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(REVIEW ARTICLE)

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Antibacterial activity of bromelain extracted from pineapple (*Ananas comosus*) against *Streptococcus mutans*

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Abstract

Background: Dental caries remains one of the most prevalent oral diseases globally, primarily caused by the activity of *Streptococcus mutans*, a highly cariogenic bacterium capable of producing organic acids and forming robust dental biofilm. Increasing concerns about antibiotic resistance have encouraged the exploration of natural antibacterial alternatives. Pineapple (*Ananas comosus*) contains bromelain, a proteolytic enzyme known for its antimicrobial, anti-inflammatory, and proteolytic properties. Bromelain has been reported to inhibit various oral pathogens, including *S. mutans*, through its ability to degrade structural proteins and interfere with bacterial adhesion mechanisms.

Purpose: To determine the antibacterial effectiveness of bromelain in pineapple (*Ananas comosus*) extract against *Streptococcus mutans*.

Method: by collecting and analyzing scientific articles from major academic databases, focusing on studies assessing bromelain's antibacterial activity toward *S. mutans*.

Results: Evidence shows that bromelain inhibits *S. mutans* by disrupting the bacterial cell wall, altering membrane permeability, and reducing biofilm formation. Multiple studies reported measurable inhibition zones at varying concentrations, confirming dose-dependent antibacterial activity.

Conclusion: Bromelain from pineapple extract demonstrates significant antibacterial potential against *Streptococcus mutans* and may serve as a natural alternative for caries prevention.

Keywords: Bromelain; *Streptococcus mutans*; Antibacterial; Caries

1. Introduction

Dental and oral health play a crucial role in maintaining overall systemic health, as teeth are essential for mastication, nutrition, and protection against pathogenic invasion[1]. Damage to dental structures may impair chewing function and facilitate the entry of microorganisms into the body, increasing the risk of systemic disease[2]. Dental caries is one of the most common oral diseases affecting individuals of all ages worldwide[3]. It is characterized by the demineralization of enamel and dentin caused by organic acids produced during bacterial fermentation of carbohydrates[4]. *Streptococcus mutans* is recognized as the primary cariogenic bacterium due to its strong adherence to tooth surfaces, acidogenicity, and ability to form a robust biofilm matrix[4,5].

Preventive strategies for caries have increasingly explored natural antibacterial agents as safer alternatives to synthetic antimicrobials, which may cause adverse effects when used long term[6]. Natural antibacterials function by interfering

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with virulence mechanisms of cariogenic bacteria without significantly compromising bacterial viability[7]. Pineapple (*Ananas comosus*) contains bromelain, a proteolytic enzyme with reported antibacterial, anti-inflammatory, and proteolytic properties[8]. Bromelain has demonstrated inhibitory activity against several oral pathogens and is capable of disrupting bacterial cell walls, altering membrane permeability, and degrading salivary proteins involved in bacterial adhesion[8,9].

Given its biological properties, bromelain extracted from pineapple (*Ananas comosus*) has the potential to serve as a natural antibacterial agent against *S. mutans*, supporting its relevance in caries prevention. Therefore, this review aims to evaluate the antibacterial effectiveness of bromelain from pineapple (*Ananas comosus*) extract against *Streptococcus mutans*.

2. Methods

This article is a narrative literature review. The collection of scientific data was conducted through a systematic search of journal databases, including Google Scholar, PubMed, ScienceDirect, and Elsevier. The literature search was performed in July 2025 using the following keywords and Boolean combinations: *"bromelain", "pineapple extract", "Ananas comosus", "antibacterial activity", "Streptococcus mutans", "dental caries"*.

3. Result

3.1. Bromelain Content in pineapple (*Ananas comosus*)

Studies consistently reported that bromelain is present in all parts of pineapple (*Ananas comosus*), including the peel, crown, stem, core, and fruit. The highest bromelain activity was found in the fruit (62.5 U/mg), followed by the peel (32.2 U/mg), and the lowest in the stem (27.3 U/mg)[10]. Bromelain isolated from ripe pineapple fruit (*Ananas comosus*) demonstrated higher proteolytic activity than that from leaves or unripe fruit[11].

3.2. Characterization of Bromelain Enzyme

Bromelain is a sulfhydryl endopeptidase capable of hydrolyzing peptide bonds, with its optimal activity reported at temperatures between 50–65°C and pH 6.0–7.0[12,13]. Exposure to extreme pH or temperature leads to enzyme denaturation, decreasing its proteolytic and antibacterial potential[11]. Bromelain contains additional bioactive components such as phosphatases, glycosidases, peroxidases, glycoproteins, and protease inhibitors that support its biological functions[14].

3.3. Antibacterial Activity of Bromelain Against *Streptococcus mutans*

The literature shows that bromelain exhibits notable antibacterial activity against *S. mutans*.

- The Minimum Inhibitory Concentration (MIC) was as low as 2 mg/mL[14].
- Disc diffusion studies showed inhibition zones ranging from 20 mm at 10% concentration [10] to 26 mm at 1000 µg/mL[15].
- Purified bromelain (ammonium sulfate fraction) produced the largest inhibition zone of 21 mm against *S. mutans*[12].

These findings indicate that bromelain's antibacterial potency increases with higher purity and optimized extraction methods.

3.4. Mechanism of Action of Bromelain

Bromelain acts by hydrolyzing bacterial proteins, disrupting the peptidoglycan layer, altering membrane permeability, and inducing cell lysis[10]. Bromelain also degrades salivary glycoproteins that mediate bacterial adhesion, reducing *S. mutans* biofilm formation[10]. Additional evidence shows bromelain can inhibit essential bacterial enzymes such as reverse transcriptase and DNA topoisomerase, contributing to its antimicrobial effect[12].

3.5. Potential of Bromelain as an Anti-Caries Agent

Bromelain demonstrates significant potential as a natural anti-caries agent. It inhibits cariogenic bacteria, reduces plaque formation, and presents minimal side effects compared to synthetic antibacterials[16,14]. The enzyme's stability,

broad-spectrum antimicrobial activity, and low toxicity support its potential incorporation into dental preventive products such as herbal dentifrices, gels, or mouth rinses.

4. Discussion

The rising concern over antibiotic resistance has increased interest in natural antibacterial agents, including plant-derived enzymes such as bromelain. Bromelain, found throughout pineapple (*Ananas comosus*), contains proteolytic compounds that have been widely used in traditional medicine and have demonstrated anti-inflammatory, anti-tumor, and antibacterial properties[14,16]. Several studies confirm that pineapple fruit (*Ananas comosus*) contains the highest enzymatic activity, with levels reaching up to 62.5 U/mg, making it a promising natural antimicrobial source[10].

Evidence consistently shows that bromelain exhibits antibacterial activity against *Streptococcus mutans*, the major causative agent of dental caries. Praveen et al. demonstrated that bromelain inhibited *S. mutans* growth at a MIC of 2 mg/mL[17]. Amini et al. reported a 21 mm inhibition zone using partially purified bromelain obtained through ammonium sulfate precipitation[12]. Similarly, Nurnaningsih and Laela found that a 10% bromelain solution produced a 20 mm inhibition zone, comparable to ciprofloxacin 20 mg[10]. Ahmed et al. observed an even larger inhibition zone of 26 mm at 1000 µg/mL These findings suggest that bromelain has strong, dose-dependent antibacterial activity[15].

The antibacterial mechanism of bromelain is primarily attributed to its proteolytic action, which disrupts bacterial cell walls and alters membrane permeability, leading to cell lysis[10]. Bromelain also degrades salivary glycoproteins and extracellular polysaccharides that facilitate bacterial adhesion and biofilm formation—key virulence factors of *S. mutans*[10]. Its ability to interfere with bacterial enzymes such as DNA topoisomerase further contributes to growth inhibition[12].

Studies on different pineapple plant parts also support bromelain's antibacterial spectrum, with peel and stem extracts showing activity against bacteria such as *Streptococcus beta-hemolyticus* and *Pseudomonas aeruginosa*[18,19]. Bromelain's optimal activity at neutral pH and physiological temperatures enhances its relevance for oral applications[13,20].

Based on the reviewed literature, bromelain demonstrates consistent antibacterial effects against *S. mutans* and has the potential to serve as a natural agent for caries prevention. Its proteolytic ability to inhibit growth, disrupt biofilms, and prevent plaque formation indicates potential use in oral care formulations such as mouth rinses and dentifrices. Nevertheless, further in vivo studies are required to assess its clinical stability and long-term effectiveness in the oral environment.

5. Conclusion

Bromelain enzyme in pineapple (*Ananas comosus*) demonstrates clear antibacterial activity against *Streptococcus mutans*. The enzyme disrupts bacterial cell integrity and reduces the ability of *S. mutans* to form biofilm, indicating its potential as a natural anti-caries agent. Bromelain may serve as an alternative antibacterial component for preventing dental caries.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

Statement of Ethical Approval

This article is a review study and does not involve human participants, animals, or clinical samples; therefore, ethical approval was not required.

Informed Consent Statement

No informed consent was required for this article.

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