THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

School of Dentistry

HEAD OF SCHOOL
Professor Laurence J. Walsh

BDSc, PhD, DDSc, GCEd, FFOP(RCPA), FICD, FADI, FPFA, FIADFE

200 Turbot Street
Brisbane Qld 4000 Australia
Telephone (07) 33658062
International +61 7 3365 8062
Facsimile (07) 3365 8118
Email l.walsh@uq.edu.au
Web www.uq.edu.au/dentistry

Black cola drinks, oral health and general health: an evidence-based approach

Laurence J. Walsh

School of Dentistry,
The University of Queensland

Recent advertising material from companies which manufacture black cola softdrinks should be of concern to all oral health professionals. Some of the advertising material on the Coca cola web site makes interesting reading, to say the least. "*MYTH: Drinking 'Coca-Cola' will rot your teeth. Drinks like 'Coca-Cola' are swallowed quite quickly and the saliva in your mouth washes away the sugar and acid.*" [1] This follows on from a public letter from the Managing Director of Coca Cola South Pacific, Mr Gareth Edgecombe, which reads "*You may have seen us in the headlines again this week with Coke being blamed for causing tooth decay and obesity. Our new "myth busting" ad campaign is aimed at dispelling the myths and misinformation around Coke*".

There appears to be a singular disconnect from the messages portrayed in the mass media and the experience of clinical practice (Fig. 1). In these days of evidence based practice in health care, what does the recent evidence from the literature actually say?

Fig. 1. The positive portrayal of black cola drinks in the media (left) is vastly different from the reality often encountered in clinical practice (right – a patient who has been consuming 2.5 liters per day for several years).

Black cola drinks and dental caries

The high cariogenicity of black cola drinks is recognized by all dental professionals as well as dieticians, and follows on from the accepted role of refined carbohydrates, particularly sucrose, in the caries process. [3] When sucrose intake exceeds 15 to 20 kilograms per person per year, such intake is directly associated with increasing caries prevalence, particularly when sucrose is consumed between meals. Indeed, current dental health education for the control of dental supports dietary restriction of sucrose to prevent caries.[4] Consumption of high-carbohydrate liquids is a risk factor for excessive caloric intake and obesity [5]. With a sucrose content typically in the range of 10-12 %, a 375 mL can contains in excess of 40 grams of sucrose, thus one can of sugared softdrink per day for one year will in itself account for 15 kilograms of sucrose per year.

Concerns regarding dental and general health issues have seen bans placed on softdrinks in schools in various jurisdictions, including Queensland. Similar nutritional concerns regarding soft drink consumption in schools have been raised internationally. For example, the American Academy of Pediatrics has highlighted the three major health problems associated with a high intake of sweetened drinks as (1) obesity attributable to additional calories in the diet; (2) displacement of milk consumption, resulting in calcium deficiency with an attendant risk of osteoporosis and fractures; and (3) dental caries and enamel erosion.[6] Their advice to restrict the sale of soft drinks to safeguard against health problems as a result of over-consumption is in line with current public health and dietetic advice in Australia.

Associations between DMFS scores and soft drink consumption in persons aged 25 and above have been seen in recent large cohort studies in the USA involving more than 30,000 subjects. These show a dose response between daily servings of sugared soft drinks in the diet, and DMFS scores in the same individuals [7]. The interpretation of this finding is self evident – a higher sucrose intake has increased dental caries activity.

It is concerning that some soft drink manufacturers continue to promote the view that their products are readily washed out from the oral cavity by saliva, and therefore do not contribute to dental caries. This view has been regarded as outdated since the early 1980's. The seminal work by Ismail *et al.* in the 1980's on the cariogenicity of soft drinks in more than 3,100 children and young adults demonstrated an association between the frequencies of at- and between-meal consumption of soft drinks and high DMFT scores. These associations remained even after accounting for the reported concurrent consumption of other sugary foods and other confounding variables. The results of this study, which were published in 1984, debunk the view that only adhesive sugary foods are cariogenic. In fact, the authors of this landmark study cautioned dental professionals that in their approach to dental health education, they must not imply that sugary solutions are less cariogenic than sticky snacks, arguing that there may be no difference in their effective cariogenicity in a modern lifestyle. [8]

The cariogenicity of black cola drinks is, of course, ably demonstrated in animal caries models, which are used widely to quantify the cariogenicity of different foodstuffs. Such animal models also demonstrate that cola drinks cause dental erosion as well as dental caries, leading to "*devastation of the dentition*" [9]. Given that black cola drinks contain 10-12% sucrose, a direct comparison of them to 10% sucrose in water is rather informative. Such caries studies in animals show that, when matched for the same sucrose content, black cola drink is the much more cariogenic of the two liquids, a fact which is explained by the combination of sucrose with other ingredients in a low pH

vehicle. Dramatic caries is seen in such animal models within 2 weeks of continuous use of Coca Cola ™ [9] (Fig. 2).

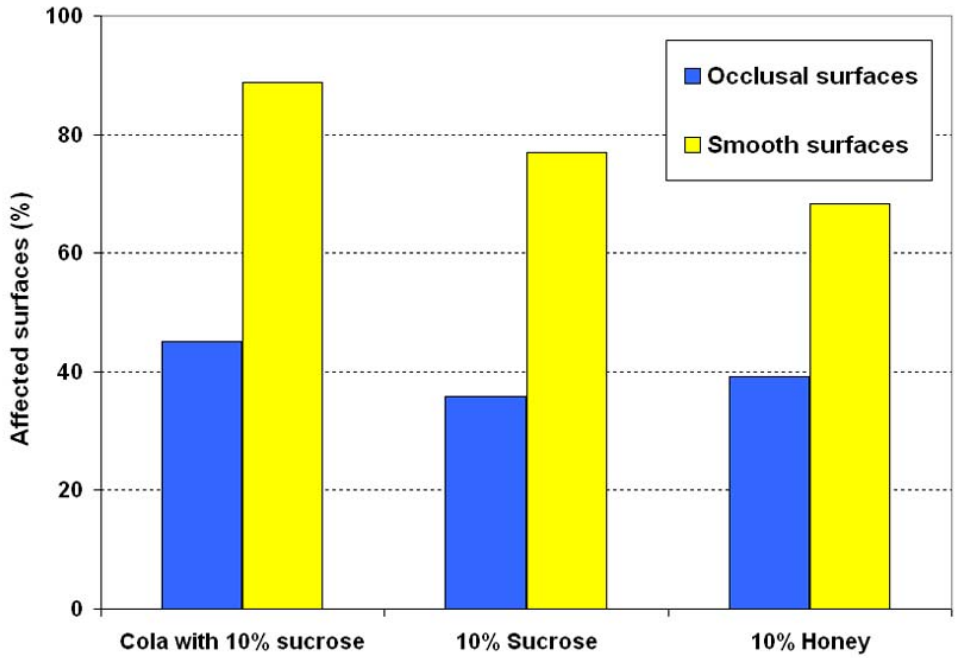

Fig. 2. Data from animal caries assessments of a black cola drink with 10% sucrose, water with 10% sucrose, and water with 10% honey. The vertical scale indicates the proportion of available occlusal surfaces (blue) or smooth surfaces (yellow) affected by dental caries after 2 weeks of continuous dietary intake. Note the higher cariogenicity of the cola drink. Based on data from Reference 7.

A high frequency of exposure to dietary acids will have ecological effects on the oral biofilm and can shift the supragingival oral flora toward aciduric microorganisms. As the intra-oral pH falls, the numbers and proportions of aciduric organisms such as mutans streptococci and Lactobacilli increase, and the proportions of acid-sensitive species fall. The reduction in pH caused by the drink not only enhances the competitiveness of cariogenic organisms, but also inhibits the growth and metabolism of non-caries-associated species [10].

Acids in black cola drinks and dental erosion

“Regular” black cola drinks contain orthophosphoric acid, which is labeled as “food acid 338”, while diet black cola drinks contain both orthophosphoric acid and citric acid (food acid 330). Lemon varieties of black cola drink contain orthophosphoric, citric and tartaric acid (food acid 334) [10].

It is well known that orthophosphoric acid will dissolve the protective pellicle layer deposited by saliva onto teeth, and will etch both enamel and dentine. This is aptly demonstrated in patients who swish black cola drinks for extended periods of time, and develop surface changes typical of acid etching (Fig. 3).

Citric acid sequesters calcium ions from saliva, preventing remineralization, etches dentine, and causes dental erosion. The combination of these various acids gives black cola drinks a low pH.

This is typically in the pH 2-3 range, depending on the drinks temperature and whether still gassed – since dissolution of carbon dioxide adds additional acid in the form of carbonic acid. More importantly, these various acids are effective buffers, giving the drinks high titratable acidity, and making their pH reducing effects in the mouth greater than the protective buffering actions of saliva. This explains why enamel and dentine hardness decrease after exposure to black cola softdrink, and erosion areas develop [10].

Fig. 3. Surface changes of labial enamel (etching and erosion) in a teenage patient who swishes black cola soft drinks around his mouth during the day.

There is an extensive literature on erosive effects of black cola drinks. Representative data for changes in enamel micro-hardness over hours (Fig. 4) and then days (Fig. 5), in the laboratory using enamel slabs confirm the often mentioned “tooth in a glass of black cola softdrink” type of experiment [11,12]. The enamel softening action is not inhibited if the teeth are first coated in salivary pellicle, since this protective layer is rapidly proteolyzed by the orthophosphoric acid to then expose the underlying enamel surface. Also noteworthy is that the softening action of these drinks is the same on the enamel of both primary and permanent teeth (Fig. 5).

The erosive effects relate to the various acids in the drink, rather than to caffeine or other components [13]. Soft drink pH (*i.e.*, initial pH) has been shown to be a causative factor in dental erosion, but it is not necessarily the primary initiating factor – this is where titratable acidity or buffering capacity becomes of greater importance. This ability of the soft drink to resist pH changes brought about by salivary buffering systems is normally assessed in the laboratory by measuring the amount of 0.1 M sodium hydroxide necessary for titration of the drink to pH levels of 5.0, 6.0, 7.0, and 8.0. Such assessments show that Coca-Cola “Classic” has a lower pH and a higher titratable acidity than Diet Coke [14].

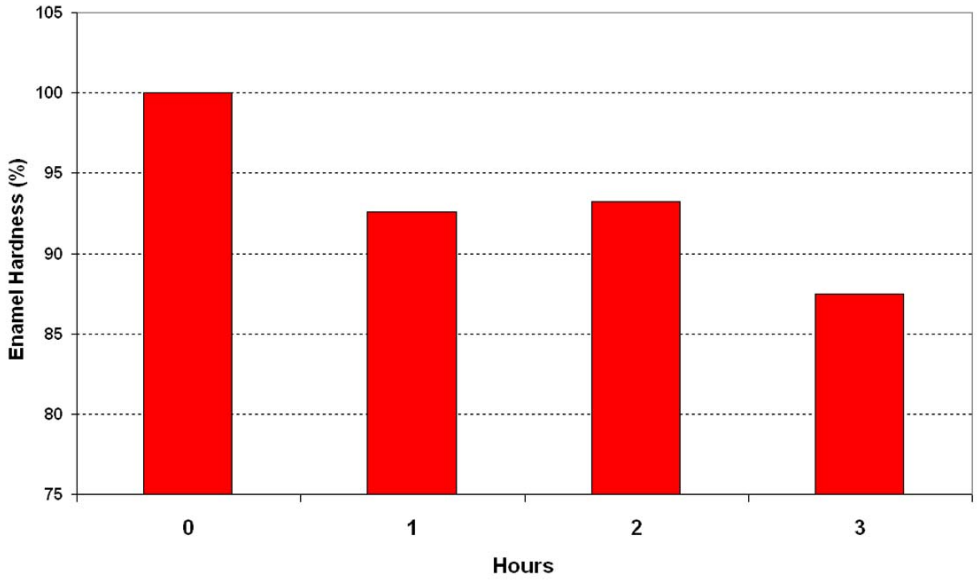

Fig. 4. Softening of enamel slabs over a 3 hour period of exposure to black cola softdrink. The vertical scale represents the hardness expressed as a percentage of the baseline value. Based on data from Reference 11.

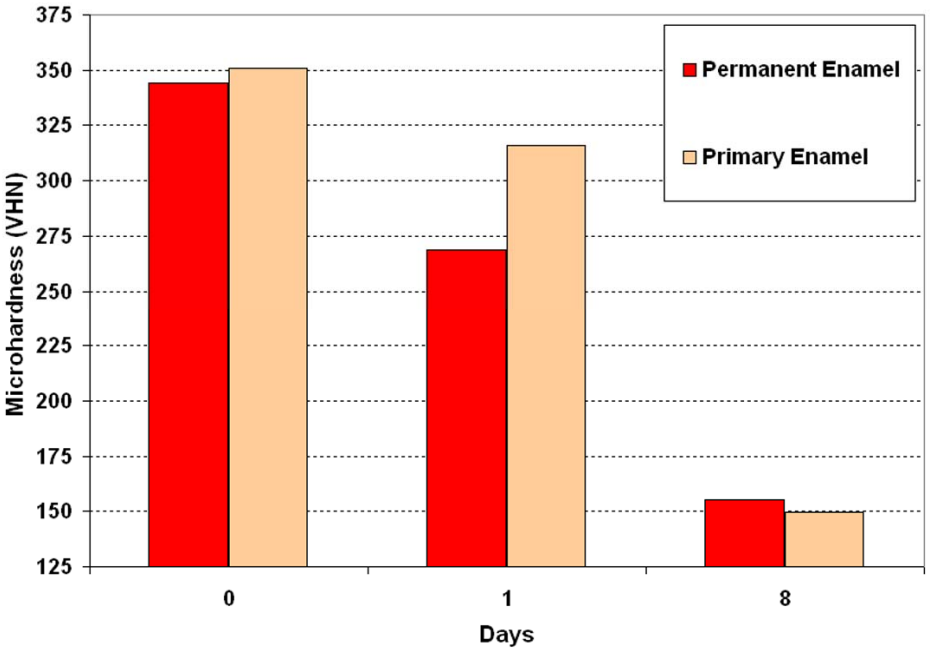

Fig. 5. Softening of enamel slabs over an 8 day period of intermittent exposure to black cola softdrink alternated with artificial saliva. The vertical scale represents the Vicker's hardness. Changes in both primary and permanent enamel hardness evident after 1 day worsen over the following week. Based on data from Reference 12.

Of particular concern, once mineral loss has occurred, even extended exposure to saliva appears unable to completely repair this. As an example of this, in the study of van Eygen *et al.*, [15] blocks of human enamel were immersed in Coca-Cola over 7 days at different frequencies: 1, 2, or 3 times per day for 20 minutes each, with each immersion followed by a 1 hour period with the block immersed in artificial saliva. Specimens in a fourth group were immersed for 1 minute in the soft drink followed by 3 minutes in artificial saliva, and this cycle repeated for 20 minutes to better simulate drinking habits. Control specimens remained in physiological serum at room temperature. Exposure to artificial saliva was unable to protect enamel from the erosive softening actions of the drink, regardless of the experimental protocol used. This raises concerns over even brief periods of intake to such drinks.

It must also be remembered that similar concerns of surface softening apply to dental restorative materials. As a typical example of this, in a recent study, specimens of dental materials were alternately immersed for 5 seconds in black cola drink and then in artificial saliva, for a total of 10 cycles. Baseline and post-immersion hardness tests showed that black cola soft drink significantly reduced surface hardness of microfilled composite and resin modified glass ionomer, as well as enamel and dentine [16].

Caffeine

Caffeine is the most widely used addictive substance in the world, and its inclusion into softdrinks is problematic since this will promote regular intake of such drinks to sustain caffeine levels at the "maintenance" intake level of 70 mg/day in an average size adult [17].

The reasons why caffeine is a popular material in the modern diet are well known. It increases wakefulness and mental alertness, giving a faster and clearer flow of thought. It has a stimulant action on the vasomotor and respiratory centres of the brain, improving physical performance by increasing cardiac contractility and output, dilating the coronary arteries, and relaxing bronchial smooth muscle [18].

Caffeine also increases secretion of gastric acid (worsening any underlying problems of gastric reflux), and increases urine output, giving a diuresis which can impact negatively on fluid balance and thus lower resting salivary flow, pH and buffer capacity, with consequential effects on oral health [10].

Because chronic high intake of caffeine through black cola drinks and other sources is associated with habituation and tolerance, sudden discontinuation of these drinks may produce a withdrawal syndrome. This needs to be borne in mind when advising patients to reduce their daily intake, which should be done gradually.

Some recent advertising material tries to downplay the significance of caffeine in black cola drinks, for example: "*MYTH: 'Coca-Cola' is packed with caffeine. The caffeine content in most soft drinks such as 'Coca-Cola', 'Diet Coca-Cola' and 'Coca-Cola Zero' is about one third the level found in the same amount of coffee and one half of the amount of caffeine that's in most teas. Caffeine is added to contribute to the complex flavour of some soft drinks and has been used for this purpose for more than 100 years*." [1] The comparison here is rather misleading, since the recognized levels of caffeine are 70 mg per 300 mL cup of instant coffee, 35 mg per 300 mL cup of tea, and 35-47 mg

per 375 mL can of black cola drink – figures which give a rather different impression of the relativity between these beverages. [10] Official figures for caffeine content from the United States Department of Nutritional Services are shown in Table 1.

Table 1. Typical caffeine content data for beverages

Coca Cola Classic (375 mL can)	**37 mg**
Diet Coke (375 mL can)	**47 mg**
Coke Zero (375 mL can)	**35 mg**
Pepsi Cola (375 mL can)	**38 mg**
Diet Pepsi (375 mL can)	**36 mg**
Regular instant coffee (cup)	**47-68 mg**
Drip filter coffee (cup)	**106-164 mg**
Black tea, 1 minute brew (cup)	**21-33 mg**

These official United States data are consistent with recently published analytical studies, such as Reference 38. For a useful history of the famous 1911 investigation of the behavioral effects of caffeine (known as the Chattanooga trial), see Reference 39. This psycho-pharmacological research was necessitated by a United States federal government lawsuit against the Coca-Cola Company for marketing a beverage with a deleterious ingredient, namely, caffeine.

General health issues

For black cola drinks, the combination of caffeine with erosive acids and either sucrose or artificial intense sweeteners raises a number of issues beyond an elevated risk of dental caries and dental erosion. What of the issue of reprogramming (raising) the threshold level for satisfaction of the desire for sweetness? What of the effect of excessive calories on weight gain, the risk of cravings for sweetness after using diet drinks, and the consequences from these in terms of obesity and related conditions such as type 2 diabetes mellitus? What of the possible effects on hard tissues other than teeth?

Osteoporosis

Soft drink consumption has increased rapidly in the general population in recent years. By so doing, it had tended to displace both water and nutrient-dense beverages such as milk from the diet. In addition to these “displacement” effects, there are several concerns regarding the direct effects of components of black cola drinks. Caffeine is a known risk factor for osteoporosis, [19-21] while orthophosphoric acid interferes with calcium absorption and can contribute to loss of calcium from long bones when consumed in modest amounts [22].

Concerns regarding the intake of black cola drink and bone problems have been expressed in the medical literature over the past 15 years. The seminal study of Wyshak and Frisch in 1994 [23] explored the association between carbonated beverage consumption and other nutritional factors, and the occurrence of bone fractures in teenagers (14-16 years of age) of both sexes, drawn from representative populations. The selection of teenagers is important because near-maximal or peak bone mass of the vertebrae and femurs is achieved at the completion of pubertal development. In teenage girls (but not boys), there was a strong association between cola beverage consumption and bone fractures [adjusted odds ratio 3.59; confidence interval 1.21-10.75], whereas a high intake of dietary calcium was protective. No association between non-cola drinks and bone fractures was

found, in either boys or girls. It was suggested at the time that high consumption of black cola beverages and a parallel declining consumption of milk were of public health significance for females because of their propensity to develop osteoporosis in later life. Later studies by others reached similar conclusions regarding cola drinks, lower bone mineral density (BMD) and fractures in adolescent girls [24,25].

It is now recognized broadly within medicine and dietetics that the trend towards a replacement of milk with cola and other soft drinks results in a low calcium intake, and that this may negatively affect bone health in both women and men. A recent study from Denmark [26] examined the impact of replacing milk with carbonated beverages in a group of young healthy men (22-29 years of age) on a low-calcium diet, and studied the effects of this replacement on calcium homeostasis and bone turnover. Subjects were given a low-calcium basic diet in two 10-day intervention periods, with an intervening 10-day washout. During one period, they drank 2.5 liters of Coca Cola per day, and during the other period 2.5 liters of semi-skimmed milk. An increase in serum levels of phosphate, parathyroid hormone and osteocalcin occurred in the cola period compared to the milk period, with greater bone resorption and increased bone turnover.

In addition to displacing healthier beverages such as milk, black cola soft drinks contain caffeine and orthophosphoric acid, both of which, as mentioned earlier, may adversely affect BMD. A recent study from Boston [27] measured BMD in the spine and at 3 hip sites in 1413 women and 1125 men. The mean intake of black cola drinks in the study cohort was 4-5 cans (servings) per week. Both regular and diet black cola soft drink intake were found to be associated with significantly lower BMD at each of the three hip site, but not in the spine, and these results related only to women, and not to men. No significant relationships between non-cola carbonated beverage consumption and BMD were found. Daily cola consumers had lower calcium-to-phosphorus ratios in their serum than non-consumers. While associations do not, of course, indicate causality, such results sustain ongoing concerns regarding intake of black cola drinks within a “normal” diet. The authors of the Boston study did not find evidence that rare or occasional use of carbonated beverages, including black cola drinks, was detrimental to bone, but cautioned in their conclusions that “*women who are concerned about osteoporosis may want to avoid the regular use of cola beverages*”.

In summary, in the Western world, increased consumption of carbonated soft drinks, particularly black cola drinks, combined with a decreasing intake of milk, may increase the risk of osteoporosis. Current recommendations are to limit the consumption of black cola beverages, for both men and women [28].

Changes in lifestyle and behaviour

Patients should avoid toothbrushing enamel which has been softened by exposure to black cola softdrinks which have been consumed immediately prior to brushing – since this may cause significant additional material loss due to toothbrush abrasion. The softening effect of such drinks is, however, rather prolonged. A typical example of the prolonged effect of a single drink of a black cola softdrink can be seen in the in vivo study of Kim *et al*., [29], in which bovine enamel slabs in intra-oral appliances were exposed to 100 mL of Pepsi-Cola (pH 2.41) for five minutes and subsequently exposed to the human intra-oral environment of health subjects through the appliances being worn for up to 48 hours (Fig. 6). As expected, the enamel micro-hardness values were reduced by the cola beverage, and then through the action of human saliva gradually increased over the next 48 hours, however even after this time they had still not reached their baseline value.

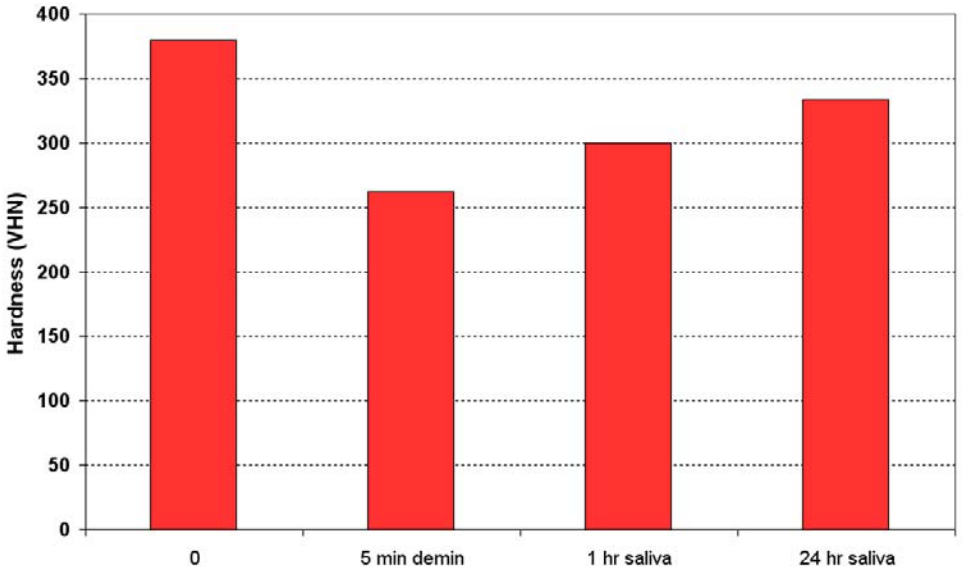

Fig. 6. Changes in enamel hardness immediately after a 5 minute exposure to black cola softdrink, and then following exposure to human saliva *in vivo* for 1 hour and then up to 24 hours. Based on data from Reference 29.

Having drinks through a straw will reduce but not dissipate all the dental concerns with these beverages. This advice is given on the Coca Cola web site [1], which states "*You can also reduce the amount of time your teeth are exposed by drinking through a straw.*"

It is worth remembering that drinks which are consumed slowly over a longer time period will warm from refrigerator temperature (nominally 4 degrees Celsius) to room temperature and then to body temperature. As this temperature increase occurs, enamel mineral loss per unit time will increase, and enamel hardness will decrease, approximately linearly with temperature [30] – simply because the rate of the chemical reactions involved with dental erosion increases with temperature.

The future – dentally safe drinks?

Chemical modifications to drinks that could ameliorate some of the above concerns would include removal of caffeine, reductions in the levels of acidity, replacement of sucrose with low glycaemic index non-cariogenic sucrose replacements such as Isomalt ™, and inclusion of ingredients which provide bio-available calcium to provide a net equilibrium of calcium gain when using drinks, to prevent both erosive and cariogenic actions. If it is possible to supplement beverages with as much as 40 mmol/L calcium and 30 mmol/L phosphate ion, then despite their pH being below the "critical pH" threshold, they should not erode the enamel and dentine, because the calcium and phosphate will saturate the drink with respect to apatite mineral.

Adding various inorganic calcium phosphate compounds is problematic because of their poor stability, relative insolubility and their limited contribution to bio-available calcium and phosphate levels. To achieve significant concentrations of these ions, a phosphor-protein stabilizer is essential. Casein phosphopeptide-stabilized amorphous calcium phosphate (CPP-ACP) can produce high levels of on bio-available calcium and phosphate [31], and would be an ideal agent for addition to black cola drinks and other beverages, because in soft drinks such as these with a pH below 3, erosion cannot be prevented by merely adding calcium or even fluoride compounds such calcium fluoride. Even total fluoride concentrations of up to 20 ppm will not prevent erosion by such beverages [32, 33].

There is evidence that adding CPP-ACP to a final level of 0.125% to erosive drinks can increase the pH, reduce the titratable acidity, provide bio-available calcium and phosphate, and prevent enamel erosion, but without affecting clarity or taste of the beverage. This has already been shown with sports drinks such as Powerade ™, where adding CPP-ACP reduced the beverage's erosivity without affecting its taste.[34] Until such drinks are developed commercially, it is useful to know that the application of CPP-ACP pastes (such as GC Tooth Mousse ™) can significantly harden tooth structure that has been softened by cola drinks [35] This therapeutic effect is much greater than that seen with stimulated saliva, milk, or hard cheese [36,37].

References

1. http://www.coca-cola.com.au/pemberton/Myths.html

2. http://www.makeeverydropmatter.com.au/

3. Shenkin JD, Heller KE, Warren JJ, Marshall TA. Soft drink consumption and caries risk in children and adolescents. *Gen Dent*. 2003;51:30-6.

4. Dye BA, Shenkin JD, Ogden CL, Marshall TA, Levy SM, Kanellis MJ. The relationship between healthful eating practices and dental caries in children aged 2-5 years in the United States, 1988-1994. *J Am Dent Assoc*. 2004;135:55-66.

5. DiMeglio DP, Mattes RD. Liquid versus solid carbohydrate: effects on food intake and body weight. *Int J Obes Relat Metab Disord* 2000;24:794-800.

6. American Academy of Pediatrics Committee on School Health. Soft drinks in schools. *Pediatrics.* 2004;113:152-4.

7. Heller KE, Burt BA, Eklund SA. Sugared soda consumption and dental caries in the United States. *J Dent Res* 2001;80:1949-53.

8. Ismail AI, Burt BA, Eklund SA. The cariogenicity of soft drinks in the United States. *J Am Dent Assoc*. 1984;109:241-5.

9. Bowen WH, Lawrence RA. Comparison of the cariogenicity of cola, honey, cow milk, human milk, and sucrose. *Pediatrics* 2005;116;921-926.

10. Walsh LJ. Lifestyle impacts on oral health. In Mount GJ, Hume WR. *Preservation and restoration of tooth structure*, 2nd edition. Brisbane: Knowledge Books and Software, 2005.

11. Devlin H, Bassiouny MA, Boston D. Hardness of enamel exposed to Coca-Cola and artificial saliva. *J Oral Rehabil.* 2006;33:26-30.

12. Maupomé G, Aguilar-Avila M, Medrano-Ugalde H, Borges-Yáñez A. *Caries Res.* 1999;33(2):140-7. *In vitro* quantitative microhardness assessment of enamel with early salivary pellicles after exposure to an eroding cola drink. *Caries Res.* 1999;33:140-7.]

13. Kitchens M, Owens BM. Effect of carbonated beverages, coffee, sports and high energy drinks, and bottled water on the in vitro erosion characteristics of dental enamel. *J Clin Pediatr Dent.* 2007;31:153-9.

14. Owens BM. The potential effects of pH and buffering capacity on dental erosion. Owens BM. *Gen Dent.* 2007;55:527-31.

15. Van Eygen I, Vannet BV, Wehrbein H. Influence of a soft drink with low pH on enamel surfaces: an *in vitro* study. *Am J Orthod Dentofacial Orthop*. 2005;128:372-7.

16. Wongkhantee S, Patanapiradej V, Maneenut C, Tantbirojn D. Effect of acidic food and drinks on surface hardness of enamel, dentine, and tooth-coloured filling materials. *J Dent.* 2006;34:214-20.

17. Watson JM, Lunt MJ, Morris S, Weiss MJ, Hussey D, Kerr D. Reversal of caffeine withdrawal by ingestion of a soft beverage. *Pharmacol Biochem Behav*. 2000;66:15-18.

18. Barone JJ, Roberts HR. Caffeine consumption. *Food Chem Toxicol*. 1996;34:119-129.

19. Massey LK, Whiting SJ. Caffeine, urinary calcium, calcium metabolism and bone. *J Nutr* 1993; 123: 1611–4.

20. Hernandez-Avila M, Stampfer MJ, Ravnikar VA, et al. Caffeine and other predictors of bone density among pre- and perimenopausal women. *Epidemiology*. 1993;4:128-34.

21. Rapuri PB, Gallagher JC, Kinyamu HK, Ryschon KL. Caffeine intake increases the rate of bone loss in elderly women and interacts with vitamin D receptor genotypes. *Am J Clin Nutr*. 2001;74:694-700.

22. Amato D, Maravilla A, Montoya C, et al. Acute effects of soft drink intake on calcium and phosphate metabolism in immature and adult rats. *Rev Invest Clin. 1998;50:185-9.*

23. Wyshak G, Frisch RE. Carbonated beverages, dietary calcium, the dietary calcium/phosphorus ratio, and bone fractures in girls and boys. *J Adolesc Health*. 1994;15:210-5.

24. McGartland C, Robson PJ, Murray L, et al. Carbonated soft drink consumption and bone mineral density in adolescence: the Northern Ireland Young Hearts project. *J Bone Miner Res*. 2003; 18: 1563–9.

25. Whiting SJ, Healey A, Psiuk S, Mirwald R, Kowalski K, Bailey DA. Relationship between carbonated and other low nutrient dense beverages and bone mineral content of adolescents. *Nutr Res.* 2001; 21: 1107–15

26. Kristensen M, Jensen M, Kudsk J, Henriksen M, Mølgaard C. Short-term effects on bone turnover of replacing milk with cola beverages: a 10-day interventional study in young men. *Osteoporos Int.* 2005;16:1803-8.

27. Tucker KL, Morita K, Qiao N, Hannan MT, Cupples LA, Kiel DP. Colas, but not other carbonated beverages, are associated with low bone mineral density in older women: The Framingham Osteoporosis Study. *Am J Clin Nutr*. 2006;84:936-42.

28. Root AW. Bone strength and the adolescent. *Adolesc Med*. 2002;13:53-72.

29. Kim JW, Jang KT, Lee SH, Kim CC, Hahn SH, García-Godoy F. *In vivo* rehardening of enamel eroded by a cola drink. *ASDC J Dent Child*. 2001;68:122-42.

30. Barbour ME, Finke M, Parker DM, Hughes JA, Allen GC, Addy M. The relationship between enamel softening and erosion caused by soft drinks at a range of temperatures. *J Dent*. 2006;34:207-13.

31. Reynolds EC. Calcium phosphate-based remineralization systems: scientific evidence? *Aust Dent J*. 2008;53:268-73.]

32. Larsen MJ. Prevention by means of fluoride of enamel erosion as caused by soft drinks and orange juice. *Caries Res*. 2001;35:229-34.

33. Larsen MJ, Richards A. Fluoride is unable to reduce dental erosion from soft drinks. *Caries Res.* 2002;36:75-80.

34. Ramalingam L, Messer LB, Reynolds EC. Adding casein phosphopeptide-amorphous calcium phosphate to sports drinks to eliminate in vitro erosion. *Pediatr Dent.* 2005;27:61-7.

35. Tantbirojn D, Huang A, Ericson MD, Poolthong S. Change in surface hardness of enamel by a cola drink and a CPP-ACP paste. *J Dent*. 2008;36:74-9.

36. Gedalia I, Ionat-Bendat D, Ben-Mosheh S, Shapira L.Tooth enamel softening with a cola type drink and rehardening with hard cheese or stimulated saliva *in situ. J Oral Rehabil.* 1991;18:501-6.

37. Gedalia I, Dakuar A, Shapira L, Lewinstein I, Goultschin J, Rahamim E. Enamel softening with Coca-Cola and rehardening with milk or saliva. *Am J Dent.* 1991;4:120-2.

38. Chou KH, Bell LN. Caffeine content of prepackaged national-brand and private-label carbonated beverages. *J Food Sci.* 2007; 72:C337-42.

39. Benjamin LT, Rogers AM, Rosenbaum A. Coca-Cola, caffeine, and mental deficiency: Harry Hollingworth and the Chattanooga trial of 1911. *J Hist Behav Sci* 2006;27:42-55.