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Pineapple (*Ananas Comosus* L. Merr) extract as a natural antibacterial agent for oral health: A systematic review

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Abstract

Background: Oral health issues such as dental caries, gingivitis, and halitosis are often caused by pathogens like *Streptococcus mutans*, *Porphyromonas gingivalis*, *Streptococcus sanguinis*, and *Staphylococcus aureus*. While chlorhexidine is effective in treating these infections, its prolonged use has adverse effects. Pineapple (*Ananas comosus* L. Merr), contains bioactive compounds such as bromelain, flavonoids, tannins, saponins, alkaloids, phenols, chlorine, iodine, and steroids which exhibit strong antibacterial activity. This study explores the potential of pineapple extract as a sustainable and eco-friendly alternative for oral health management, aligning with global sustainability goals.

Method: The procedure used in writing this systematic review is a literature search through several databases such as PubMed, ScienceDirect, Proquest, and Google Scholar.

Discussion: Pineapple extract, exhibits significant antibacterial activity against oral pathogens due to the presence of bioactive compounds such as bromelain, flavonoids, tannins, and other phytochemicals. Bromelain reduces bacterial adhesion and inhibits biofilm formation, flavonoids can interfere with bacterial metabolism and nucleic acid synthesis while tannins disrupt bacterial cell walls, leading to osmotic imbalance and cell lysis. These attributes highlight pineapple extract potential as a natural alternative for preventing oral diseases.

Conclusion: Pineapple extract can provide antibacterial effects that are beneficial for oral health.

Keywords: *Ananas Comosus* L Merr; Extract; Antibacterial; Oral Health

1. Introduction

Oral health is a crucial component of overall bodily health. Common oral health issues such as dental caries, gingivitis, and halitosis are often caused by bacterial infections in the oral cavity. These conditions are typically caused by pathogens like *Streptococcus mutans*, *Porphyromonas gingivalis*, *Streptococcus sanguinis*, and *Staphylococcus aureus*[5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 20, 21]. These bacteria produce enzymes and acids that can damage tooth enamel and periodontal tissue, as well as increase the risk of inflammation. Furthermore, when these pathogenic bacteria enter the bloodstream they can exacerbate overall health conditions, such as increasing the risk of cardiovascular disease, diabetes, and respiratory infections[1, 8].

Currently, the prevention and treatment of oral bacterial infections largely rely on chemical-based antibacterial agents such as chlorhexidine. Although chlorhexidine effectively controls bacterial growth associated with caries and periodontal diseases[3], its prolonged use is linked to several adverse effects including tooth discolouration, mucosal

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irritation, and disturbances in the natural microbial balance of the oral cavity[4, 11]. These limitations underscore the need for safer, more sustainable alternatives.

In recent years, natural plant-based ingredients have gained significant attention due to their rich bioactive compound content and minimal side effects, particularly when used over extended periods. One promising natural resource is pineapple (*Ananas comosus* L. Merr). While the fruit's flesh is commonly utilized, other parts such as the peel and core are often discarded as waste[20]. However, pineapples contain valuable chemical compounds including flavonoids, tannins, saponins, and alkaloids which are recognized for their antibacterial properties[5]. Additionally, bromelain an enzyme found in high concentrations in the pineapple's core and peel, exhibits proteolytic activity that disrupts bacterial cell walls and inhibits the growth of anaerobic and acid-producing aerobic bacteria[6, 20].

Studies have shown that pineapple extract exhibits significant antibacterial activity against key oral pathogens, including *Streptococcus mutans*, *Staphylococcus aureus*, *Streptococcus sanguinis*, and *Porphyromonas gingivalis*[5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 20, 21]. These microorganisms are among the primary causative agents of oral health issues such as dental caries, gingivitis, and halitosis. The antibacterial efficacy of pineapple extract is largely attributed to its rich composition of bioactive compounds including flavonoids, tannins, saponins, alkaloids, and bromelain. Bromelain, a proteolytic enzyme abundantly present in the peel and core of the fruit, plays a critical role in degrading bacterial cell walls, thereby compromising their structural integrity and inducing cell lysis. These bioactive constituents work synergistically, enhancing the potential of pineapple extract as an effective natural antibacterial agent for combating oral pathogens [5, 6, 20].

The application of pineapple extract as an antibacterial agent offers a sustainable approach to oral health management while simultaneously addressing the issue of agricultural waste by repurposing discarded pineapple byproducts. This initiative aligns with global efforts to promote environmentally sustainable practices and capitalize on the therapeutic potential of natural products within healthcare, in support of the Sustainable Development Goals (SDGs), particularly Goal 3 (Good Health and Well-Being) and Goal 12 (Responsible Consumption and Production). The present study seeks to evaluate the antibacterial efficacy of pineapple extract against oral pathogens and to assess its potential as a viable alternative to chemical-based antibacterial agents. By substantiating its effectiveness, this research aims to advance the development of eco-friendly and natural solutions for oral health management, thereby reducing reliance on synthetic compounds and mitigating their associated adverse effects while contributing to global sustainability objectives

2. Material and methods

The procedure used in writing this systematic review is a literature search through several databases such as PubMed, ScienceDirect, Proquest, and Google Scholar. The design of this review follows the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) method. The search terms used were: '*Ananas Comosus* L Merr'; 'antibacterial'; 'oral health'. The inclusion criteria in this study were experimental research written in English/Indonesian which explained the effectiveness of pineapple fruit extract (*Ananas Comosus* L Merr) against bacteria in the oral cavity.

A total of 544 studies were identified through database searches, with 10 duplicates removed, leaving 534 studies for screening. Based on titles and abstracts, 510 studies were excluded for reasons such as being published before 2014 (n = 279), non-research articles (n = 23), irrelevant content (n = 200), or non-English/Indonesian language (n = 8). From the remaining 34 full-text articles, 4 were inaccessible, and 16 were excluded after eligibility assessment due to unsuitable study design (n = 8), interventions (n = 7), or outcomes (n = 1). In total, 14 studies met the inclusion criteria and were included in the review (Figure 1). Data were extracted and analyzed using Microsoft® Excel 2019, with results summarized in Table 1.

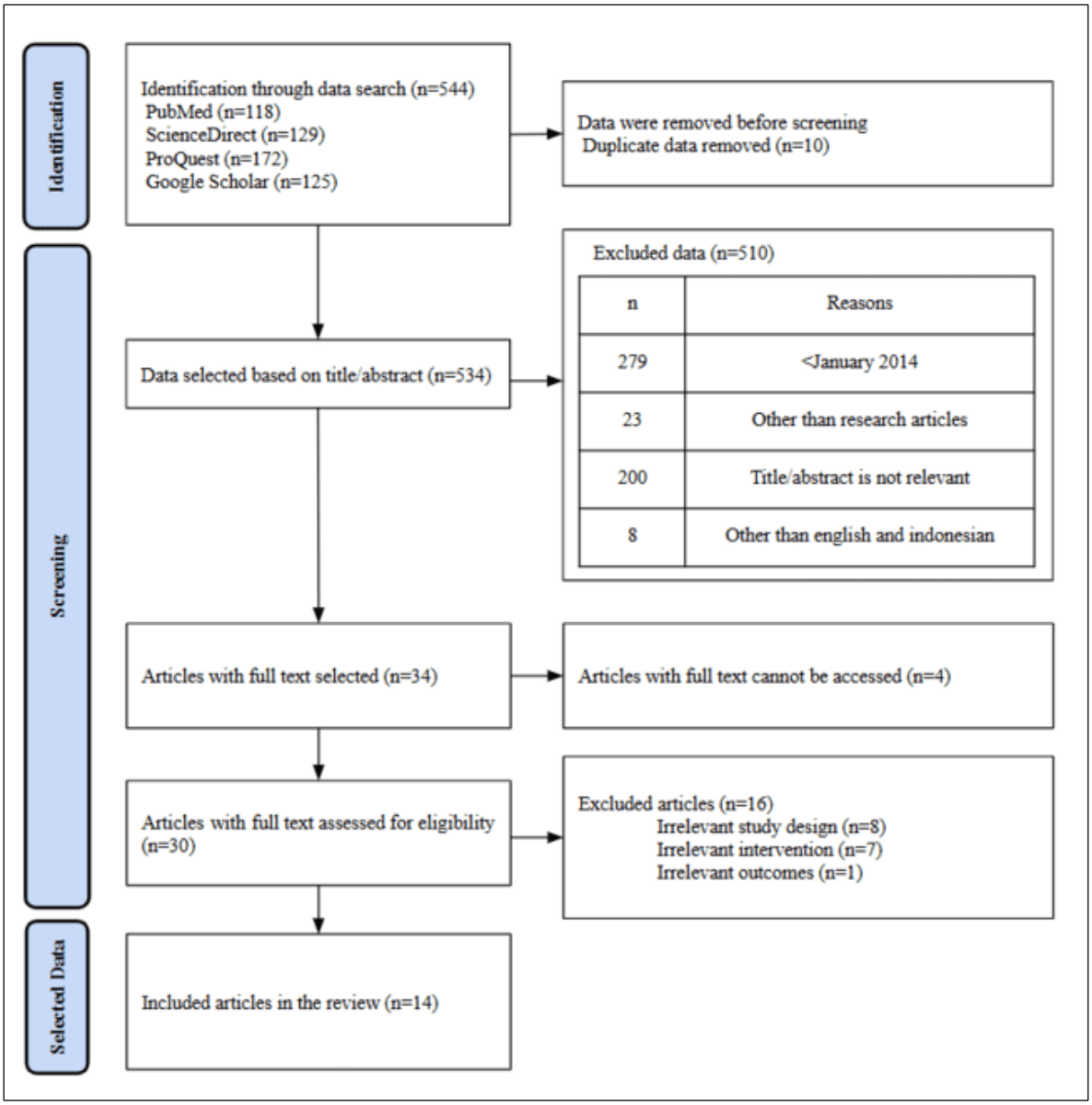

Figure 1 Flowchart illustrating the process of selecting and categorizing studies for search results '*Ananas Comosus* L Merr'; 'antibacterial'; 'oral health'.

3. Results and discussion

This study is a systematic review aimed at evaluating the antibacterial activity of pineapple extract for oral health. The research was conducted by reviewing 14 studies obtained from various databases, which provided a comprehensive overview of the effectiveness of pineapple extract in combating oral pathogens. The results derived from these studies indicate that pineapple extract, due to its bioactive compounds, can be beneficial for oral health. It contains several ingredients, including bromelain, flavonoids, tannins, and other compounds, which have been shown to possess antibacterial properties capable of preventing diseases in the oral cavity, such as dental caries and periodontal diseases.

Table 1 Summary of Included Studies on the Antibacterial Activity of Pineapple Extract

Author /Year	Phyto chemical	Source	Control (+)	Test Type	Bacterial	Result
[7]Chairunas et al / 2024	Alkaloid; Bromelain; Flavonoid; Saponin; Tannin	Core	Amoxicillin	Disc diffusion	*S. aureus*	75%: 7.146 mm; 90%: 8.65 mm; Control (+): 16.8 mm
[8]Irawati et al / 2024	Bromelain	Core		Disc diffusion	*P. gingivalis; S. aureus*	*S. aureus* 50%: 16.01 mm; 75%: 18.43 mm; 100%: 22.85 mm *P. gingivalis* 50%: 19.17 mm; 75%: 22.02 mm; 100%: 26.75 mm
[9]Amir et al / 2023	Bromelain; Flavonoid	Flesh; Juice extract	Ciprofloxacin	Disc diffusion	*S. aureus*	Flesh 25%: 7.38 mm; 50%: 7.95 mm; 75%: 8 mm; 100%: 9.72 mm; Control (+): 35.93 Juice extract 25%: -; 50%: 7.62 mm; 75% 8.60 mm; 100%: 9.09; Control (+): 34.31 mm
[12]Khairina et al /2023	Bromelain	Core	Chloramphenicol	Well diffusion	*S. mutans*	50%: 19.53 mm; 75%: 22.66 mm; 100%: 24.36 mm; Control (+): 40.52 mm
[11]Minarni & Rosmalisa / 2023	Bromelain	Core	1% Povidone iodine; 0,2% Chlorhexidine	Well diffusion	*S. mutans*	7,5%: 7.45 mm; 10%: 8.58 mm; 15%: 10.16 mm; 20%: 11.33 mm; 25%: 13.33 mm; 30%: 14.83 mm; Control (+): povidone 1%: 3.66 mm; chlorhexidine 0.2%: 11.25 mm
[10]Sagita et al /2023	Bromelain	Core; Peel	Chloramphenicol	Disc diffusion	*S. aureus*	Skin 1%: 11.45 mm; 2%: 13.28 mm; 3%: 16.11 mm; 4%: 19.23 mm Core 1%: 12.24 mm; 2%: 14.27 mm; 3%: 16.18 mm; 4%: 18.30 mm; Control (+): 21.30 mm
[20]Minarni & Rosmalia /2022	Bromelain; Flavonoid;	Core	Povidone iodine	Well diffusion	*S. mutans*	25%: 13.6 mm; 50%: 14.6 mm; 75%: 15.6 mm;

	Tannin					100%: 28.6 mm; Control (+): 4 mm
[5]Maharani et al /2021	Alkaloid; Bromelain; Flavonoid; Saponin; Tannin	Peel	Colgate	Well diffusion	*S. mutans*	5%: 11.08 mm; 10%: 13.08 mm; 15%: 15.08 mm; Control (+): 16.75 mm
[6]Nugraha et al / 2021	Alkaloid; Fenol; Flavonoid; Saponin; Tanin;	Core	Chlorhexidine 0,2%	Dilution Agar	*S. mutans*	50%: 11.25 mm; 25%: 49,25 %
[13]Sumiati et al /2021	Flavonoid; Tannin	Peel	Chlorhexidine base	Disc diffusion	*S. sanguinis*	30%: 9.92 mm; 40%: 11.39 mm; 50%: 12.51 mm; Control (+): 15.72 mm
[14]Wahyuningsih et al /2020	Bromelain; Chlorine; Iodine	Flesh	Commercial mouthwash	Disc diffusion	*S. mutans*	5%: 8.6 mm; 10%: 9.4 mm; 15%: 9.7 mm; Control (+): 12.6 mm
[15]Rahmi et al /2019	Bromelain	Peel	Chlorhexidine 0.1%	Disc diffusion	*S. mutans*	20%: 5.06 mm; 25%: 6.56 mm; 30%: 7.16 mm; 35%: 7.43 mm; 40%: 7.86 mm; 50%: 8.23 mm; 60%: 8.5 mm; Control (+): 7.40 mm
[21]Nofita et al /2018	Flavonoid; Steroid; Tannin	Peel	BT product	Disk diffusion	*S. aureus*	1.56%: 1.67 mm; 3.12%: 7.67 mm; 6.24%: 11.33mm; Control (+): 13.33 mm
[16]Umarudin et al /2018	Bromelain	Core	Bacitracin	Disk diffusion	*S. aureus*	50%: 7.6 mm; 60%: 8 mm; 70%: 9.33 mm; 80%: 10.33 mm; 90%: 13 mm; 100%: 14.67 mm; Control (+): 10 mm

Indonesia is known for its diverse tropical fruits, with pineapple (*Ananas comosus* L Merr) being one of the most popular and widely cultivated. The plant thrives in the Indonesian climate, making it a major agricultural product. Until early 2012, Indonesia was the world's largest pineapple exporter. While the fruit's flesh is commonly used, parts like the peel and core, which contain valuable bioactive compounds such as flavonoids, tannins, saponins, alkaloids, and bromelain are often discarded. These components, particularly bromelain, have shown significant antibacterial potential, making pineapple a promising natural resource for oral health applications[8].

The antibacterial activity of pineapple (*Ananas comosus* L. Merr) extract was evaluated from various parts of the fruit, including the core, peel, flesh, and juice. Among these, the core and peel extracts demonstrated the highest antibacterial efficacy against the tested bacteria, including *Streptococcus mutans*, *Streptococcus sanguinis*, *Staphylococcus aureus*, and *Porphyromonas gingivalis*.

At a 100% concentration, the core extract exhibited inhibition zones ranging from 24.36 to 28.6 mm against *Streptococcus mutans*[12, 20], 14.67 to 22.85 mm against *Staphylococcus aureus*[8,16], and 26.75 mm against *Porphyromonas gingivalis*[8]. Similarly, the peel extract at a 15% concentration produced an inhibition zone of 15.08 mm against *Streptococcus mutans*[5], while at a 50% concentration, it inhibited *Streptococcus sanguinis* with a zone of 12.51 mm[13].

In contrast, the juice and flesh extracts showed lower antibacterial activity. The flesh extract produced inhibition zones of 7.38 to 9.72 mm[9, 14], and the juice extract ranged from 7.62 to 9.09 mm[9], depending on the concentration. These values were significantly smaller compared to the core and peel extracts and, in some cases, were similar to those observed with control agents such as chlorhexidine (positive control), which exhibited inhibition zones of approximately 10–15 mm, depending on the concentration[6, 11, 13, 15]. These findings underscore the potent antibacterial potential of pineapple, particularly its core and peel, which demonstrate superior efficacy against key oral pathogens. Such results suggest that pineapple by-products could be a promising source of natural antibacterial agents for oral health applications.

Building upon these findings, bromelain emerges as a critical component in the antibacterial efficacy of pineapple extract. Bromelain, a proteolytic enzyme abundantly found in the core and peel of pineapples plays a pivotal role in disrupting bacterial integrity. Its mechanism involves the hydrolysis of peptide bonds in bacterial proteins, resulting in smaller amino acid fragments that compromise cell wall stability[12, 20]. By targeting surface proteins and glycoproteins, bromelain reduces bacterial adhesion to tooth surfaces which is a crucial factor in the formation of biofilms associated with dental caries[15, 16].

Moreover, bromelain exhibits antimicrobial activity by deactivating bacterial adhesins, enzymes, and protein transport systems within cells. This disruption not only weakens the structural integrity of bacterial membranes but also leads to osmotic imbalance and eventual cell lysis[10,14]. Specifically, its activity against *Streptococcus mutans* and *Staphylococcus aureus* has been well-documented, with studies demonstrating its ability to inhibit bacterial growth by targeting peptidoglycan structures in the cell wall[11, 16].

Other bioactive compounds in pineapple extract, such as flavonoids, tannins, saponins, alkaloids, phenols, chlorine, iodine, and steroids also contribute to its antibacterial properties. Flavonoids, particularly flavanones, act by inhibiting bacterial nucleic acid synthesis, disrupting cell membrane functions, and interfering with energy metabolism. These mechanisms are especially effective against S*treptococcus mutans,* further enhancing the antibacterial efficacy of pineapple extract[20].

Tannins exhibit antibacterial activity by inactivating microbial adhesins, disrupting enzyme activity, and interfering with protein transport within bacterial cells. By damaging the polypeptide components of bacterial cell walls, tannins impair cell wall formation, leading to osmotic imbalance and cell lysis. Additionally, tannins can form hydrogen bonds with bacterial proteins, causing denaturation and metabolic disruption[6, 7, 10].

Saponins increase the permeability of bacterial cell membranes, destabilizing the membrane and causing hemolysis, which leads to the release of essential cellular components and eventual bacterial death. Similarly, alkaloids enhance membrane permeability, destabilizing bacterial cell structures and resulting in cell lysis[5, 7].

Phenols disrupt bacterial cell walls and inactivate essential enzymes, adding to their bactericidal effects[6]. Chlorine forms hypochlorite in water, which effectively disrupts bacterial cellular processes while iodine coagulates bacterial proteins, rapidly eliminating a wide range of pathogens[14]. Steroids also contribute to antibacterial activity by disrupting microbial membranes and interfering with metabolic processes, further enhancing the overall efficacy of pineapple extract as a natural antibacterial agent [21].

4. Conclusion

The antibacterial properties of pineapple (*Ananas comosus* L. Merr) extract, particularly from its core and skin demonstrate its potential as a natural alternative for oral health. The synergistic effects of bromelain, flavonoids, tannins, and other bioactive compounds provide effective bacterial inhibition. These findings support pineapple as a sustainable and eco-friendly option for oral health care, warranting further research to explore its practical applications.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this document.

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