causing erosions and from in-vitro studies on the demineralization of polished dental enamel by different food acids. The determination of this value includes a safety margin because under in-vivo conditions the tooth enamel is not polished but in fact is covered by a thin layer of protein, the so-called pellicle, which acts as a barrier to the diffusion of

*Figure 1. Volunteer is chewing a sugar-free chewing gum (circa 8 minutes). Before, during, and for 30 minutes after, the pH of the plaque is measured. As the product does not depress the plaque pH below the critical level of 5.7, it is considered non-cariogenic. After paraffin chewing a positive control with sucrose solution demonstrates that the plaque pH drops below 4.5 after sugar consumption.*



# Diet and teeth

mineral (calcium, phosphate) from the tooth surface.

## Conclusion

In conclusion, there exist criteria for determining whether or not a food has a potential to promote dental caries and/or tooth erosion. Threshold values exist for both the cariogenic and erosive potential to distinguish foods which are innocuous for dental health from foods which are potentially noxious.

Foods, which upon normal consumption do not lower plaque pH below 5.7, as measured in-vivo by means of a plaque-covered indwelling electrode do not bear a significant cariogenic potential.

Foods, which during normal consumption do not expose teeth to an acid load of more than  $40 \mu\text{mol H}^+ \times \text{min}$ , as measured in-vivo by means of a plaque-free indwelling electrode, do not bear a significant erosive potential.

Foods, which have neither a significant cariogenic nor erosive potential, may be consumed as often as the consumer likes without exposing his teeth to a health risk. Such products qualify, therefore, for use of the Toothfriendly symbol and the term „Toothfriendly“ as an explanatory statement.

Since chewing gum and candies stimulate the flow of saliva and since saliva, by means of its elevated pH (7.4) and buffering capacity, not only has a neutralizing effect on the dental plaque but, moreover, promotes the remineralization of the tooth surface because of its calcium supersaturation, toothfriendly chewing gum and candies qualify under EU regulation for an even stronger yet somewhat clumsy claim i.e. ‘Consumption of foods/drinks containing <name of sugar replacer> instead of sugar contributes to the maintenance of tooth mineralisation‘.

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## Swiss dentists take a positive approach to sweets

The Toothfriendly labeling initiative was launched in 1982 by four Swiss University Dental Institutes to distinguish confectionery products that are safe to teeth, i.e. are non-cariogenic and non-erosive. In the same year, the first pH-telemetry test institute was opened at the University of Zurich to enable the measurement of Toothfriendly products in human volunteers.



In 1982, the Swiss Toothfriendly Association (Aktion Zahnfreundlich Schweiz) was established in Basel. Today, the association counts nearly 1'000 individual members. A survey conducted in 2010 shows that over 90% of the Swiss population recognize the Toothfriendly label. Thanks to a prevention-minded oral health education system, most Swiss children learn about the benefits of the Toothfriendly label already in kindergarten and primary school.

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