Fermented Foods and Oral Diseases - A Review on Preventive Therapies

*Bharat Joshi, VK Joshi
*Swami Devi Dyal Dental College and Hospital, Barwala 133001, Haryana; Consultant and Periodontist at Air force Station, Chandigarh 160004; General Dentist at Ace medicentre Baddi,(HP), 173205
Food Science and Technology, YSP UHF, Nauni, Solan (HP) India

Abstract
Oral diseases play an important role in hampering the systemic health of human body, as mouth is the gateway for the entry of both the food and microorganisms, thus, prone to develop infections. Among these diseases, dental caries is a kind of multifactorial oral disease, responsible for causing both morbidity and mortality of teeth. Till date, no definite treatment is available to inhibit, stop or eliminate dental caries. Restorations provide only a barrier and do not promote immunity against cariogenic bacteria. Apart from caries, periodontal diseases too are responsible for sudden loss of teeth. Fermented products in the form of Probiotics and Prebiotics are some of the newer options available in the field of preventive dentistry. Consumption of such foods can serve as a useful tool for the prevention of both caries and periodontal diseases, especially during an early age. In the present review, efforts have been made to present the additional advantages and benefits of consumption fermented foods for the prevention of oral diseases especially dental caries and periodontal diseases.

Keywords
Caries; Probiotics; Fermentation; Plaque; Prebiotics; Fermented Foods

Introduction
Human oral cavity is constantly exposed to microbes since any food substance whether sticky or non-sticky, coarse or soft, refined or non-refined, always act as a good substrate for the microorganisms to proliferate and cause dental infections. The commonly involved microorganisms are S. mutans, S. sanguis, A. viscosus, F. nucleatum and P. gingivalis [1]. The microbial infections can manifest as dental caries, periodontitis, fluorosis, malocclusion or oral cancer (in association with other factors also) as depicted in Figure 1 [1, 2]. No doubt, oral cavity is vulnerable to dental infections but certain immunogenic factors like lysozyme, myeloperoxidase and lacto-ferrin are fatal for these microorganisms [1, 3]. There is always a balance between immune response and pathological process but when this balance is affected, dental infections occur.

The general population suffers from two main diseases, dental caries and periodontal infections. While dental caries is observed among all the age groups (36% in general and 9% in babies), periodontitis affects the middle age group mainly 35-45 years [1, 4, 5]. In developing countries like India too, Dental caries has the maximum prevalence rate (50%), followed by periodontitis (44%), malocclusion (32%) while Oral cancer has the least prevalence rate (0.03%) [2]. It is actively associated with pain (acute or chronic) and may have secondary signs like pus formation [6]. However, periodontitis could be associated with pain [1]. Since, they are known to cause greater discomfort to human beings; management is must at an early level.

*Corresponding author: Joshi B and Joshi VK, Swami Devi Dyal Dental College and Hospital, Barwala 133001, Haryana; Consultant and Periodontist at Air force Station, Chandigarh 160004; General Dentist at Ace medicentre Baddi,(HP), 173205. E-mail: vkjoshipht@rediffmail.com
Received November 16, 2017; Accepted February 16, 2018; Published February 25, 2018


Copyright: © 2018 Joshi B and Joshi VK. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.
Mechanism of Fermentation

Fermentation in cavities or biofilm is the process responsible for causing dental infections. It is characterized by formation of strong organic acids like lactate, formate and pyruvate that cause demineralization of tooth surface [3]. For proper management and prevention, the process of fermentation should be focused since it is the main agent behind oral diseases. The main culprit behind fermentation for the progression of both dental caries and periodontitis is the dental plaque. The credit for association of dental plaque and dental caries goes to Stephan who in 1940 showed a rapid drop in pH after the plaque is exposed to sucrose causing production of acids and afterwards, it is followed by recovery to basic plaque pH [7, 8]. The components like hydroxyapatite, fluorapatite and cement are affected at various pH values (hydroxyapatite-5.5, fluorapatite-4.5 and cement-6.5). When the pH is lowered below the “critical value” i.e. the pH at which saliva and plaque fluid cease to be saturated with calcium and phosphate, ultimately permitting the hydroxyapatite in dental enamel to dissolve. There is dissolution of calcium phosphates present in the hydroxyapatite (the basic constituent of tooth) which causes the initial loss of the tooth mineral substances [9-11]. As the time passes out, the caries process may involve enamel, dentin and cement, causing decalcification of these tissues and disintegration of the organic substances. Progression of caries can result in infecting the tooth pulp, which often spreads to the supporting tissues and consequently, the jaws [12, 13]. Thus, periodontal diseases are fatal for human health as they are the main cause for sudden mobility and loss of teeth [1].

As mentioned earlier also bacteria are responsible for causing both periodontal infections and dental caries [2]. They are responsible for producing acids, which have a devastating effect on tooth composition. This acid production also affects the nature and composition of the dental plaque microflora. It has been found that bacteria having a high tolerance for acid (or aciduric bacteria) can produce large amounts of acid that can selectively depict the over-growth present within the microflora of supra-gingival plaque [3]. Streptococcus mutans and Lactobacillus are well illustrative examples. Influence of the resting pH plays a crucial role on the microbial ecology of dental plaque. Inside the plaque environment, the resting pH results from a delicate balance between alkali and acid generation, which is dependent upon the bacterial composition of the plaque and subsequently, on the supply...
of substrates, buffers and metabolite clearance from oral fluid [14]. It becomes lowest in the interproximal regions as there is no salivary access to this area resulting in thickening of plaque biofilm which accumulates beneath the gingival embrasure adjacent to the contact points (Figure 2).

There is also production of insoluble extra-cellular polysaccharides (e.g. glucan) that form a dense protective biofilm capable of storing future surplus substrates. The polysaccharides are known to increase the adherence of microorganisms (mutans streptococci) and propel their accumulation within dental plaque, especially in young children [15, 16]. Also, the amount of dietary substrate can alter the mechanism of fermentation. A best example is of *Streptococcus mutans*. If there is influx of sucrose from dietary intake, it produces pyruvate, acetate and formate while excessive production results in the production of lactate with small lesser amounts of pyruvate. Quality of dental plaque is equally important in determining the future fermentation product. A low cariogenic dental plaque produces primarily acetate (with lesser quantities of propionate and butyrate) and weaker acids, which can more readily demineralize dental enamel [19-22].

**Microbes of Oral Diseases**

Oral microbes are omnipresent in nature, they cannot be completely eradicated. Therefore, the process of fermentation is also universal in nature. However, Shifting or altering the ecology and environmental conditions can inhibit this process to a large extent [23]. For this, understanding of certain inborn metabolisms is required which are based on pH fall and utilization of cariogenic substrates by microbes. Further, amount of plaque content may also play a decisive role [23]. Identification of microbes however is must to eliminate their metabolic processes. Some of these are listed in table 1 [1].

Mutans streptococci are amongst the most cariogenic pathogens as they are highly acidogenic in nature, adhering strongly to tooth and encourage biofilm formation [23]. Commonest mutans streptococci are *S. mutans* and *S. sobrinus*. *S. mutans* is capable of producing mutacins (bacteriocins) which help in its colonization and establishment in the dental biofilm [24, 25]. *S. sobrinus* is responsible for a large amount of acid production and is comparatively more acid tolerant as compared to *S.*
**Preventive Therapies**

As dental caries is very destructive to the health of tooth, hence, some protective therapies are required to inhibit or eliminate it. These include consumption of prebiotics, probiotics and fermented foods.

Preventive strategies have mainly been focused upon two targets re-mineralization of the caries lesions or inhibition of cariogenic microorganisms. Dietary supplements such as prebiotics and dairy products are known to provide an un-favorable environment for the growth of cariogenic microbes [26]. Fermented papaya serve many purposes in our routine life. It reduces gingivitis, dental caries and chances of Type-2 (NIDDM) diabetes [32, 33]. It can also be used as an adjunct with plant-based fermented products.

**Pre-biotics**

They are non-digestible dietary supplements whose main function is to enhance the growth and activity of beneficial microorganisms and simultaneously, suppress the growth and activity of potentially deleterious bacteria [34]. They are also known to modify the microbial population density [35]. Some well-illustrated examples of the prebiotics include lactose, the inulin, fructo-oligosaccharides, galacto-oligosaccharides and xylo-oligosaccharides. Prebiotics offer many advantages on combination with probiotics. They stimulate selectively the growth of probiotics which being dose and strain dependent, suppress the growth of pathogenic bacteria. Prebiotics also serve as a selective growth substrate or medium for the probiotics strain during fermentation, storage, or during their passage through the alimentary canal [36]. This synergistic association introduces live microbial dietary supplements and creates a suitable environment for their survival in gut flora. Consequently, the environment in gut flora improves the healthy microbial balance. A significant work in this field has been done by Paster et al. [35] who determined the bacterial diversity in the human sub-gingival plaque by using culture-independent molecular methods [37]. It came to be about 500-600 (in no). Later, it was found that *Lactobacilli* constituted approximately 1% of the cultivable oral microflora and these lactobacilli are considered as beneficial organism. Hence, prebiotics are considered useful for modifying the bacterial flora.

**Probiotics**

Probiotics are defined as living microorganisms, principally bacteria that are safe for human consumption and, when ingested in sufficient quantities, have beneficial effects on human health, beyond basic nutrition [25]. Source of these probiotics are fermented foods like cheese, milk, lozenges, chewing gums and fermented milk. They have been used successfully for employing the cure of mouth diseases also [18, 19, 30].

Ideally, four mechanisms have been found through which these probiotics act against pathogenic microorganisms depicted in Figure 3 [27]. Probiotics secrete various antimicrobial substances namely organic acids, hydrogen peroxide and bacteriocins, which are inhibitory to the growth of pathogenic microorganisms [31]. In addition, they compete with pathogenic agents for occupying adhesion sites on the mucosa [14, 15]. They are known to possess the ability to modify the surrounding environment by modulating the pH or the oxidation-reduction potential, which may be fatal for the survival of the pathogens. Also, probiotics are useful in providing beneficial effects by stimulating non-specific immunity and modulating the humoral and cellular immune response [16, 17].

Many studies all over the world have been conducted to explore the benefits of “Probiotics” in oral diseases. Some of these are summarized in Table-2. These beneficial bacteria range from *L. rhamnosus* to *Weissella cibaria*. Their advantages include antibacterial, anti-cancerous, anti-inflammatory, bone stimulation and bad breath reductions [19-22, 34-40]. Hence, probiotics are a useful tool for the prevention and inhibition of oral diseases.
Figure 3: Mechanisms of Probiotics in Dentistry [22]

Table 2: Studies in Support of Probiotics Used in Dentistry

<table>
<thead>
<tr>
<th>Name &amp; Year</th>
<th>Prebiotic name</th>
<th>Study</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sookkhee and colleagues</td>
<td><em>Lactobacillus paracasei ssp. paracasei, L. rhamnosus</em></td>
<td>Isolation of 3,790 strains of lactic acid bacteria from 130 individuals</td>
<td>Antagonist activity against <em>Streptococcus mutans</em> and <em>Porphyromonas gingivalis</em>.</td>
</tr>
<tr>
<td>Comelli and colleagues</td>
<td><em>Streptococcus, thermophilus</em> and <em>Lactobacillus lactis ssp. lactis</em></td>
<td>Utilization of 23 bacterial strains used in dairy industry</td>
<td>Interference with <em>Streptococcus sobrinus</em>, a cariogenic agent</td>
</tr>
<tr>
<td>Kazor &amp; Colleagues (2003)</td>
<td><em>Atopobium parvulum, Eubacterium sulci</em> and <em>Solobacterium moorei</em></td>
<td>Detection of microbes in halitosis cases</td>
<td><em>S. salivarius</em> a normal commensal prevents proliferation of halitosis causing agents</td>
</tr>
<tr>
<td>Nikawa and colleagues (2004)</td>
<td><em>Lactobacillus reuteri</em></td>
<td>Observation on consumption</td>
<td>Reduction in concentration of <em>S. mutans</em> upto 80% in two weeks.</td>
</tr>
<tr>
<td>Riccia and colleagues (2007)</td>
<td><em>Lactobacillus brevis</em></td>
<td>Treatment of chronic periodontitis cases</td>
<td>Reduction in anti-inflammatory mediators and decrease in bleeding on probing</td>
</tr>
<tr>
<td>Shimazaki and colleagues (2008)</td>
<td>Lactic acid bacteria</td>
<td>Assessment of cases consuming dairy products</td>
<td>Lower probing depth &amp; less clinical attachment level loss in selected cases consuming dairy products</td>
</tr>
</tbody>
</table>
**Kimchi**

It is non-dairy fermented vegetable, Korean in origin which has been associated with various health benefits. They range from prevention of cancer, obesity, reduction in cholesterol levels and promotion of individual immunity [48]. It has been found by An Chen et al. [49] that individuals consuming kimchi had decreased insulin resistance, increased insulin sensitivity, thereby improving the health of diabetic individuals [49, 50].

**Dosa**

It is a traditional south Indian food. It contains good amount of *Lactobacillus plantarum* strain, which has been shown to inhibit the growth of a range of food-borne pathogens [51].

**Fermented Papaya (FPP)**

Fermented papaya preparation (FPP) is a popular fermented food (synonyms-Immun’Age, Osato Research Institute, Gifu, Japan) [32]. This fermented supplement has been used for managing type 2 diabetes by its ability to reduce fasting blood glucose levels, low-density lipoprotein/high density lipoprotein ratio and inflammatory biomarkers like C-reactive protein and uric acid [52, 53]. Also, FPP may prove to be a good tool in preventing oral pathologies such as dental caries and gingivitis. Certain studies have supported its mechanism of inhibiting caries and gingivitis [32, 54]. Arouma et al. [55] found that fermented papaya improves immunity and is responsible for affecting inflammatory response [55]. In addition, its water-soluble nature is responsible for secretion of saliva, which cleanse the oral cavity, thereby, returning pH to normal value and decreasing caries incidence. Kharaeva et al. [56] found that the fermented papaya acts in a synergistic mechanism with human granulocytes to induce catalase, especially during oxidative stress [56]. It results in bacterial killing and in addition, there is reduction of both plaque and gingivitis.

It is proposed that as the carbohydrate content increases (~0.97 g per g-1 FPP), dextrose might have a negative impact on the growth of bacteria through osmotic dehydration of cells (Figure 4) [33]. Also, it was observed that FPP could be useful in significant reduction of bacterial affinity to hexadecane and biofilm formation (that is independent of sucrose concentration-0.05 mg/mL) [32]. It is interesting to note there is a positive association between daily consumption of fermented papaya and antioxidant enzyme expression and their activities [57]. If comparative evaluation is done with fresh papaya extracts, the FPP has resulted in the formation of important amino acids and carbohydrates that are poly-phenolic in nature and may be useful in interacting with major bacterial hydrophobins (Figure 4) [54]. However, even after the elevated production of amino acids (arginine, leucine, glutamic acid and aspartic acid) by FPP, the buffering effect was too small to counterbalance the acid produced by the bacteria [32].

Besides these products (although dosa, kimchi and yoghurt have been explained already), a variety of fermented products are available and popular all over the world. They are depicted in table 3 [59].

*Figure 4: Mechanism Action of Fermented papaya (FPP) [58]*
But a general consideration in the context of this preventive approach is that if FPP, (highly water soluble in nature) is given in refined powdered form (on oral consumption), it would be able to stimulate the secretion of appropriate amount of saliva and thereby, would rapidly clear from the oral cavity, encouraging a rapid return to baseline (normal) pH. Also, its antimicrobial activity could be boosted by forming a synergism of fermented plant-based foods with it [32]. Also, as fermentation is the chief mechanism for caries and other oral diseases, it remain a question that fermented foods can themselves cause oral diseases. No doubt, fermented foods are selective in nature, but there are still chances of occurrence of oral diseases. Hence, the consumption of fermented foods is associated with both advantages and disadvantages. Also, there are certain controversies regarding the intake of fermented foods. Elwood et al. [60] found decreased incidence of colon cancer among individuals consuming milk & dairy products [60]. Similarly, Cho et al. [61] found after doing survey of 4992 cases that there is decreased risk (15%) of development of colon cancer after consumption of dairy products [61]. It is assumed that dairy products bind to secondary bile products and ionized fatty acids, thereby, reducing their proliferative effects in colon epithelium.

Some studies have reported increased chances of cancer with the consumption of dairy products. [62, 63]. Qin et al. [64] found 10% increased risk of prostate cancer among individuals consuming milk products while Gao et al. [65] found 39% higher risk of prostate cancer in individuals consuming dairy products [64, 65]. Genkinger et al. [66] found promotion of ovarian cancer in people consuming dairy products [66]. Reason can be attributed to higher presence of fat which promotes cancer [67, 68].

In a Chinese study, showed an increased risk of squamous cell carcinoma of the esophagus in habitual consumers of fermented fish sauce [68]. Another Chinese study showed that N-nitroso compounds and genotoxins present before and after nitrosation, appear to be responsible for the cancer risk [69].

<table>
<thead>
<tr>
<th>Fermented Food and Main Constituents</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yogurt-milk, <em>L. bulgaricus, S. thermophilus</em></td>
<td>Greece, Turkey</td>
</tr>
<tr>
<td>Kefir-milk, Kefir grains, <em>Saccharomyces cerevisiae ad L. plantarum</em></td>
<td>Russia</td>
</tr>
<tr>
<td>Sauerkraut-green cabbage, <em>L. plantarum</em></td>
<td>Greece</td>
</tr>
<tr>
<td>Kimchi-cabbage, <em>Lactobacillus mesenteroides</em></td>
<td>South Korea</td>
</tr>
<tr>
<td>Cortido-cabbage, onions, carrots</td>
<td>El Salvador</td>
</tr>
<tr>
<td>Sourdough-flour, water, <em>L. reuteri, Saccharomyces cerevisiae</em></td>
<td>Egypt</td>
</tr>
<tr>
<td>Kvass-beverage from black or eye bread, <em>Lactobacillus</em></td>
<td>Russia</td>
</tr>
<tr>
<td>Kombucha-black, green, white, pekoe, oolong, or darjeeling tea, water, sugar, <em>Gluconacetobacter</em> and <em>Zygosaccharomyces</em></td>
<td>Russia and China</td>
</tr>
<tr>
<td>Pulque-beverage from agave plant sap, <em>Zymomonas mobilis</em></td>
<td>Mexico</td>
</tr>
<tr>
<td>Kaffir beer-beverage from Kaffir maize, <em>Lactobacillus sp.</em></td>
<td>South Africa</td>
</tr>
<tr>
<td>Ogi-cereal, <em>Lactobacillus sp., Saccharomyces, Pediococcus sp.</em></td>
<td>Africa</td>
</tr>
<tr>
<td>Igunaq-fermented Walrus</td>
<td>Canada</td>
</tr>
<tr>
<td>Miso-soyabean, <em>Aspergillus oryzae, Zygosaccharomyces, Pediococcus sp.</em></td>
<td>Japan</td>
</tr>
<tr>
<td>Tepa-stinkhead fish</td>
<td>USA</td>
</tr>
<tr>
<td>Dosa-fermented rice batter and lentils, <em>L. plantarum</em></td>
<td>India</td>
</tr>
<tr>
<td>Cheddar and stilton cheeses-<em>Pencillium roqueforti, Yarrowia lipolytica, Debaryomyces hansnii, Trichosporon ovoides</em></td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Surstromming-fermented herring, brine, <em>Haloanaerobium prevalence, Haloanaerobium alcaliphilum</em></td>
<td>Sweden</td>
</tr>
<tr>
<td>Crème fraîche-soured dessert cream, <em>L. cremoris, L. lactis</em></td>
<td>France</td>
</tr>
<tr>
<td>Fermented sausage-<em>Lactobacillus, Pediococcus, or Micrococcus</em></td>
<td>Greece and Italy</td>
</tr>
<tr>
<td>Wine-various organisms particularly <em>Saccharomyces cerevisiae</em></td>
<td>Georgia</td>
</tr>
</tbody>
</table>
In our opinion, fermented foods are a useful tool because they provide many benefits, which counteract their carcinogenic mechanism. In addition, the cancer supportive reports from these products are very low in number and those, which are supportive, are exceptions only. Exceptions cannot be considered for rejection of a therapeutic therapy.

**Conclusion**

This paper has tried to highlight the benefits of fermented foods. It has focused on preventive therapies and therapeutic approaches to inhibit the universal oral diseases. The hidden properties of routine food substances have been targeted and stress has been laid upon consumption of staple food. Application of routine food substances as preventive therapy can be useful tool for elimination of further restorative and surgical therapy. These include dairy products (yoghurt, cheese) and fermented substances like FFP, Prebiotics (lactose), and Probiotics and \( \text{Phage} \) .

Application of these substances have proven to very effective for treating oral diseases. However, mechanism of each of these substances is different but still they are able to contain or inhibit progression of oral diseases. Every substance is associated with some advantages and disadvantages. It is up to the individual’s way whether he/she extracts benefits or losses from it. Hence, it can be concluded that fermented products are a useful component of preventive therapy of oral diseases. However, long-term studies are still required to explore their further benefits.

**References**


