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CARBOHYDRATES, SALIVA AND ORAL HEALTH: A LITERATURE REVIEW

CARBOIDRATOS, SALIVA E A SAÚDE BUCAL: REVISÃO DA LITERATURA

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ABSTRACT

Carbohydrate is the main source of energy and plays important functions for survival, as an energy fuel, in addition to modulating the oxidation of proteins. The relationship between carbohydrates and tooth decay is in the induction of biofilm formation with cariogenic microorganisms. This review aims to assess the structure and function of carbohydrates; the role of saliva in the oral environment; the possible interaction between the consumption of carbohydrates and the maintenance of oral health and the relationship of the mouth with other physiological, social and political aspects, through a literature review. Articles were selected from the PubMed, SciELO and Google Scholar databases from 2016 to 2021, in Portuguese and English. The studies analyzed showed that the presence of carbohydrates, sugars, in the form of monoses are factors that directly or indirectly stimulate bacterial growth and the appearance of these diseases and, therefore, a balanced diet is an essential factor to reduce colonization of the mouth by these microorganisms. It is concluded that the balance in the proper feeding, brushing and hygiene and periodic visits to the dentist are indispensable measures to guarantee oral health and all its benefits.

Keywords: Dentistry. Disease. Sugars.

RESUMO

O carboidrato é a principal fonte de energia e desempenha funções importantes para a sobrevivência como combustível energético, além de modular a oxidação das proteínas. A relação entre carboidratos e cárie dentária está na indução da formação de biofilme com micro-organismos cariogênicos. Esta revisão tem como objetivo relacionar a estrutura e a função dos carboidratos, o papel da saliva no ambiente bucal; a possível interação entre o consumo de carboidratos e a manutenção da saúde bucal e a relação da boca com outros aspectos fisiológicos, sociais e políticos por meio de uma revisão de literatura. Foram selecionados artigos nas bases de dados PubMed, SciELO e Google Acadêmico no período de 2016 a 2021, nos idiomas português e inglês. Os estudos analisados mostraram que a presença dos carboidratos e açúcares na forma de monoses é fator que estimula direta ou indiretamente o crescimento bacteriano e o aparecimento de cárie, doenças periodontais e cálculos dentários, portanto, uma alimentação equilibrada é um fator essencial para reduzir a colonização da boca por micro-organismos patogênicos. Conclui-se que o equilíbrio na alimentação, escovação e higienização adequadas e visitas periódicas ao dentista são medidas indispensáveis para garantir a saúde bucal e todos os seus benefícios.

Palavras-chave: Açúcar. Doença. Odontologia.

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INTRODUCTION

Carbohydrate is a macromolecule abundant in food and very well accepted by several metabolic pathways. Thus, the consumption of foods rich in carbohydrates combined with poor tooth brushing, can generate an increase in the proliferation of various bacteria in the oral cavity, leading to the appearance of oral diseases.

Caries, gingivitis and periodontitis are diseases that manifest in the oral cavity that are associated with frequent intake of this nutrient (COUTO *et al*., 2016; JUNIOR *et al.*, 2019).

Dental caries is a disease of complex etiology involving several determining factors, such as the presence of the host, microorganisms, time and cariogenic diet (MAGALHAES *et al*., 2021).

Excessive consumption of carbohydrates and inefficient tooth brushing create a favorable environment for the multiplication of cariogenic bacteria (acid-producing) that promote a chemical dissolution of tooth structures and develop carious lesions (COUTO *et al.*, 2016; CARDOSO; PASSOS; RAIMONDI, 2017).

Periodontal diseases are inflammatory diseases that start from the dental biofilm (Figure 1A) developing when there is dysbiosis in susceptible individuals, associated with a dysregulation of the immune-inflammatory response that causes damage (CHAPPLE *et al.*, 2017; STEFFENS; MARCANTONIO, 2018). Gingivitis and periodontitis are diseases affecting the periodontium (OLIVEIRA *et al.*, 2017; STEFFENS; MARCANTONIO, 2018).

Accumulation of bacteria on the dental surface can lead to the formation of dental biofilm (COUTO *et al.*, 2016; CARDOSO; PASSOS; RAIMONDI, 2017). The mineralization process of this dental biofilm leads to the formation of dental calculus, which despite triggering a loss of microbial virulence, provides a surface for the deposition of a new, newly formed and living biofilm, which can compromise the tooth-gingival integrity (AKCALI; LANG, 2017).

Carbohydrates have a dual role in people's health and especially in oral health. Despite being a source of nutrients for many pathogenic bacteria, some types of carbohydrates can be health allies (MEDEIROS; GOMES, 2018). In this context, the objectives of this study were to correlate the structure and function of carbohydrates; analyze the role of saliva in the oral environment; the possible interaction between the intake of carbohydrates and the maintenance of oral health and the relationship of the mouth with other physiological, social and political aspects.

METHODOLOGY

This article is a narrative review of the literature on carbohydrates, saliva and oral health. Articles were selected by a search of the PubMed, SciELO and Google Scholar databases, using the Health Sciences Descriptors (DecS): carbohydrates ("carboidratos"); dental caries ("cárie dentária"); periodontal diseases ("doenças periodontais") and oral health ("saúde bucal"). We chose to use the Boolean operator *or*. Through an active search for potentially useful articles, through the reading of titles and abstracts, 59 articles published between the years 2016 to January 2021 were included.

Texts written in Portuguese and English were selected. Articles that did not meet the inclusion criteria, after reading the title and abstract, were excluded. Thus, the texts that were not rejected by the title and/or by the abstract, were read and selected to compose this review.

To illustrate and facilitate the understanding of the contents, figures were created by the authors in the software CorelDRAW® to facilitate the understanding of the theoretical issues arising from the articles included in this review.

DEVELOPMENT

Mouth health from a physiological and social perspective

The mouth has an important influence on the formation of the individual's identity and, through it, we can communicate and represent feelings (BOTAZZO *et al.*, 2016; VOGEL; MEYER;

HARENDZA, 2018). For a person to be able to perform such functions, they have to have a healthy stomatognathic system (SUZART; CARVALHO, 2016). Any change caused to the face can cause damage, the simple early loss of teeth can impact the behavior of individuals, causing behavioral changes (MEDEIROS; GOMES, 2018).

Maintaining health is a determining factor in ensuring a person's quality of life (Figure 1B) (CARRAPATO; CORREIA; GARCIA, 2017). Oral diseases bring pain, discomfort, chewing problems and speech difficulties, removing the person from a healthy state and interfering with their quality of life (SILVA *et al.*, 2017).

Oral diseases can be directly related to systemic diseases. Periodontal diseases, for example, can be related to cardiac, cerebral and pulmonary vascular infections (GERMANO *et al.*, 2018).

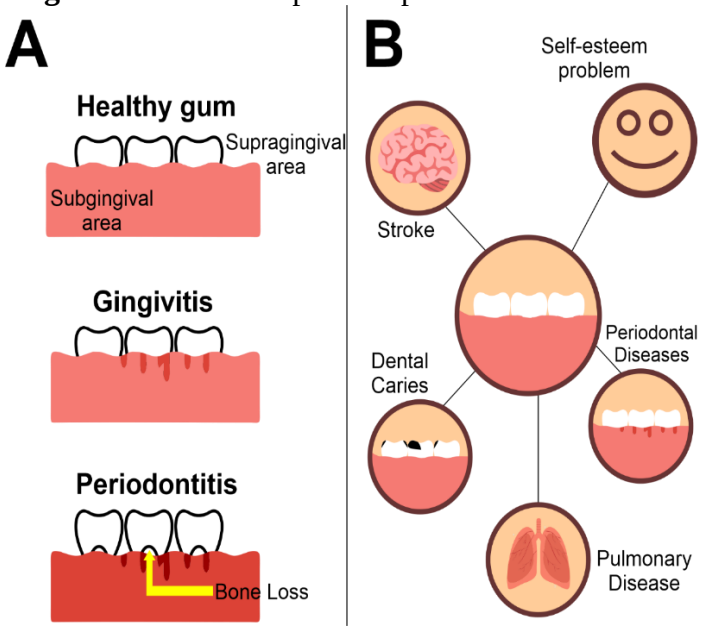
Studies suggest the relationship of oral bacteria with premature births, in addition to oral and pancreatic cancer (TESHOME; YITAYED, 2016; MAISONNEUVE; AMAR; LOWENFELS, 2017; MICHAUD *et al.*, 2017).

However, access to dental services, especially in Brazil, is not equal. Several factors interfere with access to these services, such as cultural aspects, popular beliefs and lack of financial resources (FONSECA; FONSECA; MENEGHIM, 2017; CARREIRO *et al.*, 2019).

In 2004, the Brazilian government created the National Oral Health Policy, the "Brasil Sorridente". This policy aims to take oral care, via SUS, to the entire Brazilian territory. However, studies have shown that the program, although it has increased the number of service stations in the Brazilian territory, presents some problems that need to be corrected, such as the poor distribution of dental surgeons, the lack of regulation of their employment contracts, with unjustified wages and workload (CAYETANO *et al.*, 2019; GABRIEL *et al.*, 2020; TAVARES *et al.*, 2020).

There is a consensus that many systemic diseases influence the oral environment and vice versa, therefore, the mouth should be evaluated and treated together with the whole body, to guarantee the patient's healthy state. Ensuring the health of the structures that make up the stomatognathic system is essential to guarantee a person's health, quality of life and well-being. Therefore, government programs aimed at this purpose should be improved to ensure such an act (CARRAPATO; CORREIA; GARCIA, 2017; GERMANO *et al.*, 2018; MEDEIROS; GOMES, 2018; GABRIEL *et al.*, 2020).

Figure 1 - General aspects of periodontal diseases



Notes: In (A), schematic model of the main periodontal diseases affecting the periodontium. (B) Various aspects of the need to maintain oral health.
Source: the authors.

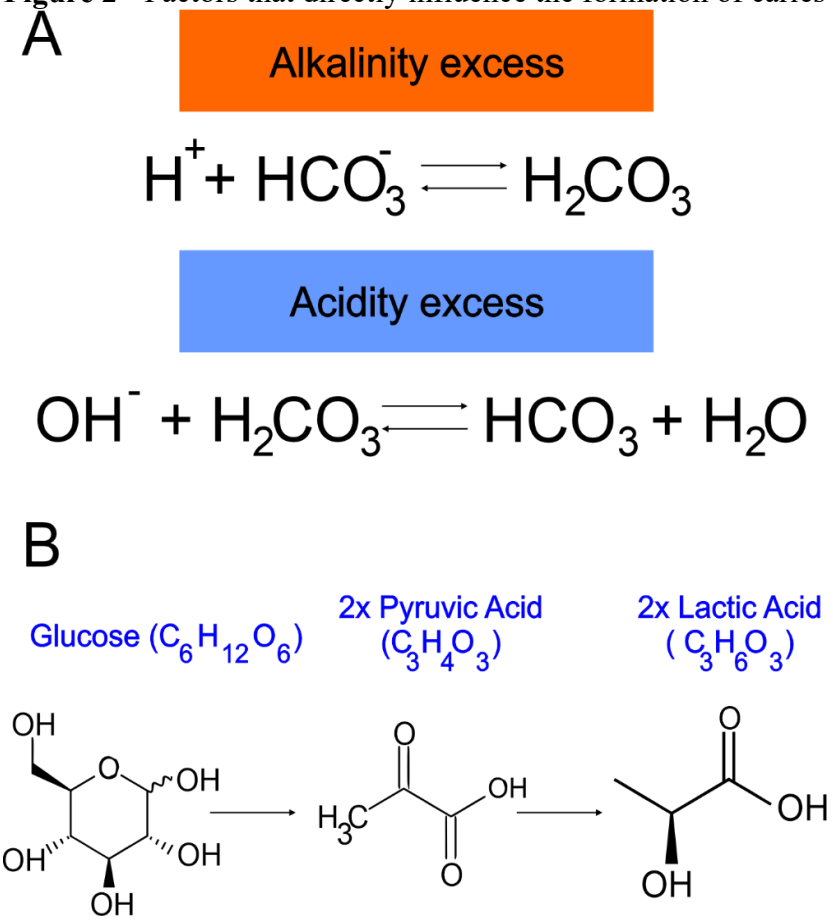
The role of saliva in maintaining oral health

Saliva is produced by salivary glands. It is a biological fluid composed of 98% water, containing electrolytes such as: Sodium, Potassium, Calcium, Magnesium, Chloride, Hydrogen phosphate and Hydrogen carbonate. Saliva also has lubricating compounds (mucin and proline-rich proteins), enzymes (amylase, lipase, ribonuclease, protease) and growth factors. In addition, proteins such as secretory immunoglobulin A (IgA), lysozyme, peroxidase, alpha-amylase and lactoferrin are some antimicrobial compounds present in saliva (LIMA *et al.*, 2017; SILVA NETO *et al.*, 2020).

Saliva has the function of maintaining oral pH around 6 to 7, so the salivary fluid behaves like a buffer system, an aqueous fluid with the ability to resist pH variation. These systems are formed by conjugated pairs, such as: mucinate/mucin, bicarbonate H_2CO_3 / HCO_3^-) and phosphate ($H_2PO_4^-$ /HPO_4^{-2}) (ALVES; SEVERI, 2016) (Figure 2A). This conjugate consists of a proton donor molecule or ion, therefore, a weak acid and its conjugated base (by a proton acceptor) (NELSON; COX, 2018). When the pH values in the mouth fluctuate, the buffering system acts to neutralize the excess acid/base present in the mouth.

The acquired film covers the teeth and oral mucous membranes and it has the function of lubrication, reduction of friction, promotion of a matrix to remineralize the enamel and protection against acids (ZANATTA, 2016). This film is composed of molecules present in saliva, such as salivary proteins, lipids and peptides and it is characterized as an organic film.

Figure 2 - Factors that directly influence the formation of caries



Notes: (A) Example of the carbonic acid/bicarbonate buffering reaction. (B) The formation of acidic molecules (lactic acid) from the most common carbohydrate metabolism (glucose) - microbial metabolism/Fermentation.
Source: the authors.

Saliva can be used as support material for various laboratory diagnostic tests. Due to the great diversity of protein and non-protein materials present (including antibodies), it is possible to identify other diseases such as Hepatitis A, B and C, Diabetes Mellitus, Hypothyroidism and HIV (ROCHA, 2018).

Its secretion in normal volumes depends on the health condition of the individuals and the use of medications. Chronic diseases, such as diabetes and kidney diseases, can change not only the composition, but also the salivary volume/flow (ALMEIDA *et al.*, 2017; MEDEIROS; GOMES, 2018; VERGUTZ *et al.*, 2019). Not only chronic diseases affect salivary flow, the use of several drugs directly affects this secretion, which is the reason for hyposalivation due to the continuous use of drugs for the treatment of gastrointestinal, cardiovascular and nervous system diseases, among others. Scientific evidence is reported to support the diagnosis of hyposalivation caused by the continuous use of various classes of drugs (WOLFF *et al.*, 2017).

In saliva we find physiological strategies to try to avoid the appearance of oral diseases, such as caries, gingivitis, periodontitis and dental calculus (ALVES; SEVERI, 2016; ZANATTA, 2016; LIMA *et al.*, 2017). Therefore, hyposalivation, caused by chronic diseases and/or medications, can contribute to the onset of oral diseases and increased tooth wear (ALMEIDA *et al.*, 2017; LIMA *et al.*, 2017; MEDEIROS; GOMES, 2018; VERGUTZ *et al.*, 2019).

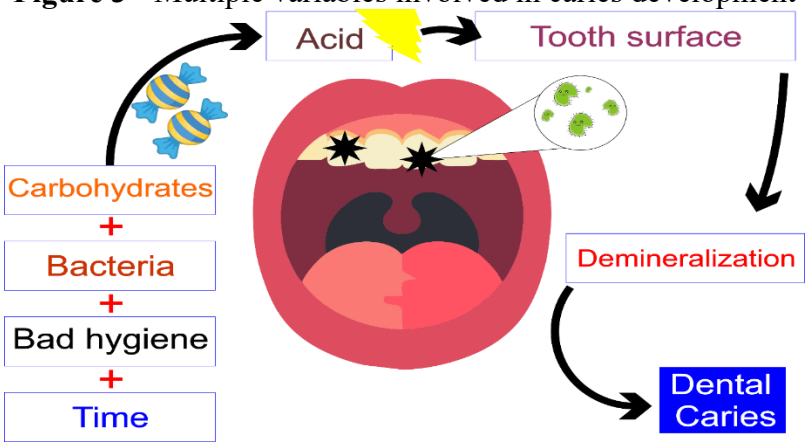
Dental Caries - etiology and social and health impact

Dental caries is considered a multifactorial disease, caused by the demineralization of dental tissues, due to the action of acids produced by cariogenic bacteria, during the fermentation of sugars (CARDOSO; PASSOS; RAIMONDI, 2017).

When bacteria accumulate on the dental surface, mainly due to the lack of hygiene, dental biofilm is formed. These microorganisms multiply forming colonies that act in mutual cooperation with each other. Dental biofilm is composed of the interaction between microorganisms, proteins of the acquired film and intercellular matrix, polysaccharides and exopolysaccharides (COUTO *et al.*, 2016; CARDOSO; PASSOS; RAIMONDI, 2017).

The production of acids is a metabolic consequence of the proliferation of fermenting bacteria (Figure 2B), however the increase in the microbial population promotes a significant drop in oral pH, making the mouth a very acidic environment, disrupting the balance of the saliva buffer and causing demineralization of the tooth, making it more susceptible to the appearance of caries lesions (MALTZ *et al.*, 2016). The main responsible organisms involved in this dynamic are the bacteria *Streptococcus mutans, Streptococcus sobrinus* and *Lactobacillus* spp. (PITTS *et al.*, 2017).

Figure 3 - Multiple variables involved in caries development



Notes: Simplified schematic model of the main factors associated with the development of caries.
Source: the authors.

Periodontal Diseases

Periodontium (Figure 1A) is composed of the tissues surrounding the teeth, such as the gingiva, the alveolar process, the periodontal ligament and the dental cementum (OLIVEIRA *et al.*, 2017). When there is a severe increase in the number of bacteria in the oral cavity, this proliferation can generate an acute inflammatory response in structures that make up the periodontium, causing periodontal diseases (CASTRO, 2016).

Gingivitis is an inflammation of the gums, without bone loss, therefore, a reversible disease (GUARDIA, 2017). Periodontitis is also an inflammatory disease, where bacteria are located in the subgingival region affecting the alveolar bone and periodontal ligament (SILVA; LESSA; MENDES, 2016). Among the main bacteria related to periodontal diseases, we can mention the species: *Porphyromonas gingivalis*, *Treponema denticola* and *Tannerella forsythia* (BOURGEOIS *et al.*, 2019).

Dental Calculus

Dental calculus is a calcified mass composed of approximately 85% inorganic content, derived from saliva. It is often located at the opening of the salivary duct (BALAJI; NIAZI; DHANASEKARAN, 2019). The development of calculus occurs with biofilm mineralization due to a local increase in calcium and phosphorus ions and with an increase in salivary pH (AKCALI; LANG, 2017). The microorganisms most frequently found in these lesions are: *Veillonella*, *Capnocytophaga*, *Actinomyces sp.*, *P. gingivalis*, *T. denticola* and *T. forsythia* (VELOZ; ALVEAR; SALAZAR, 2019).

The most effective way to avoid dental calculus is through brushing, with the use of toothpaste and dental floss (JOHANNSEN *et al.*, 2019; CHEN *et al.*, 2020).

Once formed, dental calculus can only be removed by the dentist, using specific techniques of scaling and root planing aiming the polishing of the teeth (BALAJI; NIAZI; DHANASEKARAN, 2019). Substances naturally produced and secreted by saliva also have the function of preventing/reducing the formation of dental calculus. Among these, we can mention the presence of proteins (statherins and other proline-rich acidic proteins) that act in the prevention of calcium phosphate precipitation, preventing the formation of calculus (LIMA *et al.*, 2017).

Involvement of carbohydrates in the manifestations of oral diseases

Food is closely related to an individual's health. In today's times, people's lifestyles impose an increase in the consumption of industrialized foods rich in sugars that can contribute to the emergence of diseases such as tooth decay, diabetes and obesity (COUTO *et al.*, 2016).

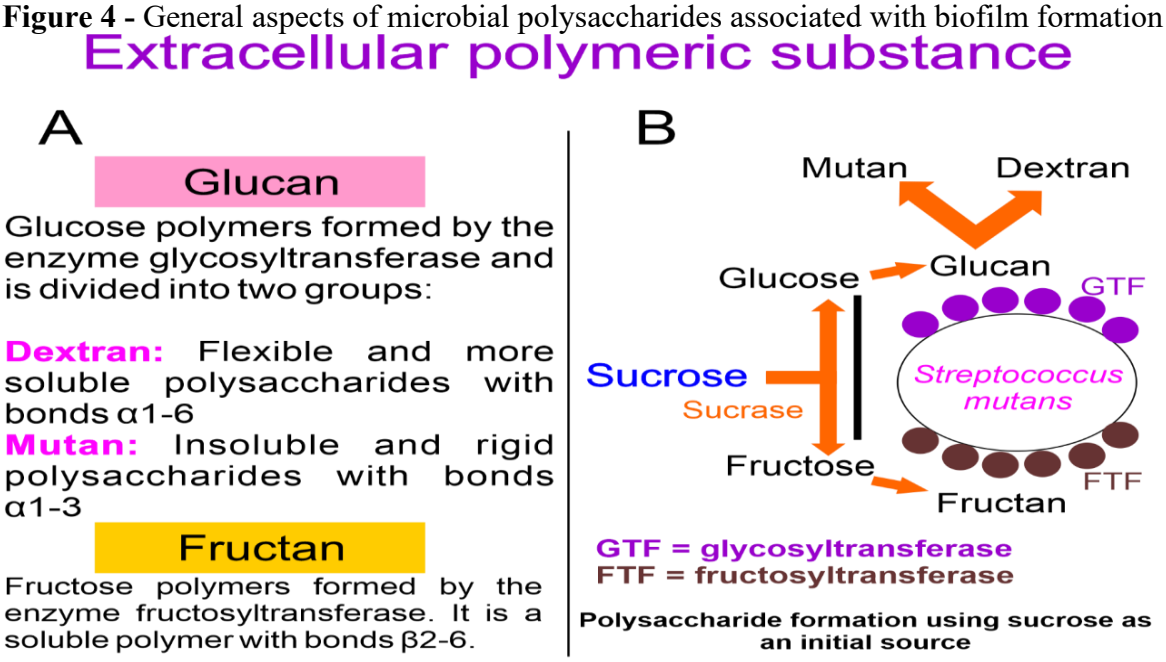
Sucrose is the sugar that shows the greatest cariogenic potential. Most microorganisms can use this sugar as a nutritional source, using it to obtain energy and synthesis of extracellular polysaccharides (soluble and insoluble), which favor the adhesion and colonization of bacteria in the oral structures.

Bacteria such as *Streptococcus mutans* (present in dental biofilm), can use sucrose to produce acids (Figure 2B) and/or to synthesize polysaccharides known as glucans and fructans (Figure 4) (BENTOS; PEREIRA, 2017; REZENDE;HASHIZUME, 2018)

Although dental caries is a multifactorial disease, the consumption of fermentable carbohydrates and the lack of hygiene drastically increases the chances of a person developing carious lesions (COUTO *et al.*, 2016) (CARDOSO; PASSOS; RAIMONDI, 2017). This is because the bacteria use sugar for the production of exopolysaccharides and for their energy metabolism, producing acids. Both compounds, exopolysaccharides and acids will act in the installation of caries (MALTZ *et al.*, 2016; WOODWARD NAISMITH, 2016; OLIVEIRA *et al.*, 2017). Among the most consumed sugars, sucrose reveals to be the carbohydrate with the highest cariogenic potential,

contributing more significantly to the mechanisms described above (BENTOS; PEREIRA, 2017; CHEDID, 2018).

Figure 4 - General aspects of microbial polysaccharides associated with biofilm formation



Notes: (A) The main characteristics of exopolysaccharides derived from microorganisms in the biofilm. In (B) relationship of cariogenic microorganisms with carbohydrate in the synthesis of glucans and fructans and with energy metabolism.
Source: the authors.

In addition to contributing to weight gain and increased adipokine secretion, excessive sugar intake can lead to oxidative stress in cells, activating pro-inflammatory proteins, via NFkB that maintain the inflammatory process intensely. Thus, controlling the diet, with reduced carbohydrate intake, can considerably reduce the chances of an individual developing gingivitis and periodontitis (NAJEEB *et al.*, 2016; WOELBER *et al.*, 2016).

Therefore, in gingivitis and periodontitis, although the bacteria responsible for these diseases are proteolytic (LEON *et al.*, 2016), carbohydrate is an important modulator. The high consumption of sugars promotes the activation of pro-inflammatory proteins, weight gain, adipokine secretion and generates oxidative stress in the cells. Thus, the consumption of carbohydrates contributes to the body's inflammation process and, consequently, to the installation of gingivitis and possible evolution to periodontitis, which are also inflammatory diseases (NAJEEB *et al.*, 2016; WOELBER *et al.*, 2016; NYVAD; TAKAHASHI, 2020).

Excessive intake of carbohydrates also contributes to the formation of dental biofilm. It has been shown that sugar is the main contributor to the formation of this biofilm. If brushing is deficient, this structure is adhered to the teeth and mineralizes, forming the dental calculus (NAJEEB *et al.*, 2016; WOELBER *et al.*, 2016).

Protective Foods

Protective foods are those that do not contribute to the development of caries disease. These foods can act to prevent the appearance of lesions and/or protect teeth (MEDEIROS; GOMES, 2018).

Milk and yogurt are foods considered anti-cariogenic. This can be associated with the ability of these foods to control the acidity of the mouth, stimulating the remineralization of the initial carious lesions. This characteristic is attributed to the components of dairy products, such as proteins (casein), lipids, calcium and phosphorus. Interestingly, phosphopeptides derived from casein contain

amorphous calcium phosphate and can have a remineralizing effect on tooth enamel, as it makes calcium and phosphate ions soluble, allowing better adhesion of these ions to dental biofilm, reducing demineralization (ÁVILA *et al.*, 2016). Lipids and fatty acids are not metabolized by cariogenic bacteria. Therefore, foods with a high content of lipids may present antimicrobial activity and bacteriostatic properties (inhibition of their metabolism and reduction of proliferation). Therefore, ingesting foods containing lipids rich in polyunsaturated fatty acids is interesting to prevent caries (GIACAMAN, 2017).

Plant-based foods can be rich in molecules with antimicrobial activity. Polyphenols are an example of a group of natural compounds present in fruits, vegetables and cereals (CUEVA *et al.*, 2020). Studies show that polyphenols inhibit the production of exopolysaccharides by bacteria, cell adhesion, the formation of water-insoluble glucan (Figure 4B) and the growth of bacteria. These characteristics of polyphenols corroborate its anticariogenic effect (MACHADO; FREITAS; SALES-PERES, 2016; FARKASH *et al.*, 2019; VELOZ; ALVEAR; SALAZAR, 2019). Some examples of foods containing polyphenols are: apple, coffee, wines, propolis, cocoa and pomegranate extract (ESTEBAN-FERNÁNDEZ *et al.*, 2017).

The researched articles agree that adequate food intake is of great importance to promote oral and systemic health. The adoption of incorrect eating habits can cause damage to dental structures (NAJEEB *et al.*, 2016; WOELBER *et al.*, 2016; NYVAD; CHEDID, 2018; JOHANNSEN *et al.*, 2019; TAKAHASHI, 2020).

However, not all products containing carbohydrates are cariogenic. There are foods with characteristics capable of preventing the onset of these diseases, therefore it is necessary to choose the right ingredients for a meal (ÁVILA *et al.*, 2016; ESTEBAN-FERNÁNDEZ *et al.*, 2017; HOLSCHER, 2017; PORTENSEIGNE, 2017; MEDEIROS; GOMES, 2018).

CONCLUSION

The consumption of carbohydrates is closely linked to the increase in the number of bacteria in the mouth, since these microorganisms require this molecule for the production of some structures and/or for their energy metabolism. There is a relationship between carbohydrates and the increase in oral diseases, such as caries, periodontal diseases

However, carbohydrate, when correctly chosen, is a strong ally to guarantee oral health. Many foods have properties capable of preventing the proliferation of bacteria and can, therefore, be used to maintain oral health.

Thus, regular visits to a dentist are essential for adequate guidance on oral hygiene care, disease prevention and maintenance of oral health.

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