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Comparative Effects of Breadfruit Leave (Artocarpus altilis) and Betel Leaves (Piper betle) Gargles on Salivary pH and Plaque: A Clinical Study

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Abstract
The high incidence of dental caries in Indonesia (90%) is attributed to a combination of diets high in sugar and poor oral hygiene. Furthermore, the lack of access to preventive products remains a major barrier to improving national oral health outcomes. Decoctions made from breadfruit leaves (Artocarpus altilis) and betel leaves (Piper betle) are known to have antibacterial properties. This study aimed to compare the efficacy of breadfruit leaf (Artocarpus altilis) and betel leaf (Piper betle) decoctions in terms of their effects on salivary pH and plaque scores and to determine whether their effects were equivalent. This study used a pretest–posttest design with two groups, involving 30 respondents aged 30–40 years who were divided into two groups: the first group used breadfruit leaf decoction (n = 15), and the second group used betel leaf decoction (n = 15). Respondents gargled with 20 mL of the assigned solution for 30 seconds. Salivary pH was measured using a pH meter, while plaque scores were assessed using the Simplified Oral Hygiene Index (OHI-S). Data were analyzed using paired t-tests and independent t-tests, with a significance level of $p < 0.05$. Gargling with both breadfruit and betel leaf decoctions significantly increased salivary pH from acidic to neutral and reduced plaque scores ($p< 0.05$). The flavonoids, tannins, and alkaloids in breadfruit leaves, as well as the phenolic compounds in betel leaves, contribute to these antibacterial effects. However, the groups did not differ significantly in the increase in salivary pH or the reduction in plaque scores ($p > 0.05$). Decoctions of breadfruit and betel leaves may serve as natural mouthwashes for maintaining oral health. Further research is needed to develop commercial formulations and assess their long-term effectiveness.

Keywords: Sugar fruit Leaves, Betel Leaves, Saliva PH, Plaque Score.

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1. INTRODUCTION

Dental caries is a major concern in Indonesia, where 90% of the population experiences problems with dental and oral health (Hasan et al., 2024). Geographically, rates of dental caries are highest in Asia and Latin America and lowest in Africa. In Indonesia, caries remains the primary oral health concern (Li et al., 2025). Dental caries develops through a process of demineralization that begins in the tooth's hard tissue, first affecting the enamel and then spreading to the dentin and pulp. This process is triggered by the accumulation of bacterial plaque, a diet high in sugar, and poor oral hygiene. If not treated properly, dental caries can lead to complications that affect an individual's quality of life (Dunleavy et al., 2023).

Various approaches have been used to prevent dental caries. In Indonesia, one such approach is the use of medicinal plants, which have long been incorporated into traditional remedies. Their use is based partly on knowledge passed down through generations and partly on findings from scientific research (Refaey et al., 2024). People have long used plants prepared according to traditional recipes to treat diseases. Indonesia is home to many plants with medicinal properties, although people may be unaware of the plants growing around them. Examples include breadfruit leaves, betel leaves, turmeric leaves, cloves, and many others, some of which can be used in mouthwashes to eliminate oral bacteria and as antimicrobial agents (Bencze et al., 2023).

Mouthwashes are widely available on the market in a variety of formulations and flavors. An effective mouthwash should kill bacteria that cause oral health problems without causing nausea or irritation, disrupting the normal balance of the oral cavity, or increasing microbial resistance (Brookes et al., 2023). Other desirable characteristics include availability, ease of use and storage, and low cost (Sarkar et al., 2024).

Among the natural ingredients with potential for use in mouthwash are breadfruit leaves (Artocarpus altilis) and betel leaves (Piper betle). These leaves have been shown to be effective in treating various diseases, including hepatitis, lymphatic enlargement, and diabetes (Osorio et al., 2021; Ulandari et al., 2023).

Breadfruit leaves are known to contain flavonoid compounds, phenols, and steroids that act as antimicrobials against bacteria that cause caries, such as Streptococcus mutans (Czerkas et al., 2024). Meanwhile, betel leaves are rich in phenolic compounds, such as catechins, which have antibacterial and antioxidant properties and can reduce plaque formation (Singh et al., 2023). Previous research has shown that these two ingredients can reduce plaque indices and increase salivary pH, thereby helping to prevent tooth demineralization (Nurzilullahningtiyas & Prasetyowati, 2023).

Several studies have confirmed that betel leaves can inhibit the growth of S. mutans, interfere with biofilm formation, and improve oral hygiene. Heliawati (2022) reported that gargling with a betel leaf solution can help maintain salivary pH and significantly reduce plaque scores. Piper betle can inhibit the adhesion of S. mutans and reduce plaque formation through antibacterial mechanisms mediated by its phenolic compounds (Florenly et al., 2022; Heliawati et al., 2022). By contrast, research on breadfruit leaves has revealed substantial antibacterial activity against S. mutans. Gargling with breadfruit leaf extract can reduce salivary viscosity, increase salivary flow, and support the oral cavity's self-cleaning effect, which ultimately helps reduce dental plaque accumulation (Khairi et al., 2026). Although various studies have confirmed the effectiveness of each ingredient in improving oral health, few studies have directly compared the effects of betel leaf decoction and breadfruit leaf decoction on salivary pH and plaque scores under standardized experimental conditions (Rahayu et al., 2024). Some important aspects, such as the optimal concentration of the solution, the volume used, and the optimal gargling duration, have not been studied in depth. In addition, most studies have focused on one ingredient without comparing the effects of both ingredients in the same study.

Although previous research has separately confirmed the antimicrobial activity of various natural extracts, little is known about whether their therapeutic effects are equivalent when assessed under identical clinical conditions. In this study, breadfruit (Artocarpus altilis) leaf decoction was selected as the primary treatment because the leaves contain high concentrations of flavonoids, tannins, and alkaloids, which have been shown to reduce salivary viscosity and inhibit the proliferation of Streptococcus mutans. To evaluate breadfruit leaf decoction as a potential public health alternative, betel leaf (Piper betle) decoction was selected as the comparator. Betel leaves are widely recognized as a potent, well-established traditional antiseptic for oral care. They contain phenolic compounds and catechins that effectively inhibit bacterial glycolysis and biofilm adhesion. A direct comparison of breadfruit leaf decoction with a proven benchmark, such as betel leaf decoction, rather than with a placebo, is essential to determine whether breadfruit leaf decoction has comparable effects on salivary pH and plaque scores. Consequently, this study aims to compare the effects of these two natural mouthwashes under standardized clinical conditions and assess whether they are equivalent, with the goal of providing an evidence-based, safe, and cost-effective oral hygiene recommendation for the community.

2. RESEARCH METHOD

This study used a quasi-experimental approach with a two-group pretest–posttest design. The study included 30 participants aged 30–40 years, who were assigned to two parallel groups (n = 15 per group) using a simple randomization method to ensure an unbiased and equal distribution. Respondents were selected through purposive sampling based on the following inclusion criteria: being 30–40 years old, having at least one tooth eligible for plaque-score assessment, and being willing to participate and sign an informed-consent form. Participants were excluded if they had a history of allergies to the study materials, were undergoing dental treatment or using other mouthwashes, or had systemic diseases such as diabetes or immune disorders.

The research began with the preparation of materials and equipment. The breadfruit leaf decoction was prepared by boiling 50 g of dried breadfruit leaves in 500 mL of distilled water for 15 minutes, then filtering the mixture and cooling it to room temperature. The same procedure was used to prepare the betel leaf decoction. Baseline measurements of salivary pH and plaque scores were taken. This study used a 10% solution concentration, with a uniform volume and duration of gargling for each participant. Salivary pH was measured using a pH meter, and dental hygiene was assessed using the Simplified Oral Hygiene Index (OHI-S). Saliva samples were collected in sterile cups and tested using a digital pH meter to ensure measurement precision. Plaque scores were measured using plaque-disclosing agents and plaque-index tables. Respondents then gargled with 20 mL of the decoction assigned to their group for 30 seconds without swallowing it. After the intervention, salivary pH measurements using the digital pH meter and plaque scores using OHI-S were repeated. The entire research process, from material preparation for measurement, was documented visually to ensure transparency.

Statistical analysis was performed using SPSS version 25. The dependent variables, salivary pH and plaque scores, were treated as continuous ratio scales based on the direct digital pH meter readouts and OHI-S index scores. Because these continuous data met the parametric assumption of normality, a paired t-test was used to assess within-group changes (pre- and post-intervention), while an independent t-test was used to compare the two study groups. For secondary descriptive purposes only, these continuous measurements were subsequently converted into ordinal categories to show clinical frequency distributions. The significance level for all parametric analyses was set at $\alpha = 0.05$; $p < 0.05$ was considered statistically significant, and $p > 0.05$ was considered not statistically significant.

Ethical clearance for this study was granted by the Health Research Ethics Committee at the Semarang Ministry of Health Polytechnic, under protocol number 1063/EA/KEPK/2024. All research procedures were conducted in accordance with the ethical principles of health research, ensuring the safety and comfort of respondents during the study. Before participating, each respondent was given a detailed explanation of the objectives, methods, and potential risks. They were also given the opportunity to ask questions and seek clarification about the study before signing an informed-consent form to indicate their voluntary participation. The study was expected to make a valid and useful scientific contribution while upholding the rights and welfare of research participants.

3. RESULTS AND DISCUSSION

Table 1. Saliva pH Frequency Distribution

Saliva pH	**Breadfruit decoction**				**Betel decoction**			
	Before		**After**		**Before**		**After**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Very Low	0	0	0	0	0	0	0	0
Low (acidic)	4	26.6	0	0	1	6.6	0	0
Normal	11	73.3	15	100	14	93.3	15	100
Height (Base)	0	0	0	0	0	0	0	0

Table 1 shows that, before gargling, most respondents in the breadfruit leaf group had salivary pH in the normal range (11; 73.3%). After gargling, all respondents had pH in the normal range. In the betel leaf group, 14 respondents (93.3%) were in the normal category before gargling. After the post-test rinse, all respondents (100%) had normal pH.

Table 2. Frequency Distribution of Plaque Score

Plaque-score category	**Breadfruit decoction**				**Betel decoction**			
	Before		**After**		**Before**		**After**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Excellent	0	0	0	0	0	0	0	0
Good	0	0	13	86.6	0	0	14	93.3
Medium	3	20	2	13.3	3	20	1	6.6
Bad	12	80	0	0	12	80	0	0

(12; 80%) had plaque scores in the poor category. After gargling, most respondents (13; 86.6%) had scores in the good category. Before rinsing with betel leaf decoction, plaque scores were also predominantly in the poor category, accounting for 12 respondents (73.3%). The post-test results showed a significant reduction in plaque scores, with most respondents (14; 93.3%) in the good category.

Table 3. Paired t-Test Results for Pre–Post Differences in Salivary pH and Plaque Scores

Variable	**p-Value**
Saliva pH before and after gargling with breadfruit leaf decoction	0.000
Saliva pH before and after gargling with betel leaf decoction	0.000
Plaque score before and after gargling with breadfruit leaf decoction	0.000
Plaque score before and after gargling with betel leaf decoction	0.000

Table 3 reports p-values of 0.000 (<0.05) for the pre–post comparisons of salivary pH and plaque scores in both treatment groups. Therefore, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted, indicating statistically significant differences in

salivary pH before and after gargling with either decoction. The plaque-score results also differed significantly before and after rinsing with either decoction.

Table 4. Independent-Samples t-Test Results Comparing the Effects of Breadfruit and Betel Leaf Decoctions

Variable	Std	Red	Sig
After gargling with breadfruit leaf decoction	0.4776	7.033	0.924
After gargling with betel leaf decoction	0.2366	7.020	
After gargling with breadfruit leaf decoction	0.5046	1.080	0.796
After gargling with breadfruit leaf decoction	0.6076	1.027	

Table 4 reports a p-value of 0.924 (>0.05), indicating no significant difference between the breadfruit and betel leaf decoctions in their effects on salivary pH. Thus, the two decoctions were equally effective in changing salivary pH. For plaque scores, the p-value was 0.796 (>0.05), indicating no statistically significant difference between the decoctions in reducing plaque scores. Both treatments were therefore equally effective in lowering plaque levels..

The results of this study show that breadfruit leaf (Artocarpus altilis) and betel leaf (Piper betle) decoctions are equally effective in raising salivary pH from acidic to normal levels. Before treatment, most respondents in the breadfruit leaf decoction group had normal salivary pH (73.3%), while 26.6% had acidic pH. After gargling with breadfruit leaf decoction, all respondents (100%) had salivary pH in the normal range. A similar pattern was observed in the betel leaf group: before treatment, 93.3% of respondents had normal pH, and after treatment, all respondents (100%) had normal pH. Statistical analysis revealed significant pre–post changes in salivary pH in both groups ($p < 0.05$).

These findings support the hypothesis that both natural extracts are effective in neutralizing oral acidity and maintaining salivary homeostasis. The increase in salivary pH after gargling with breadfruit leaf decoction may be attributed to its antimicrobial compounds, including flavonoids, tannins, and alkaloids (Soifoini et al., 2021). These bioactive compounds are recognized for their inhibitory effects on bacterial proliferation, particularly that of Streptococcus mutans. This pathogen is a primary driver of salivary acidification and the subsequent development of dental caries (Rudin et al., 2023). Meanwhile, betel leaves contain essential oils, phenols, and catechins that have antibacterial and antioxidant properties (Alam et al., 2023). These bioactive compounds can reduce bacterial activity and neutralize acid production, thereby helping to maintain pH balance in the oral cavity (Mashal et al., 2024).

In addition to increasing salivary pH, the study showed that breadfruit leaf (Artocarpus altilis) and betel leaf (Piper betle) decoctions were similarly effective in reducing dental plaque scores. In the breadfruit leaf decoction group, most respondents were in the poor category before treatment (80%), while the remainder were in the moderate category (20%). After treatment, plaque scores decreased significantly, with the majority of respondents (86.6%) in the good category. A similar trend was observed in the betel leaf group: before treatment, 80% of respondents were in the poor category, and after treatment, the majority (93.3%) had plaque scores in the good category.

Statistical analysis showed significant changes in plaque scores before and after treatment in both groups ($p < 0.05$), supporting the effectiveness of each natural ingredient in lowering plaque scores. The reduction in plaque scores after gargling with breadfruit leaf decoction may be attributed to its antimicrobial properties, which are associated with its flavonoid, tannin, and alkaloid content. These compounds can inhibit the growth of Streptococcus mutans, a primary cause of plaque formation (Heliawati et al., 2022). Similarly, betel leaves, which are rich in phenolic compounds, including catechins, act as bactericidal agents that inhibit glycolysis in cariogenic bacteria, thereby reducing plaque formation (Eka Putri et al., 2024; Maramis et al., 2024).

The similar effects of breadfruit leaf decoction and betel leaf decoction on salivary pH and plaque scores suggest that both may serve as natural alternatives for maintaining oral health. The absence of a significant difference between the two treatments ($p > 0.05$) indicates that both breadfruit and betel leaves may provide similar benefits by inhibiting the growth of cariogenic bacteria and improving dental and gum health. The results of this study provide a scientific basis for using these ingredients in natural dental health products, such as mouthwash or toothpaste (McGrath et al., 2023). Follow-up studies with larger samples, as well as investigations into the pharmacological mechanisms of the active compounds in breadfruit and betel leaves, may support the development of more effective and sustainable oral health care products (Andini et al., 2026; Rahmawati et al., 2025).

The results of this study indicate that breadfruit leaf (Artocarpus altilis) and betel leaf (Piper betle) decoctions are similarly effective in increasing salivary pH from acidic to normal levels. Before treatment, most respondents in the breadfruit leaf decoction group had salivary pH within the normal range (73.3%), while 26.6% had an acidic pH. After gargling with breadfruit leaf decoction, all respondents (100%) had salivary pH within the normal range. A similar trend was observed in the betel leaf group: before treatment, 93.3% of respondents had a normal pH, and after treatment, all respondents (100%) did. Statistical analysis showed significant differences in salivary pH before and after treatment in both groups ($p < 0.05$), supporting the hypothesis that these two natural ingredients are effective in neutralizing salivary acidity. The antimicrobial properties of these substances are well documented for their ability to suppress the proliferation of Streptococcus mutans. As a key acidogenic pathogen, S. mutans is a major contributor to lower salivary pH and the development of dental caries (Soifoini et al., 2021). These compounds are known to inhibit bacterial growth, especially that of Streptococcus mutans, which plays an important role in salivary acidification and dental caries development (Rudin et al., 2023). Meanwhile, betel leaves contain essential oils, phenols, and catechins with antibacterial and antioxidant properties. These bioactive compounds can reduce bacterial activity and neutralize acid production, thereby helping to maintain pH balance in the oral cavity (Mashal et al., 2024).

This increase in salivary pH is closely related to the antimicrobial compounds in these plants. The flavonoids, tannins, and alkaloids in breadfruit leaves inhibit the proliferation of dental caries-causing bacteria, specifically Streptococcus mutans. Furthermore, breadfruit leaf extract supports oral hygiene by reducing salivary viscosity and enhancing the mouth's natural self-cleansing mechanisms. Betel leaves, on the other hand, contain essential oils, phenols, and catechins that can help neutralize acid production by bacteria.

In addition to increasing salivary pH, the study also showed that breadfruit leaf (Artocarpus altilis) and betel leaf (Piper betle) decoctions were similarly effective in reducing dental plaque scores. In the breadfruit leaf decoction group, most respondents were in the poor category before treatment (80%), while the remainder were in the moderate category (20%). After treatment, plaque scores decreased significantly, with the majority of respondents (86.6%) in the good category. A similar trend was observed in the betel leaf group: before treatment, 80% of respondents were in the poor category, and after treatment, the majority (93.3%) had plaque scores in the good category. Statistical analysis showed significant changes in plaque scores before and after treatment in both groups ($p < 0.05$), supporting the effectiveness of each natural ingredient in lowering plaque scores. The reduction in plaque scores following the use of breadfruit leaf decoction as a mouthrinse is largely due to its antimicrobial constituents. Specifically, the flavonoids, tannins, and alkaloids in the leaves suppress the growth of Streptococcus mutans, the primary pathogen responsible for plaque development (Heliawati et al., 2022).

Similarly, betel leaves, which are rich in phenolic compounds, including catechins, act as bactericidal agents that inhibit glycolysis in cariogenic bacteria, thereby reducing plaque formation (Maramis et al., 2024). The ability of breadfruit leaves to reduce plaque may be attributed to active compounds that inhibit the adhesion of Streptococcus mutans to tooth surfaces. Meanwhile, betel leaves, which are rich in phenolic compounds, including catechins, act as bactericidal agents that inhibit glycolysis in cariogenic bacteria (Ni Wayan Rika et al., 2023). Piper betle may reduce plaque formation through the antibacterial action of its phenolic compounds and inhibit dental plaque accumulation (Abadi et al., 2025) .

The similar effectiveness of breadfruit leaf decoction and betel leaf decoction in increasing salivary pH and reducing plaque scores suggests that both may serve as natural alternatives for maintaining oral health. The absence of a significant difference between the two treatments ($p > 0.05$) indicates that both breadfruit and betel leaves may provide similar benefits by inhibiting the growth of cariogenic bacteria and improving dental and gum health. The results of this study provide a scientific basis for using these ingredients in natural dental health products, such as mouthwash or toothpaste (McGrath, Clarkson, Glenny, Walsh, & Fruit, 2023). Follow-up studies with larger samples, as well as research into the pharmacological mechanisms of the active compounds in breadfruit and betel leaves, may support the development of more effective and sustainable oral health care products (Cendekiawan et al., 2025).

Although both ingredients showed substantial clinical improvement, the results of the independent t-test yielded p values of 0.924 for salivary pH and 0.796 for plaque scores ($p > 0.05$). This indicates that the effectiveness of breadfruit leaf decoction and betel leaf decoction did not differ significantly. Both treatments appeared similarly effective in neutralizing oral acidity and reducing plaque accumulation.

This similarity in effectiveness may be explained by the similar pharmacological properties of the active compounds in the two plants. Breadfruit leaves contain flavonoids, tannins, and alkaloids that function as antimicrobial agents (Nwaneri et al., 2025). Flavonoids denature bacterial cell proteins and damage the cytoplasmic membrane, thereby inhibiting the growth of Streptococcus mutans, a major contributor to oral acidity and plaque formation (Liu et al., 2025). Betel leaves, on the other hand, contain bioactive compounds, including essential oils, phenols, and catechins, with strong antibacterial and antioxidant properties (Cendekiawan et al., 2025). The phenolic compounds in betel leaves inhibit glycolysis and the adhesion of bacteria to tooth enamel, thereby helping to prevent plaque biofilm formation (Jalil et al., 2022).

Despite the promising clinical outcomes observed in this study, several limitations should be acknowledged to guide the interpretation of the findings. First, this study evaluated only the immediate effects of breadfruit and betel leaf decoctions on oral health indicators; therefore, the long-term effects of these natural mouthwashes remain unquantified. Second, the small sample size (n=30) and restriction to participants aged 30–40 years limit the generalizability of the findings to broader populations. Lastly, the microbiological assessment was based on general plaque index measures rather than localized, high-throughput sequencing of the oral microbiome. Future research should focus on moving beyond freshly prepared crude decoctions toward standardized, shelf-stable commercial formulations, such as natural mouthwashes or toothpastes, with enhanced organoleptic properties. Moreover, longitudinal randomized controlled trials involving larger cohorts and comprehensive molecular profiling are needed to substantiate the long-term safety, optimal dosage, retention, and chemical synergy of these bioactive plant extracts in large-scale public health interventions.

4. CONCLUSION

The results showed that both breadfruit leaf and betel leaf decoctions significantly increased salivary pH and lowered plaque scores. Statistical analysis showed no significant difference in the effectiveness of breadfruit and betel leaf decoctions in increasing salivary pH

and lowering plaque scores, suggesting that both may serve as natural alternatives for maintaining oral health. Further research is needed to develop more practical formulations based on breadfruit and betel leaf extracts, such as mouthwashes or toothpastes. In addition, long-term clinical studies involving a broader population are needed to evaluate the effectiveness and safety of these ingredients over an extended period.

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