Drinks That Won't Decay: Beverage Formulation for Oral Health

There are two oral health problems that have been associated in the popular media with the consumption of soft drinks: dental caries and dental erosion. This article reviews what causes these two conditions and current trends in beverage formulation related to these conditions.

By Daniel R. Sortwell

DENTAL caries, or tooth decay, is a pit in the tooth structure that results from subsurface demineralisation caused by acids formed by the bacterial metabolism of fermentable carbohydrates. Microorganisms naturally occurring in the human mouth form dental plaque, a biofilm that adheres to the teeth. Acid-producing bacteria residing in the dental plaque ferment carbohydrates such as sucrose, glucose, and fructose and produce a mixture of organic acids, primarily Lactic Acid. These acids dissolve tooth enamel to produce dental caries since the dental plaque prevents the saliva from immediately flushing away and neutralising the acids.

Dental caries

The condition of the dental plaque itself is an important factor in dental caries. If the dental plaque is dense and not fully exposed to saliva in the mouth, then the organic acids produced by the bacteria diffuse more slowly out of the plaque and the neutralising components of the saliva such as bicarbonate diffuse more slowly into the plaque. The end result is that the tooth enamel underneath the plaque is exposed to acidic conditions for a longer time period and the rate of tooth decay is faster. The practice of good dental hygiene eliminates plaque, thereby helping to prevent dental caries. The School of Dental Sciences, University of Newcastle, UK, maintains a web site named "The Oral Environment" that provides useful information about the chemistry and microbiology of saliva and dental plaque (www.ncl.ac.uk/dental/oralbiol/oralenv/home.htm).

The risk factors for dental caries include:

- Tooth enamel structure and mineral content. Harder teeth are generally less susceptible.
- Plaque quantity and quality.
- Saliva quantity and quality. If saliva flow is lowered; for example, by radiation therapy, the risk of dental caries would rise.
- Composition and viscosity of foods and beverages. Consumption of food that sticks to the teeth and that contains fermentable carbohydrates would increase the risk of dental caries.
- Frequency of consumption of foods and beverages. Infants who continuously drink beverages containing fermentable carbohydrates from baby bottles would be at a higher risk for dental caries as well as possibly dental erosion, depending on the acidity of the beverage.

Cariogenic Sweeteners	Non-cariogenic Sweeteners
Corn Syrups	Acesulfame K
Dextrose	Alitame
Fructose	Aspartame
Sucrose	Cyclamate
	Erythritol
	Neotame
	Saccharine
	Stevioside
	Sucralose
	Tagatose

Formulating beverages with non-cariogenic sweeteners

Of the risk factors listed above, the presence or absence of fermentable carbohydrates is of

prime importance when formulating beverages. Sweeteners that are fermentable carbohydrates are cariogenic because they can be metabolised by the bacteria in the plaque. Non-cariogenic sweeteners are not fermented by the bacteria residing in the plaque and include high intensity sweeteners such as aspartame. The table on the previous page lists cariogenic and non-cariogenic sweeteners used in beverage formulations.

By selecting a non-cariogenic sweetener, a beverage that reduces the risk of dental caries can be developed. The high intensity sweeteners aspartame, sucralose, and neotame all have a more enduring sweetness than sucrose. Malic Acid has a more persistent sourness than Citric Acid and therefore complements these sweeteners, even when used as a secondary acidulant. See *Balancing the Sweet & Sour: Acidulant Selection for Beverages* in Food & Beverage Asia, April, 2004, for more information.

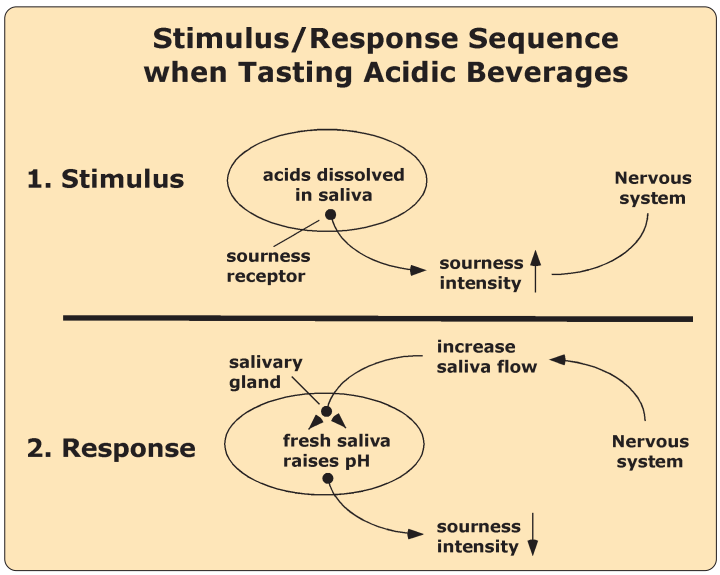
Dental erosion

Dental erosion, in contrast to dental caries, does not involve micro-organisms. The tooth is simply eroded by chemical attack, normally by acids. Tooth enamel is 98% biological apatite, which is an impure form of Calcium Hydroxyapatite, a Calcium Phosphate. When exposed to acidic liquids that do not contain dissolved Calcium, this material will be eroded from the teeth. Considering the millions of gallons of acidic beverages consumed annually, why isn't dental erosion widespread? Dental erosion is a relatively rare condition primarily because the saliva in the mouth protects the teeth by flushing away and neutralising acids and by exposing the teeth to dissolved Calcium Phosphate.

The resting flow rate of saliva for most people is about 0.30 ml/min. In response to stimulation of the sourness receptor cells in the mouth, the saliva flow rate increases five fold to 1.5 ml/min on average. This stimulus/response sequence is shown in the diagram below right. The fresh saliva that is released into the mouth from the salivary glands raises the pH to 6.3 or higher through the reaction of bicarbonate ions with acids. The bicarbonate level in the saliva also increases with flow rate. What this means is that acidic, sour beverages trigger a protective response when they enter the mouth.

Many studies have been conducted in the area of dental erosion; however, most of these studies were conducted *in vitro* as opposed to *in vivo*. An *in vivo* study would examine the erosion of live teeth in a subject's mouth. An *in vitro* study would examine the erosion of extracted teeth in a laboratory beaker and does not include the protective effects of human saliva. Therefore, it is difficult to make accurate extrapolations from what happens in an *in vitro* study to what actually happens in the human mouth. SJ Moss did an excellent review of dental erosion, including a discussion of *in vitro* versus *in vivo* studies (Moss, SJ. 1998. Dental Erosion. International Dental Journal. 48:529-539).

When dental erosion does occur, it is usually the result of either a diminished saliva flow rate or situations where acids are continuously or frequently introduced into the mouth. The risk factors for dental erosion include:



• Xerostomia (dry mouth), which may result from medical disorders, medication, radiation therapy to the head or neck, mental depression or anxiety.

• Chronic vomiting, which may result from bulimia, pregnancy, or chemotherapy. In this case, gastric hydrochloric acid enters the mouth.

• Gastroesophageal Reflux Disorder (GERD), which may also result in stomach acid entering the mouth.

• Frequent, excessive consumption of acidic foods or beverages; for example, when young children continuously drink acidic beverages from baby bottles.

• Occupations that involve exposure to high levels of environmental acids; for example, battery manufacture, metal plating, or acid etching.

Diet and dental erosion

Patients with xerostomia may be prescribed saliva substitutes or saliva stimulants such as chewing gum to increase their saliva flow rates. For patients with dental erosion related to frequent and excessive consumption of acidic foods or beverages, recommended changes in dietary habits include:

• Regulating the frequency of consumption.

• Restricting acidic foods to main meals.

• Drinking rather than sipping or swishing around acidic beverages.

• Finishing meals with neutral foods such as cheese.

• Use of sugar-free chewing gum to stimulate saliva flow.

A few "tooth friendly" beverages have been introduced in Europe and the UK. This type of beverage usually relies on fortification with Calcium and/or a reduction in the titratable acidity of the beverage. In the first case, soluble Calcium salts such as Calcium Fumarate, Calcium Gluconate, or Calcium Lactate would be used. Normal levels of beverage Calcium fortification, providing around 0.04% w/v Calcium, have been found in *in vitro* studies to dramatically reduce the rate of erosion. In the second case, it is possible to choose an acidulant combination that provides sourness while at the same time reducing the total acid level. Using a combination of Citric Acid as a primary acidulant and Malic Acid as a secondary acidulant can do this, as described in the article about beverage acidulants mentioned above.

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