ORIGINAL RESEARCH
Vol. 22, No. 1 (2026), pp. 13–20
https://doi.org/10.26753/jikk.v22i1.43

Jurnal Ilmiah Kesehatan Keperawatan
p-ISSN 1858-0696 | e-ISSN 2598-9855

Antibacterial Effectiveness of *Etlingera elatior* Extract Against *Pseudomonas aeruginosa* as an Alternative Treatment for Infected Emergency Wounds

Elizabeth Yun Yun Vinsur[1,*], Sugiyanto[2]

[1] *Department of Nursing Program, School of Health Sciences Panti Waluya Malang, Malang, Indonesia*
[2] *Department of Pharmacist Program, School of Health Sciences Panti Waluya Malang, Malang, Indonesia*
[*] Corresponding author. Elizabeth Yun Yun Vinsur, School of Health Sciences Panti Waluya Malang, Yulius Usman No. 62, Malang, Indonesia. *E-mail address:* elizabethyyvinsur@gmail.com. *ORCID:* 0000-0001-8040-3368.

ARTICLE INFO

Article history:
Received: April 29, 2026
Revised: June 22, 2026
Accepted: June 24, 2026

Keywords:
Etlingera elatior,
Pseudomonas aeruginosa,
Antibacterial activity,
Disc diffusion,
Kecombrang,

ABSTRACT

Background. *Pseudomonas aeruginosa* is a formidable opportunistic pathogen characterized by intrinsic antibiotic resistance, complicating nosocomial infection management. Indonesia's biodiversity, specifically Kecombrang (*Etlingera elatior* Jack), offers a promising reservoir of antimicrobial phytochemicals such as flavonoids and terpenoids to support evidence-based nursing and complementary therapies.

Objective. This study evaluates the antibacterial activity of various anatomical parts of *E. elatior* to identify the most effective concentration and plant part against *P. aeruginosa*.

Methods. This *in vitro* laboratory experiment utilized a single-factor Completely Randomized Design (CRD). Ethanol extracts (70%) of the flowers, stems, and pseudostems sourced from Pangandaran, West Java, were tested using the Kirby-Bauer disc diffusion method with four replications. Concentrations ranged from 60% to 100%, with Ceftazidime (10 µg) and sterile distilled water as positive and negative controls, respectively. Data were analyzed using the Kruskal-Wallis and Mann-Whitney U tests ($\alpha = 0.05$).

Results. All plant parts exhibited varying antibacterial activity. The flower extract at 90% concentration produced the largest mean inhibition zone (4.55 ± 0.79 mm). Extract potency was categorized as weak, whereas the positive control showed strong activity (15.92 ± 0.97 mm). Statistical analysis confirmed a significant difference between flowers and other parts ($p < 0.05$), though no significant difference existed between stems and pseudostems ($p > 0.05$).

Conclusion. *E. elatior* extracts possess antibacterial properties against *P. aeruginosa*, with the flower being the most significant anatomical part. While current potency is weak, these results provide a scientific foundation for developing Kecombrang as a supplementary antimicrobial agent.

1. INTRODUCTION

Bacterial infections continue to represent one of the most significant threats to global public health in the 21st century. Despite advancements in medical technology, these infections contribute to alarmingly high morbidity and mortality rates across diverse healthcare facilities worldwide [1]. Among the various pathogenic bacteria that challenge modern medicine, *Pseudomonas aeruginosa* stands out as a particularly formidable Gram-negative opportunistic bacterium. It is widely recognized for its high virulence and its propensity to cause severe, life-threatening infections, specifically in patients already compromised by immunodeficiency, extensive burns, or chronic conditions such as cystic fibrosis. The pathogenicity of *P. aeruginosa* is not merely a result of its presence but is driven by sophisticated survival mechanisms. It possesses the innate ability to form robust biofilms—complex communities of bacteria encased in a self-produced extracellular matrix—which shield the cells from both the host's immune response and pharmacological interventions. This characteristic, combined with its ability to develop resistance to multiple classes of antibiotics through efflux pumps and enzymatic degradation, presents a daunting therapeutic challenge for healthcare practitioners globally [2,3].

In the high-pressure environment of the Emergency Department (ED), patients are inherently vulnerable. The nature of emergency medicine often involves

managing individuals with open traumatic wounds, severe underlying comorbidities, or those requiring immediate invasive procedures—such as intubation or central line insertion—to achieve rapid physiological stabilization [4,5]. These clinical necessities, while life-saving, serve as gateways for opportunistic pathogens.

P. aeruginosa is frequently implicated in the etiology of nosocomial infections within these critical zones, including the Emergency Department (ED) and Intensive Care Units (ICU) [6]. The rapid onset of infections in these settings can negate the progress of initial stabilization. Furthermore, the rising phenomenon of bacterial resistance to conventional antibiotics poses a direct and serious threat to the management protocols designed for emergency patients, where time-to-treatment is a critical factor in survival [7,8].

The high prevalence of *P. aeruginosa* in hospital environments is a primary driver behind several healthcare-associated infections (HAIs), most notably ventilator-associated pneumonia (VAP), catheter-associated urinary tract infections (CAUTIs), and complex post-operative wound infections [9,10]. Global epidemiological data indicate an increasingly perilous trend: the steady rise of resistance against first- and second-line antibiotics. Most concerning is the growing resistance to carbapenems, which were long considered last-resort treatments, thereby severely limiting the remaining effective therapeutic options [11,12]. In the Indonesian context, these resistance patterns show a worrying trajectory that mirrors global concerns but is intensified by local clinical challenges. This trend directly correlates with increased healthcare expenditures and poor clinical outcomes [11,13,14]. When primary treatments fail due to multi-drug resistance, the clinical consequences are multi-faceted: the length of hospital stays is extended, the need for expensive and highly complex medical interventions increases, and the ultimate risk of patient mortality rises significantly [15,16].

Moreover, clinicians are often forced to pivot toward broad-spectrum antibiotics as a desperate alternative. These drugs are frequently associated with higher systemic toxicity and the potential to trigger "collateral sensitivity" or the emergence of new resistant strains, which ultimately diminishes the patient's long-term quality of life post-infection [17–19]. Consequently, emergency nurses—standing as the frontline of patient care—feel a profound sense of urgency to identify and implement more effective, safer, and more sustainable therapeutic solutions for their patients.

Given the stagnation in the development of new synthetic antibiotics and the limitations of current pharmacology, innovative efforts to find novel antibacterial agents have moved from a secondary interest to a primary medical necessity [12,20]. Indonesia, recognized for its vast and rich biodiversity, holds immense potential as a source of bioactive compounds derived from medicinal plants. One such plant of profound pharmacological interest is Kecombrang (*Etlingera elatior* Jack). While it has been traditionally utilized across the archipelago for culinary and basic medicinal purposes, its deeper biochemical potential is only now being rigorously scrutinized [20,21].

Preliminary literature reviews have provided a baseline for this potential, indicating that extracts from the flowers and leaves of Kecombrang possess antibacterial activity against several common pathogens [22]. However, a significant research gap exists. The antibacterial potential of other anatomical parts of the plant—specifically the stem and the pseudostem—remains largely unexplored in the context of *P. aeruginosa* [23]. Most existing studies have maintained a narrow focus on the inflorescence (flowers), despite the fact that the stems and pseudostems constitute a much larger portion of the plant's biomass. It is hypothesized that these parts contain unique distributions of bioactive compounds, such as alkaloids, saponins, and tannins, that may offer distinct or synergistic antimicrobial effects [24,25].

Emergency nurses stand at the forefront of clinical care, facing a disproportionately high risk of pathogen transmission due to continuous exposure to critical wounds and bodily fluids harboring dangerous bacteria such as *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Escherichia coli*. While strict adherence to universal precautions is mandated to disrupt this chain of transmission, the chaotic and high-acuity nature of emergency settings often demands rapid, life-saving actions [26]. These high-pressure situations frequently limit nurses' ability to execute flawless hand hygiene or manage personal protective equipment (PPE) properly [27]. Consequently, procedural gaps inevitably arise; during these hectic intervals, nurses can inadvertently act as passive intermediaries, carrying and spreading bacterial contaminants directly from one patient to another [27,28]. This operational reality transforms common work attributes—such as uniforms, stethoscopes, and ID cards—into dangerous vectors for cross-contamination, severely compounding the threat of nosocomial infections in hospitals.

Although extensive research has addressed these behavioral and systemic procedural gaps, a critical research gap remains: there is a profound lack of exploration into integrating alternative, non-synthetic antibacterial barriers—specifically target-specific phytochemical extracts—directly into emergency nursing protocols to mitigate this environmental and horizontal contamination [29]. Therefore, conducting an *in vitro* evaluation of *Etlingera elatior* extracts is a critical baseline step to scientifically verify their antimicrobial efficacy before these natural compounds can be safely integrated into emergency nursing protocols as topical antiseptics or protective barriers. To address this gap, this study introduces a distinct novelty by conducting a comprehensive,

comparative analysis of the flower, stem, and pseudostem extracts of *Etlingera elatior* against *P. aeruginosa* in a controlled *in vitro* environment. Investigating the specific efficacy of different anatomical parts of this plant provides the rigorous scientific justification required to develop innovative, alternative wound management therapies.

For the nursing profession, particularly within emergency and trauma care, the role must extend beyond basic bedside assistance to becoming a central pillar of infection prevention and early clinical management [30]. An advanced understanding of alternative antibacterial agents equips nurses with the necessary insight to offer comprehensive, holistic care. By investigating these natural alternatives, this study contributes directly to the evolution of Evidence-Based Nursing Practice (EBNP). Ultimately, establishing a scientific foundation for such complementary therapies offers an effective, safer alternative to synthetic antibiotics with minimal side effects, thereby actively improving patient recovery trajectories in emergency settings.

2. METHODS

2.1 Study Design

This study employed an *in vitro* laboratory experimental design utilizing a single-factor Completely Randomized Design (CRD) (31). The research was conducted from May to July 2025 to evaluate the antibacterial efficacy of flower, stem, and pseudostem extracts of Kecombrang (*Etlingera elatior* Jack) against the growth of *Pseudomonas aeruginosa*.

2.2 Setting and Participants (Materials)

The study was conducted across certified laboratories selected for their high-specification equipment and rigorous compliance with health safety standards. Taxonomical identification for botanical determination was performed at the Materia Medica Botanical Laboratory, Batu, while extraction, phytochemical screening, and microbiological assays—including bacterial rejuvenation and antibacterial testing—were carried out at the Chemistry and Microbiology Laboratories of the School of Health Sciences Panti Waluya Malang and Materia Medica Batu. Regarding biological materials, fresh *E. elatior* specimens were sourced from Pangandaran, West Java, based on inclusion criteria that required healthy plant parts free from decay or mold. The target pathogen, pure cultures of *P. aeruginosa*, was obtained from the Vie_Lab Laboratory in Jember.

The number of replications was determined using the Federer formula: (n–1)(t–1) > 15 (32). With 17 distinct treatment groups (t), the study utilized four replications (n = 4) to ensure statistical robustness. The experimental treatment groups were established based on preliminary screening ranges of 12.5% to 100%, leading to the selection of five primary test concentrations for the main study. Specifically, 70% ethanol extracts derived from the flowers, stems, and pseudostems of *Etlingera elatior* were prepared at concentrations of 60%, 70%, 80%, 90%, and 100%. To ensure the validity of the antibacterial assays, these extracts were compared against two distinct benchmarks: a positive control consisting of Ceftazidime (10 µg) to verify bacterial susceptibility and establish a standard for antibiotic efficacy, and a negative control utilizing sterile distilled water to confirm that neither the solvent nor the delivery vehicle possessed inherent inhibitory properties.

2.3 Instruments and Measures

Description of tools/instruments. The quantification of antibacterial activity was performed using a Vernier caliper with a precision of 0.1 mm to measure the diameter of inhibition zones. To ensure the consistency of bacterial density, a spectrophotometer was utilized to standardize the inoculum density at an optical density (absorbance) of 600 nm (OD600), equivalent to a 0.5 McFarland standard [33].

Validity and reliability. To ensure the scientific integrity and reproducibility of the data, the following validation measures were implemented. The Kecombrang (*Etlingera elatior* Jack) specimens were sourced from Pangandaran, West Java. To ensure taxonomical accuracy, the samples were authenticated at the Technical Implementation Unit (UPT) Materia Medica Batu, under the East Java Provincial Health Office. Botanical determination was officially confirmed under Letter No. 000.9.3/1770/102.20/2025, verifying the authenticity of the species and the specific anatomical parts (flower, stem, and pseudostem) used in the study. The chemical profile of the extracts was verified via standard qualitative screening tests, including the Wilstatter test for flavonoids and the FeCl3 test for tannins. This ensured the consistent presence of the targeted bioactive compounds across all extract batches. Systematic instrumental error was minimized by calibrating the Vernier caliper (0.1 mm precision) and the spectrophotometer. Inoculum reliability was maintained by standardizing the *P. aeruginosa* suspension to a consistent optical density (OD600), ensuring uniform bacterial exposure across all treatment groups. The validity of the disc diffusion assay was confirmed using Ceftazidime (10 µg) as a positive control and sterile distilled water as a negative control. In accordance with the Federer formula, four replications were performed for each treatment group, allowing the calculation of mean values and standard deviations and ensuring the internal consistency and reliability of the experimental findings.

Scoring methods. Antibacterial efficacy was quantified by measuring the diameter of the clear inhibition zone around the paper discs in millimeters (mm), including the 6 mm disc diameter. The potency of the extracts was categorized based on established clinical significance thresholds: very strong (> 20 mm), strong (10–20 mm), moderate (5–10 mm), and

weak/inactive (< 5 mm). A comparative analysis was also conducted, in which the performance of each plant extract was evaluated relative to the positive control (representing 100% efficacy) and the negative control (representing 0% efficacy). Final scores were derived from the mean values of the four replications to ensure statistical robustness across all experimental groups [34].

2.4 Data Collection Procedure

The experimental protocol followed a systematic, multi-stage process involving extraction, treatment application, and controlled incubation. The plant materials (flowers, stems, and pseudostems) were processed via maceration using 70% ethanol to derive concentrated extracts. Each extract was subsequently diluted into a dose-response range of 60%, 70%, 80%, 90%, and 100%. Bacterial suspensions of *P. aeruginosa* were standardized to a 0.5 McFarland turbidity and inoculated onto Mueller-Hinton Agar (MHA). Using the disc diffusion method, 20 µL of each extract concentration was impregnated onto 6 mm sterile paper discs and placed onto the inoculated plates. To establish clinical benchmarks, Ceftazidime (10 µg) was utilized as a positive control, while sterile distilled water served as a negative control. All plates were incubated at 37°C for 18–24 hours. To eliminate confounding variables, all experiments used a single batch of MHA to ensure uniform nutrient availability and diffusion rates, and all procedures were conducted under identical temperature and temporal conditions.

2.5 Data Analysis

Statistical analyses were performed using SPSS version 26.0. Descriptive statistics were initially employed to summarize the inhibition zone diameters as mean ± standard deviation (SD). The data were subjected to the Shapiro-Wilk test for normality and the Levene test for homogeneity of variance. As the results indicated a non-normal distribution and a lack of homogeneity ($p < 0.05$), non-parametric methods were adopted. The Kruskal-Wallis test was utilized to evaluate global significance across the various concentrations and plant parts. Pair-wise comparisons were subsequently conducted using the Mann-Whitney U post-hoc test. For all analyses, statistical significance was defined at $p < 0.05$ with a 95% confidence interval.

2.6 Ethical Considerations

This *in vitro* study utilized biological agents classified under biosafety risk categories and was conducted strictly within a certified laboratory environment equipped with standard containment protocols. Since no new clinical specimens or primary biological samples were directly isolated from human or animal subjects for this study, a formal institutional ethical review for human/animal subjects was determined to be not applicable. However, to ensure strict biosafety compliance and environmental protection against hazardous biological agents, all experimental procedures were performed in accordance with Government Regulation of the Republic of Indonesia No. 22 of 2021 on the Implementation of Environmental Protection and Management [35]. Furthermore, all generated biohazard materials, contaminated cultures, and infectious solid/liquid waste were strictly processed, autoclaved, and managed following the technical guidelines and safety requirements mandated by the Minister of Environment and Forestry Regulation No. 6 of 2021 regarding Procedures and Requirements for Hazardous and Toxic Waste Management [36].

3. RESULTS

3.1 Antibacterial Activity of Etlingera elatior Extracts

The antibacterial activity was determined by measuring the inhibition zone diameters across three different plant parts (flower, stem, and pseudostem) at concentrations ranging from 60% to 100%. The results of the disc diffusion tests are summarized in Table 1.

Table 1. Mean Inhibition Zone Diameters of Kecombrang Extracts against *P. aeruginosa* (n = 4)

Plant Part	Extract Concentration (%)	Zone of Inhibition (mm) ± SD	Antibacterial Activity Category
Flower	60	2.95 ± 1.30	Weak
	70	2.70 ± 1.41	Weak
	80	3.18 ± 1.27	Weak
	90	4.55 ± 0.79	Weak
	100	2.80 ± 0.95	Weak
Stem	60	0	Inactive
	70	0.58 ± 0.61	Weak
	80	0	Inactive
	90	1.52 ± 0.63	Weak
	100	0	Inactive
Pseudostem	60	0	Inactive
	70	1.87 ± 0.85	Weak
	80	3.02 ± 0.97	Weak
	90	0	Inactive
	100	0	Inactive
Controls	Positive (Ceftazidime)	15.92 ± 0.97	Strong
	Negative (Distilled Water)	0.00 ± 0.00	Inactive

In accordance with susceptibility standards, inhibition zone diameters were categorized as resistant (< 15 mm), intermediate (16–20 mm), or susceptible (> 21 mm). Based on these criteria, all tested extract concentrations fell within the resistant category, suggesting that *P. aeruginosa* possesses inherent resistance to the extracts at the tested concentrations. In contrast, the positive control did not fall into the resistant category, confirming the susceptibility of the microorganism to the reference antibiotic.

Table 2. Summary of Statistical Analysis

No	Statistical Test	Significance	Interpretation
1	Normality test (Kolmogorov-Smirnov)	$p < 0.05$	Data not normally distributed
2	Homogeneity test	$p < 0.05$	Data not homogeneous
3	Kruskal-Wallis test	$p < 0.05$	Significant difference observed
4	Mann-Whitney (flower vs. stem)	$p < 0.05$	Significant difference observed
5	Mann-Whitney (stem vs. pseudostem)	$p > 0.05$	No significant difference observed
6	Mann-Whitney (pseudostem vs. flower)	$p < 0.05$	Significant difference observed

In this study, a one-way ANOVA was not performed because the data failed to meet the required assumptions of normality and homogeneity of variance. Consequently, the Kruskal-Wallis test was employed as a non-parametric alternative to evaluate the influence of the independent variables (plant parts and concentration variations) on the dependent variable (inhibition zone) at a 95% confidence level.

Analysis of the distribution using the Kolmogorov-Smirnov test and Levene's test for homogeneity yielded p-values less than the significance level ($p < 0.05$). These results confirmed that the data were neither normally distributed nor homogeneous, justifying the transition to non-parametric analysis. The Kruskal-Wallis test revealed a significant difference ($p < 0.05$) in antibacterial activity across the flowers, stems, and pseudostems at various concentrations.

To identify specific differences between the groups, a Mann-Whitney U post-hoc test was conducted. The results indicated significant differences when comparing flowers vs. stems ($p < 0.05$) and pseudostems vs. flowers ($p < 0.05$). However, no significant difference was observed between stems and pseudostems ($p > 0.05$).

4. DISCUSSION

4.1 Principal Findings

The core objective of this study was to evaluate the antibacterial potential of *Etlingera elatior* (Kecombrang) across three distinct anatomical parts—flower, stem, and pseudostem—against the opportunistic pathogen *Pseudomonas aeruginosa*. The experimental data, as detailed in Table 1, reveal a clear hierarchy of efficacy. The flower extract at 90% concentration emerged as the most potent treatment group, yielding a mean inhibition zone of 4.55 ± 0.79 mm. Statistical analysis via the Kruskal-Wallis and Mann-Whitney U tests (Table 2) confirmed that the flower's bioactivity was significantly superior ($p < 0.05$) to that of the stem and pseudostem.

However, a critical finding is that despite the observable inhibition, all extract concentrations were categorized as "weak" according to the Davis & Stout criteria, and the bacteria remained "resistant" based on clinical susceptibility standards. This suggests that while *E. elatior* possesses bioactive secondary metabolites capable of disrupting *P. aeruginosa* growth, the crude ethanol extracts at these concentrations do not yet match the rapid bactericidal action of synthesized antibiotics like Ceftazidime, which maintained a "strong" inhibitory profile (15.92 ± 0.97 mm).

4.2 Comparison with Previous Studies

The superiority of the flower extract over the vegetative parts (stem and leaf sheath) is consistent with the "plant defense hypothesis," which suggests that plants allocate higher concentrations of secondary metabolites to their reproductive organs to ensure survival. According to (37), the inflorescence of *Etlingera* species contains a more complex profile of essential oils and polyphenols compared to the fibrous tissues of the pseudostem.

While noted that the stems of many Zingiberaceae plants contain tannins and saponins, they are often locked within lignocellulosic matrices, making them harder to extract efficiently via simple maceration compared to the softer tissues of the flower. This explains why, in our study, the stem and leaf sheath frequently showed "inactive" results at lower concentrations, only becoming "weakly" active at 70% and 80% [38].

The "weak" categorization observed in this study is not an indictment of *E. elatior* but rather a testament to the robust defense mechanisms of *P. aeruginosa*. Internationally, *P. aeruginosa* is recognized as a high-priority pathogen by the WHO due to its intrinsic resistance. Previous literature indicates that Gram-negative bacteria are significantly more resistant to plant extracts than Gram-positive bacteria.

As noted by [2,7], the outer membrane of *P. aeruginosa* contains lipopolysaccharides (LPS) and porins that act as a high-security barrier. Many plant-derived molecules, such as large-chain tannins or polar flavonoids, struggle to penetrate this hydrophobic barrier. This explains why our results showed resistance, whereas similar extracts of Kecombrang have been shown in other studies to have "strong" or "moderate" activity against *Staphylococcus aureus* (a Gram-positive bacterium lacking an outer membrane) [22,37,39].

Phytochemical screening of Kecombrang has identified high levels of quercetin and kaempferol. These flavonoids work by complexing with bacterial cell walls and disrupting the integrity of the cytoplasmic membrane. The clear zones observed in Table 1 are likely the result of these compounds causing "leakage" of intracellular components (ions and proteins) from the *P. aeruginosa* cells [37,40].

Kecombrang is famous for its aromatic properties, driven by terpenoids like α-pinene and dodecanol. These are lipophilic molecules; their mechanism involves the disruption of the lipid bilayer of the bacterial cell membrane [41,42]. However, their high volatility explains our observation that the 90% concentration was slightly more effective than the 100% concentration. At 100%, the lack of a water carrier (solvent) may lead to rapid evaporation of these essential terpenoids before they can effectively diffuse into the agar medium. Furthermore, the high viscosity characteristic of the 100% pure crude extract likely creates a dense physical barrier, which severely restricts the release rate and molecular diffusion of the active antimicrobial compounds from the paper disc into the surrounding agar medium [43].

The disc diffusion method relies on the molecular weight and polarity of the compounds. Large, non-polar molecules move slowly through the aqueous environment of Mueller-Hinton Agar. Therefore, a "weak" zone might not mean the extract is ineffective, but rather that its most potent compounds are too large to diffuse far from the disc. This is a common limitation noted in ethnobotanical studies using the Kirby-Bauer method [44].

4.3 Interpretation and Implications

Clinical implications

From a clinical standpoint, the resistance of *P. aeruginosa* to these crude extracts emphasizes that *E. elatior* is not yet a replacement for frontline antibiotics. However, it holds immense potential as a synergistic agent. Modern pharmacology is moving toward combination therapy, where plant extracts are used to weaken the bacterial cell wall, allowing lower doses of antibiotics like Ceftazidime to work more effectively. This could potentially reduce the side effects of synthetic drugs and slow the development of antibiotic resistance.

Community health implications

In Indonesia, Kecombrang is consumed as a vegetable (*sambal*, *urap*). The community health implication of this study is the validation of Kecombrang as a functional food. While it may not cure a systemic Pseudomonas infection, its regular consumption provides a baseline of antioxidant and mild antimicrobial activity that supports the body's natural defenses. It serves as a low-cost, culturally accessible form of preventive health.

Policy relevance

Indonesia's Ministry of Health promotes the "Back to Nature" movement through the development of Obat Herbal Terstandar (OHT). This study provides the foundational data required for the standardization of Kecombrang extracts. Policy-makers can use these data to support the cultivation of Kecombrang in Pangandaran, West Java, as a high-value medicinal crop, bridging the gap between traditional agriculture and pharmaceutical innovation.

4.4 Strengths and Limitations

This study utilized a rigorous Completely Randomized Design (CRD) and the Federer formula to ensure that the sample size was statistically significant (n = 4). The use of Ceftazidime as a positive control provided a high-standard clinical benchmark, and the official taxonomical determination at Materia Medica Batu ensured that the plant material was precisely identified, eliminating the risk of species confusion.

The limitations of this study are characterized by several technical and biological constraints, primarily the use of crude ethanol extracts which contain a complex mixture of hundreds of compounds that may exhibit antagonistic interactions, effectively neutralizing the potency of individual bioactive agents. Furthermore, the disc diffusion method inherently favors water-soluble substances, potentially causing the lipophilic compounds found in Kecombrang essential oils to remain sequestered near the disc rather than migrating through the agar medium. Finally, the *in vitro* nature of this research prevents a complete representation of physiological conditions, as a laboratory setting cannot replicate the synergistic effects of the human immune response or the complex metabolic degradation and biotransformation these compounds would undergo within the liver.

Future research should focus on fractionation. By separating the extract into its polar and non-polar fractions, researchers can identify exactly which compound—e.g., a specific flavonoid or terpenoid—is responsible for the activity. Furthermore, testing the Minimum Inhibitory Concentration (MIC) using the microdilution method would provide a more precise numerical value for potency that is not limited by agar diffusion rates.

5. CONCLUSION

In conclusion, *Etlingera elatior* exhibits undeniable antibacterial activity against *P. aeruginosa*, with the flower being the most effective part. While the current potency is classified as weak, the biological activity discovered provides a strong scientific basis for further development of Kecombrang as a supplementary antimicrobial agent in the global fight against antibiotic-resistant bacteria.

DATA AVAILABILITY STATEMENT

All data generated or analyzed during this study, including raw measurements of inhibition zones and phytochemical screening results, are included within this manuscript. Any additional datasets or supplementary information regarding the specific laboratory protocols at the School of Health Sciences Panti Waluya Malang and Materia Medica Batu are available from the corresponding author upon reasonable request.

FUNDING

This research was supported by the institutional resources of the School of Health Sciences Panti Waluya Malang (Rp 4,000,000).

CONFLICT OF INTEREST

The authors declare no competing interests.

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