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The Erosive Potential of Some Flavoured Waters

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ABSTRACT

Objectives: To assess the erosive potential of a number of readily available flavoured waters in the laboratory.

Methods: The erosive potential was assessed by measuring the pH, neutralisable acidity and ability to erode enamel. These were compared to an orange juice positive control.

Results: The pH of the flavoured waters ranged from 2.64-3.24 with their neutralisable acidity ranging from 4.16-16.30 mls of 0.1M NaOH. The amount of enamel removed following 1-hour immersion in the drinks ranged from 1.18-6.86 microns. In comparison, the orange juice control had a pH of 3.68, a neutralisable acidity of 19.68 mls of 0.1 M NaOH and removed 3.24 microns of enamel.

Conclusions: Many of the flavoured waters tested were found to be as erosive as orange juice. This information will be of use to clinicians when counselling patients with tooth surface loss. (Eur J Dent 2007;1:5-9)

Key words: Dental erosion; Dental enamel; Non-carious tooth surface loss

INTRODUCTION

Dental erosion is defined as an irreversible loss of dental hard tissues due to a chemical process without the involvement of microorganisms.[1] This process may be caused by extrinsic or intrinsic agents. Extrinsic agents include acidic food stuffs, beverages, snacks or following environmental exposure to acidic agents.[2,3] Intrinsic causes are associated with gastric acid and may present intra-orally following vomiting, regurgitation, gastro-oesophageal reflux or rumination.[4]

The evidence linking erosion with diet is based on a number of case reports and a few epidemiological studies. Millward et al[5] examined 101 school children and found a high level of erosion associated with the consumption of soft drinks, particularly carbonated beverages. Jarvinen et al[6] carried out the only case-controlled study and found that the risk for erosion was increased if citrus fruit was consumed more than twice daily or if sports drinks were consumed more than once a week.

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Sales of soft drinks within the UK have increased over seven fold since 1950[7] and Coca-Cola® is the biggest selling brand in the UK today, while Pepsi-Cola® is the eighth biggest brand.[8] Sales of mineral waters have also increased rapidly over the last decade in a similar fashion to soft drinks. Recently manufacturers have introduced flavoured waters to the market and this sector has grown rapidly with 25% of adults in the UK consuming these drinks.[9] The term flavoured water is a misnomer as under bottled water regulations nothing can be added to water, except carbon dioxide for carbonated bottled waters. As soon as any additional ingredient is added, whether it is a colour, flavour or sweetener then the product becomes a soft drink.[10] However, for the sake of clarity the term 'flavoured water' will be used throughout this article as it is in common usage.

The pH of still mineral waters has been found to be close to neutrality, while the pH of carbonated water is slightly more acidic at around 5.2.[11] The effect of still and carbonated mineral water on powdered enamel has been assessed using spectroscopy.[11] It was found that these drinks had little erosive effect on enamel and carbonated water produced a slightly greater dissolution effect compared to still water, but this is very unlikely to be of clinical significance.

The pH of some flavoured waters were found to be more acidic than plain still or carbonated waters, with a pH of around 3.3.[11] However, the effect of these drinks on enamel was not assessed.

The aim of this study was to compare a number of commercially available flavoured waters and compare these with orange juice. The hypothesis used in this study was that the flavoured waters would not be more erosive than orange juice.

MATERIALS AND METHODS

The flavoured waters chosen for inclusion in this study are listed in Table 1. These drinks were chosen as they were readily available to the public. Three of the drinks were carbonated and these are indicated with an asterix in Table 1. The remaining drinks were still water products with no carbonation.

Initial pH

The pH of each of the drinks was tested using an electronic pH meter (Model 701A, Orion Research Inc., Waltham, MA, USA) at 37°C on a heated magnetic stirrer. The pH meter was calibrated using test solutions of known pH (Fisher Scientific International, Loughborough, UK) before testing the drinks. Each drink was tested using five different samples.

Neutralisable acidity

The neutralisable acidity of each drink was tested by placing 20 mls of the drink in a glass beaker placed in a thermostatically controlled water bath held at 37°C. 0.1M sodium hydroxide solution was gradually added to the drink sample and the pH rise was continuously monitored until the pH increased to neutrality. Each sample was stirred continuously as the solution of sodium hydroxide was added. The volume of sodium hydroxide required to increase the pH of the sample to neutrality was noted; this was repeated five times for each drink.

Enamel erosion

All measurements of enamel loss were made using profilometry according to the method of West.[12] The source of enamel was extracted unerupted third molar teeth from individuals residing in a region with unfluoridated drinking water. Thus the level of fluoride incorporation into enamel was anticipated to be low, but was not further characterised. The specimens were sectioned longitudi-

Table 1. Drink contents according to manufacturers' information.

Flavoured water	Contents
Volvic Touch of Fruit still lemon and lime	Mineral water (92%), sugar, citric acid, lemon and lime natural flavours
Boots Shapers still cranberry juice spring water	Spring water, apple juice from concentrate (13.5%), cranberry juice from concentrate (6.5%), citric acid, flavourings, preservatives(E242, potassium sorbate, sodium benzoate), stabiliser (E466), sweeteners (sucralose), anti-oxidant (ascorbic acid), colour (anthocyanins), Vitamins E, B3, B6 and B12
Boots Shapers sparkling cloudy lemonade spring water*	Carbonated spring water, lemon fruit from concentrate (3%), lemon juice from concentrate (1%), citric acid, flavourings, preservatives (potassium sorbate, sodium benzoate, sulphur dioxide), sweeteners (sucralose, acesulfame K)
Boots Shapers still Floridian orange juice spring water	Carbonated spring water, Floridian orange juice from concentrate (18%), fruit from concentrate (2.5%), citric acid, flavourings, preservatives (E242, potassium sorbate, sodium benzoate), sweetener (sucralose), vitamins C, E and A
Volvic Touch of Fruit still orange and peach	Mineral water (92%), sugar, citric acid, orange and peach natural flavours
Waitrose grapefruit spring water drink*	Carbonated spring water, grapefruit juice from concentrate, fructose, citric acid, flavourings, sweetener (aspartame), preservative (sodium benzoate)
Bottlegreen presselight elderflower*	Carbonated spring water, cane sugar, elderflowers, citric acid, ascorbic acid, preservative (sodium benzoate), sweetener (aspartame)

* indicates carbonated drink

nally and embedded in a low exotherm epoxy resin (Stycast 1266, Emerson & Cuming, Westerlo, Belgium). The outer surface of the enamel samples were lightly ground with first 600-grit and then 1200-grit abrasive discs (Kemet International Ltd., Parkwood Trading Estate, Maidstone, Kent) to produce a flat surface. Three baseline readings using a profilometer (Planer Products Ltd., Sunbury on Thames, UK) were recorded for each enamel sample. Only samples with a stylus deflection of less than an average ± 0.30 µm deflection were used in the study. The diamond stylus had a tip radius of 20 µm with a head velocity of 10 mm/min. The force of the stylus varied linearly with deflection at a rate of 8 mg/µm up to a maximum of 1 g at 100 µm.

After baseline profiles were determined in duplicate, enamel samples were taped to expose a 2 mm width of enamel (approximate enamel area of 10 mm^2). Five enamel specimens were exposed to 250 mls of each drink and stirred in a thermostatically controlled water bath at 37°C for one hour. Following exposure, the enamel specimens were rinsed in water, dried and the tapes removed. Surface enamel loss was measured on the profilometer in triplicate, with the amount of enamel loss recorded in micrometers. Averages were calculated from triplicate measurements.

Five enamel specimens were also immersed in Tropicana™ brand orange juice for one hour as a positive control and in distilled water as a negative control.

Statistical analysis of the results for pH, neutralisable acidity and enamel erosion was carried out using analysis of variance followed by Tukey's test. The threshold for statistical significance was set at P<.05.

RESULTS

The results for the initial pH values are given in Table 2. The pH of the flavoured waters tested ranged from 2.64-3.24 compared to a value of 3.68 for orange juice.

The results for the neutralisable acidity values are given in Table 2. These values ranged from 4.16 mls for Volvic Touch of Fruit Still Orange and Peach to 16.30 mls for Boots sparkling cloudy lemonade spring water. The positive control orange juice had the highest neutralisable acidity value of 19.68 mls.

The amount of enamel lost following immersion in the various drinks tested is shown in Table 2. The amount of enamel removed, ranged from 1.18 to 6.86 µm. In comparison, the orange juice positive control produced a mean surface loss of 3.34 µm. Two drinks produced significantly lower levels of enamel erosion; Volvic orange and peach and the elderflower drink. The values for the Volvic orange and peach were significantly lower than Volvic lemon and lime (P<.01), cranberry (P<.001), Boots lemonade (P<.05), Boots orange juice (P<.001) and Waitrose grapefruit (P<.005).

The values for the elderflower drink were significantly lower than the Volvic lemon and lime (P<.001), cranberry (P<.001), Boots lemonade (P<.001) and Boots orange juice (P<.001).

DISCUSSION

The pH values for all the flavoured waters tested fell within a narrow band of 2.64-3.24 and all were slightly more acidic than the control orange juice. Although the values were numerically similar it must be remembered that pH is a logarithmic scale, so that small changes in pH values equate to larger changes in the hydrogen ion concentration. Previous studies have shown that the pH values of both still and carbonated bottled wa-

Table 2. Initial pH value, neutralisable acidity and enamel erosion values (SD in parentheses).

Drink	pH	Neutralisable acidity (mls)	Enamel erosion (microns)
Volvic Touch of Fruit still lemon and lime	2.64 (0.05)	7.20 (0.18)	5.00 (1.16)
Boots Shapers still cranberry juice spring water	3.14 (0.05)	11.02 (0.07)	6.86 (1.20)
Boots Shapers sparkling cloudy lemonade spring water	2.78 (0.04)	16.30 (0.09)	6.29 (0.35)
Boots Shapers still Floridian orange juice spring water	3.24 (0.05)	11.6 (0.22)	5.34 (2.46)
Volvic Touch of Fruit still orange and peach	2.82 (0.07)	4.16 (0.10)	2.01 (0.54)
Waitrose grapefruit spring water drink	2.74 (0.05)	14.04 (0.16)	4.43 (0.96)
Bottlegreen presselight elderflower	3.04 (0.05)	13.62 (0.27)	1.18 (0.14)
Tropicana natural orange juice	3.68 (0.04)	19.68 (0.31)	3.24 (0.62)

ters lie close to neutrality[10,11] but the much more acidic values found in this study of less than 3.5 suggest that flavoured waters are potentially more erosive than their non-flavoured counterparts. Furthermore, the critical pH below which enamel begins to erode significantly is 4.5.[13] This is presumably due to the addition of fruit extracts as flavouring agents. These are high in naturally occurring fruit acids, such as citric acid, used as flavouring agents. Some manufacturers also add citrate based compounds to enhance the shelf life and this adds to the acidic burden of these drinks.

However, pH measurement of a drink does not give the whole picture[14] and one must also consider the neutralisable acidity which gives a measure of all the free hydrogen ions available to cause erosion. The neutralisable acidity values of the flavoured waters varied more widely from 4.16 mls of 0.1M NaOH for Volvic still orange and peach to 16.3 mls for Boots cloudy lemonade spring water drink. The reasons for this wide variation in these values are not immediately obvious and it is difficult to form an informed opinion as the product labelling does not give any percentages or concentrations for the components of the drinks. In comparison, the neutralisable acidity of the control orange juice was slightly higher than any of the flavoured waters tested at 19.68 mls.

The range of values for the neutralisable acidity of the flavoured waters is broadly comparable to other drinks that have been evaluated including white wine, alcopops and fruit teas (Table 3).

The values for the enamel erosion also varied quite widely from 1.18 μm for the elderflower product to 6.28 μm for the lemonade based product and 6.86 μm for the cranberry based product. These values probably reflect the amount of naturally occurring fruit acids in the parent product. Elderflowers do not have a high concentration of fruit acids (Table 4), whereas lemons and cranberries both have large amounts of citric acid and it is this that probably accounts for the large amounts of erosion recorded.

Table 3. Neutralisable acidity values of other types of drinks.

Drink	Neutralisable acidity (mls 0.1M NaOH)
Alcopops[19]	15.4 - 23.1 mls
White wine[20]	9.4 - 27.1 mls
Ciders[21]	14.5 - 21.5 mls
Fruit teas[22]	3.5 - 60.3 mls
Sports drinks[23]	9.7 – 13.4 mls

Table 4. Concentration of malic and citric acids found in various fruit juices (mg per 100 gms of fruit) .[24]

Fruit juice	Malic acid	Citric acid	Total acid content
Cranberry	100	1560	15
Grapefruit	0	1460	1460
Lemon	290	6080	6370
Orange	Trace	980	980
Elderflower	66	0	66

The positive control, orange juice, removed 3.24 μm of enamel and this is typical of most orange juices that tend to remove 3-4 μm of enamel in one hour in a laboratory test.

Apart from the elderflower product and Volvic orange and peach, all the other flavoured waters were capable of producing large amounts of enamel erosion. However, the erosion results of this study must be interpreted with a certain degree of caution as clinically the enamel surface will be covered by a protective pellicle and/or plaque layer and the tooth surface will also be subject to the flushing, buffering and remineralising effects of saliva.[15,16] A further factor to consider is the clearance rates of these drinks from the mouth.[17] Oral clearance of drinks may well be related to their viscosity[17] and although this was not measured in this study, being water based, these drinks had a low viscosity.

Finally, this study was deliberately carried out at 37°C to allow comparison with previous work (Table 3). However, these sports drinks are usually consumed cold at around 5°C and the drinks will therefore have fewer dissociated H^+ ions and therefore produce less erosion.[18]

CONCLUSIONS

In spite of the limitations of this simple in vitro study, many of these flavoured waters may contribute to erosion in patients who are either susceptible to erosion or use these drinks on a daily or more regular basis.

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