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Effect of Chewing Gum on the Acid-Base and Mineral Balance in the Oral Fluid

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ABSTRACT

BACKGROUND

Despite chewing gum (CG) is widespread, discussion about its harm and benefits is still in progress. It is unknown whether the CG effect on the teeth depends on the type of sugar substitute. The aim of the present research was to study the effect of chewing gums containing aspartame and sucralose on the acid-base balance and content of mineral components in mixed saliva after carbohydrate-containing food.

METHODS

The oral fluid, or "mixed" saliva had been taken from 5 groups of volunteers: control (1), after ingestion of fruit juice (2), after ingestion of juice followed by the use of chewing gums of different composition (3-5). The pH, buffer capacity, level of total protein, pyruvate, calcium and inorganic phosphates had been determined in the oral fluid samples. The differences between groups were evaluated by Mann-Whitney U-test.

RESULTS

CGs usage prevented the pyruvate increase, and promoted normalization of the pH level and buffer capacity of the oral fluid. CGs had no impact on calcium and total protein level, and resulted in increase of inorganic phosphates.

CONCLUSION

The effect of studied CGs does not depend on the composition of sugar substitutes and most likely is caused by "cleansing" effect and decreased plaque formation.

KEYWORDS

Sweetening Agents, Saliva, Acid-Base Equilibrium, Calcium, Phosphates

INTRODUCTION

Despite chewing gum (CG) is widespread, discussion about its harm and benefits to the oral health, as to the health in general, is still in progress. The results of studies showed that CGs increases alertness, improves intellectual performance, attention and vigilance [2, 3, 14, 31] and relieves stress [14, 38], but excessive daily gum-chewing may be associated with chronic headache [37]. There are evidences that CGs cause small increase in gastric fluid volume [10, 26] and improve recovery of gastrointestinal function in postoperative period [4, 30], and have no significant effect on the rate of gastric emptying [28].

The early studies of CG influence on the dental health revealed the increased plaque growth after the usage of CG with sucrose and sorbitol [1]. Later, the sucrose-free CGs had been postulated to have caries static properties [12, 8]. This controversy emphasizes that the differences in CGs effects depend on their composition, mostly with regard to carbohydrates and sugar substitutes. The modern acidogenic theory of caries argues that the necessary condition for the development of this pathology is the presence of bacteria in dental plaque that metabolize food (mostly carbohydrates) into organic acids (pyruvate, lactate, acetate, formate), thereby create conditions for enamel demineralisation [13, 20, 25]. Sucrose is considered to be the most cariogenic, but all digestible carbohydrate foods can be involved in the caries process [16]. As a rule, modern CGs do not contain sucrose, and the most common sugar substitutes are aspartame, sucralose, sorbitol, mannitol, xylitol. However, it is unknown whether any component above is at an advantage. The effects of CGs that contain sorbitol, maltitol and xylitol have been widely reported [11, 17, 18, 32, 34]. It is believed that they have a low cariogenic effect and do not cause adverse effects being used in small quantities. We have not met the reliable information about the impact of sucralose and aspartame on the state of teeth in available literature. Since the saliva and mouth bacteria have strong impact on the dental health [9, 13, 20], we decided to focus on the changes in oral fluid composition after a meal and usage of CGs with aspartame and sucralose that could provide pro- or anti-caries effect.

The aim of this research was to study the effect of chewing gums containing aspartame and sucralose on the acid-base balance and content of mineral

components in mixed saliva after carbohydrate-containing food.

METHODS

This study was performed at the department of biological chemistry of Belarusian State Medical University in the period from December 2014 to February 2015. The participants aged 18 to 20 years were selected from the Dentistry Faculty students. Inclusion criteria involved: previously sanitised mouth cavity, natural teeth free from dental constructions and prostheses, no history and complaints of gastrointestinal diseases, no medicines used that could affect the results, informed consent. Study design involved five groups of volunteers (n=10 in each group, 6 female and 4 male). Not less than 3 hour fasting preceded the experiment in all groups. The oral fluid, or "mixed" saliva was collected by spitting within 6 minutes.

In group 1 ("control") the material was collected after the mouthwash. In group 2 ("juice") the natural orange juice with pulp was used to induce changes in the oral fluid composition. Juice contains, besides fruit acids, a significant proportion of digestible carbohydrates - 10 g per 100 ml, which include 8 g of sucrose. In group 2 the oral fluid was collected 20 minutes after drinking 200 ml of juice. In groups 3-5 ("juice + CG") CGs were used for 5 minutes after ingestion of juice, and 15 minutes later the oral fluid was collected. Three kinds of used CGs differed in composition: in group 3 CG contained aspartame and mannitol; in group 4 - aspartame, mannitol and sodium bicarbonate; in group 5 - maltose syrup and sucralose. Other ingredients of CGs were the same and included gum base, sorbitol, xylitol, acesulfame potassium, glycerol, soy lecithin, flavours.

We studied the level of pH, buffer capacity, the concentration of pyruvic acid, total protein, inorganic phosphates and calcium ions in the oral fluid samples. The investigated parameters are widely used to evaluate the caries risk and remineralising capacity of the mixed saliva [6, 27, 36].

Determination of pH. We used the universal indicator paper with graduated colour scale for determination of pH. The method has been chosen because of the small volume of biological material. Since it is subjective and gives approximate results, we measured also the buffer capacity which is related to pH.

Determination of buffer capacity. Buffer capacity with respect to acids was determined by titration of 1 ml of oral fluid with 0.1 M solution of hydrochloric acid in the presence of methyl red; with respect to alkali – by titration with 0.1M solution of sodium hydroxide in the presence of phenolphthalein [25]. Buffer capacity had been calculated and expressed in milligram equivalent (mg.eq) of acid and alkaline, respectively.

Determination of total protein. Total protein concentration was determined by the Lowry method, which represents the combination of biuret test with oxidation of aromatic amino acid residues in presence of Folin-Ciocalteu reagent [22]. The concentration of the coloured product was assessed by absorbance at 750 nm. The data are presented in milligram of protein per liter (mg/l).

Determination of pyruvate. The method based on pyruvate interaction with 2,4-dinitrophenylhydrasine in alkaline medium followed by formation of 2,4-dinitrophenylhydrasone derivatives of red-brown color was used [15]. The absorbance was measured at 490 nm; pyruvate content in milligram per liter (mg/l) was determined using the calibration graph.

Titrimetric method using ethylenediaminetetraacetic acid (EDTA) and eriochrome black [15] performed determination of calcium. The results are presented in mmol per liter (mmol/l).

Determination of inorganic phosphates. Phosphate content was determined after protein sedimentation with 10% solution of trichloracetic acid. The method is based on interaction of phosphate with molybdic acid to form phosphomolybdic acid, which is subsequently reduced in the presence of ascorbic acid to produce stable blue complex. The absorbance was measured at 680 nm. Phosphate content in mmol per liter was determined using the calibration graph [15].

Statistical analysis. The differences between groups were assessed using Mann-Whitney U-test and considered significant at $p<0.05$. Data are shown as median (25th percentile; 75 percentile).

RESULTS

The study showed a significant decrease in median pH of the oral fluid after the juice ingestion by volunteers - from 7.25 (6.5; 7.5) in control group to 6.25 (5.5; 6.5) in-group "juice", $p<0.05$ (fig. 1). In groups

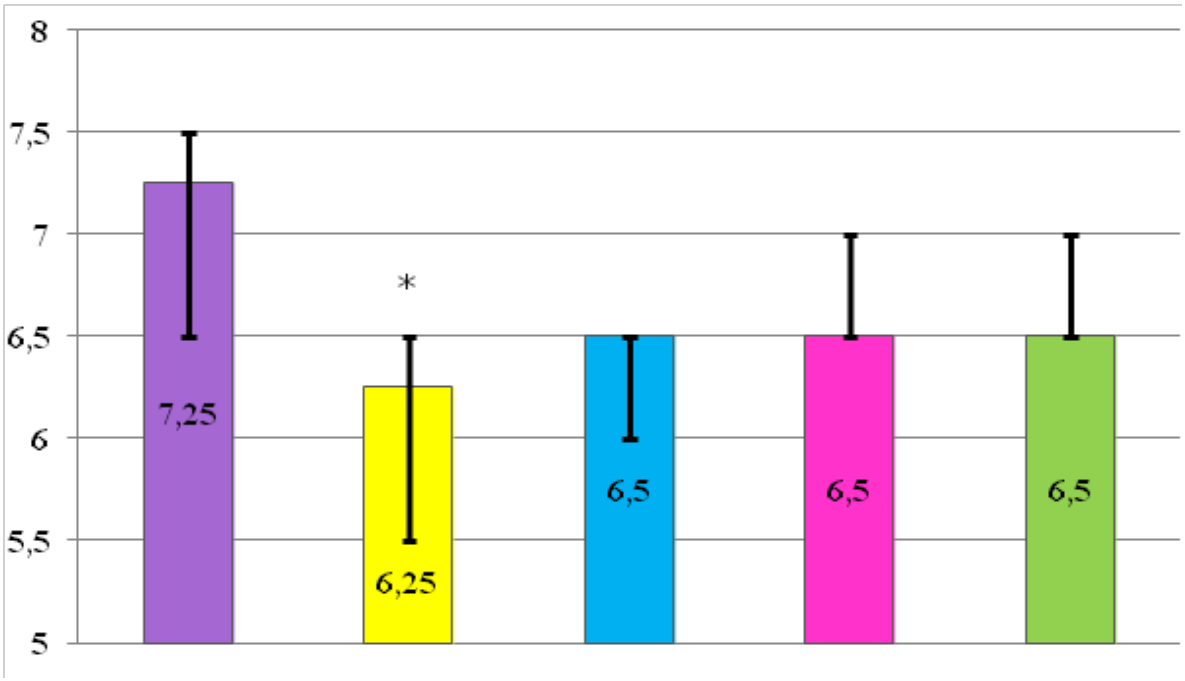

Fig. 1. The oral fluid pH after juice intake and usage of chewing gums
* - $p<0.05$ as compared to control

3-5 pH values were as follows: group 3 – 6.5 (6; 6.5); groups 4 and 5 – 6.5 (6.5; 7). Though the pH increase after usage of CG seemed to be slight, comparison of data in groups 3-5 with the control group revealed no statistically significant difference.

The results of oral fluid buffer capacity determination in studied groups are shown in fig. 2. Juice drinking resulted in significant reduction (by 33.3%, $p<0.05$) of saliva buffer capacity to acid (fig. 2A, group 2), while buffer capacity to alkali was not significantly changed (fig. 2B). After gum chewing the median buffer capacity to acid in groups 4-5 did not reach control levels, but the differences with the control group were not significant. Only two fluid samples in group 3 were sufficient in volume to perform the whole set of tests, therefore buffer capacity in this group was not evaluated.

The results of analysis of chemical components in the volunteers' oral fluid are summarized in table 1. In group 2 (juice exposure) the level of pyruvic acid in the oral fluid significantly increased (by 48.3%, $p<0.05$). Usage of all studied chewing gums resulted in a reduction of pyruvic acid in the oral fluid to a level of control values. The reduction degree in group 3 was 44.9%; in group 4 – 48.4%; in a group of 5 – 50.7%. All of these changes were statistically significant.

Total protein content in mixed saliva increased after juice intake by 97.8% as compared to control ($p<0.05$). Similar changes were found in groups 3-5, in which CGs have been used.

The oral fluid calcium level did not vary considerably among groups; the median value was 2.2 mmol/l. The concentration of inorganic phosphates increased by 40.3% after juice intake ($p<0.05$, table 1). Maximal phosphate levels, even higher than in the group "juice" (the difference is statistically significant), had been detected in mixed saliva after using CGs. Phosphate content did not differ greatly in groups 3-5 and measured up to 168% of control.

It is known that besides absolute values of calcium and phosphate in biological fluids, the calcium to phosphorus ratio is of importance. Therefore we calculated the molar Ca: P ratio in the studied groups. In the control group it was 1: 1.4, after the juice intake - 1: 2, and after the chewing gums (groups 4-5) about 1: 2.6. Such a change in the Ca: P ratio was the logical consequence of the phosphate increase when calcium level was unchanged.

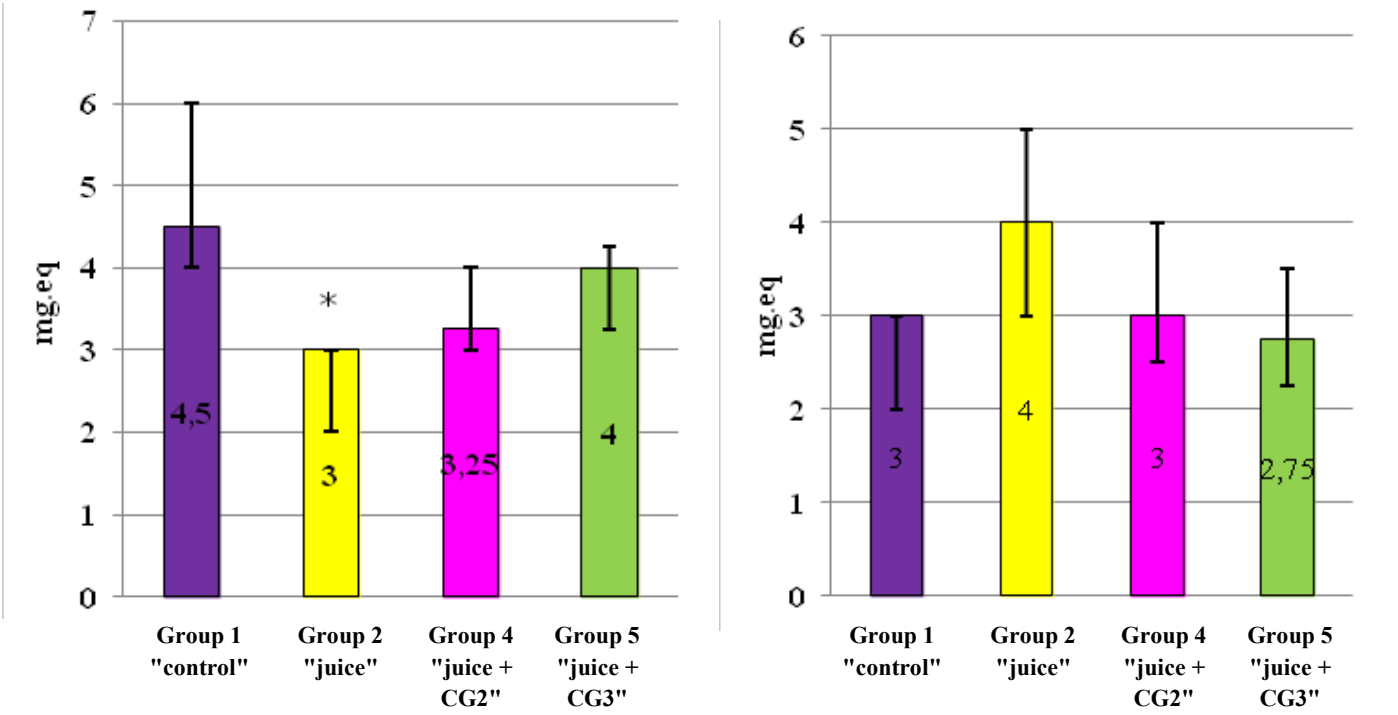

Fig. 2. The buffer capacity of the oral fluid with respect to acid (A) and alkali (B) after juice intake and usage of chewing gums
* - p<0.05 as compared to control

Index	Group 1 "control"	Group 2 "juice"	Group 3 "juice + CG1"	Group 4 "juice + CG2"	Group 5 "juice + CG3"
Pyruvate, mg/l	25.5 (17.2; 31.2)	37.8 (28.4; 49.5)*	20.8 (16.6; 24.4)^	19.5 (17.4; 21.9)^	18.6 (11.9; 23.7)^
Me (% of control)	100	148.2	81.6	76.5	72.9
Total protein, mg/l	841.7 (608.3; 1295.8)	1664.6 (1533.3; 1958.3)*	1566.7 (1270.8; 1745.8)*	2000.0 (1945.8; 2233.3)*	1737.5 (1591.7; 1952.1)*
Me (% of control)	100	197.8	186.1	237.6	206.4
Calcium, mmol/l	2.0 (1.9; 2.2)	2.2 (1.8; 2.5)	–#	2.2 (1.6; 2.2)	2.2 (2.1; 2.2)
Me (% of control)	100	110	–#	110	110
Inorganic phosphates, mmol/l	103.9 (80.9; 112.3)	145.8 (135.6; 156.7)*	174.2 (162.7; 198.1)*^	169.3 (162.6; 186.3)*^	170.0 (165.8; 178.4)*^
Me (% of control)	100	140.3	167.7	162.9	163.6

Table 1. Effect of orange juice and chewing gums on the oral fluid composition
Values are median (25 percentile; 75 percentile). * – p<0.05 as compared to group 1 (control); ^ – p<0.05 as compared to group 2 (juice); # – data not obtained because of the small sample volume.

DISCUSSION AND CONCLUSION

In present study, the orange juice was used to cause the cariogenic changes in the oral cavity. The used model resulted in significant decrease of oral fluid pH: 20 minutes after the juice intake it remained less than in controls (6.25 versus 7.25). The results were concordant with the data of buffer capacity analysis: the acid tolerance of the oral fluid samples after juice drinking was statistically significant lower, than in controls. The shift in oral pH to the acid side seems to be caused not only by the fruit acids that are present in juice, but also by activation of sugar breakdown by bacteria in mouth. To confirm this suggestion we determined the content of pyruvic acid, one of the glycolytic products, in the oral fluid of volunteers. Its increasing concentration contributes to changes in pH and indirectly indicates increasing cariogenic processes [20]. The juice intake caused almost 1.5-fold elevation of pyruvate level in oral fluid. These findings are consistent with the revealed changes in pH and buffering capacity.

Changes of the oral fluid pH and buffering capacity after CGs usage showed similar trend: normal median values were not reached, but significant differences in groups 3-5 in comparison with control group were absent. The pH changes were associated with decrease of pyruvate concentration in oral fluid to the control level. This allows speaking about a moderate normalising effect of CGs on pH and buffering capacity of mixed saliva after drinking juice. Interestingly, the effect of CGs did not depend on their composition. We hypothesised maltose in CG #3 (group 5) to be cleaved by salivary maltase to produce glucose, and thus, contribute to acid production by bacteria. We expected a more pronounced alkalising effect of the CG #2 (group 4), which contained sodium bicarbonate, the basic component of bicarbonate buffer system.

However, this did not happen. The observed in the study pH increase may be caused by following. The gum chewing stimulates salivation, this leads to an increase in the liquid component of the saliva, and hence, hydrogen ion concentration reduces [7]. Besides, the "cleansing" effect of saliva and chewing gum itself should be considered. It is known that bacteria exhibit maximum activity (including proliferation) after adhesion to the enamel surface or to the soft tissues (tongue, gums) [20, 23]. In this regard, the normalisation of pyruvate level in the oral fluid after CGs usage, found in our study, is most likely due to the mechanical clearance of the teeth surface from plaque. This suggestion is in an accordance with the previously reported decrease in dental plaque scores and Streptococci mutans after gum chewing [11,17, 32].

The increase of oral fluid protein was demonstrated in all experimental groups, and the extent of such increase was similar. This effect seems to be the result of stimulated salivation. In contrast to unstimulated secretion, provided mainly by submandibular glands, food and beverage intake, as well as gum chewing, stimulate the saliva secretion from parotid glands; and parotid secrete is characterized by a predominance of the protein component [21]. Salivary proteins represent a large heterogeneous group of molecules. Nevertheless, increase of protein level in mixed saliva after stimulation of secretion can be regarded as a defensive response: 1) the negatively charged mucin (rich in sialic acid) adsorb on the surface of the enamel and inhibit bacterial adhesion [5]; 2) proteins can cause agglutination of bacteria [19, 29]; 3) the secret of the parotid salivary glands is rich in secretory IgA, which has anti-bacterial and anti-allergenic properties [19, 24]; 4) proteins possess buffering properties [33]. Furthermore, the proteins form micelle-like structures with calcium, preventing spontaneous precipitation of calcium salts in oral fluid, and handling the remineralisation process [19].

We studied the influence of juice and CGs on the oral fluid calcium and inorganic phosphate concentration. Calcium and phosphorus are the basic elements in hydroxyapatite and fluoroapatite crystals, which are structural components of the tooth hard tissue. The presence of calcium and phosphate ions in saliva provides a process of enamel remineralisation [13, 21]. The used models did not cause changes in calcium levels.

Phosphates essentially increased following juice intake, and their level became still higher after CGs usage. Orange juice itself contains phosphates, but their concentration is too low to influence the composition of the oral fluid. Among the factors that could cause such a high content of phosphates, an increase in the activity of phosphatases in the oral fluid cannot be excluded. The saliva contains both alkaline and acid phosphatase [21]. They cleave phosphates from organic phosphate compounds and regulate (mostly alkaline phosphatase) mineralisation of bones and teeth. Noteworthy, according to available in the literature data increased activity of phosphatases in "mixed" saliva accompanies inflammatory changes

and damage of periodontal tissues [35]. The discovered in our study mineral imbalance in oral fluid, caused by increased phosphate and unchanged calcium, is equivalent to a decreased calcium level [21, 33], and may weaken the remineralisation function of the oral fluid. However, it should be noted that on the basis of data obtained in the present study, it is impossible to conclude whether this effect is long-term, and whether it has a significant impact on the oral cavity health.

Conclusions:

1. Usage of studied sucrose-free chewing gums after orange juice intake promotes normalisation of the oral fluid pH and buffering capacity, partly due to prevention of pyruvic acid accumulation; has no effect on the level of protein and calcium; and significantly increases the concentration of phosphates in "mixed" saliva.

2. The effect of studied chewing gums does not depend on the composition of sugar substitutes and seems to be caused by «cleansing» effect and decreased plaque formation.

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