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Antimicrobial Effects of Cassava Peel and Leaves against Oral Pathogens

Florencia L. Kurniawan,[1] Octarina,[1] Astri Rinanti,[2] Komariah,[3] Mark L. Lauw,[4] Ilman N. Maulana[1]

[1]Departemen Bahan Kedokteran Gigi Fakultas Kedokteran Gigi Universitas Trisakti, Jakarta, Indonesia
[2]Departemen Ilmu Rekayasa Lingkungan Fakultas Arsitektur Lanskap dan Teknologi Lingkungan, Universitas Trisakti, Jakarta, Indonesia
[3]Departemen Biologi Oral Fakultas Kedokteran Gigi Universitas Trisakti, Jakarta, Indonesia
[4]Platform Engineering, Digital Office, M1 Limited, Singapore 609928, Singapore
Email: florencia@trisakti.ac.id
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Abstract: Cassava peel and leaves (*Manihot esculenta* Crantz) are agro-waste materials rich in secondary metabolites with potential antimicrobial properties. Research exploring their effects against oral pathogens remains limited. This study aimed to evaluate the antibacterial and antifungal activity of cassava peel and leaf extracts against *Staphylococcus aureus*, *Streptococcus mutans*, and *Candida albicans*. This was a laboratory and experimental study. Samples of cassava leaves, outer and inner young peel (six months), outer and inner mature peel (10 months) were dried, powdered, and subjected to ethanol maceration. Phytochemical screening assessed flavonoids, alkaloids, saponins, tannins, quinones, steroids, and triterpenoids. Antimicrobial activity was tested using the microdiffusion well method, and inhibition zones were measured in millimeters. Positive controls were chloramphenicol (for bacteria) and nystatin (for fungi). Negative control was sterile aquadest. The results showed that leaf extract produced inhibition zones of 8.90 mm (*S. aureus*), 6.00 mm (*S. mutans* and *C. albicans*). Peel extracts showed varying activity, with outer young peel (6 months) yielding 7.25 mm (*S. aureus*), 6 mm (*S. mutans* and *C. albicans*) and inner young peel (6 months) yielding 8.74 mm (*S. aureus*), 35.27 mm (*S. mutans*), 6 mm (*C. albicans*) while outer mature peel (10 months) yielding 6.13 mm (*S. aureus*), 6.00 mm (*S. mutans* and *C. albicans*) and inner mature peel (10 months) yielding 10.44 mm (*S. aureus*), 55.36 mm (*S. mutans*), 6 mm (*C. albicans)*. Phytochemical screening confirmed the presence of flavonoids, tannins, and saponins in most of cassava peel and leave samples. In conclusion, cassava peel and leaf extracts exhibit antimicrobial activity against major oral pathogens, with inner mature peels (10 months) showing the strongest effect against *Streptococcus mutans*. These results support their potential use as natural antimicrobial agents in herbal oral care formulations.
Keywords: antibacterial; cassava peel; cassava leaves; oral pathogens; phytochemicals

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a widely cultivated tropical plant, and its agricultural by-products—such as peels and leaves—are often discarded as waste despite containing high levels of bioactive secondary metabolites. These plant parts are rich in flavonoids, tannins, alkaloids, saponins, and phenolic compounds, which have been reported to exhibit antimicrobial properties.[1-3] These phytochemicals act through multiple mechanisms, including disruption of microbial membrane integrity, inhibition of cell wall synthesis, protein precipitation, and enzyme inhibition.[4-5]

The growing global concern over antimicrobial resistance and the increasing demand for natural and environmentally friendly alternatives in oral healthcare have stimulated research on plant-derived antimicrobial agents.[6-7] In the oral cavity, several pathogenic microorganisms play important roles in the initiation and progression of disease. *Streptococcus mutans* (*S. mutans*) is the primary etiological agent of dental caries due to its strong acidogenic and biofilm-forming abilities. *Staphylococcus aureus* (*S. aureus*) is an opportunistic pathogen linked to oral mucosal infections and systemic complications, while *Candida albicans* (*C. albicans*) is the most common fungal species responsible for oral candidiasis, especially in immunocompromised individuals and denture wearers.[8-10]

Previous studies have demonstrated the antimicrobial potential of cassava leaf and peel extracts against various pathogenic bacteria, including *S. aureus*, although their efficacy varies depending on the extraction method and plant maturity.[11] Flavonoids found in cassava by-products have shown inhibitory activity against *S. mutans*, while tannins exhibit bacteriostatic and bactericidal actions by precipitating bacterial proteins and inhibiting adhesion mechanisms. Additionally, saponins are known to increase membrane permeability, leading to cell lysis in both bacteria and fungi.[12]

Despite increasing evidence supporting the antimicrobial activity of cassava by-products, research specifically targeting oral pathogens remains limited. Furthermore, comparative analyses of antimicrobial activity between cassava peels of different maturities (6-month and 10-month-old peels) have not been well documented. Maturity-related variations in phytochemical concentration may influence the antimicrobial potency of the plant material.[13]

Based on these considerations, the present study aims to evaluate the antimicrobial activity of cassava leaf extract and cassava peel extracts of different maturities (6-month and 10-month-old peels) against *S. aureus*, *S. mutans*, and *C. albicans*. The findings are expected to support the development of natural antimicrobial agents for oral healthcare products, including herbal toothpaste, mouthwash, and intraoral gels.[14-15]

METHODS

This laboratory experimental study utilized outer and inner cassava peel samples of two maturity levels (6 months and 10 months) and cassava leaves collected from local cultivation sites. Samples were washed, air-dried, oven-dried, and ground into powder. Ethanol maceration was performed for 72 hours, followed by filtration and solvent evaporation to obtain crude extracts.

Phytochemical screening assessed flavonoids, alkaloids, tannins, saponins, quinones, steroids, and triterpenoids using qualitative colorimetric methods. Antimicrobial activity was evaluated using the microdiffusion well method with size disc diameter of 6 mm. Each extract was tested against *S. aureus*, *S. mutans*, and *C. albicans*. Positive controls included chloramphenicol (for bacteria) and nystatin (for fungi), while sterile aquadest served as the negative control. Inhibition zones were measured in millimeters.

RESULTS

Phytochemical screening showed that all cassava samples—leaves, 6-month-old outer and inner peels, and 10-month-old outer and inner peels—contained flavonoids, tannins, and saponins, while other compounds such as alkaloids, quinones, steroids, and triterpenoids showed negative or inconsistent results.

The presence of these bioactive metabolites indicates potential antimicrobial activity across all extracts. Phytochemical screening showed the presence of flavonoids, tannins, and saponins in most of the cassava peel and leaf samples.

Table 1. Phytochemical profile

Samples	Compounds	Result	Method
Leaf	Flavonoid, tanin, saponin	Positive	Color test
Outer peel (6 months)	Flavonoid, alkaloid mayer, tanin, saponin	Positive	Color test
Inner peel (6 months)	Flavonoid, tanin, saponin	Positive	Color test
Outer peel (10 months)	Saponin	Positive	Color test
Inner peel (10 months)	Flavonoid, tanin, saponin	Positive	Color test

In the antimicrobial assay, the cassava extracts exhibited varying levels of inhibition against *S. aureus*, *S. mutans*, and *C. albicans*. Leaf extract produced inhibition zones of 8.90 mm (*S. aureus*), 6.00 mm (*S. mutans* and *C. albicans*). Peel extracts showed varying activity, with outer young peel (6 months) yielding 7.25 mm (*S. aureus*), 6 mm (*S. mutans* and *C. albicans*); inner young peel (6 months) yielding 8.74 mm (*S. aureus*), 35.27 mm (*S. mutans*), 6 mm (*C. albicans*); outer mature peel (10 months) yielding 6.13 mm (*S. aureus*), 6.00 mm (*S. mutans* and *C. albicans*); meanwhile, inner mature peel (10 months) yielding 10.44 mm (*S. aureus*), 55.36 mm (*S. mutans*), 6 mm (*C. albicans)*.

As a result, the leaf extract produced moderate inhibition against *S. aureus* (8.90 mm) and mild inhibition against *S. mutans* and *C. albicans* (6.00 mm each). The outer young peel (6 months) extract showed moderate activity against *S. aureus* (7.25 mm) and strong inhibition of inner young peel (6 months) against *S. mutans* (35.27 mm). Notably, the inner mature peel (10 months) extract demonstrated the highest antimicrobial activity, producing a large inhibition zone against *S. mutans* (55.36 mm), while showing moderate inhibition of *S. aureus* (10.44 mm). Both outer and inner of 6-month and 10-month-old peel extracts showed no meaningful inhibition against *C. albicans*, with values similar to the negative control.

Overall, the 10-month-old cassava peel extract exhibited the strongest antibacterial effect, particularly against *Streptococcus mutans*. The leaf extract showed consistent but lower activity across all microorganisms.

Table 2. Inhibition zone results against *S. aureus, S. mutans,* and *C. albicans*

Samples	Microorganism	Inhibition Zone (mm)	Method
Leaf	*S. aureus*	8.90	Microdiffusion
Leaf	*S. mutans*	6.00	Microdiffusion
Leaf	*C. albicans*	6.00	Microdiffusion
Outer peel (6 months)	*S. aureus*	7.25	Microdiffusion
	S. mutans	6.00	Microdiffusion
	C. albicans	6.00	Microdiffusion
Inner peel (6 months)	*S. aureus*	8.74	Microdiffusion
	S. mutans	35.27	Microdiffusion
	C. albicans	6.00	Microdiffusion
Outer peel (10 months)	*S. aureus*	6.13	Microdiffusion
	S. mutans	6.00	Microdiffusion
	C. albicans	6.00	Microdiffusion
Inner peel (10 months)	*S. aureus*	10.44	Microdiffusion
	S. mutans	55.36	Microdiffusion
	C. albicans	6.00	Microdiffusion

The results indicate that peel maturity significantly influences antimicrobial potency, with older peels producing greater inhibitory effects. This suggests a higher concentration of active phytochemicals in the 10-month-old peel extract compared to the 6-month-old peel and leaf extracts.

DISCUSSION

The present study demonstrates that cassava peel and leaf extracts exhibit antimicrobial activity against major oral pathogens, particularly *S. mutans*. The phytochemical screening confirmed the presence of flavonoids, tannins, and saponins in most of tested samples, which likely contributed to the observed antimicrobial effects. These findings are consistent with previous reports indicating that cassava leaves and peels contain bioactive secondary metabolites with antibacterial potential.[1-3,11]

The inhibition zones observed against *S. mutans* were markedly higher in peel extracts compared to leaf extracts, especially in the 10-month-old peel (55.36 mm). This result aligns with findings by Olaniyan and Ajayi who reported significant antimicrobial activity of cassava peel extracts due to their high phenolic and tannin content.[3] Similarly, Fachriyah et.al demonstrated that cassava peels contain substantial levels of phenolic compounds that contribute to antimicrobial activity.[2] The greater inhibition observed in mature peels may be explained by increased accumulation of phenolic compounds during plant maturation, as phenolic biosynthesis is known to intensify with age and environmental exposure.[5]

Flavonoids have been reported to exert antibacterial activity by disrupting cytoplasmic membranes, inhibiting nucleic acid synthesis, and interfering with energy metabolism. Xie et al. showed that plant-derived flavonoids significantly inhibit *S. mutans*, supporting the strong anti-cariogenic effect observed in the present study.[12] Tannins contribute through protein precipitation and enzyme inhibition, thereby impairing bacterial adhesion and biofilm formation.[4] Since *S. mutans* relies heavily on adhesion and biofilm development for cariogenicity, tannin-rich extracts may exhibit enhanced inhibitory effects against this bacterium.

The moderate inhibition observed against *S. aureus* is consistent with previous research by Silva et al, who reported that cassava leaf extract exhibited antibacterial activity against *S. aureus*, although with lower potency compared to standard antibiotics.[11] This suggests that while cassava extracts possess antibacterial properties, their activity may be selective and concentration-dependent.

In contrast, antifungal activity against *C. albicans* was minimal, with inhibition zones comparable to the negative control. Although saponins are known to disrupt fungal cell membranes by interacting with sterols[8], the crude extract concentration used in this study may not have been sufficient to produce significant antifungal effects. Raut and Karuppayil[9] and de Castro et al[10] reported that effective antifungal activity of plant extracts often requires higher concentrations or purified fractions. Therefore, further fractionation and determination of minimum inhibitory concentration (MIC) values are recommended to clarify antifungal potential.

Another important finding of this study is the significant difference in antimicrobial activity between 6-month and 10-month-old peel extracts. The stronger activity of mature peel suggests that phytochemical composition changes with plant maturity. This supports the concept that agricultural waste valorization should consider optimal harvest time to maximize bioactive compound yield. Previous phytochemical analyses have shown that phenolic and tannin concentrations increase during plant aging, potentially explaining the enhanced antibacterial effect observed in mature peel samples.[2,5]

From a clinical perspective, the strong inhibition of *S. mutans* indicates promising potential for cassava peel extract as a natural anti-cariogenic agent. Considering the increasing demand for herbal-based oral healthcare products and concerns regarding antimicrobial resistance[6-7], cassava by-products may serve as sustainable, low-cost alternatives for the development of herbal toothpaste, mouthwash, or intraoral gels.

Although the present study demonstrated promising antimicrobial activity, several limitations should be acknowledged. The evaluation was limited to inhibition zone measurement using the microdiffusion method, which does not provide quantitative information regarding minimum inhibitory or bactericidal concentrations. Future investigations should include MIC and MBC determination, time-kill kinetics, antibiofilm assays, cytotoxicity evaluation, and formulation stability testing. Furthermore, isolation and characterization of specific active phytochemical constituents would provide deeper insight into the mechanisms underlying the observed antimicrobial effects.

Overall, the findings confirm that cassava by-products possess selective antibacterial activity, particularly against *S. mutans*, with peel maturity playing a significant role in antimicrobial potency. These results contribute to the growing body of evidence supporting plant-based antimicrobial agents in dental research.

Beyond its antimicrobial potential, the present study also demonstrates the environmental relevance of utilizing cassava agricultural waste as a biomedical material. The valorization of such natural resources contributes to sustainable development and responsible environmental practices, consistent with the concept of environmental accountability discussed in sustainability research.[16]

CONCLUSION

Cassava (*Manihot esculenta* Crantz) peel and leaf extracts contain phytochemicals with antimicrobial activity against *Staphylococcus aureus* and *Streptococcus mutans*, with inner peel of mature cassava (10 months) showing the strongest inhibitory effect. These findings demonstrate the potential of cassava by-products as natural alternatives for antibacterial agents in oral healthcare applications.

Conflict of Interest

The authors affirm no conflict of interest in this study.

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