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Food Components in Oral Health

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Abstract: *Tooth decay and dental erosions are the most frequent diseases of hard dental tissues. One of their origins is poor dietary habits. E.g. consumption of large amount of sweets in combination with poor oral hygiene can lead to tooth decay. On the other hand frequent consumption of acidic food can be the reason of erosive tooth wear. Tooth-friendly products are generally known like products without cariogenic as well as erosive potential. Therefore their consumption is safe for teeth. They mostly contain noncariogenic sweeteners which can not be metabolised by oral microflora and do not contain the acids. After their consumption the pH in oral cavity does not decreases under critical level (5.7 for enamel and 6.5 for dentine). Functional foodstuffs are another group of food that are safe for oral health. They contain some substances like vitamins, minerals (calcium, fluoride, phosphorous, iron, copper), casein phosphopeptide amorfous calcium phosphate (CPP-ACP), glycomacropeptide, xanthan gum, xylitol, that are beneficial for hard dental structures. These products are dairy products, fruit juices enriched by calcium or fluoride, chewing gums or candies with xylitol or CPP-ACP and many others. Their regular intake can help to strengthen the hard dental tissues. So tooth-friendly and functional foods seem to be useful in dental caries and erosion prevention.*

Keywords:*tooth-friendly products, functional food, noncariogenic sweeteners, dental caries, dental erosion*

I. Dietary habits and dental health

Diet plays an important role both in general and oral health. Dietary habits can influence teeth generally during their development and eruption or locally after eruption into the oral cavity [1].

Tooth decay and dental erosions are the most frequent pathological changes of hard dental tissues. They are occurred in patients of all age groups with the highest prevalence between adolescents and young people [2]. One of the main origins of these diseases is poor dietary habits. If the individual consumes a lot of sweets and does not provide adequate hygiene of oral cavity, so the tooth decay can be gradually developed. It is well known that tooth decay is characterized by hard dental tissues demineralization caused by organic acids produced by cariogenic microorganisms of dental plaque through the anaerobic metabolic processes of fermentable carbohydrates contained in food [3]. Due to these chemical processes (formation of organic acids, mostly lactic, acetic, propionic and butyric acid) the pH in oral cavity decreases under the critical value (5.5–5.7) that leads to hard dental tissues hydroxyapatite dissolution [3]. If these periods occur frequently, the tooth decay can be developed. Before the cavity formation this process is reversible and due to remineralization the lesion can heal [1].

There are a lot of evidences that fermentable carbohydrates especially sugars are the main diet factor of tooth decay etiology. However sugars alone are not determinant of food cariogenicity [1]. Just if the sugars are refined and added to foodstuffs, significant number of tooth decay can be present [1]. Added or "free" sugars are non-milk extrinsic sugars in combination with sugars in syrups, honey and fruit juices in high concentration. These "free" sugars are the major diet factor of tooth decay origin. Due to WHO recommendation their amount should be no more 10 % of total energy intake [4]. However in many countries their intake is much more higher that leads to high prevalence of tooth decay among the population of these countries. So one of the most effective way of dental caries prevention is sugars intake reduction [1]. The sugars reduction in the diet includes two methods: the first, reduction of total amount of refined sugars with emphasis on necessary intake more fruit, vegetables and starchy foods and the second, substitution of "free" sugars in foodstuffs, beverages and medicines by alternative sweeteners [1].

The main etiological factor of dental erosions are the acids that can have extrinsic source- dietary acidscontained in fresh vegetables and fruit (especially in citruses), juices, carbonated beverages, wine, pickles, some mineral waters etc.; acids contained in some medicines (vitamin C, acetylsalicylic acid, iron remedies),

environment or employment (wine tasters, swimmers) or intrinsic source- stomach acids that contact with tooth surfaces during the vomiting, reflux or regurgitation [2]. So the most frequent causes of dental erosions are the so called dietary acids. These acids determine a low level of pH that is one of factors of erosive potential. Fresh fruit, especially citruses, due to low pH has the highest erosive potential (Table 1). The critical frequency of citrus consumption is if you eat two or more citruses per day [5]. A high amount of acids is also characterized for acidic kinds of cucumbers and tomatoes as well as tomato sauce, salad dressings and vinegar (acetic acid-additive E 260). With respect to drinks the highest erosive potential is typical for fruit juices, soft drinks, mineral waters, sports and energetic drinks, fruit tea, wine and others. The most of these beverages contain citric acid (additive E 330), phosphoric acid (additive E 338), carbonic acid (additive E 290) or other acids. They have pH 4.0 and lower (Table 1).

Table 1 pH of most frequent consumed foodstuffs and beverages [2, 6, 7, 8]

Foodstuff	pH	Beverage	pH
Apricot	3.5–4.0	Milk	6.7–7.0
Pear	3.4–4.7	Distilled water	5.6
Peach	3.1–4.2	Carrot juice	4.2
Pineapple	3.3–4.1	Apple juice	3.4
Cherry	3.2–4.7	Orange juice	3.7
Strawberry	3.0–4.2	Grapefruit juice	2.9–3.4
Grapefruit	3.0–4.5	Coca-Cola	2.2.–2.6
Orange	2.8–4.0	Pepsi	2.53
Lemon/lime	1.8–2.4	Pepsi Light	3.1
Tomatoes	3.7–4.7	Fanta Orange	2.86
Cucumbers	5.1–5.7	Sprite	2.64
Ketchup	3.7	Sports and energetic drinks	3.05–3.8
Salad dressing	3.6	Coffee	2.4–3.3.
Vinegar	3.2	Black tea	4.2
Yogurt	4.1–.4.4	Red wine	3.4
		White wine	3.7
		Bear	4.0–5.0

Sports and energetic drinks have both cariogenic and erosive potential. Their main component are carbohydrates (glucose, fructose, sucrose or glucose synthetic polymer maltodextrin), the main function of them is supplying of human body by sufficient amount of energy during the exercises. The higher content of carbohydrates determines their high cariogenic potential. These beverages also contain different electrolytes, first of all Na^+, K^+, Cl^-which help to maintainthe water electrolyte balance. On other hand they contain just little amount of ions that are beneficial for tooth structure (Ca^{2+}, PO_4^{3-} and F^-) [9]. Their pH is between 2.38 and 4.46. These beverages also have high level of titratable acidity[10]. Most of them contain citric or malic acids. The drinks with citric acid have significantly higher erosive potential [11]. It was detected that, individuals consuming these beverages once per week have four times higher risk of tooth erosions with comparison with individuals who do not consume sports and energetic drinks [2].

Flavoured beverages except for fruit and cola flavours are generally safe for teeth [12]. Ideal flavours are the flavours that do not contain acids, like green tea, herbal extracts, mint, flower flavours, banana, coconut or chocolate. If it is necessary they can be also used in combination with a slightly acidic fruit note (e.g. combination of banana and strawberry) [12].

However erosive potential of acidic foodstuffs and beverages is done not only by low level of pH, but also another chemical and physical parameters, like titratable acidity. This is the amount of basic substances that is needed for neutralization of acids contained in the foodstuff or beverage [2, 13]. The higher value of titratable acidity needs the higher amount of saliva for neutralization of acidic environment formed after acidic foodconsumption. Titratable acidity determines the amount of damaging hydrogen ions produced after acid dissociation that are able to react with the substances of hard tooth tissues. It was determined that fruit juices have 2–3 times higher titratable acidity than another drinks with erosive potential (soft drinks, sports and energetic drinks) [9]. Further chemical properties of foods and drinks, like type, concentration and power of acids determinedby value of dissociation constant, can also have influence on the erosive potential. Chelation property (ability to bind the calcium from hard dental tissues hydroxyapatite) or mineral components content can significantly influencethe foods erosive potential. Mineral components, like calcium, phosphate and fluoride can reduce the erosive potential[8, 14]. Another factors as frequency, acidic foods method and beverages consumption, their temperature and adhesion ability can influencethe susceptibility of tooth surface to erosive damage. For example drinking using strawdecreases the time of drink contact with tooth surface in comparison with drinking from cup [2, 15]. Frozen beverages have reduced erosive potential [16]. The time during which the food is present in oral cavity is also important. The most aggressive way of acidic foodstuffs and beverages consumption is holdingin the mouth, when time of contact with teeth is longer.

With respect to determination of food risk for oral health two terms: cariogenicity and acidogenicity are used. Generally cariogenicity can be described like the potential of food to produce dental caries, while acidogenicityis described like the potential of food to produce acids [1]. Therefore like beneficial for dental health the foods with low cariogenicity and acidogenicity are considered. Cariogenicity of the foodstuff depends directly on the content of carbohydrates that can be fermented to organic acids by bacteria in dental plaque [3]. Moreover foodstuffs that contain large amount of acids may have additional indirect cariogenic potential due to promotion of cariogenic microorganisms growth by frequent acidification of dental plaque [3]. This plaque acidification can be measured by different methods, however the most frequent is plaque- pH telemetry. In this method pH-electrode measures the pH of plaque on proximal sites of the artificial teeth placed on special partial prosthesis in volunteers oral cavity. The plaque has accumulated on electrode surface for at least three but no more than seven days. Like non-cariogenic food is considered the food after its consumption the pH of plaque is not decreased under 5.7 [3].

The erosive potential of the food can be only determined in in vivo conditions, because factors such as food dissolutionperiod, acids neutralization by saliva as well as period for food contact with teeth can significantly influence the erosive potential [3]. For erosive potential measuring the same method of pH telemetry is used. The only difference is that in this case the electrode measures pH on tooth surface free of plaque. According to this method an exposure to acid of 40 µmol H^+/min is considered like critical level of food acidogenicity.

II. Tooth-friendlyproducts

Due totooth-friendlyproductsconsumption, dentalplaque pH will not decreaseunderthe 5.7 as well as they do not haveerosivepotential [17]. So these products are safeforteeth. Allof these productshavespecial logo „Happy Tooth“ (Fig. 1).TheTooth-friendlymarkwasregistered in Switzerland in 1982 forconfectionaryproduction[3]. Consequentlyanothereuropeancountriesregisteredthismark. Tooth-friendlyproducts do not containcertain food componentsthatcandamagetheteeth [3, 12]. Someofthemcontaindifferentsubstancesthat are beneficialfordentalhealth. They are mineralcomponents, caseinephosphopetideamorphouscalciumpshosphate (CPP-ACP), sweeteners, macropeptides, xanthan gum and others.

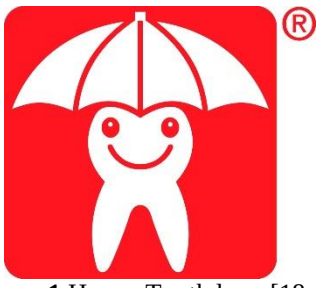

Figure 1 Happy Tooth logo [18, 19]

Additionofmineralcomponentslike fluoride, calcium and phosphatereducescariogenic and erosivepotentialoffoods. These mineralscanbefound in fruitjuices, carbonatedbeverages, sweets, chewinggumsetc. [2, 14, 20, 21].Themeanswith CPP-ACP (caseinphosphopeptideamorphouscalciumphosphate-RECALDENT) provide a simile effect [2]. Itiscontained in dairybeveragesMeijiMilk de RECALDENT orchewing gum Trident.Theirconsumptioniscontraindicated in the case ofallergicreaction to milk protein.

As wasmentionedabove, onestrategyof food cariogenicpotentialreductionissubstitution by differentsweeteners. There are two groups of sweeteners that are used in food technology: reduced-calorie (nutritive)bulk sweeteners with calories and low-calorie (non-nutritive) intense sweetenerswith little or no calories [1].

1. Reduced-calorie bulk sweeteners

1.1. Erythritolis a sugar alcohol and has promising properties like sugar substitution in the reduction of cariogenic potential. However there are limited evidences about its anticariogenic effect. Some studies established significant plaque reduction in the case of daily use of erythritol chewable tablets and dentifrice [22]. Based on currently available evidences, erythritol is considered like non-cariogenic. In contrast to many other polyols used like bulk sweeteners erythritol does not have laxative effect. So its usage should be wider in the future. Erythritol is added to different beverages, chewing gum, chocolate, candies and bakery products. It is also used as top-table sweetener [1].

1.2. Isomaltcan beconsidered like non-acidogenic sweetener [1]. Many studies showed that cariogenic bacteria are not able to ferment it that leads to the reduction of their amount [1]. These different studies concluded that isomalt is non-cariogenic. It is used in chocolate, chewing gum, candies, fruit spreads and cereals [1].

1.3. Lactitolhas low cariogenic potential. Due to the study of Grenby and Desai dental plaque of individualswho consumed sweets with lactitol during 3 days contained less soluble carbohydrate and more calcium and phosphates in comparison with individuals who consumed sweets with sucrose [23].Lactitol is applied in chewing gum, confectionary products, ice-cream and frozen desserts, chocolate, preserves and others [1].

1.4. Maltitol. There are a limit evidences of maltitol dental effect. Available studies established that streptococci are not able to ferment maltitol [1]. After maltitol application dental plaque pH does not fall under 6.0 [24]. Based on these facts maltitiol can be considered like non-acidogenic, non-cariogenic and possibly caries inhibitory [1]. It is used in chewing gum, confectionary, sweets, some dairy and bakery products [1].

1.5. Sorbitol has been widely investigated in different studies. They showed a really slow rate of sorbitol fermentation by microorganisms of dental plaque as well as slight decrease of pH after sorbitol application [1]. Sorbitol is applied in chewing gums, sweets, bakery products, chocolates and other products [1].

1.6. Mannitol has similar effect on pH and fermentation by bacteria [1]. The application is the same like for sorbitol.

1.7. D-tagatoseis added to different foodstuffs, beverages and food supplements. It is also used in some toothpastes and mouthwashes like an alternative to sorbitol, a humectant and sweetener, as well as to improve taste. D-tagatose can have some potential effect in preventionand reduction of plaque formation as well as subgingival microflora alteration[25].

1.8. Xylitol is the mostly used sweetener that has been investigated in numerous in vitro and in vivo studies [1]. It is a natural sweetener occurring in fruit, vegetables and in the wood of some trees (xylem) [26]. Its cariostatic and anti-cariogenic effect is already known for several years [26]. Xylitol can neutralize the plaque acids. It also acts like bacteriostatic agent. Xylitol can form some complex compounds with calcium ions that subsequently penetrate into the enamel and prevent loss of calcium and phosphate ions from hard dental tissues hydroxyapatite during demineralization. Thus, xylitol plays important role in the remineralization of hard dental tissues [26]. Besides this xylitol increases the buffering capacity of saliva, which helps to increase the pH in the oral cavity [26]. Xylitol is available in the form of pellets, powder, chewing gum or nasal spray. It is added into confectionery products, chocolate, dairy products, frozen desserts, baked goods [1]. It is also part of some mouthwashes, toothpastes and gels [26].

According to different studies xylitol has a positive dental effect even in really small doses: less than 1 g per day in toothpaste, 5–20 g in confectionery and 2–10 g in chewing gums [1].

2. High-intensity sweeteners. There is a few evidence about effects of high-intensity sweeteners on dental health [1]. These sweeteners provide a sweet taste with low calories. For improving of their functional properties they are often used in combination with bulk sweeteners such as polydextrose, maltodextrin, resistant maltodextrin or other bulking polysaccharides [1]. High-intensity sweeteners are widely used in carbonated drinks.

2.1. Acesulfame Khas a property to inhibit the growth of S. mutans as well as to decrease the formation of acids from sucrose [1]. So it can be suggested as non-cariogenic. Acesulfame K is added to beverages, dairy products, edible ices, bakery products, cereals, different sweets and chewing gums as well as to jams, marmalades, preserves and canned fruit. It is also used like table-top sweetener [1].

2.2. Aspartame. Due to available studies aspartame is non-fermentable and non-cariogenic sweetener [1]. It is used in soft drinks, confectionery, pharmaceutical tablets and dry syrups, dairy products, dry mix products, bars as well as table-top sweetener [1].

2.3. Cyclamate and Saccharin are the further sweeteners that used in food industry for reduction of cariogenic potential. After their application the pH in dental plaque is not higher than critical values. They are used in beverages and like table-top sweetener [1].

2.4. Sucraloseis chlorinated derivative of sucrose. Available studies provided in in vitro conditions showed that sucralose is non-cariogenic and unable to support the growth of cariogenic bacteria [1]. These studies also showed that sucralose is non-acidogenic. Sucralose is used in beverages, dairy products, confectionery production, baked products and in some pharmaceutical means [1].

2.5. D-psicose (D-allulose) is a novel non-laxative and tooth-friendly sweetener that can have particular interest for confectionery manufacturers in the future. Nowadays its use is limited to some countries (e.g. USA, Japan) [27].

2.6. Thaumatin, Neohesperidine DC, Isomaltulose (Palatinose) are further low-calorie sweeteners that are used in food industry. However there is a few studies investigated their effect on dental health. Therefore further investigations are needed. They are added to chewing gums, selected soft drinks as well as in liquid medicines, oral care products and in the nutraceutical/fortified foods industries [1].

2.7. Bulking agents like polydextrose, inulins, maltodextrines, gellan gum are another substances that are added to foodstuffs and beverages to reduce their cariogenic potential [1, 27]. The mechanism of its non-cariogenic effect is the similar like for sweeteners: they are unable to be the substrate for cariogenic bacteria as well as their application do not lead to pH decrease or decrease it insignificantly [1]. However it is advisable to provide a detailed research of their dental effects.

III. Functional food

Some foodstuffs besides macronutrients, mineral components and vitamins contain so called functional substances that have beneficial effect on human health generally. These foodstuffs and beverages are called functional. They have besides their main, nutritional, function supporting effect on normal physiological functions as well as they can help to stop some pathological processes [28, 29]. The history of functional food starts from 80s years of the 20th century. Due to Food and Agriculture Organization (FAO) the functional food is defined as food that is a part of diet containing biologically active substances helping to save health and reduce risk of diseases [28].

Functional foodstuffs are first of all the dairy products with high content of bioactive proteins and calcium. It is well known from many studies that regular consumption of milk,cream cheese and cheese leads to reduction of cariogenicity [29]. They contain mineral components (calcium, phosphates), lipids and so called bioactive proteins like caseinphosphopeptideand glycomacropeptide. These casein derivatives can be also contained in some beverages, waffles, cookies, chocolate, pudding, nut butter, cereals, gelatin and help to remineralize hard dental tissues (increase of absorption of calcium, iron and zinc) as well as reduce dental plaque formation and protect the tooth surface against tooth decay and erosion [28, 29]. Their combination with amorphous calcium phosphate is patented substance RECALDENT that is a part of many foodstuffs, beverages and oral hygiene means with anticariogenic and antierosive effects. This substance inhibits the growth of cariogenic Streptococci as well as forms on the enamel surface the reservoir of mineral components for its healing after acidic reaction [28, 29]. Dairy products are recommended to be consumed like final product after main meal and they are both effective in prophylaxis of dental caries as well as erosion. Besides mentioned active substances they also contained protein binding the folate, lactoferrin, lysocim, lactoperoxidase that in in vitro conditions inhibit the growth and adherence of Streptococcus mutans [30].

Some fruit and plant also contain functional components. For example cranberries have anticariogenic effect due to polyphenols and polyalcohols helping to reduce the number and adherence of Stretococcusmutans on the tooth surface [31]. The similar effect is characterized for cacao that contains procyanidins, antioxidants, trigonelline and polyfenols. Tea leaves contain catechin that inhibits the metabolism of cariogenic microorganisms and due to block of glycosyltransferase worsen adherence of some cariogenic bacteria on the tooth surface [32].

Another group of functional components are some preservatives, like sorbates, benzoates, sulphites andnitrite that inhibits the growth of cariogenic streptococci [33].

Honey and its products are also very beneficial for general and oral health. It contains phosphate ethers of glucose and sucrose as well as salts of inositol hexaphosphate acid that in in vitro conditions are able to interference with cariogenic bacteria and inhibit the adherence of Streptococcus mutans on the tooth surface [34]. The further honey product with anticariogenic property is the propolis that contains flavonoids and antimicrobial substances and due to this has biocidal effect on cariogenic bacteria [34].

Probiotics are another foods with functional components. These are the products that contain microorganisms beneficial for health. These microorganisms can form some antimicrobial substances that inhibit another, pathological, kinds of microorganisms. Dairy products with probiotic kinds of lactobacillae and bifidobacteria are widely used in therapy of gastroenterological and gynecological diseases. It was established that these bacteria can also have anticariogenic effect [35]. Nowadays some probiotic chewing gums and dragée for tooth decay reduction are available on the market. But it is necessary to keep in mind that further clinical studies of probiotics influence on tooth decay formation and prevention are needed [1].

IV. Conclusion

Consumption of tooth-friendly and functional products instead usual sweets and foods with high erosive potential seems to be one of the ways of dental caries and erosion prevention. Use of sweeteners instead sugar, has positive effect in caries prevention that has been confirmed in many clinical and experimental studies.Use of reduced-calorie sweeteners in ‘safe for teeth’confectionery products provided a tooth-friendly alternative to confectioneryproducts with sugar. Addition of mineral components like calcium, fluoride, phosphate to different foodstuffs and beverages reduces their cariogenic and erosive potential. Another functional components that can be found in different plants, fruit, honey, milk, dairy products, preservatives, probiotics etc. seem to be also effective addition to complex prevention of these pathological changes of hard dental tissues. However further investigations in this field are needed.

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