



Mini Review

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# Removing Dental Plaque Biofilm: A Review of Dextranases

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## Abstract

Various types of resident microorganisms are colonized in the human oral cavity, and they are mainly probiotics that are beneficial to the health of the host. These bacteria and foreign temporary bacteria mainly gather in the dental plaque biofilm on the tooth surface. Dextranase is a glycosidic bond hydrolase, which specifically hydrolyzes the  $\alpha$ -1,6 glycosidic bond of dextran that is the mainly component of the biofilm and can be used to remove dental plaque biofilm. This article mainly reviews the removal of dental plaque biofilm by dextranase.

**Keywords:** Dextranase; Dental Plaque; Biofilm; *Streptococcus Mutans*

## Introduction

The human oral cavity is a very suitable environment for microbial colonization. Studies have found that these microorganisms mainly accumulate on the biofilm (plaque) on the tooth surface. Dental plaque biofilm is a chronic bacterial disease that occurs on or inside teeth. It is characterized by high incidence and wide distribution, which seriously endangers human health, especially oral health. Removal of these plaques can effectively reduce the adhesion of microorganisms to the surface of the plaque mucosa. *Streptococcus mutans* presented in the human oral cavity ferments the residual sucrose in the oral cavity to produce water-soluble dextran with  $\alpha$ -1,6,  $\alpha$ -1,3 glucan bond as the main extracellular polysaccharide. Controlling dextran to reduce the formation of dental plaque biofilm has become an important means to prevent dental caries. This review mainly focuses on the removal of dental plaque biofilm with dextranase.

## The Formation of Dental Plaque Biofilm

There are a large number of microorganisms in the oral cavity of animals [1]. Dental plaque biofilm is composed of many microbial flora and adheres to the surface of teeth, which has an important impact on oral health. many oral diseases are related to the formation of dental plaque [2,3]. At present, *S. mutans* plays significant role in the forming of dental caries. Therefore, *S. mutans* is often used as a model strain in researching and constructing dental plaque biofilms [4]. The formation of dental plaque biofilm changes dynamically with time. Kolenbrander found that the initial stage of dental plaque biofilm is mainly *Streptococcus*, and the later stage is mainly *Bacillus*, *Filamentous* and *Actinomyces* [5]. *S. mutans*, *S. sobrinus* and *S. sanguis* are the early strains of dental plaque biofilm formation and play a key role in the formation of dental caries [4, 6]. Alahmad found that the main component of

dental plaque biofilm was *Streptococcus* on the first day [7]. In addition, studies have found that dead bacteria are also one of the components in the biofilm.

In the early process of dental plaque biofilm formation, they compete with live bacteria for contact positions, thereby promoting the formation of biofilm [8]. In the early days, the adsorption of biofilm was implemented by *Streptococcus* mainly, which produced adhesin to bind to the protein receptors on the formed tooth-acquired membrane and colonized the tooth surface [9]. *Streptococcus* can produce three kinds of glucosyltransferases, namely GtfD that synthesizes water-soluble  $\alpha$ -1,6-glucan, GtfB that synthesizes water-insoluble  $\alpha$ -1,3-glucan, and a mixture of two glucans. GtfC, they can quickly synthesize extracellular polysaccharides from dietary sucrose [9-11]. These two extracellular polysaccharides are connected in an orderly spiral form to form a dental plaque matrix, provided a colonization site for other oral microorganisms, thereby other oral microorganisms were promoted to colonize the dental plaque matrix. Finally, a plaque biofilm was formed and attached firmly on a surface of the tooth [12,13].

## The Source and Characteristics of Dextranase

Dextranase has been found in animals, plants, and microorganisms. The most reported dextranases are from microorganisms, including fungi and bacteria. Compared with dextranase derived from yeast and bacteria, molds usually have higher enzyme activity [14]. The dextranases produced by *Chaetomium* and *Penicillium* have been used in industrial production. *P. lilacinum* NRRL896 and *P. funiculosum* NRRL1132 have been reported they could produce dextranases that have relatively high optimal reaction temperature. Furthermore, the optimal p<sup>H</sup> of reaction was in slightly acidic condition. The characteristics of dextranase from molds were listed in Table 1&[15]. There are different sources of bacteria that could produce dextranase, and the enzymatic properties are also quite different. The time of bacterial fermentation to produce dextranase is shorter than that of mold fermentation, generally about 2 days. With less secondary metabolites, it would be conducive to the purification of dextranase in the later stage, and has little toxicity [16]. The properties of dextranase secreted from bacteria was listed in Table 1 [17-25]. The optimal of temperature and p<sup>H</sup> were diversity.

**Table 1:** Classification and characteristics of dextranase producing bacteria.

Category	Strain Name		Enzymatic Properties	References
Fungus	<i>Penicillium</i>	<i>Penicillium funiculosum</i>	T 55°C, p <sup>H</sup> 5.0-5.5	[17]
		<i>Penicillium notatum</i> 1	T 55°C, p <sup>H</sup> 5.0	[18]
		<i>Penicillium aculeatum</i>	T 50-60°C, p <sup>H</sup> 5-6	[19]
	<i>Sporothrix</i>	<i>Sporothrix schenckii</i>	T 55, p <sup>H</sup> 5.0, Mw 79 kDa	[20]
	<i>Paecilomyces</i>	<i>Paecilomyces lilacinus</i>	T 65°C, p <sup>H</sup> 5.4	[21]
	<i>Hypocrea</i>	<i>Hypocrea lixi</i> F1002	T 25°C, p <sup>H</sup> 5.0	[22]
	<i>Chaetomium</i>	<i>Chaetomium globosum</i>	T 60°C, p <sup>H</sup> 5.2, Mw 59k Da	[23]
		<i>Chaetomium erraticum</i>		[24]
	<i>Fusarium</i>	<i>Fusarium moniliforme</i>	T 55°C, p <sup>H</sup> 5.5	[25]
	<i>Lipomyces</i>	<i>Lipomyces starkeyi</i>	T 37°C, p <sup>H</sup> 6, Mw 67.6 kDa	[26]
Bacterial	<i>Arthrobacter</i>	<i>Arthrobacter oxydans</i> KQ11	T 50°C, p <sup>H</sup> 7, Mw 66.2 kDa	[27]
		<i>Arthrobacter</i> sp.	T 45°C, p <sup>H</sup> 5.5	[28]
		<i>Arthrobacter oxydans</i> CB-8	T 40°C, p <sup>H</sup> 7.2	[29]
	<i>Bacillus</i>	<i>Bacillus</i> sp.	T 50°C, p <sup>H</sup> 6.8	[30]
	<i>Thermoanaerobacterium</i>	<i>Thermoanaerobacterium thermo-saccharolyticum</i>	T 65-70°C, p <sup>H</sup> 5.5, Mw200kDa	[31]
	<i>Actinomyces</i>	<i>Actinomyces israelii</i>	p <sup>H</sup> 6.3	[32]
	<i>Streptomyces</i>	<i>Streptomyces</i> sp. NK458	T 60°C, p <sup>H</sup> 9.0, Mw 130 kDa	[33]
<i>Thermoanaerobacter</i>	<i>Thermoanaerobacter</i> sp. AB11Ad	T 70°C, p <sup>H</sup> 5-6	[34]	
<i>Thermotoga</i>	<i>Thermotoga lettingae</i> TMO	55-65°C, p <sup>H</sup> 4.3	[35]	

## Dextranase Removing Dental Plaque

Dextranase has represented excellent effect value in the prevention and removal of dental plaque biofilm [26-35]&[Table 2]. As early as 1971, Caldwell and Robert conducted related studies on adding dextranase to mouthwashes to treat dental

plaque biofilm [36]. In 1972, Keyes reported that dextranase can effectively remove dental plaque, and researchers continue to study the inhibitory effect of dextranase on dental plaque [37]. In 2002, Marotta hydrolyzed the water-insoluble glucan produced by *S. sobrinus* with commercial dextranase and also eliminated glucan

that had already formed [38]. In recent years, more and more researchers have carried out research on dextranase to remove and defend dental plaque biofilm. Qiu used *S. mutans*, *Lactobacillus acidophilus* and *Actinomyces* to establish a biofilm system in vitro, and then he added dextranase, sodium fluoride and the mixture to treat the biofilm. It was found that the biofilm treated with

the mixture was very thoroughly damage [39,40] discovered the dextran-dependent aggregation of *S. mutans* through microarray analysis of clinical strains. When dextranase was added, *S. mutans* also cannot aggregate, thereby the formation of dental plaque biofilm was reduced significantly [40].

**Table 2:** Biofilm inhibitory rates at dextranase.

Strain Name	Addition of Dextranase (U/mL)	Biofilm Formation Inhibition Rate (%)	References
<i>Catenovulum agarivorans</i> MNH15	7	91.79±0.68	[41]
<i>Catenovulum sp.</i> DP03 Cadex2870	8	90.8±2.26	[43]
<i>Catenovulum sp.</i> Cadex	35	94.21±1.13	[44]
<i>Arthrobacter sp.</i>	6	76.787±3.8	[45]
<i>Arthrobacter oxydans</i> KQ11-1	9	91.10±0.05	[46]
<i>Penicillium sp.</i>	1	9.93±0.29	[39]

Xiaohua Lai isolated the marine bacterium *Catenovulum agarivorans* MNH15 that could secrete dextranase. The study showed that the dextranase could be very effectively inhibited the formation of dental plaque biofilm. Furthermore, there was a good removal effect on the dental plaque biofilm that had already shaped by *S. mutans* [41]. Otsuka linked the mutanase gene derived from *Paenibacillus humicus* NA1123 and the dextranase gene derived from *S. mutans* ATCC 25175 into the vector at the same time and the *E. coli* expressed a chimera with two enzyme functions. The chimeric enzyme could degrade water-insoluble glucan and it expressed efficiency ability to destroy the biofilm. Moreover, removal rate was over 4 times higher than the mixture of dextranase and mutanase [42]. At present, most of the oral care products on the market are added with antibacterial agents such as alcohol, lysozyme, while products containing non-antibacterial dextranase are rare [43-46]. Some companies in the United States and Japan are mainly producing oral care products containing dextranase. Compared with the mechanical method and the chemical drug method, the biological enzyme method has significant advantages such as safety, effectiveness and low price. Therefore, the research and development of adding biological enzymes in oral care products have broad prospects.

## Conclusion

The unlimited construction of dental plaque biofilm is a natural phenomenon that exists in everyone's mouth. As a result, *S. mutans* causes severe dental caries, dental plaque and endocarditis, which seriously affects human health. Therefore, necessary precautions need to be taken to avoid these troublesome infections. For oral care products, they must have a tooth-protecting effect without disturbing the natural environment of probiotics in mouth. The inhibitory effect of dextranase on *S. mutans* has been confirmed. The dextranase that is appropriately added in oral care products

research should be selective and targeted. The optimal temperature and pH of dextranase are important, and the dextranase will not be affected by other additives of oral care products. Furthermore, the stability of dextranase in room temperature need to focus on. Dextranases have broad prospective to protect human oral health of the microenvironment of human mouth.

## Conflict of Interest

The authors confirm that there is no conflict of interests regarding this paper.

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