Borneo Journal of Pharmascientech
Vol 10 No 01, April 2026
Halaman 462-470
https://jurnalstikesborneolestari.ac.id/index.php/borneo/article/view/794
DOI: https://doi.org/10.59053/bjp.v10i1.794
e-ISSN : 2548 – 3897; p-ISSN : 2541 – 3651

Biomedicine Potential of Oil Palm (Elaeis guineensis) Leaves: In Vitro Evaluation of Antibacterial, Antibiofilm, and Antioxidant Activities

Deni Setiawan[a, 1*], Samsul Hadi[a, 2], Nur Mahdi [a, 3], Nurul Mardiati [a, 4], Dita Ayulia Dwi Sandi [a, 5], Muhammad Rasyid Ridha[b, 6], Moch. Saiful Bachri [c, 7]

[a] Department of Pharmacy, Faculty of Mathematics and Natural Sciences, Lambung Mangkurat University, Banjarbaru, South Kalimantan, Indonesia
[b] Department of Public Health, Faculty of Medicin, Lambung Mangkurat University, Banjarbaru, South Kalimantan, Indonesia
[c]Department of Pharmacy, Faculty of Pharmacy, Ahmad Dahlan University, Yogyakarta, Indonesia.
[1] deni.setiawan@ulm.ac.id *, [2] samsul.hadi@ulm.ac.id, [3] nur.mahdi@ulm.ac.id, [4] nurul.mardiati@ulm.ac.id, [5] dita.sandi@ulm.ac.id, [6] m.rasyidridha@ulm.ac.id, [7] msaifulbachri@yahoo.co.id
* deni.setiawan@ulm.ac.id

Kata kunci:
E. Guineenses;
Antibakteri;
Antibiofilm;
Antioksidan

ABSTRAK

Daun kelapa sawit (*Elaeis guineensis*) memiliki beragam sifat farmakologis dengan potensi pengembangan yang menjanjikan, terutama sebagai agen antibiofilm dan antioksidan. Penelitian ini bertujuan untuk mengevaluasi aktivitas antibakteri antibiofilm, dan antioksidan dari ekstrak daun *E. guineensis*. Daun dimaserasi dalam acetone selama lima hari. Aktivitas antibakteri ditentukan menggunakan metode difusi cakram terhadap empat spesies bakteri yaitu *Staphylococcus aureus*, *Propionibacterium acnes*, *Escherichia coli*, dan *Pseudomonas aeruginosa*. Ekstrak menunjukkan aktivitas antibakteri sedang, dengan inhibisi tertinggi diamati terhadap *P. acnes* (6.79 mm pada konsentrasi 25%). Aktivitas antibiofilm dievaluasi menggunakan metode mikrodilusi, menunjukkan inhibisi yang bergantung pada konsentrasi, dengan aktivitas tertinggi pada konsentrasi 1%, mencapai 83,90% (fase pertengahan, *S. aureus*) dan 71,28 terhadap *E. coli.* Aktivitas antioksidan dinilai menggunakan uji DPPH, FRAP, dan ABTS, menghasilkan nilai IC_{50} masing-masing sebesar 99.19 ppm, 119.12 ppm, dan 123.37 ppm, yang menunjukkan kapasitas antioksidan sedang (IC_{50} > 50-150 ppm). Secara keseluruhan, ekstrak daun *E. guineensis* menunjukkan aktivitas antibakteri, antibiofilm, dan antioksidan sedang, yang menunjukkan potensinya sebagai kandidat awal untuk investigasi farmakologis lebih lanjut.

Key word:
E. Guineensis;
Antibacterial;
Antibiofilm;
Antioxidant

ABSTRACT

Oil palm (*Elaeis guineensis*) leaves possess diverse pharmacological properties with promising development potential, particularly as antibiofilm and antioxidant agents. This study aimed to evaluate the antibacterial, antibiofilm, and antioxidant activities of *E. guineensis* leaf extract. The leaves were macerated in acetone for five days. Antibacterial activity was determined using the disc diffusion method against four bacterial species: *Staphylococcus aureus*, *Propionibacterium acnes*, *Escherichia coli*, and *Pseudomonas aeruginosa*. The extract exhibited moderate antibacterial activity, with the highest inhibition observed against *P. acnes* (6.79 mm at 25%). Antibiofilm activity was evaluated using a microdilution method, showing concentration-dependent inhibition, with the highest activity at 1% concentration, reaching 83.90% (mid-phase, *S. aureus*) and 71.28% (*E. coli*). Antioxidant activity was assessed using DPPH, FRAP, and ABTS assays, yielding IC_{50} values of 99.19 ppm, 119.12 ppm, and 123.37 ppm, respectively, indicating moderate antioxidant capacity (IC_{50} > 50-150 ppm). Overall, *E. guineensis* leaf extract demonstrates moderate antibacterial, antibiofilm, and antioxidant activities, suggesting its potential as a preliminary candidate for further pharmacological investigation.

https://jurnalstikesborneolestari.ac.id/index.php/borneo/article/view/794
DOI: https://doi.org/10.59053/bjp.v10i1.794
e-ISSN : 2548 – 3897; p-ISSN : 2541 – 3651

Introduction

Oil palm (*Elaeis guineensis* Jacq.) represents one of Indonesia's most strategically important plantation commodities and constitutes a major pillar of the national agricultural economy. Spanning over 16.83 million hectares with an annual fresh fruit bunch (FFB) output of approximately 46.82 million tons, the palm oil sector substantially contributes to state revenue, job creation, and the advancement of rural communities (Pusat Data dan Sistem Informasi Pertanian, 2024). However, alongside its economic significance, the industry generates substantial biomass waste—including fronds, leaves, empty fruit bunches, and fibers—that is often underutilized (Wardhono et al., 2025). Large quantities of palm leaves and fronds, which can exceed 10,000 fronds per hectare annually, are typically discarded, piled, or burned, contributing to environmental problems such as soil degradation, greenhouse gas emissions, and air pollution (Asian Agri, 2020). The underutilization of palm biomass presents an opportunity for value-added exploration, particularly in the biopharmaceutical and natural product sectors (Abnisa et al., 2011). Recent studies have demonstrated that multiple parts of the oil palm plant, particularly the leaves and fronds, are rich in secondary metabolites such as flavonoids, phenolics, alkaloids, tannins, and steroids. These bioactive constituents exhibit a broad spectrum of pharmacological effects, including antioxidant, antibacterial, anti-inflammatory, and antibiofilm activities (Kedir et al., 2023). Collectively, these findings highlight the potential of oil palm leaf extracts as a source of natural therapeutic agents, while also supporting the valorization of plantation biomass within a sustainable framework.

Bacterial biofilms pose a significant challenge in modern clinical practice. Pathogens such as *Staphylococcus aureus* and *Escherichia coli* can form complex biofilm structures, which enhance bacterial resistance to antibiotics and host immune responses (Zhao et al., 2023). The presence of biofilms is strongly associated with persistent and recurrent infections, complicating treatment outcomes and exacerbating antimicrobial resistance. Consequently, the search for new antibiofilm compounds, particularly from natural sources, has become an important focus in biomedical research (Ehrlich et al., 2023). Plant-derived polyphenolic compounds have been widely reported to interfere with bacterial adhesion, inhibit the formation of extracellular polymeric matrix, or destabilize established biofilms (Vandana et al., 2023). Given the high phenolic content and antioxidant potential of *E. guineensis* leaves, these biomaterials may offer dual functionality, providing both antimicrobial and antioxidant benefits. Antioxidants also play a critical role in mitigating oxidative stress, a key factor involved in inflammation and various degenerative diseases (Tow et al., 2021). Considering these potential advantages, this study was conducted to evaluate the pharmacological properties of oil palm (*Elaeis guineensis*) leaf extract, with particular emphasis on its antibacterial and antibiofilm activities. The findings of this research are expected to contribute to the development of sustainable bioactive products from oil palm biomass, supporting both environmental sustainability and innovation in natural biomedical applications.

Methods

Tools and Materials

Glassware, refrigerator, drying cabinet, macerator, micropipette (*Socorex*®), mortar, oven, pH meter (*ATC*®), capillary tube (*Nesco*®), graduated pipette (*Pyrex*®), dropper pipette, volumetric pipette (*Pyrex*®), TLC plate plethysmometer, propipette, test tube rack, rotary evaporator, spatula, UV-Vis spectrophotometer (*PerkinElmer UV/Vis*®). The materials used in this study included pro-analytical glacial acetic acid (*Merck*), acetone (*Technica*l), aluminum foil, distilled water (*Technical*), bovine serum albumin (*Himedia*), methanol (*Merck*®), 10% $FeCl_3$, 10% H_2SO_4, carrageenan, filter paper (Whatman No.

https://jurnalstikesborneolestari.ac.id/index.php/borneo/article/view/794
DOI: https://doi.org/10.59053/bjp.v10i1.794
e-ISSN : 2548 – 3897; p-ISSN : 2541 – 3651

1), pro-analytical methanol (*Merck*®), NaCl (*Merck*®), n-hexane (Technical), Na-CMC, diclofenac sodium (Aarti Drugs Limited), TLC plates (silica gel GF254), Dragendorff's reagent, *E. guineensis* leaf, and Tris base (*Merck*®), DPPH, FRAP, and TPTZ.

Extraction

Oil palm leaf were cleaned with water, then cut and dried in an oven for three hours at 40 °C. The entire 1,500 g of powder was soaked in acetone for extraction of the leaf. Extraction was carried out for five days, stirring every 6 h.

Antibacterial Test

Antibacterial activity was evaluated using the disc diffusion method (*Kirby-Bauer* assay) with extract concentrations of 5, 10, 15, 20, and 25%. Nutrient agar (NA) plates were inoculated with suspensions of *S. aureus, P. acnes, P. aeruginosa*, and *E. coli*, followed by placement of discs impregnated with the respective extracts, with 10% DMSO as the negative control, chloramphenicol and tetracycline as positive controls. After incubation at 37 °C for 24 h, a vernier caliper was used to measure the zone of inhibition (Setiawan et al., 2021).

Antibiofilm Test

The antibiofilm activity was assessed using a microbroth dilution assay in 96-well microplates, employing *E. guineensis* leaf extract at concentrations of 1%, 0.5%, 0.25%, and 0.125% (w/v) against *S. aureus* and *E. coli*. Bacterial suspensions were standardized to a 0.5 McFarland (1.5×10^8 CFU/mL) in BHI medium. The extract was prepared in 1% DMSO as the negative control, whereas 1% chloramphenicol was used as the positive control. Each well contained 100 µL of BHI medium, 50 µL of bacterial inoculum, and 30 µL of the extract solution, followed by incubation at 37°C for 24 h (mid-log phase), 48 h (maturation phase), and 72 h (eradication phase) to facilitate biofilm development (Setiawan et al., 2025).

Antioxidant Activity

DPPH Assay

A range of extract concentrations (20, 40, 80, 100, 120, and 160 ppm) was prepared for the assay. Subsequently, 1 mL of 0.4 mM DPPH solution was combined with 4 mL of the respective sample solution. The mixtures were homogenized and incubated in the dark to prevent photodegradation. Absorbance was then recorded using UV-Vis spectrophotometer at the predetermined maximum wavelength, with pro-analytical (PA) methanol serving as the blank (Asmawati Saad et al., 2023).

FRAP Test

In the FRAP assay, ascorbic acid was prepared at concentrations of 2, 4, 6, 8, and 10 ppm as the reference standard, while the extract was tested at 20, 40, 80, 100, 120, and 160 ppm. An aliquot of 1 mL of each sample solution was transferred into a test tube, followed by the addition of 3 mL of freshly prepared FRAP reagent. The mixtures were incubated at 37 °C for 16 minutes, after which absorbance was measured at 596 nm, the predetermined maximum wavelength. The ascorbic standard was processed under identical experimental conditions (Knez et al., 2025).

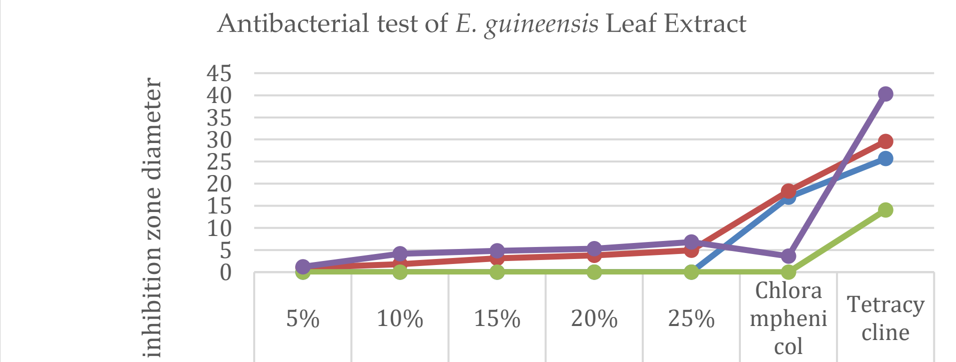
ABTS Test

The absorbance of the ABTS working solution was monitored at regular intervals until it reached a value between 0.7 and 0.8, indicating optimal stability for analysis. For the positive control, 10 mg of ascorbic acid was dissolved in 100 mL of distilled water to prepare a 100 ppm stock solution, which was subsequently diluted to final concentrations of 2, 4, 6, 8, and 10 ppm in a 10 mL volumetric flask using distilled water. For the sample preparation, 10 mg of plant extract was dissolved in 100 mL of distilled water to obtain a 100 ppm stock solution. This stock was further diluted to yield concentrations of 20, 40, 80, 100, 120, and 160 ppm for the assay (Sadeer et al., 2020).

https://jurnalstikesborneolestari.ac.id/index.php/borneo/article/view/794
DOI: https://doi.org/10.59053/bjp.v10i1.794
e-ISSN : 2548 – 3897; p-ISSN : 2541 – 3651

Result and Discussion

Antibacterial test



	5%	10%	15%	20%	25%	Chloramphenicol	Tetracycline
E. coli	0	0	0	0	0	16.94	25.66
S. aureus	1	1.81	3.13	3.77	4.95	18.3	29.57
P. aeruginosa	0	0	0	0	0	0	14.03
P. acnes	1.22	4.16	4.81	5.28	6.79	3.6	40.255

Fig. 1. Result of Antibacterial E. Guineensis leaf extract

The antibacterial efficacy of *E. guineensis* leaf extract was assessed against four test organisms, namely *E. coli*, *S. aureus*, *P. aeruginosa*, and *P. acnes*. The extract was tested at concentrations of 5%, 10%, 15%, 20%, and 25%, and the inhibition zones were compared to chloramphenicol and tetracycline as positive controls (Fig.1). Overall, the extract exhibited weak to moderate antibacterial activity, with varying effects depending on bacterial species and concentration. At low concentrations (5–15%), inhibition zones were generally minimal, ranging from 0 to 4.81 mm. A slight increase in activity was observed at 20% and 25%, particularly against *S. aureus* and *P. acnes*. *P. acnes* showed the highest sensitivity among all tested bacteria, reaching an inhibition zone of 6.79 mm at 25%. *S. aureus* exhibited moderate inhibition (4.95 mm at 25%), while *E. coli* and *P. aeruginosa* showed no inhibition at any extract concentration. As expected, the positive controls displayed potent antibacterial activity, with tetracycline producing the widest zones (25.66–40.255 mm). The findings suggest that *E. guineensis* leaf extract demonstrates selective antibacterial effects, predominantly against Gram-positive strains (*S. aureus* and *P. acnes*) whereas Gram-negative organisms (*E. coli* and *P. aeruginosa*) appear resistant to the extract.

The result indicate that *E. guineensis* leaf extract has concentration-dependent antibacterial activity, with greater effects observed at higher concentrations (20–25%). The preferential activity against Gram-positive bacteria aligns with established differences in cell wall architecture. Gram-negative species possess an additional outer membrane enriched with lipopolysaccharides, which acts as a permeability barrier to many phytochemicals, thereby accounting for the lack of inhibitory effect on *E. coli* and *P. aeruginosa (Nazzaro et al., 2013)*. The moderate inhibition detected against *S. aureus* and *P. acnes* indicates the presence of bioactive constituents capable of compromising the integrity of Gram-positive bacterial membranes (Pacyga et al., 2024). Previous studies have reported that *E. guineensis* leaves contain flavonoids, tannins, alkaloids, and steroid phytochemicals known for their antibacterial mechanisms, including protein precipitation, membrane disruption, and inhibition of nucleic acid synthesis (Febriani et al., 2020). Among the tested bacteria, *P. acnes* was the most susceptible, showing the largest inhibition zone (6.79 mm at 25%). This suggests that certain compounds in the extract may target anaerobic, lipid-rich environments, aligning with the organism's biology as a skin-associated pathogen (Jung et al., 2022). The moderate effect against *S. aureus* further supports the plant extract's antimicrobial potential

Borneo Journal of Pharmascientech
Vol 10 No 01, April 2026
Halaman 462-470
https://jurnalstikesborneolestari.ac.id/index.php/borneo/article/view/794
DOI: https://doi.org/10.59053/bjp.v10i1.794
e-ISSN : 2548 – 3897; p-ISSN : 2541 – 3651

but remains significantly lower than those of tetracycline (29.57 mm) and chloramphenicol (18.3 mm). The lack of activity against *P. aeruginosa* indicates the extract's limitations. *P. aeruginosa* is known for its multidrug resistance and efflux pump mechanisms, which may prevent phytochemicals from exerting sufficient antibacterial pressure (Alharbi et al., 2025).

Antibiofilm test

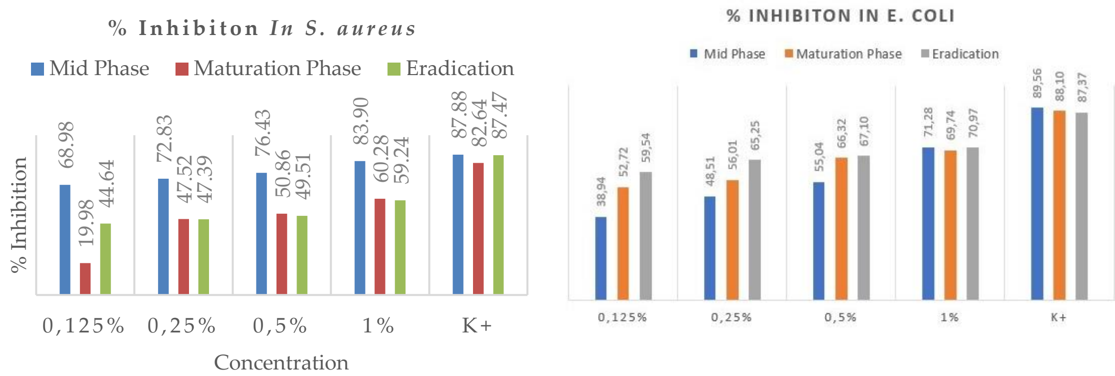


Fig. 2 Antibiofilm test result of *E. guineensis* leaf extract

The extract demonstrated dose-dependent antibiofilm activity across the mid-, maturation-, and eradication phases of *E. coli* biofilms. At the lowest concentration (0.125%), inhibition ranged from 38.94% (mid-phase) to 59.54% (eradication phase). Increasing the concentration to 0.25% enhanced biofilm inhibition, reaching 48.51–65.25%, while 0.5% produced slightly higher inhibition values (55.04–67.40%). A more substantial inhibitory effect was observed at 1%, where the extract inhibited 71.28% (mid-phase), 69.74% (maturation phase), and 70.97% (eradication). The positive control (K^+) exhibited the most potent inhibition across all phases (87.37–89.56%), as expected. These results indicate that the extract effectively inhibits *E. coli* biofilm formation and reduces mature biofilm mass, although with lower potency than the reference control.

The extract also showed concentration-dependent antibiofilm activity against *S. aureus*. At 0.125%, inhibition ranged from 19.98% (maturation) to 68.98% (mid-phase), indicating a more variable response than in *E. coli*, increasing the concentration to 0.25% further improved inhibition, with values ranging from 44.64% to 72.83%. At 0.5%, biofilm inhibition further increased, reaching 76.43%, 59.86%, and 49.51% in the mid-phase, maturation phase, and eradication phase, respectively. At 1%, the extract exhibited robust inhibition in the mid-phase (83.90%) but moderate activity in the maturation (60.28%) and eradication phases (59.24%). The positive control produced the highest inhibition across all phases (82.64–87.88%), similar to the pattern observed in *E. coli*. Collectively, the extract shows notable antibiofilm effects against *S. aureus*, particularly during the early stage of biofilm development.

The results demonstrate that *E. guineensis* leaf extract exhibits marked antibiofilm efficacy against both *E. coli* and *S. aureus*, with differential activity profiles influenced by the bacterial species and the stage of biofilm development. Across both bacteria, the extract exhibited more potent inhibition in the mid-phase (initial adhesion) than in the maturation and eradication phases. This indicates that the extract is more effective in preventing biofilm formation than in disrupting established biofilm matrices (Tasmia Asma et al., 2022). Initial-stage inhibition is likely attributable to disruption of bacterial adhesion to surfaces, modulation of quorum-sensing mechanisms, or suppression of early extracellular polymeric substances (EPS) biosynthesis (Rather et al., 2021). The extract produced higher inhibition

Borneo Journal of Pharmascientech
Vol 10 No 01, April 2026
Halaman 462-470
https://jurnalstikesborneolestari.ac.id/index.php/borneo/article/view/794
DOI: https://doi.org/10.59053/bjp.v10i1.794
e-ISSN : 2548 – 3897; p-ISSN : 2541 – 3651

percentages in *S. aureus* mid-stage biofilms (up to 83.90%) compared to *E. coli* (71.28%). This suggests that Gram-positive bacteria may be more susceptible to the phytochemicals in *E. guineensis*, consistent with typical differences in cell wall architecture (Nikolic & Mudgil, 2023). The dense outer membrane of Gram-negative bacteria often limits the penetration of plant-derived antimicrobial compounds. Although the extract showed considerable antibiofilm activity, the positive control consistently produced higher inhibition (>80%) across all conditions. This confirms that while the extract is bioactive, it functions as a moderate natural antibiofilm agent rather than a potent pharmaceutical alternative (Grari et al., 2025).

Antioxidant test

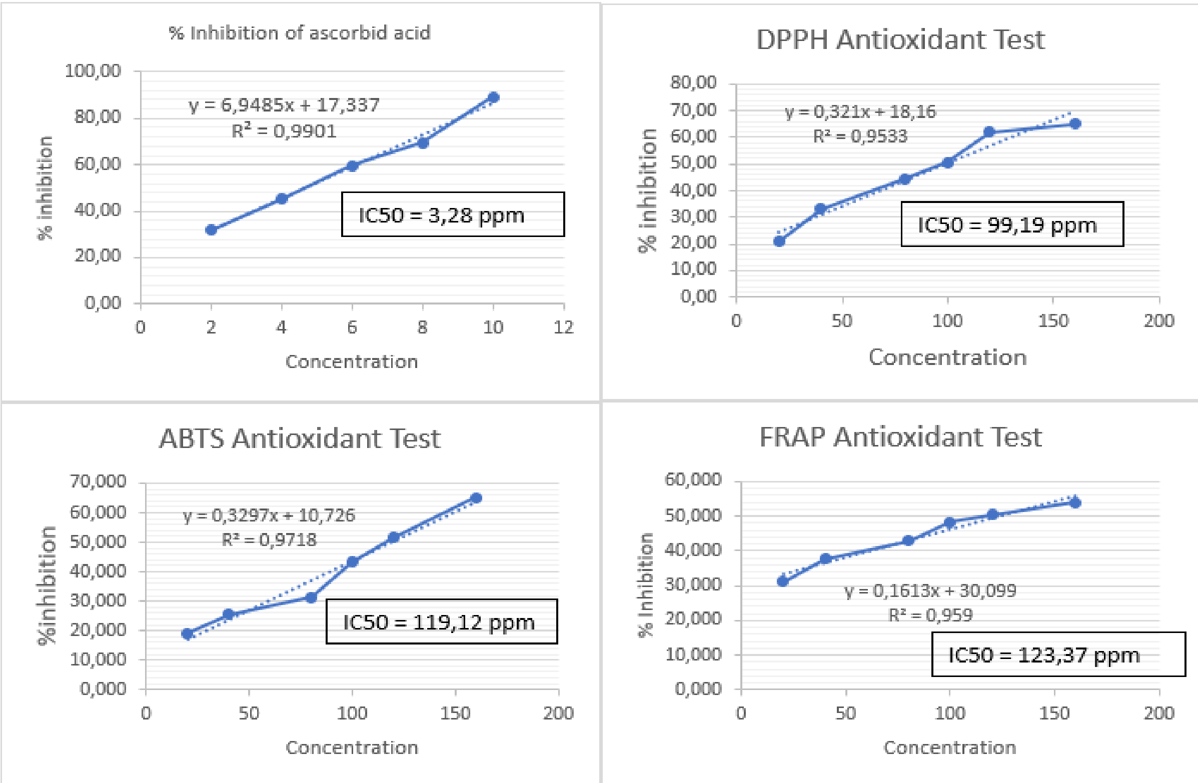


Fig. 3 Antioxidant test result of *E. Guineensis* leaf extract

Ascorbic acid, employed as the reference standard, exhibited a pronounced linear correlation between concentration and percentage inhibition ($R^2 = 0.9901$). The IC_{50} value obtained was 3.28 ppm, confirming the assay system's reliability and serving as a benchmark for evaluating the antioxidant strength of the *E. guineensis* leaf extract. The DPPH assay showed increasing % inhibition with increasing extract concentration, with an R^2 value of 0.9533. The calculated IC_{50} was 99.19 ppm, indicating moderate antioxidant capacity. Although markedly weaker than the ascorbic acid standard (IC_{50} = 3.28 ppm), the extract demonstrates substantial free radical scavenging potential. In the ABTS assay, the extract showed a concentration-dependent antioxidant response ($R^2 = 0.9718$). The IC_{50} value was 119.12 ppm, slightly lower than that observed in the DPPH assay. This suggests that the extract scavenges $ABTS^+$ radicals less efficiently, possibly due to the polarity or solubility of its active phytochemicals. The FRAP assay revealed a linear increase in antioxidant reducing power ($R^2 = 0.959$). The IC_{50} obtained was 123.37 ppm, the highest among the three antioxidant assays. This suggests that the extract possesses modest electron-donating capacity for ferric reduction compared to its ability to neutralize DPPH or ABTS radicals (Seleshe et al., 2022). The antioxidant evaluation of *E. guineensis* leaf

https://jurnalstikesborneolestari.ac.id/index.php/borneo/article/view/794
DOI: https://doi.org/10.59053/bjp.v10i1.794
e-ISSN : 2548 – 3897; p-ISSN : 2541 – 3651

extract using DPPH, ABTS, and FRAP assays demonstrates that the extract possesses moderate antioxidant activity, although not comparable to the potent antioxidant ascorbic acid. The IC_{50} values obtained (DPPH: 99.19 ppm; ABTS: 119.12 ppm; FRAP: 123.37 ppm) indicate that the extract is capable of scavenging free radicals and reducing oxidants at relatively higher concentrations (Munteanu & Apetrei, 2021). The observed IC_{50} values place the extract within the moderate antioxidant category, supporting its role as a supplementary rather than primary antioxidant agent. This level of activity may be attributed to the presence of phenolic and flavonoid compounds, which are known to contribute to antioxidant mechanisms through hydrogen atom donation and electron transfer.

Conclusion and Suggestions

The results demonstrate that *Elaeis guineensis* leaf extract exhibits moderate biological activity, including selective antibacterial effect against Gram-positive bacteria, concentration-dependent antibiofilm activity, particularly during early biofilm formation, and moderate antioxidant capacity. Although its activity is lower than that of standard antibiotics and ascorbic acid, the extract consistently exhibits dose-dependent effects, indicating the presence of bioactive phytochemicals. Therefore, this extract may serve as a promising preliminary candidate for further investigation, requiring additional studies including phytochemical isolation, mechanistic evaluation, and in vivo validation to confirm its pharmacological potential.

Acknowledgments

The researchers would like to thank the Ministry of Higher Education, Science, and Technology for their support under the Fundamental Research Program 2025 (contract no. 075/C3/DT.05.00/PL/2025; derivative contract no. 1381/UN8.2/PG/2025).

Reference

Abnisa, F., Daud, W. M. A. W., Husin, W. N. W., & Sahu, J. N. (2011). Utilization possibilities of palm shell as a source of biomass energy in Malaysia by producing bio-oil in pyrolysis process. *Biomass and Bioenergy*, *35*(5), 1863–1872. https://doi.org/10.1016/j.biombioe.2011.01.033

Alharbi, M. S., Moursi, S. A., Alshammari, A., Aboras, R., Rakha, E., Hossain, A., Alshubrumi, S., Alnazha, K., Khaja, A. S. S., & Saleem, M. (2025). Multidrug-resistant Pseudomonas aeruginosa: Pathogenesis, resistance mechanisms, and novel therapeutic strategies. *Virulence*, *16*(1), 1–23. https://doi.org/10.1080/21505594.2025.2580160

Asian Agri. (2020). *Asian Agri Sustainability Report 2019-2020*.

Asmawati Saad, A., Reski Fajar, D., & Widya Sari, I. (2023). Evaluation of Antioxidant Activity in Lemon Juice (Citrus limon) Marketed in Makassar City Using the DPPH (2,2 diphenyl-1-picrylhydrazyl) Method. *Jurnal Ilmiah Berkala: Sains Dan Terapan Kimia*, *17*(2), 38–42.

Ehrlich, G., Król, J. E., Sharma, S., Mohler, J., Mahajan, S. D., Schwartz, S. A., Bruggemann, L., & Aalinkeel, R. (2023). microorganisms Microbial Biofilm: A Review on Formation, Infection, Antibiotic Resistance, Control Measures, and Innovative Treatment. *Microorganisms*, *11*(1614), 1–32. https://doi.org/10.3390/microorganisms11061614

Febriani, A., Syafriana, V., Afriyando, H., & Djuhariah, Y. S. (2020). The utilization of oil palm leaves (Elaeis guineensis Jacq.) waste as an antibacterial solid bar soap. *IOP Conference Series: Earth and Environmental Science*, *572*(1), 1–11. https://doi.org/10.1088/1755-1315/572/1/012038

Grari, O., Ezrari, S., El Yandouzi, I., Benaissa, E., Ben Lahlou, Y., Lahmer, M., Saddari, A., Elouennass, M., & Maleb, A. (2025). A comprehensive review on biofilm-associated infections: Mechanisms,

https://jurnalstikesborneolestari.ac.id/index.php/borneo/article/view/794
DOI: https://doi.org/10.59053/bjp.v10i1.794
e-ISSN : 2548 – 3897; p-ISSN : 2541 – 3651

diagnostic challenges, and innovative therapeutic strategies. *Microbe (Netherlands)*, *8*. https://doi.org/10.1016/j.microb.2025.100436

Jung, I. G., Jeong, J. Y., Yum, S. H., & Hwang, Y. J. (2022). Inhibitory Effects of Selected Medicinal Plants on Bacterial Growth of Methicillin-Resistant Staphylococcus aureus. *Molecules*, *27*(22), 1–13. https://doi.org/10.3390/molecules27227780

Kedir, W. M., Geletu, A. K., Weldegirum, G. S., & Sima, M. F. (2023). Antioxidant activity of selected plants extract for palm oil stability via accelerated and deep frying study. *Heliyon*, *9*(7), 1–16. https://doi.org/10.1016/j.heliyon.2023.e17980

Knez, E., Kadac-Czapska, K., & Grembecka, M. (2025). Evaluation of Spectrophotometric Methods for Assessing Antioxidant Potential in Plant Food Samples—A Critical Approach. *Applied Sciences (Switzerland)*, *15*(11), 1–24. https://doi.org/10.3390/app15115925

Munteanu, I. G., & Apetrei, C. (2021). Analytical methods used in determining antioxidant activity: A review. *International Journal of Molecular Sciences*, *22*(7), 1–30. https://doi.org/10.3390/ijms22073380

Nazzaro, F., Fratianni, F., De Martino, L., Coppola, R., & De Feo, V. (2013). Effect of essential oils on pathogenic bacteria. *Pharmaceuticals*, *6*(12), 1451–1474. https://doi.org/10.3390/ph6121451

Nikolic, P., & Mudgil, P. (2023). The Cell Wall, Cell Membrane and Virulence Factors of Staphylococcus aureus and Their Role in Antibiotic Resistance. *Microorganisms*, *11*(2), 1–20. https://doi.org/10.3390/microorganisms11020259

Pacyga, K., Pacyga, P., Topola, E., Viscardi, S., & Duda-Madej, A. (2024). Bioactive Compounds from Plant Origin as Natural Antimicrobial Agents for the Treatment of Wound Infections. *International Journal of Molecular Sciences*, *25*(4), 1–44. https://doi.org/10.3390/ijms25042100

Pusat Data dan Sistem Informasi Pertanian. (2024). *Outlook Kelapa Sawit Pusat Data dan Sistem Informasi Pertanian Sekretariat Jenderal-Kementerian Pertanian 2024*. Sekretrian Jendral Kementrian Pertanian RI.

Rather, M. A., Gupta, K., & Mandal, M. (2021). Microbial biofilm: formation, architecture, antibiotic resistance, and control strategies. *Brazilian Journal of Microbiology*, *1*(52), 1701–1718. https://doi.org/10.1007/s42770-021-00624-x

Sadeer, N. B., Montesano, D., Albrizio, S., Zengin, G., & Mahomoodally, M. F. (2020). The versatility of antioxidant assays in food science and safety—chemistry, applications, strengths, and limitations. *Antioxidants*, *9*(8), 1–39. https://doi.org/10.3390/antiox9080709

Seleshe, S., Ameer, A., & Kang, S. N. (2022). Exploration of the Antioxidant Chemical Constituents and Antioxidant Performance of Various Solvent Extracts of Eighteen Plants. *Preventive Nutrition and Food Science*, *27*(2), 212–222. https://doi.org/10.3746/PNF.2022.27.2.212

Setiawan, D., Hadi, S., Mardiati, N., Mahdi, N., Aqifah, A., & Hamzah, H. (2025). Nanogel of Lollipop Leave Extract: A Promising Antibiofilm Agent for Diabetic Ulcer Infections. *Egyptian Journal of Chemistry*, *68*(8), 659–666. https://doi.org/10.21608/EJCHEM.2024.317699.10326

Setiawan, D., Mahdi, N., & Praristiya, M. R. S. (2021). FORMULASI SEDIAAN GEL PEEL-OFF EKSTRAK BUAH LIMPASU (Baccaurea lanceolate (Miq) Mull.Arg.) SEBAGAI ANTIBAKTERI. *Jurnal Ilmiah Ibnu Sina (JIIS): Ilmu Farmasi Dan Kesehatan*, *6*(2), 361–367. https://doi.org/10.36387/jiis.v6i2.745

Tasmia Asma, S., Imre, K., Morar, A., Herman, V., Acaroz, U., Mukhtar, H., Arslan-Acaroz, D., Rizwan, S., Shah, A., & Gerlach, R. (2022). An Overview of Biofilm Formation-Combating Strategies and Mechanisms of Action of Antibiofilm Agents. *MDPI Life*, *1*(1110). https://doi.org/10.3390/life12081110

https://jurnalstikesborneolestari.ac.id/index.php/borneo/article/view/794
DOI: https://doi.org/10.59053/bjp.v10i1.794
e-ISSN : 2548 – 3897; p-ISSN : 2541 – 3651

Tow, W. K., Goh, A. P. T., Sundralingam, U., Palanisamy, U. D., & Sivasothy, Y. (2021). Flavonoid composition and pharmacological properties of elaeis guineensis jacq. Leaf extracts: A systematic review. *Pharmaceuticals*, *14*(10), 1–20. https://doi.org/10.3390/ph14100961

Vandana, Priyadarshanee, M., & Das, S. (2023). Bacterial extracellular polymeric substances: Biosynthesis and interaction with environmental pollutants. *Chemosphere*, *332*, 138876. https://doi.org/10.1016/J.CHEMOSPHERE.2023.138876

Wardhono, E., Kustiningsih, I., Yustanti, E., Kurniawan, B., Sukamto, D., Meliana, Y., & Guénin, E. (2025). Enhanced cellulose extraction from delignified oil palm empty fruit bunches using sequential ultrasound-microwave processing. *South African Journal of Chemical Engineering*, *54*, 179–190. https://doi.org/10.1016/j.sajce.2025.07.015

Zhao, A., Sun, J., & Liu, Y. (2023). Understanding bacterial biofilms: From definition to treatment strategies. *Frontiers in Cellular and Infection Microbiology*, *13*(113), 1–23. https://doi.org/10.3389/fcimb.2023.1137947