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The Effect of Dried Fruits Consumption on Dental Plaque pH

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ABSTRACT

Introduction: In this randomized controlled clinical trial, we evaluated the effect of three dried fruits (date, raisin, and apricot) in comparison to 40% sucrose and sorbitol solutions (as positive and negative controls, respectively) on the pH of dental plaque.

Materials and Methods: 20 healthy dental students were requested to stop their oral hygiene 24 hours before and also avoid eating and drinking 2.5 hours before each session for five sessions. At each session, initial pH was measured using a pH meter electrode. Then, 20 grams of the randomly selected food was chewed, spread in the mouth, and swallowed after 5 minutes. The pH of the dental plaque was measured 1, 5, 10, 20, and 30 minutes after consumption. Data were analyzed using repeated-measure ANOVA ($p < 0.05$).

Results: Following consumption of date, raisins, and apricots, the plaque pH loss was significantly higher than that of sorbitol at both 1,5 minutes ($p < 0.05$), but there was no significant difference between these groups in comparison to sucrose in these intervals ($P > 0.05$). Comparison of pH changes after 10, 20, and 30 minutes did not show statistically significant differences between any of the groups ($P > 0.05$). In the sucrose and apricot groups, pH significantly decreased compared to its initial pH ($P = 0.006$ and $P < 0.0001$, respectively), but there was no significant difference in date, raisins, and sorbitol ($P < 0.05$).

Conclusion: The results indicated that date, raisin, and apricot could reduce dental plaque pH similar to sucrose and significantly higher than sorbitol. However, no significant difference was observed in reducing plaque pH at different time intervals between other dried fruits.

Keywords: Apricot; Dried fruit; Dental plaque; Dental caries.

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Introduction

Numerous epidemiological studies suggest that fruits and vegetables can reduce the risk of chronic diseases such as cancer, heart disease, and stroke [1-3]. According to the National Cancer Institute and National Research Council dietary guidelines, humans should ideally consume at least five servings of fruits and vegetables per day [4]. Fresh fruits and vegetables contain 80% water and are classified as highly perishable products. Therefore, the world production and consumption of dried fruit have increased accordingly. Dried fruits and vegetables have attracted considerable attention due to simple production and storage, low transportation cost, low packaging costs, and low moisture content, which prevents the growth of some destructive microorganisms and harmful enzymes [5-7].

Consumption of fruits, including traditional dried fruits without added sugar, has been issued to reducing the prevalence of non-communicable diseases (NCDs) and has beneficial effects on several risk factors that are shared by cardiovascular and other diseases [8]. The nutrient content of traditional dried fruits is equivalent to that of fresh fruits; however, their contents are more concentrated compared to those of fresh fruits. Thus, traditional dried fruits are a rich source of significant amounts of several micronutrients, except vitamin C [9]. Traditional dried fruits are a favorite handy snacks which filled with fiber [10,11]. Furthermore, traditional dried fruits contain micronutrients helpful for teenagers (especially girls) who have low intakes of some micronutrients (vitamins and minerals) [12,13]. Dried fruits have the potential to stimulate saliva production and may influence the balance between demineralization and remineralization of dental enamel. The chewy texture and pleasant taste of dried fruits promote the flow of saliva. In addition, the polyphenol contents of dried fruits may exhibit antibacterial activity against oral bacteria [10,14]. In the fruit drying process, changes occur in the polyphenol composition and antioxidant activity of the fruit, making them much more tannic. Some polyphenol contents are more susceptible to this type of change. There is little evidence to support the effect of polyphenols on oral bacteria; however, the more tannin-like polyphenolic compounds, the more antimicrobial activity [14]. Dates are a very rich food that contains large amounts of carbohydrates, minerals, proteins, vitamins, amino acids and saturated and unsaturated fatty acids [15]. Similarly, dates with the potent antioxidant and antimutagenic properties have been recognized to be good sources of anthocyanins and phenolics and free and bonded acids [16,17]. Sayyedi et al., 2007 examined the effect of date extract on the growth of Mutans Streptococci and suggested that dates have inhibitory effects against caries development [18]. Raisins (dried grapes) are a rich source of carbohydrates, vitamins and minerals, fiber, and many phenolic compounds that enhance their nutrient value. There is a direct correlation between phenolic compounds and antioxidant and antimicrobial activity of raisins [19].

Apricots are a rich source of beta-carotene (a precursor to vitamin A). Studies have shown that apricots contain saccharides, organic acids, and minerals (iron, boron, potassium, and calcium) and vitamins such as vitamins A, B, and C, and polyphenols [20]. Dried fruits, due to the higher concentration of sugar and sticky texture properties, are recommended to intake in the mealtime (National Health Service guidelines, 2017) [10,21]. Edgar et al.1975 studied the effect of 54 snack foods on the extent and duration of pH fall in plaque after 5 minutes of consumption of the test foods. The measurements of food retention ranked dates equal to 15 for carbohydrate retention and raisins were ranked 29 for carbohydrate retention [22].

The cariogenic potential of various foods has been of great interest for a long period of time and remarkable effort has been made to determine the relative cariogenic potential of foods [23]. Numerous factors associated with assessing the relative cariogenicity of foods, including the content and physical form and type of fermentable carbohydrates of foods, the degree of oral clearance and buffer capacity, effects of intake of a mixed diet, the order of consumption, and the frequency of consumption [24]. Carbohydrates are the main component of dried fruits. Fructose and glucose are the sugars mainly found in all dried fruits. However, dates and peaches contain detectable amounts of sucrose compared to other dried fruits [8]. Despite the countless benefits of dry fruits, they can heighten the risk of diseases, including diabetes and dental caries. So, in order to prevent dental caries and preserve good oral health the effects of dried fruits on dental caries should be determined. The present study aimed to evaluate the effects of three traditional dried fruits on dental caries using the pH plaque-sampling method.

Materials and Methods

This cross-over randomized controlled clinical trial was conducted in 2018 at the Dental Materials Research Center, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran. The

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study was conducted in accordance with ethical principles for medical research involving human subjects (World Medical Association Declaration of Helsinki). The study was confirmed by the Ethics Committee of Mashhad University of Medical Sciences (Registration No:IR.MUMS.DENTISTRY.REC.1397.033).

Participants

A total of 20 dental students (8 male and 12 female) participated in the study. The participants were presented with pertinent information and informed consent was obtained before participation in the study. The sampling method was a purposive non-probability sampling method. Caries status of the participants was recorded using the Decayed, Missing, and Filled Teeth (DMFT) index. To encourage saliva flow, each person was asked to sit quietly and start chewing 1g piece of paraffin for one minute and then swallow all his/her saliva or empty his/her mouth. Afterwards, the participants were asked to chew the softened bolus of paraffin for 5 minutes and collect saliva for 30 seconds and drain it into a graduated container. The salivary flow rate was calculated (mL/min) as follows: the capacity of saliva secreted divided by the time (5 min) the paraffin was in the mouth [25]. The sample size was calculated according to the same article by Pollard et al. [26] with 95% confidence and 80% power, which resulted in at least 16 samples. To narrow the confidence interval, the number of samples was increased to 20.

The inclusion criteria were as follows: having full dentition of 28 teeth and the whole unstimulated salivary flow rate should be 1m/min. The exclusion criteria were as follows: history of systemic disease, smoking, taking antibiotics for one month before the start of the test, symptoms of dry mouth, symptoms of permanent or temporary restorations containing glass ionomer, orthodontic appliances or prostheses, pregnancy, periodontal disease and active caries, allergy symptoms to the studied substances and refusal to participate in the study.

Experimental sessions

For each participant, five sessions were scheduled at intervals of one week to test one of the substances: dates, raisins, apricots, sucrose solution and sorbitol solution. The order of these sessions was determined randomly for each person, by first assigning a number from 1 to 5 to each of the materials and then using research randomizer.com website, 20 numerical sets from 1 to 5 were arranged. Each of these numerical sets showed the sequence of sessions for each participant.

All pH measurement sessions were performed around 9 to 12 AM. For each participant, all plaque evaluation sessions were scheduled at the same time of day, so that the differences in the saliva flow at different times did not interfere with the results. In order to reach to the plaque which able to produce enough acid and at the same time not to conflict with dental and periodontal health, participants were asked to give up oral hygiene procedures including toothbrushing, flossing and using mouthwashes for 24 hours, avoid eating and drinking except water for 2.5 hours, and also refrain from drinking water for one hour before the start of the test session. Before taking a pH measurement, the pH meter was calibrated with pH buffer solutions (pH 4, pH 7, pH 11). During pH measurement, the pH meter electrode was in contact with the solution and was far from direct contact with the walls of the test tube.

The Plaque sampling

In each session, a plaque sample was taken to assess the initial pH. The plaque sample was collected from the buccal and lingual surfaces using a sterile excavator. The collected plaque was immediately transferred to a vial containing 1 ml of distilled water and vortexed for 1 minute using a vortex mixer (VX-200, Tuba Negin, Iran).

Study groups

In this study, traditional dried fruits, including raisins, apricots, and dates, were examined. The dried fruits were packed in 20 gr packages. Sucrose solution (40%) and sorbitol solution (40%) were used for positive and negative controls, respectively. To make these solutions, 20 gr of sucrose and sorbitol were dissolved in 50cc of water. The reason for choosing 20 gr of sucrose and sorbitol was to equalize the volume of solution with the volume of dried fruits. The participants were asked to chew the selected dried fruit for five minutes and spread it all over the mouth at the point they felt ready to swallow and then swallow it completely. Then, plaque sampling was performed in the same manner as for baseline 1, 5, 10, 20, and 30 minutes after dried fruit consumption. Before each pH measurement, participants were asked to swallow saliva so that the plaque was not contaminated with saliva. In the case of control solutions, participants were asked to rinse 50cc of the solution in three portions and then remove it from the mouth. The author who measured the pH values was blind to the substances that were consumed. The ΔpH of each time interval was measured as follows: ΔpHn= pHn-prevoius pH measurement.

Data analysis

The Kolmogorov–Smirnov test suggested that the data were normally distributed. Due to the correlation between the given data and the normal distribution, the repeated-measures ANOVA was used for comparison between the groups. The Fisher Least Significant Difference (LSD) test was used for pairwise comparison of the studied groups. Data were analyzed using SPSS (SPSS Inc., Chicago, Ill., USA) version 23. The significance level was set to 0.05.

Results

In the present study, the acidity of dental plaque after 30 minutes of consumption of raisins, dates, and dried apricots in 20 students was evaluated and compared with sucrose and sorbitol as the positive and negative control groups. The demographic information of the participants is shown in Table 1.

ΔpH of Dental plaque following dried fruits consumption at each time interval

ΔpH1: The results of the repeated measure ANOVA showed a significant difference between ΔpH in the first minute after consumption of different substances (P = 0.001). The LSD post hoc test showed that ΔpH1 of dates, raisins and apricots were statistically significant compared to sorbitol (P = 0.008, 0.015, < 0.0001 and 0.002, respectively). But no significant difference was observed between other groups (P > 0.05). The highest plaque pH drop was seen for apricots.

ΔpH5: There was a significant difference between the ΔpH5 of different substances. Dates, raisins, apricots, and sucrose reduced plaque pH value more than sorbitol (p = 0.002, 0.001, 0.002 and 0.001, respectively). However, there was no significant intergroup difference in the ΔpHs between the other groups (P > 0.05). The highest plaque pH drop five minutes after consumption was related to sucrose.

ΔpH10: There was no significant difference between the ΔpH10 of different substances (p = 0.093). The highest plaque pH drop at this time interval was related to sucrose.

ΔpH20: The results of the repeated measure ANOVA test showed no significant difference between the ΔpH20 of different substances (p = 0.101). The highest plaque pH drop was seen for apricots.

ΔpH30: There was no significant difference between the ΔpH30 of different substances (P = 0.055). The highest plaque pH drop 30 minutes after consumption was seen after sucrose consumption (Table 2).

Comparison of ΔpHs between different time intervals in each dried fruit

To determine the trend in the pH decrease, the dental plaque ΔpHs after consumption of each dried fruit at different time intervals were also evaluated using the repeated measure ANOVA.

Dates: There was a significant decrease in pH at the intervals of 1, 5 and 10 minutes compared to 30 minutes post-consumption (P = 0.014, 0.011, 0.02, respectively). This indicates the reduction trend in the plaque pH was more evident until 10 minutes, but in the time interval of 20 and 30 minutes post-consumption, it approached the baseline. Additionally, no plaque pH drop below the critical pH value (5.5) was observed in the studied groups.

Raisins and apricots: There was no statistically significant difference between ΔpHs compared to baseline at different time intervals (P = 0.14 and P = 0.95, respectively). The highest plaque pH drop was associated with apricots after one minute.

Sucrose: There was no statistically significant difference in ΔpHs at different time intervals (P = 0.49). The lowest plaque pH was recorded five minutes after consumption and the highest plaque pH was recorded 20 minutes post-sucrose consumption.

Sorbitol: There was no statistically significant difference in ΔpHs at different time intervals (P = 0.66). The highest ΔpH was recorded 20 minutes post-sorbitol consumption.

Following consumption of raisins and dates, the plaque pH reached near the baseline level within 30 minutes. Even the plaque pH 30 minutes post-sorbitol consumption was higher than the baseline value. However, the plaque pH following consumption of apricots and sucrose was significantly lower than the baseline within 30 minutes. Likewise, the trend of pH plaque reduction in sucrose was more than in apricots. The highest plaque pH drop within 30 minutes was associated with apricots and the lowest plaque pH drop within 30 minutes was associated with raisins compared to sucrose (positive) and sorbitol (negative) groups.

Absolute plaque pH in different time intervals (Stephan curves)

The trend of dental plaque pH changes in the studied groups is presented in Figure 1 and Table 3. The pH of dental plaque remained relatively constant after sorbi-

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tol consumption, while after eating dried fruits, it first decreased and then returned to the baseline value. The trend of pH plaque reduction following sucrose and apricots consumption was more prominent than that of raisins and dates.

Table 1. Demographic information of the study participants.

Variables	*Number*	*Min*	*Max*
Age	*20*	*22*	*26*
DMFT	*20*	*0*	*9*
Gender		*Female = 12 (60%)* *Male = 8 (40%)*	

Table 2. ΔpH of dental plaque in the studied groups at different time intervals.

ΔpH (Mean ± SD)	*1 min*	*5 min*	*10 min*	*20 min*	*30 min*	*Repeated Measure ANOVA*
Dates	*-0.39 ± 0.50^{ai}*	*-0.35 ± 0.51^{ej}*	*-0.34 ± 0.55k*	*-0.24 ± 0.46*	*-0.16 ± 0.55ijk*	*P = 0.027*
Raisins	*-0.27 ± 0.40^{b}*	*-0.25 ± 0.31^{f}*	*-0.15 ± 0.45*	*-0.10 ± 0.54*	*-0.09 ± 0.4*	*P = 0.14*
Apricots	*-0.51 ± 0.46^{c}*	*-0.41 ± 0.54^{g}*	*-0.26 ± 0.39*	*-0.27 ± 0.56*	*-0.32 ± 0.54*	*P = 0.95*
Sucrose	*-0.45 ± 0.48^{d}*	*-0.46 ± 0.53^{h}*	*-0.34 ± 0.56*	*-0.24 ± 0.43*	*-0.36 ± 0.39*	*P = 0.5*
Sorbitol	*0.03 ± 0.30^{abcd}*	*0.06 ± 0.30^{efgh}*	*0.006 ± 0.35*	*0.10 ± 0.40*	*0.02 ± 0.38*	*P = 0.66*
Repeated Measure ANOVA	*P = 0.001*	*P = 0.008*	*P = 0.093*	*P = 0.101*	*P = 0.055*	

Similar superscripts indicate a significant difference between groups.

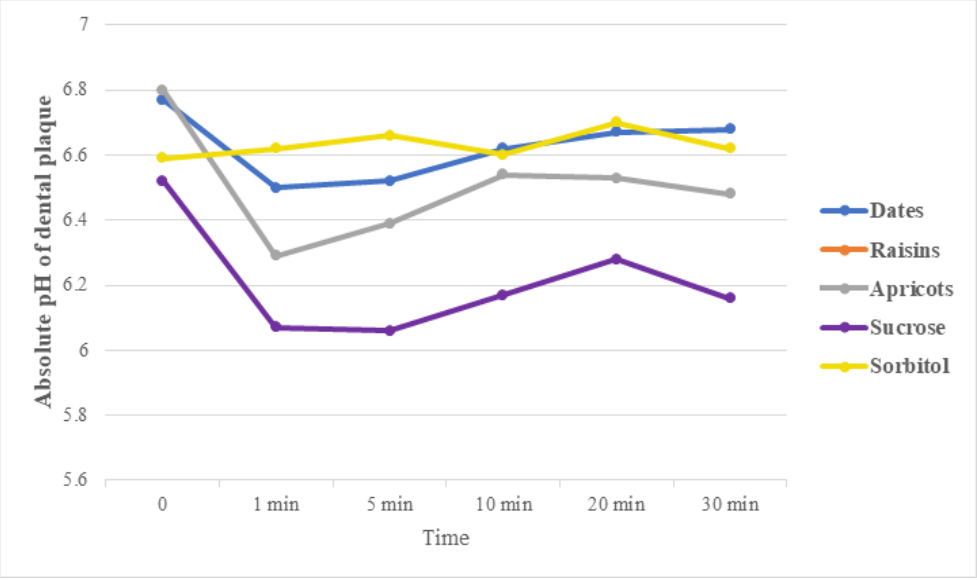

Figure 1. Trend of dental plaque pH at different time intervals following consumption of different test foods (Stephan Curve).

Table 3. Absolute pH of dental plaque following consumption of different studied substances.

Absolute pH (Mean ± SD)	0 min	1 min	5 min	10 min	20 min	30 min	Repeated Measure ANOVA
Dates	6.77 ± 0.56	6.50 ± 0.51	6.52 ± 0.54	6.62 ± 0.50	6.67 ± 0.46	6.68 ± 0.34	$P < 0.0001$
Raisins	6.77 ± 0.57	6.51 ± 0.51	6.52 ± 0.54	6.62 ± 0.50	6.67 ± 0.46	6.69 ± 0.34	$P = 0.26$
Apricots	6.80 ± 0.57 ^{abcde}	6.29 ± 0.67 ^{afg}	6.4 ± 0.51 ^{b}	6.54 ± 0.57 ^{cf}	6.53 ± 0.58 ^{d}	6.49 ± 0.57 ^{eg}	$P < 0.0001$
Sucrose	6.52 ± 0.46 ^{abcde}	6.07 ± 0.7 ^{a}	6.06 ± 0.78 ^{b}	6.18 ± 0.77 ^{c}	6.28 ± 0.59^{d}	6.16 ± 0.56 ^{e}	$P = 0.006$
Sorbitol	6.6±0.41	6.63 ± 0.45	6.66 ± 0.41	6.60 ± 0.42	6.70 ± 0.51	6.62 ± 0.37	$P = 0.713$

Similar superscripts indicate a significant difference between groups.

Discussion

In the present study, the pH level of dental plaque post consumption of three types of dried fruits and two control groups was analyzed. The dental plaque ΔpH values of dates, raisins, apricots, and sucrose at one and five minutes post-consumption showed significantly higher drops compared to sorbitol. The highest plaque pH drop within one minute was associated with apricots and the highest plaque pH drop within 5 minutes was associated with sucrose. However, no statistically significant difference was found in the dental plaque ΔpH values within 10, 20, and 30 minutes following the test food's consumption. In dates and raisins, the maximum drop in plaque pH was related to one minute after consumption and the highest pH value was recorded within 30 minutes post consumption. The pH value was lower than the baseline for all time intervals. Likewise, the pH value was higher than the critical pH value (5.5) for all time intervals. The plaque pH was increased after one minute and returned close to the baseline value.

After consumption of apricot, the maximum drop in plaque pH occurred after 1 minutes and the highest pH was seen after 10 minutes. Then pH dropped slightly again, but did not reach the baseline value. The pH remained below its baseline value for all time intervals. In this study, the greatest drop in plaque pH for all time intervals was related to the apricot group within one minute of consumption compared to other studied groups. The maximum drop in dental plaque pH after rinsing with sucrose solution occurred after 5 minutes and the highest pH value was recorded after 20 minutes. In regard with sorbitol solution rinsing, the dental plaque pH was higher than its baseline for all time intervals. The pH value in the sorbitol group within 30 minutes was higher than its baseline value. However, for the apricot and sucrose groups, the pH value within 30 minutes was significantly lower than their baseline value. As well as the pH drop in sucrose was more than in apricots. The maximum and minimum pH drop within 30 minutes was recorded in apricots and raisins, respectively, compared with positive (sucrose) and negative (sorbitol) control groups. Robert Stephan, 1943, first described the curve on a graph (Stephan curve) to determine pH drop and recovery in dental plaque after consumption of different foods and drinks [27]. The typical pattern of the Stephan curve is influenced by three main factors: **1**- Ingredients of the tested product, including acids, sugars, calcium, and phosphorus, **2**- Individual factors such as salivary conditions, volume and age of dental plaque, and type of oral microflora, **3**- Food and beverage consumption pattern [28,29]. In the present study, to minimize the impact of these interfering factors, samples were selected from an age group with a similar dietary pattern. seems to consume less sucrose-containing foods and are probably better at maintaining oral health than other people [30-32].

The critical pH point is not constant and varies among individuals and in different parts of the oral cavity, so it is not possible to determine the precise critical pH point. The general pH range of 5-6 is considered the critical point for enamel demineralization [33,34]. Moieni et al., 2016 examined the effect of chocolate milk and plain milk on dental plaque pH and considered ph = 6 as the critical point, which seems a more conservative value for evaluation of the acidity of snacks [35]. In the present study, the level of 24-hour plaque pH post consumption of 40% sucrose solution did not drop below the critical pH and the result was somewhat unexpected. Similarly, Mirzakhani et al., 2014 studied the effect of four types of chewing gums on dental plaque pH changes. The results showed a pH drop within 10 minutes post consumption of sucrose (initial pH = 6.3). However, the pH did not fall below 5.8 post-sucrose consumption, and after that, it gradually increased until the 60th minute and reached

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the final pH value of 6.2. The authors suggested that this may be due to the increased stimulant effect of sucrose solution on saliva secretion, which can neutralize plaque acids [36]. Holgerson et al., 2005 showed that the salivary pH had dropped immediately after rinsing with 10% sucrose solution [37]. The reason could be explained by the diffusion of acidogenic concentrations from dental plaque and bacterial mass on the tongue into the saliva, because in vivo acid production from salivary bacterial flora required a considerable time [38]. In the present study, one-day-old dental plaque was analyzed. Since the participants (dental students) are considered to have satisfactory knowledge about proper dental care and practicing good oral hygiene, the pH value above the critical point was predictable. Axelsson, 2005 showed that marked pH drop after sucrose solution consumption among toothbrushers only occurred in 3-day-old dental plaque [39]. In this study, the plaque samples were collected from the maxillary and mandibular buccal and lingual tooth surfaces. Kleinberg and Jenkins, 1964 showed a direct correlation between the rates of saliva flow and pH values in different areas of the mouth. This study clearly showed that the pH level of different dental plaques varies according to their intraoral location. The oral cavity is separated into two sections of oral vestibule and the oral cavity proper. The vestibule is the area where plaques are located on the buccal and labial surfaces of the tooth surfaces and the openings of the ducts from the parotid and minor glands of the buccal mucosa.

The second area, the oral cavity proper, is the area where the plaques are located on the lingual surfaces of tooth and the submaxillary and sublingual salivary glands ducts. The saliva may supply more the second area (oral cavity proper area) due to the higher secretory rate of submaxillary compared to parotid saliva. Moreover, the saliva moves from the vestibule region to the oral cavity proper region. Therefore, plaques on lingual surfaces would be exposed to more saliva than those on the labial or buccal surfaces. Thus, lingual plaques are more exposed to saliva and contain higher pH levels than labial or buccal surfaces [40]. One of the common approaches for determining the acido/cariogenicity potential of dental plaque is using 10% sorbitol solution as negative control and 10% sucrose solution as positive control [41]. However, in the present study, in order to equalize the amount of sorbitol and sucrose with the amount of dried fruits, a total of 20 g of sucrose and sorbitol was dissolved in 200 cc of water, which was a very large amount of dissolved solute. To solve this problem, the concentration of the solutions was increased to 40% by dissolving 20 g in 50 cc. This can be one of the limitations of the present study. In this study, the individual plaques were collected and mixed in 1 mL distilled water using a vortex mixture. In order to measure the pH of a solution, the probe must be completely immersed in the solution. Frostell, 1970 examined the acid potentialities of foods; the collected plaque was mixed with 10 ml of distilled water [42]. In Jordan et al.'s study, the collected plaque sample was mixed with 3 ml of distilled water [43].

Conclusion

The plaque pH did not fall below the critical threshold point at any time intervals following consumption of all five studied groups. Nevertheless, the pH drop rate after one and five minutes of consumption of dates, raisins, and apricots was not statistically different from that of sucrose. However, the pH decrease was significantly higher than that of sorbitol. The pH drop rate after five minutes of consumption of all studied materials was not significant. Similarly, the pH drop rate after apricots and sucrose consumption at all interval times was significantly decreased compared to the baseline, while in other groups, the pH decrease was not statistically different from the baseline. The highest plaque pH drop was associated with sucrose and the lowest plaque pH drop was associated with sorbitol.

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Conflict of Interest

There is no conflict of interest to declare.

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