

The Antibacterial Effectiveness Of Green Tea Leaf Extract (*Camellia Sinensis. L*) From Pagar Alam Against *Streptococcus Mutans*

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ABSTRACT

Introduction: Dental caries remains a prevalent oral health issue in Indonesia, with *Streptococcus mutans* identified as the main causative agent. While 0.2% chlorhexidine is effective, its side effects highlight the need for natural alternatives. Green tea (*Camellia sinensis. L*) contains antibacterial compounds like catechins and flavonoids.

Purpose: To evaluate the antibacterial effectiveness of green tea leaf extract from Pagar Alam against *Streptococcus mutans*.

Methods: This in vitro study used a post-test only control group design with the disk diffusion method. Samples consisted of green tea extract at concentrations of 5%, 15%, and 25%, and a 0.2% chlorhexidine as control. Inhibition zones were measured with a caliper and analyzed using One Way ANOVA and Post Hoc LSD tests.

Results: The average inhibition zone diameters were 5.900 mm (5%), 7.908 mm (15%), and 10.033 mm (25%). The positive control showed 16.700 mm. Significant differences were observed among all groups ($p < 0.05$). The 25% concentration yielded the highest inhibitory effect compared to the other concentrations. However, green tea leaf extract from Pagar Alam is still not effective as antibacterial compared to CHX 0,2%.

Conclusion: Green tea leaf extract from Pagar Alam can inhibit significantly the growth of *Streptococcus mutans*, with increasing antibacterial activity at higher concentrations.

Keywords : Green tea, *Streptococcus mutans*, Antibacterial

INTRODUCTION

Oral and dental health problems remain highly prevalent worldwide.¹ According to the World Health Organization (WHO), dental caries is among the most common oral health problems affecting the population. Approximately 60-90% of elementary school children suffer from dental caries, and nearly 100% of adults experience the same issue, with 15-20% of middle-aged adults (35-44 years) also affected.² Nationally, the 2023 Basic Health Research (RISKESDAS) reports a caries prevalence rate 82.8%, with 84.8% of children aged 5-9 years experiencing caries.¹ Dental caries is a chronic disease that gradually destroys the hard tissues of the tooth, initiated with the erosion of the enamel, dentin, and cementum.³ The etiology of dental caries is multifactorial, involving the oral cavity environment (host),

substrate, time, and the fermentation of carbohydrates.²

Streptococcus mutans is a facultative anaerobic, Gram-positive coccus-shaped bacterium that is considered the primary causative agent of dental caries and is a part of the normal oral flora.⁴ *S. mutans* metabolizes sucrose into insoluble polysaccharides, facilitating colonization on the tooth surface. It thrives in acidic environments (aciduricity) and produces lactic acid through carbohydrate fermentation (acidogenicity), which contributes to the lowering of pH on the tooth surface. When the pH drops below the critical threshold (pH < 5.5), demineralization of hard dental tissues occurs, eventually leading to caries.⁵ Moreover, *Streptococcus mutans* is considered an opportunistic microorganism that can exhibit pathogenic behavior under favorable oral environmental conditions, thereby contributing to the progression of dental caries. Therefore, antimicrobial agents are necessary to inhibit the growth of cariogenic microorganisms and prevent dental caries.^{6,7}

Antimicrobials are compounds capable of killing or inhibiting microorganisms, including bacteria, viruses, fungi, and parasites.⁸ Common antimicrobial agents with proven effectiveness include chlorhexidine, triclosan, cetylpyridinium chloride, and essential oils.⁹ Chlorhexidine is frequently used due to its antibacterial properties, and 0.2% chlorhexidine mouthwash has been showing to reduce oral bacterial counts by up to 89.25%. However, in long-term use of chlorhexidine may cause side effects such as oral tissue damage, extrinsic staining, mucosal desquamation, altered taste sensation, and discoloration of dental restorations.^{7,10} As a result, research that is into alternative strategies to prevent caries, particularly involving plant-based extracts, is increasingly important.¹¹ Herbal substances generally have lower toxicity, greater affordability, wide availability, and fewer side effects.¹²

Indonesia is known for its rich biodiversity, including numerous plants with potential medicinal applications, one of them is tea. Tea plantations in Indonesia are primarily located in regions such as West Java, Central Java, East Java, North Sumatra, and South Sumatra, with the city of Pagar Alam serving as a notable production area. According to data from the Pagar Alam Statistics Center, sourced from PTPN 7, tea production in Pagar Alam has shown a consistent annual increase, rising from 2,589.00 tons in 2019 to 3,434.00 tons in 2020.¹⁴ Tea is a plant widely used as a natural antibacterial agent. Based on the processing method, tea is categorized into four types: green tea (non-fermented), white tea (non-fermented), oolong tea (semi-fermented), and black tea (fully fermented). The primary distinction among these types lies in their polyphenol content, particularly catechins, which are most abundant in non-fermented teas. Among them, green tea has the highest concentration of polyphenols.² Green

tea (*Camellia sinensis* L.) is commonly used in traditional medicine and contains active compounds such as flavonoids, saponins, tannins, and alkaloids, all of which possess antibacterial potential.¹⁵ Flavonoids, as polyphenolic compounds, have been shown to exhibit antioxidant, anti-tumor, anti-inflammatory, antibacterial, and antiviral effects.¹⁶

Green tea contains epigallocatechin-3-gallate (EGCG), a potent catechin known to inhibit *S. mutans* and is more effective against Gram-positive than Gram-negative bacteria.^{17,18} Research by Shubhi Goel (2021) demonstrated that green tea leaf extract at concentrations of 4% yielded a minimum inhibitory concentration (MIC), with the largest inhibition zone at 10%.¹¹ Wijaya (2021) found that concentrations of 3.125%, 6.25%, 12.5%, 25%, and 50% were effective in inhibiting *S. mutans* growth, with the greatest inhibition at 50%.² Lindsay et al. (2023) compared *Camellia sinensis* and *Bixa orellana* extracts and found that *C. sinensis* was more effective, with a minimum bactericidal concentration (MBC) at 50%.¹⁹ Nisa (2024) also evaluated the combination of green tea and cherry leaf extracts, reporting that a 25% green tea and 12.5% cherry leaf ratio produced the largest inhibition zone (15.50 mm).²⁰

Based on the background above, this study specifically aims to evaluate the antibacterial effectiveness of green tea (*Camellia sinensis* L.) leaf extract from Pagar Alam against *S. mutans*, furthermore using concentrations of 5%, 15%, and 25%.

METHODS

This study applied a true experimental in vitro design with a post-test only control group. The research was conducted after the thesis proposal seminar in two different laboratories. The first was the Biochemistry Laboratory of the Faculty of Medicine at Sriwijaya University. The second was the Microbiology Laboratory of the Faculty of Medicine at Muhammadiyah University of Palembang. This study has received ethical clearance from the Research Ethics Committee of the Faculty of Medicine, Sriwijaya University, with Certificate of Ethical Approval No. 025-2025. The biological sample in this study was green tea leaves (*Camellia sinensis* L.) collected from plantations in the Pagar Alam region. The bacterial subject used was a pure isolate of *Streptococcus mutans* ATCC 25175. Furthermore, the total number of samples in this study was calculated using the Federer formula to ensure the minimum requirement for statistical reliability.²¹ Based on this calculation, six repetitions were applied to each of the four treatment groups. These consisted of three groups of extract at concentrations of 5%, 15%, and 25%, and one group using 0.2%

chlorhexidine as the positive control.

Inclusion criteria required that the tea leaves come from the Pagar Alam plantations and be of high quality, with fresh top buds consisting of two to three young leaves (P+3).¹³ Exclusion criteria included wilted or diseased leaves.

Extract Preparation

The extract was prepared using the maceration method, beginning with drying 1 kg of tea leaves at 50°C for 48 hours. After drying, the leaves were ground into powder and sieved into uniform particle size (simplicia). The powder was then soaked in 96% alcohol, stirred, left to stand for 24 hours, and filtered three times. The resulting solution was evaporated at 50°C to obtain a thick extract, which was stored in airtight containers until further use. Specific concentrations of green tea leaf extract were obtained through dilution. The concentrated extract was diluted with sterile distilled water in a ratio 10 ml per total volume.

Inhibition Assay

The antibacterial test used was the Kirby-Bauer disk diffusion method. Sterile 6 mm paper discs were soaked in each concentration and the control solution for 15 minutes. The discs were then aseptically placed onto Mueller Hinton Agar (MHA) plates that had been inoculated with *S. mutans*. The suspension was standardized to match the McFarland 0.5 turbidity (1.5×10^8 CFU/ml). All plates were incubated for 24 hours at 37°C before measurements were taken.

After incubation, the antibacterial activity was assessed by observing the clear zones formed around each disc on the agar surface.²¹ These inhibition zones were measured using a digital caliper in both horizontal and vertical directions.²² The final zone diameter was determined by averaging both dimensions and subtracting the disc diameter. Each treatment group was repeated six times to ensure accuracy and consistency of results.

Data Analysis

The data obtained were analyzed using SPSS version 25 statistical software. The Shapiro-Wilk test was first conducted to assess normality of the data. Levene's test was then used to evaluate the homogeneity of variance. The data met both assumptions ($p \geq 0.05$), a One-Way ANOVA was performed, followed by a Post Hoc LSD test to examine significant differences.

RESULTS

The antibacterial activity test of green tea (*Camellia sinensis* L.) leaf extract from Pagar

Alam against *Streptococcus mutans* was conducted using the disk diffusion method (Kirby-Bauer) at concentrations of 5%, 15%, and 25%, with 0.2% chlorhexidine serving as the positive control. The bacterial growth inhibition was measured by calculating the diameter of the clear inhibition zone formed around each paper disk using a vernier caliper, with results expressed in millimeters (mm). Measurements were taken after 24 hours of incubation at 37°C. This test was later performed in six replications, and the results of the inhibition zone diameter measurements are presented in Figure 2 and Table 1.

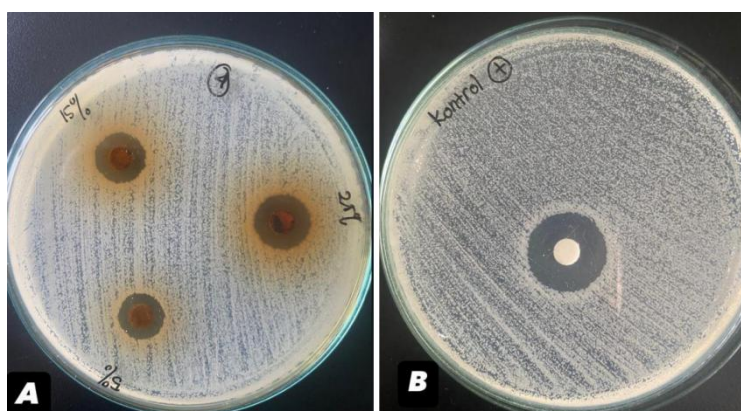


Figure 2. Inhibition Zone Test Results Using the Disk Diffusion Method (A) Pagar Alam's Green Tea Leaf Extract Group (B) Positive Control Group (K⁺)

Table 1. Mean Inhibition Zone Diameter Measurements

Treatment	Replications (mm)						Mean Inhibition Zone Diameter (mm ± SD)
	1	2	3	4	5	6	
Green tea leaf extract 5%	5.00	6.00	6.45	6.55	5.90	5.50	5.900 ± 0.583
Green tea leaf extract 15%	7.45	7.75	7.45	8.70	7.60	8.50	7.908 ± 0.550
Green tea leaf extract 25%	9.75	10.50	9.50	10.20	10.00	10.25	10.033 ± 0.362
Positive control (CHX 0.2%)	16.80	1.750	16.50	16.00	17.30	16.10	16.700 ± 0.616

The results of the antibacterial activity test demonstrated that the 5%, 15%, and 25% concentrations of green tea leaf extract from Pagar Alam were able to inhibit the growth of *Streptococcus mutans*. As shown in Table 1, the 25% concentration of green tea leaf extract produced the largest inhibition zone diameter against *S. mutans*, with a mean of 10.033 mm, followed by the 15% concentration (7.908 mm) and the 5% concentration (5.900 mm). The positive control group using 0.2% chlorhexidine (CHX) exhibited the highest mean inhibition zone diameter among all groups, with a value of 16.700 mm. These findings

indicate that the average diameter of the inhibition zones increased proportionally with the concentration of green tea leaf extract, although the effect remained lower than that of the positive control. The Shapiro–Wilk normality and Levene’s homogeneity test showed significance values greater than 0.05 ($p > 0.05$), the data in all groups were normally distributed and homogeneous. Subsequently, the data were analyzed using a One-Way ANOVA test, as presented in Table 2

Table 2. One-Way ANOVA Test Results

	F	Sig.
Between Groups	456.734	0.000*

Note: (*) indicates a statistically significant difference (p -value < 0.05)

Based on Table 2 above, it can be concluded that there is a statistically significant difference between the various concentrations of Pagar Alam’s green tea leaf extract and the control group, as evidenced by a p -value of 0.000 ($p < 0.05$). To further explore these differences, a follow-up analysis was conducted using the Post Hoc Least Significant Difference (LSD) test. This test allows for pairwise comparisons to determine which specific treatment groups show statistically significant variations in their mean inhibition zone diameters. The application of the LSD test is essential for identifying the most effective concentration of green tea leaf extract in relation to both lower concentrations and the positive control. The results of this detailed comparison are presented in Table 3.

Table 3. Post Hoc LSD Test Results Significance Values Between Groups

Sig. Value Between Groups	5%	15%	25%	K+ (CHX 0.2%)
5%		0.000*	0.000*	0.000*
15%			0.000*	0.000*
25%				0.000*
K+				

Note: (*) indicates a statistically significant difference (p -value < 0.05)

The results of the Post Hoc LSD test presented in Table 3 indicate a statistically significant difference ($p < 0.05$) between all treatment groups. The 25% concentration of Pagar Alam’s green tea leaf extract produced a significantly larger inhibition zone compared to the 5% ($p = 0.000$) and 15% ($p = 0.000$) concentrations, suggesting dose-dependent antibacterial activity. However, the inhibition zone produced by the 25% extract was still

significantly smaller than that of the positive control group, CHX 0.2%. The positive control exhibited a significantly greater antibacterial effect than all concentrations of the green tea leaf extract ($p = 0.000$). These findings imply that Pagar Alam's green tea leaf extract does possess antibacterial properties, particularly at higher concentrations. However, its efficacy remains inferior to that of CHX 0.2%.

DISCUSSION

The antibacterial effectiveness of green tea leaf extract from Pagar Alam against *Streptococcus mutans* in this study was evaluated using the disk diffusion method (Kirby-Bauer) to determine the inhibition zones. The findings showed that all concentration of the green tea leaf extract were capable of inhibiting the growth of *S. mutans*, as indicated by the presence of clear zones surrounding the paper discs. The inhibition zones were categorized into four levels: < 5 mm as weak, 5-10 mm as moderate, 10-20 mm as strong, and > 20 mm as very strong.²³ In this study, the average inhibition zone diameters for the 5% (5.900 mm) and 15% (7.908 mm) concentrations of Pagar Alam's green tea leaf extract fell into the moderate category, while the 25% concentration (10.033 mm) fell into the strong category. These results are allign with the findings of Wijaya (2021), which reported that green tea leaf extract inhibited *S. mutans* with moderate efficacy at concentrations of 3.125% (5.18 mm), 6.25% (7.73 mm), and 12.5% (9.23 mm), and showed strong inhibition at 25% (12.85 mm) and 50% (14.66 mm).² The increase in concentration was directly associated with larger inhibition zones. Similarly, Goel reported that the average inhibition zone of *S. mutans* increased with higher concentrations of *Camellia sinensis* extract.¹¹ Higher extract concentrations typically yield a greater amount, resulting in larger inhibition zones.

The presence of secondary metabolites in plants plays a crucial role in their function as natural antibacterial agents.²⁴ Among these, polyphenols are one of the most prominent phytochemical groups found in green tea, with catechins being the major constituents. Epigallocatechin-3-gallate (EGCG) stands out as the most abundant catechin in green tea, comprising approximately 50-70% of its total catechin content.²⁵

EGCG has demonstrated significant antibacterial properties through multiple mechanisms. One key action involves binding to bacterial cell membranes, disrupting membrane integrity, causing leakage of intracellular contents, and ultimately leading to bacterial cell lysis.²⁶ In addition to this physical disruption, EGCG also targets bacterial metabolic systems. A study conducted by Han et al. showed that EGCG inhibits both acid

production and the growth of *Streptococcus mutans* by interfering with the phosphoenolpyruvate-phosphotransferase system (PEP-PTS), which plays a role in sugar transport and bacterial aggregation.²⁷ The phosphoenolpyruvate phosphotransferase system (PEP-PTS) is a crucial sugar transport mechanism involving a series of enzymes embedded in the bacterial cell membrane and cytoplasm. Epigallocatechin-3-gallate (EGCG) disrupts this system by inhibiting the activity of enolase, an essential enzyme in glycolysis. It also downregulates the expression of the *eno* gene, which encodes enolase and plays a key role in both glycolysis and sugar phosphorylation. In addition, EGCG binds non-competitively to the enzyme complex II (EIIC), a membrane-bound protein complex that facilitates sugar uptake into the bacterial cell. This binding interferes with the internalization of sugars, thereby limiting the substrates available for glycolysis. As a result, the glycolytic pathway in *S. mutans* is suppressed, leading to a significant reduction in acid production, so that it can inhibit the demineralization process of tooth enamel. By targeting both sugar transport and metabolism, EGCG effectively weakens the pathogenicity of *S. mutans*.²⁸

Another antibacterial mechanism of EGCG is the inhibition of extracellular polysaccharide (EPS) production, a major component of biofilm, by suppressing the activity of the glucosyltransferase (GTF) enzyme. This mechanism disrupts the bacterial cell structure and membrane, thereby reducing the bacteria's ability to adhere on tooth surfaces and form plaque.²⁸ Overall, this mechanism interferes with bacterial survival.

Catechin also contribute to antibacterial activity by inhibiting the function of the DNA gyrase enzyme. They bind to the ATP-binding site and the gyrase B subunit, which is responsible for the DNA supercoiling process. Inhibiting this enzyme activity results in failed DNA replication, thereby suppressing bacterial growth and proliferation.²⁶ In addition to catechins, green tea leaf extract also contains other bioactive compounds such as saponins, tannins, and alkaloids, all of which contribute to its antibacterial effects.

Streptococcus mutans possesses a cell wall structure rich in peptidoglycan, making it more polar and thus more susceptible to polar antimicrobial agents. Phenolic compounds found in green tea leaf, such as flavonoids and tannins, are also polar in nature. This similarity in polarity facilitates the penetration of these compounds into the bacterial cell wall. Once inside, the phenolic compounds could disrupt the integrity of the peptidoglycan layer. This disruption compromises the bacterial membrane, leading to leakage of intracellular contents and ultimately causing cell lysis. Furthermore, supporting evidence can also be found in the study which was conducted by Nadya, which explored the antibacterial properties of betel leaf

extract against *S. mutans*. Betel leaf contains phenolic compounds similar to those in green tea, including tannins and flavonoids.²⁹

The positive control group (CHX 0.2%) exhibited the largest average inhibition zone diameter, measuring 16.700 mm. Chlorhexidine (CHX) is a well-known antiseptic widely used in dentistry due to its broad-spectrum antimicrobial activity. Its mechanism of action involves altering the permeability of bacterial cell membranes, leading to the disruption of cellular integrity. CHX binds electrostatically to the negatively charged surface of bacterial cells, thereby becoming permeable. Upon entering the cell, CHX induces cytoplasmic precipitation, interferes with membrane repair processes, and ultimately causes cell lysis.²⁹ At higher concentrations, specifically above 0.1%, CHX causes significant leakage of essential intracellular components, enhancing its bactericidal effect.³⁰

A comparison of antibacterial activity testing methods, well diffusion and disk diffusion, was conducted by Nurhayati.³¹ The study concluded that the well diffusion method produced higher antibacterial activity than the disk diffusion method. This is due to a more homogeneous and efficient osmotic diffusion process in the well method, making it more effective in inhibiting bacterial growth. However, the well diffusion method has a drawback: the agar media is prone to crack or break around the well area, which can interfere with the diffusion of the antibiotic and affect the clarity of the inhibition zone.³¹ This consideration led the researcher in the present study to use the disk diffusion method. The disk diffusion method has advantages such as being quick and simple to perform, without the need for specialized equipment.

One limitation of this study lies in the measurement of the inhibition zones. The inhibition zones observed in the green tea leaf extract groups appeared less distinct and more difficult to interpret compared to those in the positive control group treated with CHX 0.2%. This discrepancy is likely due to the brownish coloration of the Pagar Alam's green tea leaf extract. The color is attributed to its high polyphenol content, which can stain the agar and obscure the clear boundaries typically used to measure inhibition.³²

CONCLUSION

Pagar Alam's green tea leaf extract (*Camellia sinensis* L.) has the ability to inhibit the growth of *Streptococcus mutans*. The 25% concentration of the extract produced the largest average inhibition zone (10.033 mm), although this was still significantly smaller than the positive control group (chlorhexidine 0,2%). This indicates that while the green tea extract is

effective, its antibacterial effect is still relatively moderate compared to synthetic antiseptics like CHX. Nevertheless, the extract has shown promising antibacterial potential and may serve as a basis for developing natural alternatives to synthetic oral antiseptics.

REFERENCES

1. Riskesdas. Hasil Utama Riskesdas [Internet]. Kementerian Kesehatan Republik Indonesia; 2023.
2. Wijaya S, Suryantika T. Efektivitas Antibakteri Ekstrak Daun Teh Hijau Terhadap Bakteri *Streptococcus mutans*. *Prima J Oral Dent Sci*. 2021;4(2):39-44.
3. Roberts WE, Mangum JE, Schneider PM. Pathophysiology of Demineralization, Part II: Enamel White Spots, Cavitated Caries, and Bone Infection. *Curr Osteoporos Rep*. 2022;20(1):106-19.
4. Hamidah MN, Rianingsih L, Romadhon R. Aktivitas Antibakteri Isolat Bakteri Asam Laktat Dari Peda Dengan Jenis Ikan Berbeda Terhadap *E. coli* Dan *S. aureus*. *J Ilmu Teknol Perikan*. 2019;1(2):11-21.
5. Rusmayati A, Isyana E, M N. Perbedaan Perubahan Warna Resin Komposit Nanofiller Dipoles dan Tidak Dipoles Pada Perendaman Larutan Teh Hijau. *J Kedokt Gigi*. 2017;2(1):72-7.
6. Marsh PD, Martin MV. *Oral Microbiology*. 6th ed. London: Churchill Livingstone Elsevier; 2016.
7. Poluan FH, Marlina L. The Effectiveness Test of 0.9% NaCl Solution and 0.2% Chlorhexidine Gluconate on Bacterial Growth in the Oral Cavity of Students Batch 2018 at the Medical Faculty, Universitas Kristen Indonesia. *Int J Med Heal Res*. 2021;7(10):27-32.
8. GARDP Revive. Antibiotic, antibacterial, and antimicrobial [Internet]. Available from: <https://revive.gardp.org>
9. Garrido L, Lyra P, Rodrigues J, Viana J, Mendes JJ, Barroso H. Revisiting Oral Antiseptics, Microorganism Targets and Effectiveness. *J Pers Med*. 2023;13(9):1332.
10. Kidd E, Fejerskov O. *Essentials of Dental Caries*. 3rd ed. Oxford: Oxford University Press; 2005.
11. Goel S, CS BR, Chandan S. Evaluation of Antioxidant and Antimicrobial Efficacy of *Camellia Sinensis* and *Alstonia Scholaris* Extracts on *Streptococcus Mutans* and *Lactobacillus Acidophilus*—An in Vitro Study. *Biomed Pharmacol J*. 2021;14(1):455-

- 65.
12. Sajadi F, Shokrizadeh M, Sharifi M, Aftabi R. Evaluating the Effects of *Camellia Sinensis* (Green Tea) and *Teucrium Polium* Extracts on Salivary *Streptococcus Mutans* Levels in Children. *J Dent*. 2023;24(1):19.
 13. Anggraini T. *Proses dan Manfaat Teh*. Jakarta: Erka; 2017.
 14. Badan Pusat Statistik Kota Pagar Alam. *Kota Pagar Alam Dalam Angka 2021* [Internet]. 2021.
 15. Asmah N, Ilmianti I, Abdi MJ, Irawati E, Nursaid H. Effectiveness of *Camellia Sinensis* L Extract in Inhibiting the Growth of *Staphylococcus aureus*. *J Syiah Kuala Dent Soc*. 2023;8(2).
 16. Baby B, Shobah AN, Insani N. Kombinasi Daya Hambat Daun Pepaya (*Carica papaya* L.) dan Teh Hijau (*Camellia sinensis*) terhadap *Streptococcus mutans*. *J Kesehat Perintis*. 2022;9(2):94–102.
 17. Setiawati Y, Ramadhani M, Bobsaid J, Hulwah DOZ. MIC and MBC Levels of Combination *Camellia sinensis* and *Mentha piperita* Extract Mouthwash Against *Streptococcus mutans*. *Nusant Med Sci J*. 2022;39-49.
 18. Hattarki SA, Bogar C, Bhat KG. Green Tea Catechins Showed Antibacterial Activity on *Streptococcus mutans* - An In Vitro Study. *Indian J Dent Res*. 2021;32(2):226–9.
 19. Granados-Jamanca L, Medrano-Colmenares SM, Gamboa-Alvarado E, Ladera-Castañeda M, Castañeda-Pérez L, Cervantes-Ganoza LA, et al. Antibacterial Activity of *Bixa Orellana* Compared with *Camellia sinensis* Against *Streptococcus Mutans*: An in vitro Comparative Study. *J Int Oral Health*. 2023;15(2):174–83.
 20. Fitria NS, Istriningsih E, Pramiastuti O. Aktivitas Antibakteri Ekstrak Daun Kersen Kombinasi Daun Teh Hijau Terhadap Bakteri *Streptococcus mutans*. *JITK Bhamada*. 2024;15(1):22-8.
 21. Aviany HB, Pujiyanto S. Analisis Efektivitas Probiotik di Dalam Produk Kecantikan sebagai Antibakteri terhadap Bakteri *Staphylococcus epidermidis*. *Berk Bioteknol*. 2020;3(2).
 22. Sela K, Beumaputra AP, Mozartha M. Antibacterial Effectiveness of Red Watermelon Rind (*Citrullus lanatus*) Extract Against *Streptococcus mutans*. *J Kesehat Gigi dan Mulut*. 2023;5(1):1-7.
 23. Pratiwi RD, Kuswandari S, Utomo RB. Antibacterial effect of ethanol extract of *moringa oleifera* seeds against *enterococcus faecalis* atcc 29212. *Odonto: Dental*

Journal. 2023 Dec 29;10(2):180.

24. Bullock S, Manias E. *Fundamentals of Pharmacology*. Australia: Pearson Australia; 2014.
25. Higuchi M, Abiko Y, Washio J, Takahashi N. (2024). Antimicrobial effects of epigallocatechin-3-gallate, a catechin abundant in green tea, on periodontal disease-associated bacteria. *Arch Oral Biol*. 1(167).
26. Capasso L, De Masi L, Sirignano C, Maresca V, Basile A, Nebbioso A, et al. Epigallocatechin Gallate (EGCG): Pharmacological Properties, Biological Activities and Therapeutic Potential. Vol. 30, *Molecules*. Multidisciplinary Digital Publishing Institute (MDPI); 2025.
27. Han, S., Washio, J., Abiko, Y., Zhang, L., & Takahashi, N. (2023). Green Tea-Derived Catechins Suppress the Acid Productions of *Streptococcus mutans* and Enhance the Efficiency of Fluoride. *Caries research*, 57(3), 255-264.
28. Li Y, Cheng L, Li M. (2024) Effects of Green Tea Extract Epigallocatechin-3-Gallate on Oral Diseases: A Narrative Review. Vol. 13, *Pathogens*. Multidisciplinary Digital Publishing Institute (MDPI); 13(634): 6-7.
29. Owu NM, Fatimawali, Jayanti M. Uji Efektivitas Penghambatan Dari Ekstrak Daun Sirih (*Piper Betle L.*) Terhadap Bakteri *Streptococcus mutans* 2020;12(3):145-152.
30. Brookes ZLS, Bescos R, Belfield LA, Ali K, Roberts A. Current Uses of Chlorhexidine for Management of Oral Disease: A Narrative Review. *J Dent*. 2020;103:103497.
31. Nurhayati LS, Yahdiyani N, Hidayatulloh A. Perbandingan Pengujian Aktivitas Antibakteri Starter Yogurt dengan Metode Difusi Sumuran dan Metode Difusi Cakram. *J Teknol Hasil Peternakan*. 2020;1(2):41-6.
32. Rusmayati A, Isyana E, M N. Perbedaan Perubahan Warna Resin Komposit Nanofiller Dipoles dan Tidak Dipoles Pada Perendaman Larutan Teh Hijau. *J Kedokt Gigi*. 2017;2(1):72-7.