



## BRIEFING PAPER:

# The potential of sugar-free beverages, sugar-free confectionery and sports drinks to cause dental erosion

Although the link between sugar and dental caries is widely recognised, dental erosion, another damaging dental condition, is less well known and is caused by some foods and beverages that are perceived by consumers to be healthy.

This briefing paper summarises recent studies by the Oral Health CRC on the erosive potential of sugar-free beverages, sugar-free confectionery and sports drinks.

# ABOUT THE ORAL HEALTH CRC

The Oral Health CRC brings together world-class scientific and clinical research teams with Australian and global manufacturers, marketers and distributors to address the economic and social burden of oral disease.

## Our challenge

Oral diseases are among the most prevalent diseases in the Australian community. Almost 60% of 14 year-olds in Australia have had decay in their permanent teeth.<sup>1</sup> Moderate to severe forms of periodontal disease affect almost one quarter of adults.<sup>2</sup> More than 60,000 Australians are hospitalised each year for preventable oral health conditions.<sup>3</sup>

The cost to the Australian economy of oral diseases is \$8.7 billion a year.<sup>4</sup> A growing body of evidence links oral disease to other health conditions including diabetes, cardiovascular diseases, kidney disease, respiratory diseases, inflammatory diseases and some cancers.

## Our work

- Researching, developing and commercialising novel professional dental products to improve the prevention, early diagnosis and treatment of oral diseases.
- Researching, developing and commercialising tooth-friendly functional foods and beverages to reduce erosion of tooth enamel and assist in preventing dental caries.
- Increasing understanding of oral health problems in the Australian community, particularly within vulnerable population groups including children, the elderly, and rural and Aboriginal and Torres Straits Islander communities.
- Researching biological and epidemiological links between oral disease and diabetes, cardiovascular disease, kidney disease, arthritis and certain cancers.
- Partnering with dental service providers to research and develop evidence-based clinical protocols and models of care, and to build the research capacity of oral health practitioners.

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<sup>1</sup> Chrisopoulos S & Harford JE 2013. *Oral health and dental care in Australia: key facts and figures 2012*. Cat. no. DEN224. Canberra: AIHW.

<sup>2,3</sup> AIHW 2014. *Oral health and dental care in Australia: key facts and figures trends 2014*. Cat. no. DEN 228. Canberra: AIHW.

<sup>4</sup> AIHW 2014. *Health expenditure Australia 2012-2013. Health and welfare expenditure series no. 52*. Cat no. HWE 61. Canberra: AIHW.

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# GLOSSARY

<b>Bioavailable</b>	Able to be used by the body, in this case able to be absorbed by the teeth
<b>Chelator</b>	A chemical that binds or traps other chemicals, in this case citrate is a chelator of calcium.
<b>Crown</b>	An artificial restoration that fits over a damaged or weakened tooth
<b>Enamel</b>	The hard, protective outer layer of the tooth
<b><i>In vitro</i></b>	In the laboratory
<b><i>In vivo</i></b>	In the living body
<b>Demineralisation</b>	The weakening of tooth structure through the loss of minerals
<b>Remineralisation</b>	The strengthening of tooth structure by incorporation of calcium, phosphate and/or fluoride
<b>µm</b>	Micrometre, one millionth of a metre

# INTRODUCTION

With growing community awareness of the links between high sugar intake and obesity, diabetes and dental decay, consumers are becoming increasingly health conscious in their choice of beverages and confectionery.

Beverage and confectionery manufacturers have responded to this with a proliferation of new 'sugar-free', 'low-sugar' and 'healthy' products. Traditional soft drink manufacturers are now producing iced teas, vitamin drinks and soft drinks marketed as 'diet' or 'zero' products. Lollies, lozenges, fruit chews and mints are now also available in sugar-free varieties. Market analysts are predicting further development of the sugar-free market.

Sugar is fermented by bacteria in the dental plaque on the tooth surface to produce acid, which, if not thoroughly removed, leads to dental decay (caries). Dental caries is one of Australia's most prevalent health conditions. The proportion of Australian children with teeth affected by caries ranges from 5% for 6 year olds to 58% for 14 year olds.<sup>5</sup>

It is generally agreed that the use of sugar substitutes (including polyols such as xylitol, sorbitol, and mannitol) in confectionery and beverages has contributed to a decline in the prevalence of dental caries in children in industrialised countries. In 2008 the FDI World Dental Federation issued the following position:

*"Non-cariogenic sugar substitutes, when used in products such as confectionary, chewing gum and drinks, reduce the risk of dental caries".<sup>6</sup>*

Reducing sugar intake is essential to reducing the risk of dental caries. However, consumers should be aware that many sugar-free products remain potentially harmful to teeth due to their chemical composition.

**"CONSUMERS SHOULD BE  
AWARE THAT MANY SUGAR-FREE  
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<sup>5</sup>Chrisopoulos S & Harford JE 2013. *Oral health and dental care in Australia: key facts and figures 2012*. Cat. no. DEN 224. Canberra: AIHW.

<sup>6</sup>FDI Policy Statement, 'Sugar substitutes and their role in caries prevention', adopted by the FDI General Assembly, 26 September 2008, Stockholm, Sweden.

# DENTAL EROSION

Like dental caries, dental erosion is also a prevalent dental condition. Unlike dental caries, dental erosion is not a disease and is not caused by sugar or bacteria. It occurs when acid dissolves the hard tissues of the tooth. In its early stages, erosion strips away the surface layers of tooth enamel. In advanced stages it can expose the softer dentin or even the pulp of the tooth.

A recent systematic review of epidemiological studies of erosion has found that the overall prevalence of dental erosion is just over 30%.<sup>7</sup>

The clinical indicators of dental erosion include chalkiness of the tooth surface, pitting, opacity, tooth sensitivity, and a scalloping of the occlusal (biting) surface of the teeth that in some cases can leave fillings exposed. Dental erosion can also increase the risk of dental caries.


Early dental erosion can be treated by a dentist with fluoride in conjunction with a bioavailable (able to be absorbed by teeth) source of calcium and phosphate. In more advanced cases, the lost surface of a tooth may need a filling or a crown.

Heightened levels of acid in the mouth can occur for a range of medical and lifestyle reasons, but the most common cause of dental erosion is repeated exposure to acids in foods and drinks.

Beverages with pH levels below 5.5 are comparatively acidic. This includes soft drinks, sports drinks, energy drinks, fruit juices, cordials and wine.

However, pH level is only one indicator of erosive potential. The mix of chemicals present in a food or beverage also determines whether or not it is erosive. Some chemicals, such as citrate, are chelators – that bind or trap other chemicals such as calcium. These chemicals are particularly erosive because they effectively remove calcium from teeth.

The frequency and length of time teeth are exposed to acids and chelators also determine erosive potential, as does a person's salivary flow because a healthy amount of saliva helps dilute and neutralize acid.



**“THE MOST COMMON CAUSE OF  
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<sup>7</sup>Salas MMS et al 2015. Estimated prevalence of erosive tooth wear in permanent teeth of children and adolescents: An epidemiological systematic review and meta-regression analysis. *Journal of Dentistry*, 43:42-50.

# SOFT DRINKS

Soft drinks have low pH levels, in some cases as low as 2.4. They often contain relatively high levels of one or more of the following food acids:

Additive	Ingredient number
phosphoric acid	338
sodium citrate	331
citric acid	330
tartrates	336

Phosphoric acid is mainly found in colas while citric/citrate is found mainly in lemon and lime flavoured drinks. All of the compounds listed above are chelators of calcium.

The Oral Health CRC conducted testing on the erosive potential of 15 beverages commonly sold in Australian school canteens, including three sugar-free soft drinks. Each of the 15 drinks was tested on extracted human molars free of dental caries\*.

Following exposure to the beverages, the teeth were analysed for weight loss, changes in calcium levels, and surface loss. White-light non-contact surface profilometry was used to measure surface loss in micrometres.

The study identified that both the sugar-containing and the sugar-free soft drinks produced significant erosion of the dental enamel, with teeth showing measurable weight loss and surface loss. The researchers found that there was no significant difference between the erosive potential of sugared and non-sugar soft drinks. In the resulting journal article in the *Australian Dental Journal*, the researchers concluded:

*"Therefore, banning sugar-containing beverages from schools may have positive health effects for reducing obesity, diabetes and dental caries but it may not reduce the risk of dental erosion."*<sup>8</sup>

\*Human molars were collected from the Royal Dental Hospital of Melbourne with ethics approval from the University of Melbourne Human Research Ethics Committee.

<sup>8</sup> Cochrane NJ, Cai F, Yuan Y, Reynolds EC. 2009. Erosive potential of beverages sold in Australian schools. *Australian Dental Journal* 54:238-244.

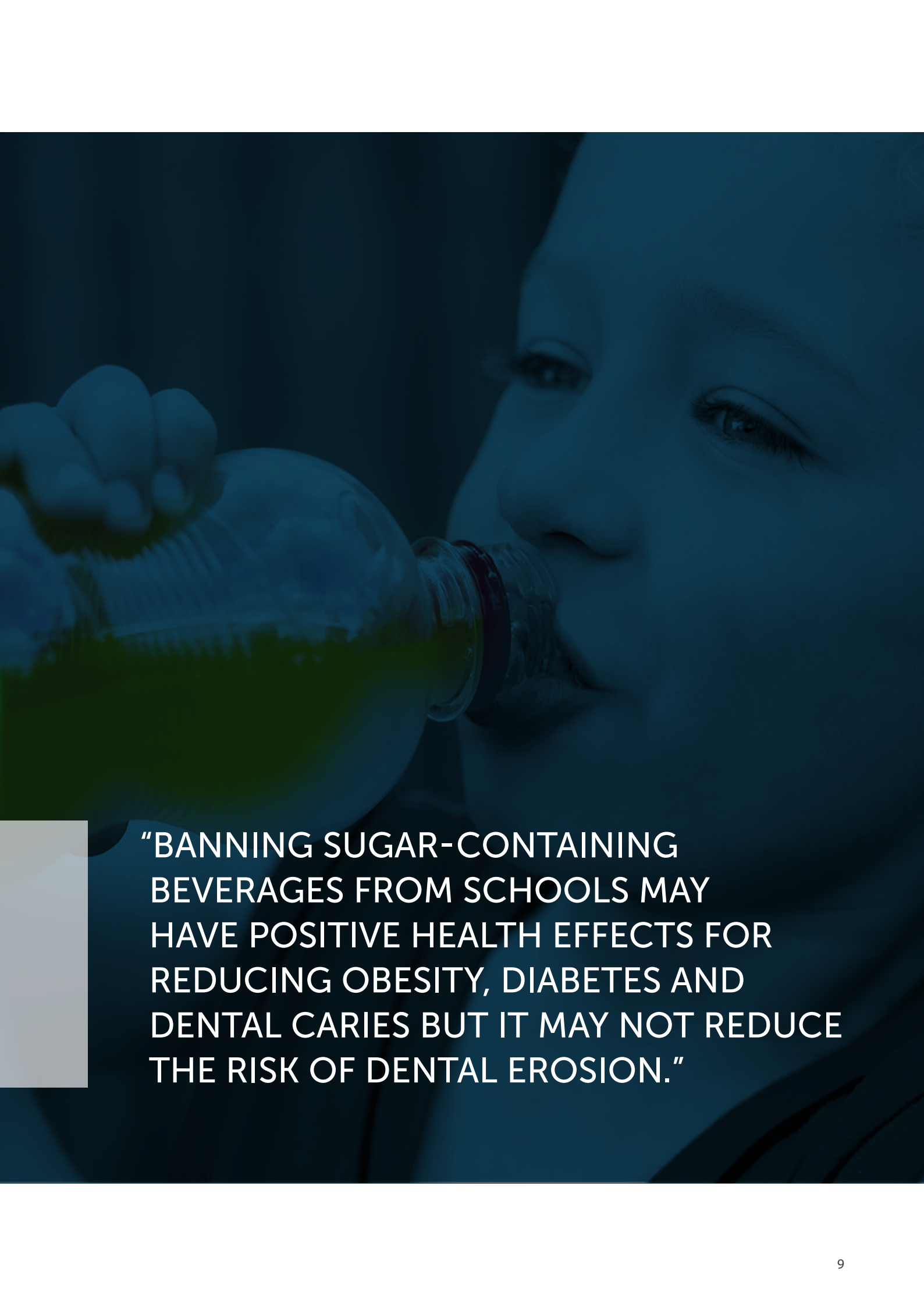
## STUDY RESULTS: EROSIVE POTENTIAL OF BEVERAGES SOLD IN AUSTRALIAN SCHOOLS

Average pH, tooth weight loss and tooth surface loss by beverage group (mean  $\pm$  sd)

	pH (initial)	Weight loss (mg/mm <sup>2</sup> )	Surface loss ( $\mu$ m)
Sugar-containing carbonated beverages	2.72 $\pm$ 0.32	0.57 $\pm$ 0.22	4.18 $\pm$ 2.10
Non-sugar- containing carbonated beverages	2.97 $\pm$ 0.11	0.40 $\pm$ 0.10	4.46 $\pm$ 1.55
Sports drinks	3.24 $\pm$ 0.05	0.33 $\pm$ 0.10	2.37 $\pm$ 0.96
Milk drinks	6.69 $\pm$ 0.04	0.01 $\pm$ 0.03	0.07 $\pm$ 0.13

“THERE WAS NO SIGNIFICANT  
DIFFERENCE BETWEEN  
THE EROSIVE POTENTIAL  
OF SUGARED AND NON-  
SUGARED SOFT DRINKS.”



A young girl is shown in profile, drinking from a clear plastic bottle. The image is heavily overlaid with a dark blue color. A quote is displayed in white text on the right side of the image.

**"BANNING SUGAR-CONTAINING  
BEVERAGES FROM SCHOOLS MAY  
HAVE POSITIVE HEALTH EFFECTS FOR  
REDUCING OBESITY, DIABETES AND  
DENTAL CARIES BUT IT MAY NOT REDUCE  
THE RISK OF DENTAL EROSION."**

# SPORTS DRINKS

Sports beverages are specially formulated carbohydrate-electrolyte products designed to provide fast rehydration. Although these drinks are usually not sugar-free, they are often perceived by consumers to be a healthier alternative to traditional soft drinks.

Dentists and dental researchers have become increasingly concerned about a potential link between sports drinks and dental erosion, with research showing higher than average rates of erosion among sportspeople, thought to be possibly associated with sipping sports drinks during times of lower saliva levels (during and after exercise).<sup>9</sup>

The Oral Health CRC tested eight commercially available sports drinks (including powdered drinks) for their impact on tooth enamel.<sup>10</sup> Coca-Cola and bottled spring water were used for comparison.

Using 70 human molars\*, the erosive potential of the beverages was determined by measuring enamel surface loss and enamel surface softening following exposure to the beverages. Surface loss was measured using a white light non-contact surface profilometer.

Surface softening was measured by changes in enamel hardness values using a Knoop microhardness tester.

The study found that all but two of the eight sports drinks caused significant enamel surface loss and enamel surface softening.

The two sports drinks (with a total of three flavours) that did not have this effect had a higher pH along with a higher bioavailable calcium content.

Coca-Cola produced the highest amount of surface loss. Water and the two sports drinks with higher calcium levels did not produce any detectable surface loss. All other sports drinks produced measurable surface loss. Coca-Cola and the majority of the sports drinks caused enamel hardness to decrease by 30% to 50%.

The study also used a taste testing panel of 20 adults to assess the palatability of the sports beverages. The two sports drinks found to have lower erosivity were determined by the panel to be less palatable.

The study's authors concluded that the majority of sports drinks were erosive, and that consumers choosing the less erosive brands should expect to compromise on taste. The authors recommended moderation in the consumption of all sports drinks, even those which are less acidic, due to their sugar content and the associated risk of dental caries.

**“THE STUDY FOUND THAT ALL BUT TWO OF THE EIGHT SPORTS DRINKS CAUSED SIGNIFICANT ENAMEL SURFACE LOSS AND ENAMEL SURFACE SOFTENING.”**

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\* Human molars were collected from the Royal Dental Hospital of Melbourne with ethics approval from the University of Melbourne Human Research Ethics Committee.

<sup>9</sup> Porter Mark Shimmin et al. 2015. Oral health and elite sport performance. *British Journal of Sports Medicine* 49:3-6.

<sup>10</sup> Cochrane NJ, Yuan Y, Walker GD, Shen P, Chang CH, Reynolds C, Reynolds EC. 2012. Erosive potential of sports beverages. *Australian Dental Journal* 57:1-6.

## STUDY RESULTS: EROSIVE POTENTIAL OF SPORTS BEVERAGES

Enamel surface loss and change in enamel hardness after exposure to beverages,  
and preferences of a testing panel for the different beverages (mean  $\pm$  sd)

	Brand	Flavour	Surface loss ( $\mu\text{m}$ )	Surface softening ( $\Delta$ Knoop hardness number) <sup>^</sup>	Taste preference @
Liquids	Mount Franklin	Spring Water	nd	$8 \pm 24$	Not tested
	Coca-Cola	Original	$3.22 \pm 0.52$	$-178 \pm 22$	$6.73 \pm 2.57$
	Gatorade	Lemon Lime	$2.00 \pm 0.29$	$-188 \pm 22$	$6.73 \pm 2.57$
	Powerade	Blackcurrant	$1.59 \pm 0.40$	$-155 \pm 34$	$6.25 \pm 2.43$
Powders	Gatorade	Lemon Lime	$2.50 \pm 0.52$	$-116 \pm 22$	$5.70 \pm 1.93$
	Powerade	Blackcurrant	$1.18 \pm 0.37$	$-99 \pm 36$	$6.07 \pm 2.09$
	Staminade	Lemon Lime	$2.55 \pm 0.60$	$-113 \pm 39$	$4.05 \pm 2.96$
	Sukkie	Lemon	nd	$-28 \pm 22$	$2.41 \pm 1.65$
	Sukkie	Berry	nd	$-23 \pm 8$	$2.52 \pm 2.59$
	Endura	Raspberry	nd	$-28 \pm 12$	$2.66 \pm 2.01$

<sup>^</sup> mean hardness of sound enamel samples was  $348 \pm 26$ .

@ taste assessed on a 0–10 visual analogue scale where 0 was most unpleasant and 10 was most pleasant.

nd no detectable change in surface profile (below the limits of detection).

# SUGAR-FREE CONFECTIONERY

Sugar-free confectionery is widely available in Australia and is often promoted as tooth-friendly. These products typically contain acids to produce a sour or fruity taste.

Acids commonly used in sugar-free confections include the following:

Additive	Ingredient number
phosphoric acid	338
malic acid	296
fumaric acid	297
citric acid	330
tartaric acid	334

Concern has been raised by dental researchers about the oral health implications of consuming sugar-free confectionery. In 2011 the *British Dental Journal* published an article titled 'Are sugar-free confections really beneficial for teeth?' in which the authors concluded that:

*"...polyol-based sugar-free products may decrease dental caries incidence but they may bring another dental health risk, dental erosion, if they contain acidic flavouring. There is a need for properly conducted clinical studies in this area."*<sup>11</sup>

The Oral Health CRC has conducted initial studies to measure the acid content and the erosion potential of 32 commercially available sugar-free confections.


The study has investigated three indicators of erosive potential: (1) analysis of acidic content of confections; (2) the effect on human saliva; and (3) tooth enamel softening and surface loss on human molars.\*

The pH and acidic content of each confection was measured *in vitro* in accordance with the testing protocol of Toothfriendly International<sup>12</sup> which requires that 1g of each confection be dissolved in 15ml of distilled deionised water. A total of 22 of the confections had a pH below 4.5. Fruit flavoured confections were found to have the lowest pH and also to contain high levels of citrate. Mints and menthol confections had lower acid content.

\* Human molars were collected from the Royal Dental Hospital of Melbourne with ethics approval from the University of Melbourne Human Research Ethics Committee.

<sup>11</sup> C. Nadimi H, Wesamaa H, Janket SJ, Bollu P, Meurman JH. 2011. Are sugar-free confections really beneficial for dental health? *British Dental Journal*, 211:1-5.

<sup>12</sup> Toothfriendly International is a not-for-profit organisation based in Switzerland that tests and certifies products and services according to oral health criteria.



OF THE 32 COMMERCIALLY AVAILABLE  
SUGAR-FREE CONFECTIONS TESTED BY  
ORAL HEALTH CRC, 22 HAD A pH BELOW 4.5.

FRUIT-FLAVOURED CONFECTIONS  
CONTAINED HIGHER LEVELS OF ACID WHILE  
MINTS AND MENTHOL CONFECTIONS HAD  
LOWER ACID CONTENT.

# SUGAR-FREE CONFECTIONERY

According to the Toothfriendly International testing methodology, products found to have a pH below 5.7 are required to be tested on saliva *in vivo*. Our study selected a product (a lemon/mint lozenge) with a pH measurement of 2.78 for saliva testing on adult volunteers with healthy salivary flows to determine the effect of acid release from the confection on saliva. The study detected a drop in the pH of the saliva in all subjects. The study also measured a drop, to below healthy levels, of bioavailable calcium and phosphate, which is necessary to maintain the integrity of tooth enamel and prevent tooth demineralisation.

The acidic products were also tested on tooth enamel in an *in vitro* erosion assay. This test confirmed their erosive potential, with exposure to the confections resulting in loss of tooth enamel and softening of the tooth surface.

In an interim report (unpublished), the study's researchers advised that people choosing to stimulate saliva for health reasons through the use of sugar-free confections should avoid confections with high levels of food acid, particularly citrate.

They advised that this can be done by choosing mint or menthol flavoured sugar-free confections and avoiding those that are fruit flavoured, particularly lemon-flavoured.

An interesting finding to come from the study was that the Toothfriendly International logo was present on 11 of the 32 confections. A further three products carried the message that they were 'sugar free for healthy teeth', and one had a 'Kind to Teeth' logo. The products selected by Oral Health CRC researchers for saliva and enamel testing were among those carrying the Toothfriendly logo. Although it met the requirements of Toothfriendly certification, it was found in our study to cause significant enamel loss and softening. The researchers concluded that: "Many sugar-free confections even some with 'toothfriendly' certification contain high levels of citric acid and have erosive potential."<sup>13</sup>

**"MANY SUGAR-FREE  
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<sup>13</sup> Cochrane NJ, et al. 2014. Food acid content and erosive potential of sugar-free confections. Unpublished research report.

# PRODUCT LABELLING

## International

The most widely used oral health logo is the Toothfriendly logo which is administered by the not-for-profit association Toothfriendly International based in Switzerland. This logo is in use primarily in Europe, though can be found on products commercially available in Australia.

The Toothfriendly International certification criteria requires that certified products be neither cariogenic (decay-causing) nor erosive.

Toothfriendly International testing to determine erosive potential is conducted by university dental schools in Europe and China. Products are tested in distilled water to measure pH. If the pH value is below 5.7, or if it is impossible to make an aqueous solution of the product, an *in vivo* test is performed to measure the pH of both plaque and saliva in at least two subjects. A product is regarded as not presenting significant erosive potential if plaque-pH does not fall below 5.7 and if the acid exposure of the teeth does not exceed 40  $\mu\text{mol H}^+$  per min (this is a measure of the total amount of acid teeth are exposed to over a period of one minute). This is equivalent to exposure to a solution of pH5 for 4 minutes.

Studies conducted by the Oral Health CRC indicate some limitations to the Toothfriendly International testing protocol for erosive potential. In particular:

- Acid release only is measured, and not the level of calcium chelators (such as citrate) that may also contribute to erosion. Erosive potential may be more accurately estimated by the combined impact of acid and calcium-chelator release.

- The current methodology assumes a healthy quality and quantity of saliva. People who are consuming confections or beverages to alleviate dry mouth symptoms are likely to have poor salivary function and so may be more vulnerable to the erosive effects of acids and chelators.
- Exposure to saliva is tested only once and does not measure any possible cumulative effect that may occur if people are consuming products frequently over the course of a day.

## Australia

In Australia, the only product labelling standard relating to the oral health impact of a food or beverage is in relation to chewing gum.

Food Standards Australia New Zealand (Standard 1.2.7, Schedule 3, Part 4) allows claims that chewing gum can contribute to the maintenance of tooth mineralisation and the neutralisation of plaque acids. To be eligible to make these claims, a chewing gum must contain 0.2% or less fermentable carbohydrate and/or must not lower plaque pH below 5.7 during 30 minutes after consumption.



# CONCLUSION

**Studies carried out in the Oral Health CRC on sugar-free beverages, sugar-free confectionery and sports drinks demonstrated that many of these products contained multiple acids and had low pH values.**

**Researchers concluded that most of the products were potentially erosive, indicated by measurable softening and loss of tooth enamel following exposure to the products, and a reduction in healthy mineral levels in saliva.**

**In light of its studies, the Oral Health CRC is of the view that current product testing and labelling regulations for foods and beverages are not sufficient to enable consumers to make informed choices in order to avoid the risk of dental erosion.**

# PREVENTING DENTAL EROSION

The Oral Health CRC recommends that consumers be wary of claims that sugar-free beverages and confections are safe for teeth – while they may not cause dental caries, they may be erosive. Consumers should check ingredients for acidic additives, particularly citric and phosphoric acid, for an indication of erosive potential.

There are a number of ways of effectively reducing and neutralising the impact of acidic foods and beverages on teeth. The Australian Dental Association makes the following recommendations:

- Drink more water (preferably fluoridated), particularly between meals.
- After eating or drinking acidic products, don't brush your teeth straight away as this can remove the softened tooth layer. Instead, rinse your mouth with water and wait one hour before brushing.

- Limit the intake of soft drinks, fruit juices, sports drinks and diet drinks.
- If drinking acidic beverages, do so at meal times.
- Chew sugar-free gum (particularly one with bioavailable calcium phosphate) - this can stimulate saliva flow, rinse away acids, and re-harden softened enamel.
- Have regular check-ups with your oral health professional.

People who believe they are at risk of dental erosion can talk to their oral health professional about using a remineralising treatment to replace lost calcium and phosphate.





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