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ORIGINAL ARTICLE

Xylitol content and acid production of chewing gums available in the markets of Saudi Arabia

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Abstract *Objective:* To assess the actual xylitol content in sugar-free chewing gums available in a market of Saudi Arabia and investigate its effect on acid production and pH change *in vitro*. Materials and methods: A total of 29 different brands of xylitol-containing sugar-free chewing gums were collected from five major grocery stores in Saudi Arabia. Xylitol was extracted and its concentration was determined using the D-Sorbitol/Xylitol Enzymatic Kit (Megazyme; Bray, Wicklow, Ireland). The pH of the extracts and the amount of acid production for each product was measured after 15-minute and 30-minute incubation with *Streptococcus mutans*. Descriptive analysis, concentrations, and one-way analysis of variance (ANOVA) with the least significant difference (LSD) as multiple comparisons were performed. Results: The xylitol content in grams was clearly stated on the labels of 16 products, while it was stated in percentages on the labels of ten products. The mean pH of most of the tested products was 5.857 ± 0.096. Significant differences in pH were recorded among 20 products ($p \leq 0.05$). Highly significant differences in pH ($p = 0.001$) were observed in five of the products. Conclusion: The results of this study indicate, using an *in vitro* model, that xylitol can significantly affect salivary pH. The actual xylitol content in most brands of chewing gums currently available in the markets of Saudi Arabia is less than the concentration recommended for prevention

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of caries. Accurate information with proper labeling is required to enable dental professionals to take correct and informed decisions about recommending the use of these products.

1. Introduction

Dental caries is one of the most common non-communicable diseases and is considered a major public health problem. It is characterized by the localized destruction of susceptible dental hard tissues caused by the fermentation of dietary carbohydrates by oral cariogenic bacteria. There is a definite dose–response relationship between the consumption of free sugars and dental caries. Dental caries disproportionally affects poor and disadvantaged populations with less access to prevention and care. Currently, the attention of the dental community is centered on prevention rather than treatment. To prevent dental caries, several factors need to be controlled, including oral hygiene, fluoride intake, and the amount of carbohydrates consumed by individuals (Barber and Wilkins, 2002; Soderling, 2009; Chi and Scott, 2019).

Xylitol, a five-carbon natural sugar polyol, is an artificial sweetener commonly used as a sugar substitute. It is found in small quantities in certain fruits and berries. It may also be sometimes referred to as birch sugar (from which it was originally derived). In human carbohydrate metabolism, xylitol is considered to be a normal intermediate. In addition, approximately 5–15 g of xylitol may be formed daily in the human body, mostly in liver cells. Xylitol is non-acidogenic and has anticaries properties owing to its antimicrobial actions. Studies have demonstrated that the consumption of xylitol decreased the growth and metabolism of cariogenic oral flora. Several *in vitro* and *in vivo* studies have provided evidence for the effectiveness of xylitol-containing products in prevention of dental caries in children and adults (Riley et al., 2015). In case of xylitol-containing chewing gums, the chewing action stimulates the flow of saliva further adding to the caries protection property of the product. Reports indicate that frequently chewing xylitol-containing gum between meals produces a considerable anticariogenic effect (Bassler, 1976; Birkhed 1994; Caglar et al., 2007).

Dietary products containing xylitol, including gums, candies, and drinks are widely available in the market and are generally accessible to consumers. A large proportion of the dental community regularly promotes the use of these products as a method to help prevent or control decay initiation. Generally, all ingredients are listed on the product packaging in order of content (in percentages); however, the exact amount of xylitol and other noncariogenic sweeteners may not be clearly stated on the label. The aim of the current study was to assess the actual xylitol content in sugar-free chewing gums available in the Kingdom of Saudi Arabia (KSA) market and investigate their effects on acid production and pH change *in vitro*.

Table 1 Xylitol contents in each sample and the volume added from the xylitol and artificial saliva (AS) to bacterial culture.

Sample Number	Xylitol mg/ml	Volume added to 15 ml tube (mL)	Volume of AS (mL)
Sample 1	0.0804	124	376
Sample 2	0.0676	147	353
Sample 3	0.0784	127	373
Sample 4	0.0802	124	376
Sample 5	0.0859	116	384
Sample 6	0.0688	145	355
Sample 7	0.0546	182	318
Sample 8	0.0559	178	322
Sample 9	0.0751	133	367
Sample 10	0.1173	100	400
Sample 11	0.0725	137	363
Sample 12	0.0365	273	227
Sample 13	0.0645	154	346
Sample 14	0.0639	156	344
Sample 15	0.0694	143	357
Sample 16	0.0696	143	357
Sample 17	0.0694	144	356
Sample 18	0.0610	163	337
Sample 19	0.0538	185	315
Sample 20	0.0581	172	328
Sample 21	0.0199	500	200
Sample 22	0.0708	141	359
Sample 23	0.0528	189	311
Sample 24	0.0816	122	378
Sample 25	0.0816	122	378
Sample 26	0.0659	151	349
Sample 27	0.0708	141	359
Sample28	0.0776	128	372
Sample 29	0.0849	117	383

2. Material and methods

2.1. Experimental design

A total of 31 different brands of sugar-free chewing gums were collected from five major grocery stores in Saudi Arabia. The ingredients and nutritional facts were checked on the labels, and only 29 chewing gums that contained xylitol were included in the study. All chewing gums used in this investigation were weighed, frozen in liquid nitrogen, ground using a mortar and pestle, and collected in 10 ml tubes containing distilled water. The tubes were then placed in a Stuart Magnetic Stirrer Hotplate, allowed to boil for 5 min and then mixed using a Digital Vortex mixer for 1 min at 3000 rpm. The solutions were then centrifuged at 6000 rpm and filtered using a 0.45 µm Whatman filter. The filtered clear solutions were then used to determine the xylitol amount. The xylitol concentration was measured using a Microplate Spectrophotometer (BioTek Instruments, Winooski, VT, USA) and an enzymatic kit, D-Sorbitol/Xylitol (Megazyme; Bray, Wicklow, Ireland). The absorbance rate was measured using the absorbance endpoint at a wavelength of 492 v/f and normal read speed. According to the manufacturer's instructions, a mathematical equation was used to convert the absorbance values into xylitol concentrations of milligrams per milliliter (mg/ml). Multiple readings

Table 2 Xylitol chewing gum types available in KSA market, their parent company, country of origin, xylitol content, and measured xylitol concentration in each product with its possible preventive potential.

	Product name	Parent company	Country of origin	Xylitol as 1st or 2nd Ingredient	Gum weight (g)/ per piece	Xylitol/piece (g or %) given on label	Xylitol/piece (g) as measured	Preventive potential
1	Wrigley's Extra White (Peppermint)	Mars	Russia	No	3	N	0.08	No
2	Wrigley's Extra (Spearmint)	Wrigley	France	Yes	1.9	15 %	0.067	No
3	Wrigley's Extra (Bubblemint)	Mars	Russia	Yes	1.4	30.4 %	0.078	No
4	Wrigley's Extra (Peppermint)	Wrigley	France	Yes	1	15 %	0.08	No
5	Smint & Gum Freshness Explosion longer lasting xylitol (Blackberry)	Gumlink	Turkey	Yes	13.9/8 pieces	37%	0.085	Yes
6	Smint & Gum Freshness Explosion longer lasting xylitol (Strong mint)	Gumlink	Turkey	Yes	13.9/8 pieces	31%	0.068	Yes
7	Smint & Gum Freshness Explosion longer lasting xylitol (Peppermint)	Gumlink	Turkey	Yes	13.9/8 pieces	35%	0.054	Yes
8	Mentos 3D (Red fruit-lime)	Perfetti Van Melle	Vietnam	No	24.5/14 pieces	9.1 %	0.055	Yes
9	Mentos White (Tutti Fruitti)	Perfetti Van Melle	Vietnam	No	54/38 pieces	15.7 %	0.075	Yes
10	Mentos 3D (Watermelon)	Perfetti Van Melle	Vietnam	No	24.5/14 pieces	9.6 %	0.117	Yes
11	Mentos (Strawberries)	Perfetti Van Melle	Turkey	No	90/45 pieces	3.9 %	0.072	Yes
12	Mentos (Wintergreen)	Perfetti Van Melle	Vietnam	No	56/ 32 pieces	5 %	0.036	Yes
13	Mentos White (Sweet Mint)	Perfetti Van Melle	Vietnam	No	54 /38 pieces	16 %	0.064	Yes
14	Mentos White (Spearmint)	Perfetti Van Melle	Vietnam	No	103/72 pieces	15.9 %	0.063	Yes
15	Mentos Pure Fresh (Fresh Mint)	Perfetti Van Melle	Vietnam	No	56/32 pieces	5.2 %	N	Yes
16	Tic tac gum (cool Watermelon)	Ferrero	Italy	Yes	12.1/25 pieces	5.8 %	0.069	Yes
17	Tic tac gum (cool bubble)	Ferrero	Italy	Yes	12.1/25 pieces	51.3%	0.069	Yes
18	Tic tac gum (spearmint)	Ferrero	Italy	Yes	12.1/25 pieces	51.4%	0.061	Yes
19	Tic tac gum (Freshmint)	Ferrero	Italy	Yes	12.1/25 pieces	51.2%	0.053	Yes
20	Dr. Ginger Xylitol Ginger Gum	Lemon Phama GmbH & Co.Kg,	Germany	Yes	30/20 pieces	73.22%	0.07	Yes
21	Steviagum	Lemon Phama GmbH & Co.Kg,	Germany	Yes	30/20 pieces	99.8%	0.052	Yes
22	Mentos (Mint with lemon)	Perfetti Van Melle	Vietnam	No	56/32 pieces	5.2 %	0.081	Yes
23	Mentos Bubble Gum (18 Maxi Dragees)	Perfetti Van Melle	Turkey	No	64/30 pieces	5.3%	0.081	Yes
24	Mentos Pure Fresh (Bubble Fresh)	Perfetti Van Melle	Vietnam	No	87.5/50 pieces	10 %	0.065	Yes
25	Wrigley's Extra Mega (Watermelon)	Wrigley	China	Yes	51.5 /23 pieces	53.5 %	0.07	Yes
26	Mentos Squeez (Blackberry)	Perfetti Van Melle	Turkey	No	90 /45 pieces	3.7%	0.077	Yes
27	Wrigley's Extra (Strawberry)	Wrigley	France	Yes	27/14 pieces	15 %	0.084	No
28	Smint & Gum Freshness Explosion longer lasting xylitol (Strawberry)	Gumlink	Turkey	Yes	13.9/8 pieces	33%	0.09	Yes
29	Gandour Everdent Sugarfree Gum (Peppermint)	Gandour	Saudi Arabia	No	30 /12 pieces	N	0.021	Yes

were recorded for each product and the mean value was calculated.

The Benchtop pH meter FiveEasy™ F20 (Mettler-Toledo Vietnam LLC) was used to measure the pH of the suspensions and the amount of acids in each product. The suspensions were then filtered, and the amount of fermentable sugars was determined as previously described in the literature (Haukioja et al., 2008; Alanzi et al., 2016). Briefly, the extracts were incubated with freshly grown *Streptococcus mutans*, and the pH of the extracts was measured at baseline, at 15 min, and at 30 min. The greater the pH decrease, the higher is the amount of fermentable carbohydrates. Glucose was used as the reference carbohydrate.

The bacteria (*Streptococcus mutans*) were grown in brain–heart-infusion (BHI) agar for 2 days. The culture was then inoculated into two different tubes of BHI liquid medium (broth) and placed in Excella E24 Incubator Shaker Series. A volume of 10 ml of bacterial cell stock culture was added to 2E flasks containing 250 ml BHI broth; the flasks were covered with foil and placed in an Excella E24 Incubator Shaker for 24 h. Two flasks of artificial saliva (AS) were prepared by dissolving the contents in distilled water using a hotplate stirrer under maximum stirring without heat. The pH was measured using the same pH meter as before. In a 15 ml tube, a 5-ml sample of bacterial culture was added and centrifuged at maximum speed for 15 min; the supernatants were discarded and the bacterial cells were washed twice with phosphate-buffered saline (PBS). The bacterial cell pellets were subsequently resuspended in 4 ml of AS for pH measurement. After adding the appropriate volume of xylitol per sample (Table 1), the pH was measured at baseline, 15 min, and 30 min.

2.2. Statistical methods

Data are represented as mean ± standard deviation (SD). Comparisons between groups were performed using one-way ANOVA with the least significant difference (LSD) as multiple comparisons. A probability value (p value) ≤ 0.05 was considered statistically significant. All statistical calculations were performed using SPSS (Statistical Package for Social Science, IBM Inc. Chicago, USA) software version 21.0.

3. Results

Twenty-nine xylitol-containing chewing gums, which are identified as sugar-free products, were selected from a market of Saudi Arabia (Table 2). Among these, only 15 products had xylitol as the first or second ingredient (in terms of content) as indicated on the label. The xylitol content (in grams) was clearly stated on the labels of the 16 products. Ten products indicated the percentage of xylitol on the labels, which ranged from 3.7% to 99.8% (for one of the products). Two products did not specify the amount of xylitol on their labels. Most of the included products had a xylitol content between 0.05 g and 0.08 g. Only one product had 0.117 g and one product had 0.019 g of xylitol.

The pH of xylitol chewing gum extracts was measured *in vitro* using a Benchtop pH meter (FiveEasy™ F20) at baseline, at 15 min, and at 30 min. The mean pH value of most of the tested products was 5.857 ± 0.096. Significant differences in pH were recorded for 20 products ($p \leq 0.05$) (Table 3). Samples from products 1–9 showed a significant reduction in pH at 15 min when compared to that of AS alone and baseline, followed by a significant increase at 30 min, while samples from products 11–29 showed significantly higher pH at 15 min as well as 30 min compared to AS alone and/or baseline. The most significant differences in pH ($p = 0.001$) were reported for products 4, 20, 21, 22, and 23 (Figs. 1, 2, and 3).

4. Discussion

Dental caries is a chronic disease with a high prevalence rate that constitutes a major health burden worldwide. Thus, interventions aimed at prevention, such as fluoride supplementation, the use of pit and fissure sealants, and dietary modifications have earned sufficient attention. The role of fermentable sugars in the etiology of dental caries is well recognized, and it has been suggested that the substitution of sugar in chewing gum and candies with alternatives such as xylitol might contribute to the prevention of dental caries. The effect of sugar substitutes, especially xylitol, in reducing dental caries has been reported in several *in vitro* and *in vivo* studies since the early 1970 s (Scheinin et al., 1975; Manning et al., 1992; Machiulskiene et al., 2001; Peng, et al., 2004).

Xylitol cannot be metabolized by typical acid-forming bacteria found in dental plaques. It is converted into xylitol 5-phosphate after its uptake into the bacterial cells. Xylitol 5-phosphate inhibits bacterial metabolism and acid production. Consequently, the growth of cariogenic bacteria is suppressed, and the plaque pH cannot reach to the level necessary to demineralize enamel, thus explaining the role of xylitol in preventing dental decay. Additionally, consuming xylitol with gums or pastilles stimulates saliva flow, increases mechanical cleansing action, delivers salivary minerals to demineralized enamel and acts as a buffer to plaque acids (Van Loveren, 2004; Antonio et al., 2011).

The effectiveness of additional aids containing xylitol and other compounds as useful tools in daily oral hygiene home care has received constant attention in caries prevention studies (Riley et al., 2015). A combined mouth rinse containing purified water, sea salt, xylitol, lysozyme, and menthol significantly decreased the bacterial load and plaque index and was effective in the management of biofilm formation and gingival health in a group of young adults (Ballini et al., 2021). In a recent study, children using xylitol-probiotic toothpaste showed a significant reduction in the number of cariogenic bacteria after six weeks (Maden et al., 2018).

The findings of the current study indicated that xylitol produced significant differences in pH for 20 out of 29 of the products included in the experiment. Most of the studied products resulted in a significant increase in pH after either 15 min or 30 min. These findings confirm earlier observations demonstrating a marked reduction in plaque acidogenicity associated with the regular consumption of xylitol gums and lozenges (Hayes, 2001; Van Loveren, 2004; Sengun et al., 2004; Splieth et al., 2009). Consumption of xylitol decreases the growth and metabolism of acidogenic and aciduric oral flora and stimulates salivary defense mechanisms, according to clinical and *in vivo* studies. Several clinical trials have indicated that the occurrence of caries decreases significantly in association with the daily use of xylitol-containing gum (Makinen, 1988; Isokangas et al., 1988; Makinen, 1992; Isokangas

Table 3 Comparison between all groups using one-way ANOVA test with LSD as multiple comparison for all parameters.

Product	Samples	Mean ± SD	Percent change	P value
1. Wrigley's Extra White (Peppermint)	Artificial Saliva	5.747 ± 0.036	100.00	0.131
	Base line	5.758 ± 0.037	100.20	
	15 mins	5.690 ± 0.002 [d]	99.01	
	30 mins	5.764 ± 0.004[c]	100.30	
2. Wrigley's Extra (Spearmint)	Artificial Saliva	5.736 ± 0.029	100.00	**0.025**
	Base line	5.780 ± 0.005[c]	100.77	
	15 mins	5.701 ± 0.016 [b,d]	99.39	
	30 mins	5.782 ± 0.009[c]	100.80	
3. Wrigley's Extra (Bubblemint)	Artificial Saliva	5.728 ± 0.019 [b,c,d]	100.00	**0.009**
	Base line	5.769 ± 0.017 [a,c]	100.72	
	15 mins	5.684 ± 0.006 [a,b,d]	99.23	
	30 mins	5.765 ± 0.001 [a,c]	100.65	
4. Wrigley's Extra (Peppermint)	Artificial Saliva	5.725 ± 0.010 [b,c,d]	100.00	**0.001**
	Base line	5.750 ± 0.008 [a,c]	100.43	
	15 mins	5.680 ± 0.005 [a,b,d]	99.21	
	30 mins	5.763 ± 0.001 [a,c]	100.66	
5. Smint & Gum Freshness Explosion longer lasting xylitol (Blackberry)	Artificial Saliva	5.722 ± 0.007[c,d]	100.00	**0.002**
	Base line	5.739 ± 0.008[c,d]	100.29	
	15 mins	5.689 ± 0.007 [a,b,d]	99.42	
	30 mins	5.767 ± 0.008 [a,b,c]	100.79	
6. Smint & Gum Freshness Explosion longer lasting xylitol (Strong mint)	Artificial Saliva	5.719 ± 0.001[c,d]	100.00	**0.003**
	Base line	5.734 ± 0.010[c,d]	100.27	
	15 mins	5.700 ± 0.004 [a,b,d]	99.67	
	30 mins	5.754 ± 0.006 [a,b,c]	100.62	
7. Smint & Gum Freshness Explosion longer lasting xylitol (Peppermint)	Artificial Saliva	5.710 ± 0.013	100.00	0.400
	Base line	5.725 ± 0.019	100.25	
	15 mins	5.382 ± 0.440	94.26	
	30 mins	5.754 ± 0.006	100.77	
8. Mentos 3D (Red fruit-lime)	Artificial Saliva	5.706 ± 0.023	100.00	0.116
	Base line	5.716 ± 0.022	100.17	
	15 mins	5.698 ± 0.004 [d]	99.85	
	30 mins	5.748 ± 0.006[c]	100.74	
9. Mentos White (Tutti Fruitti)	Artificial Saliva	5.706 ± 0.026	100.00	0.357
	Base line	5.718 ± 0.037	100.22	
	15 mins	5.700 ± 0.007	99.90	
	30 mins	5.744 ± 0.001	100.67	
10. Mentos 3D (Watermelon)	Artificial Saliva	5.703 ± 0.031	100.00	0.514
	Base line	5.725 ± 0.059	100.38	
	15 mins	5.696 ± 0.003	99.88	
	30 mins	5.232 ± 0.706	91.74	
11. Mentos (Strawberries)	Artificial Saliva	5.755 ± 0.042 [b,c,d]	100.00	**0.008**
	Base line	5.831 ± 0.004 [a,c]	101.32	
	15 mins	5.910 ± 0.005 [a,b]	102.69	
	30 mins	5.865 ± 0.001 [a]	101.91	
12. Mentos (Wintergreen)	Artificial Saliva	5.805 ± 0.035[c,d]	100.00	**0.018**
	Base line	5.832 ± 0.004[c]	100.47	
	15 mins	5.901 ± 0.001 [a,b]	101.65	
	30 mins	5.874 ± 0.000 [a]	101.20	
13. Mentos White (Sweet Mint)	Artificial Saliva	5.809 ± 0.030[c,d]	100.00	**0.008**
	Base line	5.852 ± 0.006[c]	100.73	
	15 mins	5.924 ± 0.008 [a,b,d]	101.98	
	30 mins	5.877 ± 0.004 [a,c]	101.16	
14. Mentos White (Spearmint)	Artificial Saliva	5.806 ± 0.034[c,d]	100.00	**0.011**
	Base line	5.840 ± 0.008[c]	100.58	
	15 mins	5.923 ± 0.008 [a,b]	102.02	
	30 mins	5.880 ± 0.002 [a]	101.27	
15. Mentos Pure Fresh (Fresh Mint)	Artificial Saliva	5.803 ± 0.036[c,d]	100.00	**0.029**
	Base line	5.849 ± 0.006[c]	100.80	
	15 mins	5.924 ± 0.004 [a,b]	102.09	
	30 mins	5.902 ± 0.035 [a]	101.71	
16. Tic tac gum (Cool Watermelon)	Artificial Saliva	5.810 ± 0.033[c,d]	100.00	**0.003**
	Base line	5.855 ± 0.005[c,d]	100.77	
	15 mins	5.912 ± 0.006 [a,b,d]	101.75	
	30 mins	5.968 ± 0.002 [a,b,c]	102.71	

(*continued on next page*)

Table 3 (*continued*)

Product	Samples	Mean ± SD	Percent change	P value
17. Tic tac gum (Cool Bubble)	Artificial Saliva	5.820 ± 0.042[c,d]	100.00	**0.006**
	Base line	5.855 ± 0.008[c,d]	100.61	
	15 mins	5.923 ± 0.002 [a,b]	101.77	
	30 mins	5.975 ± 0.001 [a,b]	102.67	
18. Tic tac gum (Spearmint)	Artificial Saliva	5.825 ± 0.050[c,d]	100.00	**0.013**
	Base line	5.865 ± 0.006 [d]	100.69	
	15 mins	5.902 ± 0.003 [a,d]	101.33	
	30 mins	5.985 ± 0.001 [a,b,c]	102.76	
19. Tic tac gum (Freshmint)	Artificial Saliva	5.835 ± 0.037[c,d]	100.00	**0.004**
	Base line	5.863 ± 0.002 [d]	100.48	
	15 mins	5.905 ± 0.005 [a,d]	101.20	
	30 mins	5.994 ± 0.004 [a,b,c]	102.73	
20. Dr. Ginger Xylitol Ginger Gum	Artificial Saliva	5.866 ± 0.001 [b,c,d]	100.00	**0.001**
	Base line	5.962 ± 0.013 [a,c,d]	101.65	
	15 mins	6.013 ± 0.001 [a,b,d]	102.51	
	30 mins	5.926 ± 0.010 [a,b,c]	101.03	
21. Steviagum	Artificial Saliva	5.867 ± 0.016 [b,c,d]	100.00	**0.001**
	Base line	5.998 ± 0.004 [a,d]	102.23	
	15 mins	6.014 ± 0.004 [a,d]	102.51	
	30 mins	5.920 ± 0.006 [a,b,c]	100.91	
22. Mentos (Mint with lemon)	Artificial Saliva	5.859 ± 0.013 [b,c,d]	100.00	**0.001**
	Base line	6.007 ± 0.003 [a,d]	102.53	
	15 mins	6.021 ± 0.005 [a,d]	102.76	
	30 mins	5.923 ± 0.005 [a,b,c]	101.08	
23. Mentos Bubble Gum (18 Maxi Dragees)	Artificial Saliva	5.854 ± 0.013 [b,c,d]	100.00	**0.001**
	Base line	6.012 ± 0.007 [a,d]	102.70	
	15 mins	6.014 ± 0.020 [a,d]	102.73	
	30 mins	5.923 ± 0.001 [a,b,c]	101.18	
24. Mentos Pure Fresh (Bubble Fresh)	Artificial Saliva	5.966 ± 0.001	100.00	0.139
	Base line	5.919 ± 0.001	99.20	
	15 mins	5.992 ± 0.009 [d]	100.43	
	30 mins	5.885 ± 0.074[c]	98.64	
25. Wrigley's Extra Mega (Watermelon)	Artificial Saliva	5.960 ± 0.016	100.00	0.437
	Base line	5.937 ± 0.018	99.61	
	15 mins	5.948 ± 0.013	99.80	
	30 mins	5.957 ± 0.001	99.94	
26. Mentos Squeez (Blackberry)	Artificial Saliva	5.972 ± 0.003[b]	100.00	**0.004**
	Base line	5.926 ± 0.013 [a,c,d]	99.23	
	15 mins	5.983 ± 0.001[b]	100.18	
	30 mins	5.987 ± 0.008[b]	100.25	
27. Wrigley's Extra (Strawberry)	Artificial Saliva	5.971 ± 0.006	100.00	0.125
	Base line	5.942 ± 0.025 [d]	99.51	
	15 mins	5.977 ± 0.004	100.09	
	30 mins	5.989 ± 0.013[b]	100.29	
28. Smint & Gum Freshness Explosion longer lasting xylitol (Strawberry)	Artificial Saliva	5.972 ± 0.012	100.00	0.130
	Base line	5.970 ± 0.008 [d]	99.97	
	15 mins	5.975 ± 0.009	100.05	
	30 mins	5.996 ± 0.005[b]	100.40	
29. Gandour Everdent Sugarfree Gum (Peppermint)	Artificial Saliva	5.884 ± 0.018 [b,c,d]	100.00	**0.024**
	Base line	5.941 ± 0.007 [a]	100.97	
	15 mins	5.985 ± 0.005 [a]	101.71	
	30 mins	5.943 ± 0.030 [a]	100.99	

[a] There is significant difference with artificial saliva.
[b] There is significant difference with base line sample.
[c] There is significant difference with 15 mins sample.
[d] There is significant difference with 30 mins sample.

et al., 1993; Makinen et al., 1995). Studies investigating the use of xylitol-containing gum indicated that 7–10 g daily xylitol intake per child reduced the incidence of dental caries by 30%–80% compared with children from the control group who did not use the gum (Isokangas et al., 1988; Isokangas et al., 1993).

According to most reports, the recommended effective dose of xylitol is approximately 6–8 g per day. Alanzi et al. (2016)

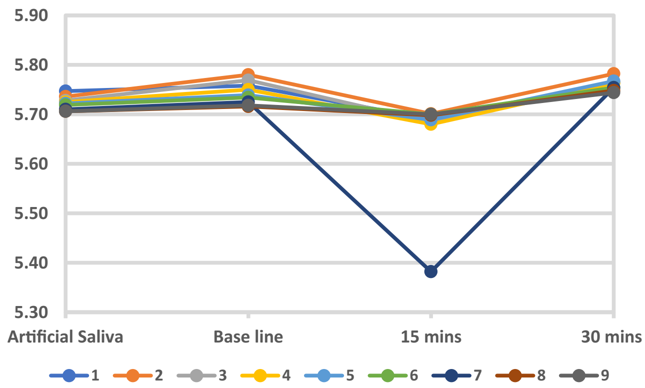

Fig. 1 pH of the 4 samples of products 1–9.

investigated the xylitol content in sugar-free chewing gums available in the Gulf Cooperation Council (GCC) countries in order to identify possible products that provide the recommended daily dose of xylitol for caries prevention. They reported that the majority of xylitol-containing chewing gums sold in the GCC market do not provide consumers with the required concentration of xylitol to achieve a preventive dental effect. Bouges et al. (2017) examined all sugar-free products in the KSA market and calculated the xylitol content in chewing gums. They found that only two products could provide a protective effect upon consumption of a reasonable amount of chewing gum pellets.

The most significant differences in pH in the current study samples were reported for five of the 29 tested products. Despite these significant differences for products of certain brands, the change in pH was minor and far from clinical effectiveness so as to noticeably prevent demineralization. According to the results of Alanzi et al. (2016), none of the tested products in their study caused a decrease in the salivary pH below 6.5, while a significant increase was noted in the mean salivary pH at the 30-min time point for five products. The difference between the results of their study and those of the current study can be ascribed to the differences in analysis techniques and types of products tested.

Based on the results of our study, in an *in vitro* model, salivary pH showed some increase in presence of xylitol extracts, indicating that the use of xylitol-containing gum could have some beneficial effects on oral health; however, it is important

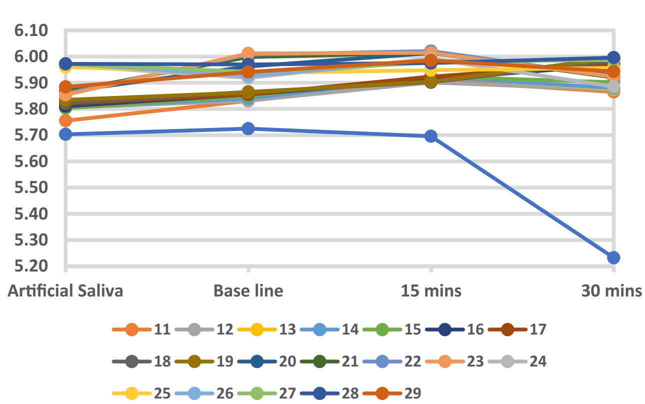

Fig. 2 pH of the 4 samples of products 11–29.

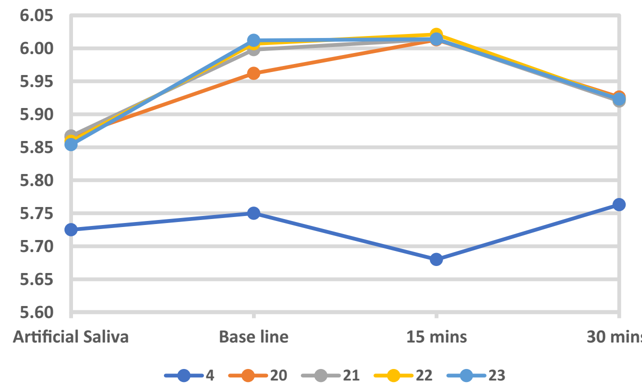

Fig. 3 pH of the 4 samples of products showing the most significant differences (p = 0.001).

to note that these are short-term outcomes associated with the immediate effects of xylitol. The results of our study also indicated that more accurate and clearer labeling of xylitol-containing gums, which includes details about the exact content and concentration of xylitol, is essential. Determining whether products containing xylitol actually provide the necessary anti-caries effects is very challenging for the dental community as long as this information is either missing or the labels are misleading.

5. Conclusion

The results of this study indicate that xylitol significantly affects pH in an *in vitro* model. The xylitol content in most different brands of chewing gums available in the KSA market is less than the suggested concentration required for the prevention of dental caries. More accurate labeling is required to provide dental professionals with the correct evidence, which is essential for making informed decisions about recommending the use of these products.

6. Disclosure statement

The authors do not have any financial interest in the companies whose materials are included in the article.

Ethical statement

This study was approved by the Research Ethics Review Committee of Princess Nourah bint Abdulrahman University, Riyadh, KSA.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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