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Food acid content and erosive potential of sugar-free confections

ABSTRACT (200 words)

Background: Dental erosion is an increasingly prevalent problem associated with frequent consumption of acidic foods and beverages. The aim of this study was to measure the food acid content and the erosive potential of a variety of sugar-free confections.

Methods: Thirty sugar-free confections were selected and extracts analysed to determine pH, titratable acidity, chemical composition and apparent degree of saturation with respect to apatite. The effect of the sugar-free confections in artificial saliva on human enamel was determined in an *in vitro* dental erosion assay using change in surface microhardness.

Results: The change in surface microhardness was used to categorise the confections as high, moderate or low erosive potential. Seventeen of the thirty sugar-free confections were found to contain high concentrations of food acids, exhibit low pH and high titratable acidity and have high erosive potential. Significant correlations were found between the dental erosive potential (change in enamel surface microhardness) and pH and titratable acidity of the confections. Ten of these high erosive potential confections displayed dental messages on the packaging suggesting they were safe for teeth.

Conclusions: Many sugar-free confections, even some with “Toothfriendly” messages on the product label contain high contents of food acids and have erosive potential.

Key words: sugar-free confections; candies; food acid; acidity; dental erosion

INTRODUCTION

Dental erosion is the chemical loss of tooth structure due to acids and/or chelators that are not produced by bacteria [1]. Recent epidemiological data suggest that the prevalence of dental erosion has been increasing [2]. This has been attributed to frequent exposure of the teeth to intrinsic (gastric acid) or extrinsic erosive agents such as soft drinks and sports drinks due to their high acid content [3]. Food acids are a common ingredient in modern processed foods as manufacturers frequently add them to foods and beverages to improve their organoleptic properties and shelf life. Some of the various acidulants frequently used include acetic, citric, phosphoric, fumaric, lactic, malic, tartaric and ascorbic acid [4].

Confections may also contain food acids [5], typically used to enhance flavour and provide a “tangy” or “fruity” taste [4]. Confections are considered deleterious for oral health due to their sugar content, but many sugar-free confections are now available that contain sugar substitutes such as polyols that cannot be easily fermented by bacteria [6]. These sugar-free confections can stimulate saliva which may assist in preventing the initiation or progression of dental caries [7, 8]. However, newer varieties of these sugar-free confections have been developed containing a blend of food acids with novel “fruit” flavours. The acid content of some of these sugar-free confections appears very high and may therefore increase the risk of dental erosion [5, 9]. Concern has recently been raised about the use of sugar-free confections in an article titled "are sugar-free confections really beneficial?"[6].

There are a range of sugar-free confections available to the public. Some of these display "Toothfriendly" logos or messages suggesting that they are safe for teeth [10]. However, these products may contain calcium-chelating food acids (e.g. citric acid) which if consumed frequently may cause dental erosion, particularly in individuals with poor quality saliva. This is of particular importance given the aging population and the increase in the number of people who suffer from problems with saliva production and/or quality [11]. The aim of this study was to determine the erosive potential of a range of commercially available sugar-free confections.

MATERIALS AND METHODS

Confection selection, preparation and analysis

A range of commercially available confections (n = 30) was purchased for analysis (Table 1). Three different samples of each confection were individually weighed then dissolved overnight in 40 mL of distilled deionised water to approximate the testing protocol of Toothfriendly International [10]. Subsequently, the pH of the mixture was determined and the titratable acidity (TA) measured using a TitraLab titration manager (TIM 856, Radiometer Analytical, France). Values for titratable acidity were determined as described previously and expressed as mmol of OH^- required to adjust the pH of 1 L of dissolved confection [12].

The chemical composition of the confections was determined using an automatic ion chromatography system (Dionex Corporation, CA, USA) equipped with two columns for both cation (IonPac CS12) and anion (IonPac AS18) analysis using two conductivity detectors (ICS3000). The ions that were measured were calcium, inorganic phosphate, sodium, chloride, fluoride and citrate. These ion concentrations were used in an iterative computational procedure with the expanded Debye-Huckel equation to calculate ion activity fugacities [9]. The ion activities were then used to determine the apparent ion activity product (IAP) for hydroxyapatite (HA). The solubility product (Ksp) for HA [13] and the respective IAP were then used to determine the degree of saturation with respect to HA using the equation: $DS = (IAP/Ksp),^{1/n}$ where *n* equals the number of ions in a unit cell. In determining the degree of saturation of the dissolved confection, if phosphate was not detected the value of the lowest ion chromatography phosphate standard was used taking into account the dilution factor of the samples (30 µM).

Determination of erosive potential

Ninety human third molars extracted due to impaction were collected with informed patient consent and ethics approval (HREC # 1136929) and sectioned into enamel blocks embedded in epoxy resin as described previously [12]. Test confections were then dissolved completely overnight in 40 ml of artificial saliva (AS). The AS consisted of 50 mM NaCl, 0.5 mM $CaCl_2$ and 0.5 mM Na_2HPO_4. Ten ml of this confection solution was then exposed to an enamel block for 30 min at room temperature on a flatbed shaker oscillating at 120 rpm. Surface softening was determined by measuring the percentage change in enamel surface microhardness (%ΔSMH) using a Knoop microhardness tester (402 MVD, Wolpert Wilson, Germany, 50 g, 10-second dwell) through indentation of sound and exposed enamel of each block in triplicate as described by Cochrane *et al*. [12].

Statistical analyses

Change in surface microhardness (%ΔSMH) was compared across the 30 confections to determine which differences were statistically significant. The data were transformed using a Box-Cox transformation and the distribution of residuals was checked using Q-Q plots. Heterogeneity of variance of residuals was checked using Levene's test. A one-way ANOVA was performed to compare %ΔSMH across all 30 confections. As the variances of the residuals were heterogeneous, the Brown-Forsythe statistic was used to test for the overall differences in mean %ΔSMH values between all confections and the differences between mean values for each of the 30 confections were measured using a *post hoc* Dunnett T3 test. The relationships between pH, TA at pH 5.5 and TA at pH 7.0 with %ΔSMH were investigated using scatter plots and the strength of the correlations was determined using the Pearson product-moment correlation coefficient. All statistical tests were performed using SPSS version 22 (IBM SPSS Inc. Chicago IL, USA.) and Box-Cox transformations were performed using Minitab version 17 (Minitab Inc. State College PA, USA).

RESULTS

The confections purchased for analysis are shown in Table 1. Of the 30 confections, 19 had an acid listed in their ingredients with 15 of those having the acid listed as one of the first three ingredients. Fourteen confections out of the 30 had dental messages with 10 having "Toothfriendly" logos, 3 having the message "Sugarfree for healthy teeth" and 1 having the "Kind to teeth" logo.

Food acid content and acidity of the confections

The pH, titratable acidity and citric acid/citrate content for each confection are shown in Table 2. Twenty of the confections had a pH below 4.5 with those containing food acids exhibiting the lowest pH (2.99 ± 0.49). All confections contained detectable calcium but most had undetectable levels of phosphate or fluoride. Of those listing citric acid as an ingredient all but one (Sweet Enough Lemon) were found to contain substantial levels of citrate. Twenty-eight of the 30 confection solutions were undersaturated with respect to HA (Table 2).

Erosive potential of the confections

The erosive potential of the confections was confirmed in an *in vitro* erosion assay. Enamel surface softening after exposure to the 30 sugar-free confections in artificial saliva was determined by measuring the percentage change in enamel surface microhardness (%ΔSMH) and the results are presented in Table 2. The mean hardness of the enamel samples before exposure to the thirty sugar-free confections was 339.86 ± 28.13 $g_f.mm^{-2}$. Confections with high and low mean %ΔSMH values that were significantly different ($p < 0.05$) were categorised as having high and low erosive potential, respectively (Table 2). Confections that had %ΔSMH values that were intermediate and not significantly different to the %ΔSMH values for confections with high and low %ΔSMH values were categorised as moderate erosive potential. Of the thirty sugar-free confections seventeen caused the enamel hardness to decrease by approximately 24% to 52% (high erosive potential) and three caused the enamel hardness to decrease by approximately 10% to 17% (moderate erosive potential). Ten sugar-free confections produced no significant change (< 8%) in surface microhardness (low erosive potential). Significant correlations were found between %ΔSMH and pH (-0.892, $p < 0.001$); between %ΔSMH and TA pH 5.5 (0.817, $p < 0.001$); and between %ΔSMH and TA pH 7.0 (0.829, $p < 0.001$).

Sugar-free confections with "Dental Messages"

Of the 30 sugar free confections, 3 had "Sugarfree for healthy teeth" messages. These three confections; Extra Drops (Wild Berry, Lemon and Watermelon) produced changes in surface microhardness (%ΔSMH) of 35.60 ± 4.77%, 41.88 ± 18.61% and 48.68 ± 4.96% respectively, so were all considered to exhibit a high erosive potential. Ten of the confections displayed a "Toothfriendly" logo. Six of these confections produced changes in surface microhardness (%ΔSMH) of 24.40 ± 4.15% to 44.57 ± 9.27%, so were also considered to exhibit a high erosive potential. One sugar-free confection (Kaiser) displayed a "Kind to teeth" logo. This confection had a pH of 2.72 and produced a change in surface microhardness (%ΔSMH) of 35.85 ± 12.09% so was also considered to exhibit a high erosive potential.

DISCUSSION

This study found that many of the commercially-available sugar-free confections contained food acids. Of the 30 sugar-free confections, 19 had food acids listed as ingredients with citric acid, malic acid or fruit juice extracts being the most commonly added. These acids were labelled in a variety of ways that can make identification difficult to consumers as they could be listed as food acids, acidity regulators, antioxidants or fruit concentrates (Table 1). For example Jols Pastilles Blackcurrant listed acidity regulator (330), black current fruit concentrate (0.8%) and antioxidant (300) which correspond to citric acid, a combination of citric acid, malic and ascorbic acids [14], and malic acid respectively. Overall the majority (20) of confections had a pH below 4.5. The acid content of foods and beverages has previously been linked to erosion [15]. In addition, citrate/citric acid can be of concern to the oral environment as citrate can reduce calcium activity by chelation and produce erosion at higher pH [9, 16]. Taking into account the citrate, calcium, inorganic phosphate, pH and ionic strength the apparent degree of saturation of HA was below 1 in nearly all cases, indicating that most of these confection solutions were undersaturated with respect to HA and so may have erosive potential. In addition, the TA of most confection solutions was high, indicating that they may resist the buffering effects of saliva [17]. Despite this, 14 of the 30 sugar-free confections had some form of labelling that contained a positive dental message. The Toothfriendly Logo was present on 10 of the confections, three had the message that they were "Sugarfree for healthy teeth" and one had a "Kind to teeth" logo. Only three of the confections with a dental friendly message produced a solution that had a pH above 4.5. The average solution pH of the confections with: 1) the Toothfriendly Logo was 3.93 ± 1.05; 2) the message "Sugarfree for healthy teeth" was 2.52 ± 0.13; and 3) the "Kind to teeth" logo was 2.72. Therefore, while not containing sugars to increase the risk of dental caries some of these confections may increase the risk of dental erosion particularly when consumed frequently and by individuals with compromised salivary function.

To further investigate the erosive potential of the confections their ability to soften human molar enamel was determined when dissolved in artificial saliva. Of the 30 sugar-free confections 17 produced changes in enamel surface microhardness of 24% to 52% and were considered of high erosive potential, and 3 caused changes of 10% to 17% and were considered of moderate erosive potential. Only 10 of the 30 sugar-free confections produced no change or little change in surface microhardness (low erosive potential).

It is worth noting that the three sugar-free confections (i.e. Extra Drops Wild Berry, Lemon and Watermelon) with "Sugarfree for healthy teeth" message produced changes in enamel surface microhardness of 35.60 ± 4.77%, 41.88 ± 18.61% and 48.68 ± 4.96% respectively, demonstrating high erosive potential. Six of the 10 confections with the "Toothfriendly" logo produced changes in enamel surface microhardness between 24.40 ± 4.15% and 44.57 ± 9.27%, exhibiting high erosive potential, in fact three of these confections produced changes in surface microhardness of 31.57 ± 7.03%, 44.16 ± 4.12% and 44.57 ± 9.27% and were amongst the most erosive examples. The sugar-free confection with the "Kind to teeth" logo (Kaiser) had a pH of 2.72 and also produced a change of 35.9 ± 12.1% in surface microhardness, which was also of high erosive potential.

The erosive potential of the sugar-free confections was significantly correlated with pH and titratable acidity ($p < 0.001$). This is in agreement with previous study by Jensdottir *et al* [18] in which sixteen soft drinks from the Icelandic market were tested to determine the properties related to the soft drinks that were important for erosive potential. They reported that significant correlations were obtained between erosive potential and titratable acidity and pH of the soft drinks [18].

It was surprising to find that some confections (Extra Drops, Kaiser and some of the Ricola Drops) exhibited high erosive potential given that they displayed the "Toothfriendly", or “Sugarfree for healthy teeth” or ‘Kind to teeth” messages on the product label. The “Toothfriendly” certification methodology first measures the pH of a solution made by dissolving 1g of confection in 15 mL of distilled deionised water. If this pH is below 5.7 then this confection must then be tested *in vivo*. It is considered to not have a significant erosive potential if plaque pH does not drop below 5.7 and the acid exposure to a plaque-free electrode does not exceed 40 mM H^+.min [10]. The dilution of the sugar-free confections in this study was comparable to the Toothfriendly specified dilution. However, this “Toothfriendly” methodology only estimates an acid challenge for one *in vivo* exposure. Frequent consumption of the confection would result in frequent acid challenges in an undersaturated environment which may increase the risk of erosive damage. Furthermore, it is not only intra-oral acid release, (e.g. H^+.min) that should be considered for erosive potential as calcium chelators (e.g. citrate) may contribute to enamel erosion under less acidic conditions [9]. Hence, erosive potential should be estimated by the combined impact of acid and calcium-chelator release. The “Toothfriendly” certification methodology is also based on the assumption of normal salivary flow and compositional quality of a healthy individual. Patients with poor salivary flow or function may consume these products frequently to help alleviate dry mouth symptoms.

When the products were grouped on the basis of containing a fruit, mint / menthol or other flavour there were significant differences between the products in terms of their acid content. The fruit flavoured confections had the lowest pH (2.99 ± 0.49) with both mints / menthols (6.43 ± 2.8) and others (5.03 ± 0.59) being significantly higher ($p < 0.002$). The fruit flavoured confections were also those that contained high levels of citrate.

The results presented here may not necessarily translate to these confections producing erosion *in vivo* on occasional consumption in healthy individuals [19, 20]. However, frequent consumption would increase that risk, particularly in individuals with poor quantity or quality of saliva which may not be able to neutralise the erosive potential [11]. This is consistent with clinical cases of dental erosion associated with the long term and frequent consumption of some of the high erosive potential sugar-free confections with dental messages identified in this study. These clinical cases were the major reason why this investigation was conducted.

Patients seeking to improve their oral health by stimulating saliva should avoid sugar-free confections containing food acids and should choose more pH-neutral, sugar-free confections. In general this can be done by choosing mint flavoured sugar-free confections and avoiding those that have fruit flavours which contain high levels of food acids, particularly citric acid. Patients can check the confection ingredient list for food acids by name or number. Furthermore "toothfriendly" certification or the use of manufacturer dental messages like "Sugarfree for healthy teeth" or "Kind to teeth" should not be issued/used for sugar-free confections containing food acids unless they can be demonstrated to be safe for teeth of all individuals when consumed frequently. This study highlights the importance of factoring patients' salivary characteristics into dietary advice as stimulating saliva with acidic sugar-free confections may be counter-productive to oral health, particularly in patients with compromised saliva quantity and/or quality.

CONCLUSIONS

In conclusion 17 of the 30 sugar-free confections assayed contained high concentrations of food acids, exhibited low pH and high titratable acidity and had high erosive potential in artificial saliva in an enamel erosion assay. Ten of these high erosive potential sugar-free confections displayed dental messages on the packaging suggesting they were safe for teeth.

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Table 1. Sugar-free confections selected for analysis: brand name, flavour, listed ingredients and the presence of a dental message on the package. Acids in the ingredients are highlighted in bold.

	Brand Name	Flavour	Ingredients (as listed by manufacturer)	Dental message
1	Sweet Enough Drops	Lemon	Sweetener (953, 955), **antioxidant (330)**, lemon oil, colour (101)	No
2	Extra Drops	Watermelon	Isomalt, **food acids (330, 296)**, xylitol, flavor, sweeteners (951, 950), herb extracts, colours (141, 100)	Yes[†]
3	Ricci Chews	Fabulous Fruits	Polydextrose, isomalt, vegetable oil, sorbitol, emulsifier (471), **food acid (330)**, flavours, sweetener (sucralose), colours (102, 110, 122, 123, 124)	No
4	Ricola Drops	Sea Berry	Isomalt, **food acid (citric acid)**, **concentrated sea berry juice**, extract of Ricola's herb mixture, flavours, sweeteners (aspartame, acesulphame-K), **concentrated lemon juice**, colour (paprika extract)	Yes[‡]
5	Ricola Drops	Cranberry	Isomalt, **acid (citric acid)**, **concentrated cranberry juice**, extract of Ricola's herb mixture, **concentrated black chokeberry juice**, sweeteners (aspartame, acesulphame-K), flavourings	Yes[‡]
6	Extra Drops	Lemon	Isomalt, **food acids (330, 296)**, xylitol, flavor, sweeteners (951, 950), herb extracts, colour (100)	Yes[†]
7	Sweet Enough Drops	Raspberry	Sweetener (953), **antioxidant (330)**, artificial flavour, colour (162), sweetener (955)	No
8	Ricci Lozenges	Menthol and Eucalyptus	Isomalt, **vitamin C (ascorbic acid)**, eucalyptus oil, menthol, sweetener (sucralose), colour (133)	No
9	Ricci Drops	Lemon	Isomalt, **food acid (330)**, flavour, sweetener (sucralose), colour (102)	No
10	Kaiser	Strawberry	Isomalt, **citric acid**, **ascorbic acid**, flavours, menthol, natural colour, (E 163), sweetener (E 951)	Yes[§]
11	Extra Drops	Wild Berry	Isomalt, **food acids (330, 296)**, xylitol, flavor, sweeteners (951, 950) colour (163),	Yes[†]

			herb extracts	
12	Jols Pastilles	Grapefruit with Echinacea	Sorbitol 33g, Maltitol 8.9g, Dietary Fibre 44g, Vegetable Gum (Gum Acacia), Sweetener (420, 965), **Acidity Regulator (330)**, Echinacia Extract (1.3%), Humectant (422), Natural Flavour, **Antioxidant (300)**, **Grapefruit Concentrate (0.3%)**, Colour (100, 120)	No
13	Ricola Drops	Elderflowers	Isomalt, **acid (malic acid)**, extracts of elderflowers and Ricola's herb mixture, **concentrated lemon juice**, sweeteners (aspartame, acesulphame-K), flavourings, fruit and plant preparation (cherries, red cabbage).	Yes‡
14	Jols Pastilles	Blackcurrant	Sweetener (420, 965), vegetable gum (gum acacia), **acidity regulator (330)**, natural flavour, **blackcurrant fruit juice concentrate (0.8%)**, **antioxidant (300)**, humectant (422), sweetener (951, 950), colour (E163), essential oil	Yes‡
15	Jols Pastilles	Raspberry Apple	Sweetener (420, 965), Vegetable Gum (Gum Acacia), **Acidity regulator (330)**, **Apple Juice Concentrate (0.7%)**, Humectant (422), **Antioxidant (300)**, **Natural Flavours (raspberry, apple)**, Colour (E120), Sweetener (951, 950), Essential Oil	Yes‡
16	Ricci Chews	Creamy Caramels	Polydextrose, isomalt, sorbitol, vegetable oil, butter (milk), emulsifiers (471, soy lecithin), flavours, colour (150d), salt, sweetener (sucralose)	No
17	Jols Pastilles	Forest Berries	Sweetener (420, 965), vegetable gum (gum acacia), **acidity regulator (330)**, humectant (422**), antioxidant (300)**, natural flavours, sweetener (951, 950), colour (E163), **raspberry fruit juice concentrate (0.1%)**, essential oil	Yes‡
18	Jols Pastilles	Orange	Sweetener (420, 965) Vegetable Gum (Gum Acacia), **Acidity Regulator (330)**, Orange Fruit Juice Concentrate (0.5%), Humectant (422), Antioxidant (300), Flavour, Sweetener (951. 550), Colour (E163a), Essential oil	Yes‡
19	Jols Pastilles	Cranberry with Greentea	Sorbitol 33g, Maltitol 8.9g, Dietary fibre 44g,Vegetable Gum (Gum acacia), Sweetener (420, 965), **Acidity Regulator (330)**, Echinacia Extract (1.3%), Humectant (422), Natural Flavour, Antioxidant (300), Cranberry Fruit Juice Concentrate (0.3%), Sweetener (951, 950), Colour (120)	No
20	Kopiko	Real Coffee	Sweetener (953, 965), Vegetable Oil (Palm Oil), Coffee Extract (4.9%), Emulsifier, Soy Lecithin (322), Butter, Natural Coffee Flavour, Salt, Sweetener	No

			(950)	
21	Jila Mints	Peppermint	Sorbitol, Natural Flavour, Anticaking Agent (407), Sweeteners (955, 950), Natural Colour (Spirulina)	No
22	Sweet Enough Chews	Strawberry & Cream	Sweeteners (953, 955), cream, partially hydrogenated soy bean oil, flavours, emulsifier (471, 478), **antioxidant (330)**, colours (102, 110, 129, 133)	No
23	Licorette Pastilles	Licorice	Vegetable gum (gum acacia), sweetener (420, 965), licorice extract (1.4%), essential oil, flavour, sweetener (951, 950)	Yes‡
24	Ricola Drops	Menthol	Isomalt, sorbitol, natural flavourings, extract of eucalyptus leaves and Ricola's herb mixture, sweeteners (aspartame, acesulphame-K), colour (chlorophyll)	Yes‡
25	Zones Drops	Fresh Mint	Isomalt (98%), Flavours, Artificial Sweetener (950), Colour (141), Vivazol 1% (Mint Oil, Menthol, Parsley Oil)	Yes‡
26	Sweet Enough Chews	Vanilla Caramel	Sweetener (953), butter (cream, salt), palm kernel oil, sodium caseinate, artificial flavours, emulsifiers (471, 476), colour (caramel), sweetener (955)	No
27	Sweet Enough Chews	Chocolate Cream	Sweetener (953), cream, partially hydrogenated soy bean oil, cocoa mass, emulsifier (471, 476), flavours, colour (171), sweetener (955)	No
28	Sweet Enough Chews	Coffee Rio	Sweeteners (953, 955), partially hydrogenated vegetable oil, coffee (0.7%), butter (cream, salt), emulsifier (322), flavours	No
29	Sweet Enough Drops	Mint	Sweeteners (953, 955), peppermint oil	No
30	Sweet Enough Drops	Butterscotch	Sweetener (953), butter (cream, salt) natural & artificial flavours, colours (101,160B), sweetener (955)	No

Dental messages: †Sugarfree for healthy teeth; ‡Toothfriendly logo; §Kind to Teeth logo.
Food additive number code: 100 = Curcumin or Turmeric, 101 = Riboflavin or Riboflavin 5'-phosphate sodium, 102 = Tartrazine, 110 = Sunset yellow FCF, (E)120 = Carmines or Carminic acid or Cochineal, 122 = Azorubine, Carmoisine, 123 = Amaranth, 124 = Ponceau 4R, Cochineal Red A, Brilliant Scarlet 4R, 129 = Allura red AC, 133 = Brilliant blue FCF, 141 = Chlorophyll-copper complex, 150d = Sulphite ammonia caramel, E160a = Carotene, alpha-, beta-, gamma, 160B = Annatto, bixin, norbixin, 162 = Beet red, E163 = Anthocyanins, 171 = Titanium dioxide, 270 = lactic acid, 296 = Malic acid, 300 = Ascorbic acid, 322 = lecithin, 330 = citric acid, 407 = Carrageenan, 420 = Sorbitol or sorbitol

syrup, 422 = Glycerin or glycerol, 470 = magnesium stearate, 471 = mono- and diglycerides of fatty acids - glyceryl monostearate, glyceryl distearate, 476 = polyglycerol polyricinoleate, 478 = Lactylated fatty acid esters of glycerol and propane-1 -, 550 = Sodium silicate, 950 = acesulfame potassium, 951 = aspartame, 952 = cyclamic acid, cyclamates, 953 = isomalt, 954 = saccharin, 955 = sucralose, 965 = Maltitol and maltitol syrup or hydrogenated glucose syrup.

Table 2. Erosive potential of sugar-free confections: weight, pH, titratable acidity (TA), calcium, inorganic phosphate, fluoride and citrate levels, apparent degree of saturation with respect to hydroxyapatite (DS HA), and change in enamel surface microhardness (%ΔSMH).

Table 2a. High erosive potential confections

	Brand	Flavour	Weight (g)	pH	TA to pH 5.5 (mmol OH^- /L)	TA to pH 7.0 (mmol OH^- /L)	Calcium (µmol/g)	Inorganic phosphate (µmol/g)	Fluoride (µmol/g)	Citrate (µmol/g)	DS HA	%ΔSMH
1	Sweet Enough Drops	Lemon	3.88 ± 0.09	2.45 ± 0.09	8.04 ± 0.01	8.93 ± 0.28	1.90 ± 0.76	ND	ND	ND	0	52.22 ± 6.09
2	Extra Drops[†]	Watermelon	2.61 ± 0.04	2.40 ± 0.28	3.61 ± 0.02	4.66 ± 0.01	1.86 ± 0.52	ND	ND	36.90 ± 2.33	0	48.68 ± 4.96
3	Ricci Chews	Fabulous Fruits	6.26 ± 0.41	2.62 ± 0.10	4.05 ± 0.01	5.49 ± 0.01	0.17 ± 0.06	ND	ND	24.08 ± 1.02	0	44.69 ± 6.85
4	Ricola Drops[‡]	Sea Berry	2.60 ± 0.07	2.68 ± 0.40	4.62 ± 0.01	6.22 ± 0.00	1.02 ± 0.30	0.59 ± 0.31	2.84 ± 0.07	61.59 ± 2.55	0	44.57 ± 9.27
5	Ricola Drops[‡]	Cranberry	2.57 ± 0.06	2.94 ± 0.01	4.75 ± 0.00	6.4 ± 0.01	0.77 ± 0.04	ND	1.28 ± 0.04	63.42 ± 4.68	0	44.16 ± 4.12
6	Extra Drops[†]	Lemon	2.62 ± 0.01	2.49 ± 0.12	5.41 ± 0.02	7.03 ± 0.02	1.87 ± 0.59	ND	ND	58.67 ± 5.21	0	41.88 ± 18.61
7	Sweet Enough Drops	Raspberry	3.92 ± 0.09	2.57 ± 0.28	6.07 ± 0.16	8.25 ± 0.22	2.19 ± 0.69	ND	ND	51.94 ± 7.50	0	41.66 ± 8.35
8	Ricci Lozenges	Menthol and Eucalyptus	2.39 ± 0.19	3.03 ± 0.05	3.38 ± 0.02	3.57 ± 0.00	1.24 ± 1.31	ND	ND	ND	0	38.88 ± 9.04
9	Ricci Drops	Lemon	2.97 ± 0.08	2.59 ± 0.01	2.23 ± 0.02	3.07 ± 0.01	0.24 ± 0.07	ND	ND	30.96 ± 1.04	0	38.63 ± 4.94
10	Kaiser[§]	Strawberry	1.44 ± 0.01	2.72 ± 0.38	3.10 ± 0.04	4.04 ± 0.03	1.19 ± 0.16	ND	ND	72.02 ± 0.46	0	35.85 ± 12.09
11	Extra Drops[†]	Wild Berry	2.63 ± 0.03	2.66 ± 0.05	5.05 ± 0.02	6.60 ± 0.01	2.68 ± 0.92	ND	ND	56.44 ± 3.44	0	35.60 ± 4.77
12	Jols Pastilles	Grapefruit with Echinacea	1.29 ± 0.02	3.69 ± 0.06	3.02 ± 0.02	3.56 ± 0.03	54.32 ± 4.00	ND	ND	59.57 ± 1.54	0.006	32.16 ± 6.53
13	Ricola Drops[‡]	Elderflowers	2.62 ± 0.17	3.01 ± 0.05	4.38 ± 0.01	5.04 ± 0.00	1.15 ± 0.19	0.91 ± 0.10	0.58 ± 0.12	6.65 ± 0.66	0	31.57 ± 7.03
14	Jols Pastilles[‡]	Blackcurrant	0.70 ± 0.03	3.68 ± 0.02	2.05 ± 0.04	2.49 ± 0.03	53.36 ± 4.01	ND	ND	80.51 ± 2.75	0.004	26.57 ± 4.21
15	Jols Pastilles[‡]	Raspberry Apple	0.75 ± 0.01	3.7 ± 0.06	1.83 ± 0.01	2.22 ± 0.01	55.77 ± 2.40	ND	ND	81.48 ± 6.54	0.005	25.50 ± 4.16
16	Ricci Chews	Creamy Caramels	6.62 ± 0.11	3.88 ± 0.17	0.12 ± 0.00	0.18 ± 0.00	0.21 ± 0.05	ND	ND	ND	0.001	25.16 ± 13.84
17	Jols Pastilles[‡]	Forest Berries	0.69 ± 0.02	3.61 ± 0.04	2.55 ± 0.04	3.08 ± 0.04	54.24 ± 0.86	ND	ND	98.89 ± 5.70	0.004	24.40 ± 4.15

Table 2b. Moderate erosive potential confections

	Brand	Flavour	Weight (g)	pH	TA to pH 5.5 (mmol OH^- /L)	TA to pH 7.0 (mmol OH^- /L)	Calcium (µmol/g)	Inorganic phosphate (µmol/g)	Fluoride (µmol/g)	Citrate (µmol/g)	DS HA	%ΔSMH
18	Jols Pastilles[‡]	Orange	0.76	3.65 ± 0.15	1.99 ± 0.08	2.39 ± 0.10	49.99 ± 4.64	ND	ND	65.32 ± 0.48	0.004	17.34 ± 6.42
19	Jols Pastilles	Cranberry with Green tea	1.29	3.62 ± 0.00	3.51 ± 0.09	4.16 ± 0.09	53.64 ± 1.29	ND	ND	68.95 ± 4.28	0.005	13.95 ± 5.54
20	Kopiko	Real Coffee	3.11	4.94 ± 0.02	0.14 ± 0.00	0.45 ± 0.00	1.35 ± 0.36	2.11 ± 0.19	11.15 ± 1.39	1.35 ± 0.31	0.003	10.36 ± 3.85

Table 2c. Low erosive potential confections

	Brand	Flavour	Weight (g)	pH	TA to pH 5.5 (mmol OH^- /L)	TA to pH 7.0 (mmol OH^- /L)	Calcium (µmol/g)	Inorganic phosphate (µmol/g)	Fluoride (µmol/g)	Citrate(µmol/g)	DS HA	%ΔSMH
21	Jila Mints	Peppermint	0.69 ± 0.01	9.36 ± 0.00	N/A	N/A	1.30 ± 0.46	ND	ND	ND	2.199	7.46 ± 6.64
22	Sweet Enough Chews	Strawberry & Cream	5.80 ± 0.17	3.31 ± 0.02	2.34 ± 0.02	3.41 ± 0.02	3.02 ± 0.22	0.51 ± 0.02	ND	ND	0	6.36 ± 2.32
23	Licorette Pastilles[‡]	Licorice	0.97 ± 0.01	5.50 ± 0.00	N/A	0.13 ± 0.00	62.10 ± 2.58	ND	ND	ND	0.140	3.39 ± 3.91
24	Ricola Drops[‡]	Menthol	2.52 ± 0.07	5.50 ± 0.00	0.00 ± 0.00	0.04 ± 0.00	0.42 ± 0.09	ND	ND	ND	0.016	3.02 ± 7.50
25	Zones Drops[‡]	Fresh Mint	1.53 ± 0.04	5.07 ± 0.25	0.01 ± 0.00	0.02 ± 0.00	2.87 ± 0.87	ND	ND	ND	0.018	1.56 ± 3.37
26	Sweet Enough Chews	Vanilla Caramel	9.09 ± 0.21	5.11 ± 0.23	0.19 ± 0.02	2.27 ± 0.03	1.25 ± 0.29	0.60 ± 0.14	ND	ND	0.008	1.34 ± 2.41
27	Sweet Enough Chews	Chocolate & Cream	4.89 ± 0.27	5.50 ± 0.00	N/A	0.37 ± 0.02	2.12 ± 0.46	0.28 ± 0.13	ND	ND	0.009	0.89 ± 4.51

28	Sweet Enough Chews	Coffee Rio	4.30 ± 0.06	4.78 ± 0.14	0.24 ± 0.00	0.75 ± 0.01	1.59 ± 0.10	ND	3.59 ± 0.41	ND	0.011	-0.10 ± 1.29
29	Sweet Enough Drops	Mint	3.90 ± 0.03	9.21 ± 0.00	N/A	N/A	1.53 ± 0.37	ND	ND	ND	5.591	-0.87 ± 1.16
30	Sweet Enough Drops	Butterscotch	3.71 ± 0.10	5.50 ± 0.00	N/A	0.09 ± 0.00	2.24 ± 0.46	ND	ND	ND	0.051	-1.38 ± 3.63

Dental messages: †Sugarfree for healthy teeth; ‡Toothfriendly logo; §Kind to teeth logo.
ND = not detected, N/A = not applicable, DSHA = degree of saturation with respect to hydroxyapatite.
Each confection was analysed in triplicate after dissolving in 40 ml of distilled de-ionized water or artificial saliva.