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RESEARCH ARTICLE

Ethnomedicinal Plants Used for Treatment of Infectious Diseases by Dayak Ethnic in Borneo, Indonesia

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Abstract

The Dayak tribe, residing on the island of Borneo in Indonesia, continues to uphold their ancestral cultural customs involving using medicinal plants for disease treatment. To assess the efficacy of chosen Dayak traditional medicinal plants, commonly utilized for treating diverse infectious ailments, against bacteria responsible for infections. Samples of medicinal plants (*Garptophyllum pictum*, *Eleutherine bulbosa*, *Oscimum sanctum*, *Cassia alata*, *Callicarpa longifolia* Lam., *Hibiscus rosa-sinensis*, *Dracaena cantleyi*, *Uncaria gambir* Roxb., *Rhodomyrtus tomentosa*, *Gomphrena globose*) were extracted using absolute methanol and water and tested for their antimicrobial activities against stock isolates and standard strains of *Staphylococcus aureus*, *Streptococcus pyogenes*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Enterobacter aerogenes* using agar well diffusion and micro-titer plate methods. Crude extracts of *Eleutherine bulbosa*, *Dracaena cantleyi*, *Oscimum sanctum*, and *Uncaria gambir* Roxb. inhibited bacterial growth by 100%, 100%, 40%, and 25% against the test organisms, respectively. These plants inhibited the growth of bacteria from 7 mm to 16 mm in diameter. Most of the plant extracts had antibacterial activities, among which *Eleutherine bulbosa* and *Dracaena cantleyi* inhibited the growth of 100% of the test organisms, respectively. The activities of methanolic extracts were greater than those of their corresponding water extracts. *Streptococcus pyogens* was the organism most susceptible to the extract, while *Enterobacter aerogenes* demonstrated the highest resistance.

Keywords: Bacteria, Dayak tribe, infections, traditional medicinal plants

Introduction

Bacterial infections are diseases that can affect various body parts, such as the skin, lungs, brain, and blood, resulting from single-celled organisms multiplying or releasing toxins in the body. Diseases caused by bacterial infections continue to be a significant concern, particularly in poor and developing countries, due to the growing issue of antibiotic resistance.[1] The uncovering of antibiotics represents a remarkable triumph in human history; however, the growing issue of antibiotic resistance casts a shadow over this achievement.[2] To address the issue of antibiotic resistance in the management of infectious diseases, it is crucial to persistently investigate natural substances as potential sources for novel antibacterial agents.[3–5]

There is a growing curiosity in uncovering the mysteries of traditional herbal treatments, drawing upon insights gathered from local inhabitants and customary practitioners across various regions worldwide.[6,7] Medicinal plants are plants that can be used to treat a disease. Since ancient times, medicinal plants have been used by rural communities.[8–10] Traditional medicine for diseases using concoctions with essential ingredients from plants and everything that exists in nature is still in great demand by the public because usually the ingredients can be found easily in the environment.[11–13] Plants have long been used as a source of medicine for the treatment of various diseases. Around 35,000–70,000 plant species have been screened for their medicinal use.[14] More than 4,000 phytochemicals have been cataloged and classified by protective function and physical and chemical characteristics, of which 150 phytochemicals have been studied in detail.[15] Plants synthesize hundreds of chemical compounds for various functions, including

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defense and protection against insects, fungi, diseases, and herbivorous mammals. However, it is essential to note that the number of compounds derived from plants for traditional medicine may vary as research and discoveries continue.

Indonesia is the fourth most populous country, with more than 300 distinct ethnic and linguistic groups. One of the ethnic groups in Indonesia inhabiting the island of Kalimantan is the Dayak tribe. The renowned Dayak ethnic community in Kalimantan is known for its expertise in using plants for traditional medicinal practices, which are transmitted orally through successive generations.[16] The utilization of medicinal plants is distinctive and differs across specific regions, encompassing the creation and application of potions and occasionally being associated with legends.

The accumulated biological richness in diverse ecosystems has played a significant role in fulfilling the daily necessities of native populations, such as food, attire, housing, medical care, and spiritual well-being. One example includes various tribes or indigenous groups residing in remote areas using plants for medicinal purposes. The traditions and understanding of rural communities regarding medicinal plant usage are inextricably linked to the long-standing local culture. Research in ethnobotany has shown that a wider variety of Dayak plants are employed to treat infectious and other illnesses within the traditional healthcare practices of the community. Examination of Dayak plant extracts in different locations demonstrated potent antibacterial properties, suggesting that these plants may be a valuable source of efficient medications to combat bacteria-causing infections. Consequently, this study aimed to assess the efficacy of specific Dayak medicinal plants traditionally utilized in treating infectious diseases.

Methods

The research adhered to regional protocols and regulations. Local governing bodies and individual owners of the medicinal plants at each location approved plant collection. Plant data is collected through direct observation activities at several related agencies and literature studies such as research results, survey reports, books, journals, and other sources. The medicinal plants were collected from East, Central, North, West and South Kalimantan. Surveys were conducted periodically in the isolated regions of Kalimantan. Data about the medicinal applications of various plants was gathered via discussions with residents and traditional healers. Each conversation employed a semi-structured questionnaire to acquire details such as local terminology, plant components used, and their therapeutic purposes. Samples from every plant were compressed, desiccated, and arranged on herbarium sheets for identification.

The test bacteria were *Staphylococcus aureus* (*S. aureus*), *Streptococcus pyogenes* (*S. pyogens*), *Escherichia coli* (*E. coli*), *Pseudomonas aeruginosa* (*P. aeruginosa*), *Enterobacter aerogenes* (*E. aerogenes*), from stockical specimens stock of Department of Microbiology Faculty of Medicine of Universitas Palangka Raya, and standard strains [(American Type Culture Collection (ATCC)], *S. aureus* (ATCC 25923), *S. pyogens* (ATCC 19615), *E. coli* (ATCC 25922), *P. aeruginosa* (9027) and *E. aerogenes* (ATCC 13048).

The examined microorganisms were cultivated in 5 ml of brain heart infusion broth at 37°C and then confirmed and preserved in Mueller-Hinton agar medium.[18] Pure bacterial cultures that were 24 hours old were employed to create a concentration of 108 cells per ml^{-1}, adhering to the 0.5 McFarland standards for each assessment.[19] The Mueller-Hinton agar was prepared per the manufacturer's guidelines, sterilized using an autoclave, and then distributed onto a sterile plate.

The bacterial broth culture was created with 108 cells per ml^{-1} density, conforming to the 0.5 McFarland standard. A sterile cotton swab was used to distribute the sample uniformly onto Mueller-Hinton agar. Subsequently, the prepared medium was left to dry at ambient temperature for 30 minutes.[20] On every plate, uniformly spaced wells were created using a sterilized, 6 mm diameter cork borer situated 2 mm from the plate's edge. Each agar well received 50 microliters of plant extract (500 mg/ml) in a sterile manner. Ciprofloxacin (5 µg/ml) and amoxicillin (4 µg/ml) served as positive controls, while methanol and distilled water functioned as negative controls. The agar plate was then allowed to rest on the bench for 40 minutes for pre-diffusion before being incubated at 37°C for 24–48 hours. A clear inhibition zone with a diameter of ≥7 mm around the wells indicated significant susceptibility of the organisms to the extract. The test was conducted

twice, and if conflicting results emerged, a third trial was performed to facilitate a straightforward decision.[21]

The minimum inhibitory concentration (MIC) was established for extracts displaying a growth inhibition zone of at least 7 mm diameter. Both agar well diffusion and microtiter plate (microtube dilution) methods were used for the test. In the agar well diffusion method, the extract solution (500 mg/ml) was progressively diluted in a series of ratios: 1:2, 1:4, 1:8, 1:16, 1:32, 1:64, 1:128, and 1:256, resulting in concentrations of 250 mg/ml, 125 mg/ml, 62.5 mg/ml, 31.25 mg/ml, 15.63 mg/ml, 7.81 mg/ml, 3.91 mg/ml, and 1.95 mg/ml, respectively. The extract was then aseptically applied as outlined in Table 3. After incubating for 24 hours at 37°C, the inhibition zone was measured, and the lowest concentration that inhibited growth was deemed the MIC value for the extract.[20]

In the microtiter plate (microtube dilution) method, a 500 mg/ml extract underwent serial dilution in nutrient broth, as outlined earlier. Then, 20 µl of a standardized test organism suspension was incorporated into each extract concentration. The microtiter plates were incubated for 24 hours at 37°C, and bacterial growth was assessed by comparing the optical density (OD) of each well pre and post-incubation. The OD for the microtube dilution approach was measured using a Thermo Scientific™ Multiskan™ FC microplate spectrophotometer at 405 nm. If the OD difference (post-incubation–pre-incubation) for the test sample (broth, extract, and organism) exceeded that of the control (broth and extract) at any given concentration, it indicated the presence of bacterial growth or turbidity. The minimum extract concentration that showed no turbidity was considered the MIC value for the extract.

The minimum bactericidal concentration (MBC) was established by subculturing samples with a value less than or equal to the MIC value. The most significant dilution with no bacterial colonies present (lower concentration) was considered the MBC.

Results

The medicinal plants were collected from East, Central, North, West and South Kalimantan. Surveys were conducted periodically in the isolated regions of Kalimantan. Data about the medicinal applications of various plants was gathered via discussions with residents and traditional healers. Each conversation employed a semi-structured questionnaire to acquire details such as local terminology, plant components used, and their therapeutic purposes. Samples from every plant were compressed, desiccated, and arranged on herbarium sheets for identification. Ten plant samples were used in this study and came from locations all over the island of Kalimantan (Table 1).

Crude extracts of *Eleutherine bulbosa*, *Dracaena cantleyi*, *Oscimum sanctum*, and *Uncaria gambir* Roxb. showed bacterial growth inhibition of 100%, 100%, 40%, and 25% against the test organisms, respectively. These plants inhibited the growth of bacteria from 7 mm to 16 mm in diameter (Table 2). Both water and methanol extracts from *Eleutherine bulbosa* bulbs and *Dracaena cantleyi* leaves produced zones of inhibition with variations between 7 mm and 16 mm. *Eleutherine bulbosa* bulb extracts

Table 1 Plant Samples Used in This Study

No.	Plant Species Name	Local Name	Collected Part	Origin of Area	Province
1	*Garptophyllum pictum*	*Berakak bediang*	Leaf	Ketapang	West Kalimantan
2	*Eleutherine bulbosa*	*Bawang dayak*	Bulbs	Paku	Central Kalimantan
3	*Ocimum sanctum*	*Bawing*	Leaf	Malinau	North Kalimantan
4	*Cassia alata*	*Serugan*	Leaf	Sanggau	West Kalimantan
5	*Callicarpa longifolia* Lam.	*Sangkareho*	Leaf	Berau	East Kalimantan
6	*Hibiscus rosa-sinensis*	*Kambang bahandang*	Leaf	Pulang Pisau	Central Kalimantan
7	*Dracaena cantleyi*	*Tewukak*	Leaf	Palangkaraya	Central Kalimantan
8	*Uncaria gambir* Roxb.	*Bajakah kalalawit*	Root	Katingan	Central Kalimantan
9	*Rhodomyrtus tomentosa*	*Karamunting*	Leaf	Tapin	South Kalimantan
10	*Gomphrena globose*	*Bunga kancing*	Root	Ketapang	West Kalimantan

Table 2 The Average Inhibition Zones for Bacterial Growth Used the Agar Well Diffusion Method When Treated with 500 mg/ml of Plant Extracts

Plant Species		Bacteria									
		S. aureus		*S. pyrogens*		*E. coli*		*P. aeruginosa*		*E. aerogenes*	
		Stk	Std	Stk	Std	Stk	Std	Stk	Std	Stk	Std
Garptophyllum pictum	W	-	-	-	-	-	-	-	-	-	-
	M	-	-	-	9	-	7	-	-	-	-
Eleutherine bulbosa	W	11	14	13	12	7	8	9	10	10	12
	M	10	14	10	14	7	9	11	12	8	13
Oscimum sanctum	W	-	-	-	12	-	-	7	-	-	-
	M	14	15	9	13	-		8	9	-	-
Cassia alata	W	-	-	-	-	-	-	-	-	-	-
	M	-	-	-	7	8	12	-	-	-	-
Callicarpa longifolia Lam.	W	-	-	-	-	-	8	-	-	-	-
	M	-	-	-	-	-	7	-	-	-	-
Hibiscus rosa-sinensis	W	-	-	-	8	-	-	-	-	-	-
	M	-	13	-	-	-	-	-	-	-	-
Dracaena cantleyi	W	10	11	10	14	8	9	8	14	11	15
	M	9	14	8	10	9	10	12	8	12	16
Uncaria gambir Roxb.	W	-	-	-	10	-	-	-	-	-	-
	M	8	-	-	9	-	-	7	9	-	-
Rhodomyrtus tomentosa	W	-	-	-	-	-	-	-	7	-	-
	M	-	8	-	-	-	-	-	8	-	-
Gomphrena globose	W	-	7	-	-	-	-	-	-	-	-
	M	-	9	-	-	-	-	-	-	-	-
Amoxicillin		12	15	21	28	23	25	15	-	19	22
Ciprofloxacin		15	20	20	28	33	30	25	28	33	31

Note: measured in millimeters, Stk: stock isolate, Std: standard (ATCC) strains, W: water extract, M: methanol extract

with the highest inhibition zone of 14% were on the test bacteria *S. aureus* (ATCC) (both water and methanol extracts) and *S. pyrogens* (ATCC) water extract. *Dracaena cantleyi* extracts with the highest inhibition zone of 16% were seen in *E. aerogenes* (ATCC) methanol extract. The water extract of *Eleutherine bullbosa* bulb with the higher inhibition zone compared with methanol extract against stock isolates are *S. aureus* (11 mm), *S. pyogens* (13 mm), and *E. aerogenes* (10 mm). Isolates with the lowest inhibition zone (7 mm) were seen in the test bacteria, e. coli, in both water and methanol extracts.

The water extract of *Eleutherine bulbosa* bulb with the higher inhibition zone compared with the methanol extract against stock and standard isolates are *S. aureus* stock isolate (10 mm), *S. pyrogens* stock, and ATCC isolate (10 mm, 12 mm), and *P. aeruginosa* ATCC isolates (14 mm).

Methanolic extract of *Ocimum sanctum* leaf was the second to inhibit the growth of 6 bacterial strains with inhibition zones ranging from 8 mm (against stock isolated *P. aeruginosa*) to 15 mm [against standard *S. aureus* (ATCC)]. Its water extract inhibited *S. pyogens* (ATCC) growth within 12 mm diameter and *P. aeruginosa* stock isolate (7 mm). *Uncaria gambir* Roxb. leaf extract was the third to inhibit the growth of 5 bacterial strains, with the highest inhibition zone at 10 mm on water extract (against standard ATCC-isolated *P. aeruginosa*).

S. pyogens (ATCC) was the most inhibited bacteria by most of the plant extracts. The water extract of *Eleutherine bulbosa* and methanolic extracts of *Dracaena cantleyi* highly inhibited it. The standard strains of *S. aureus* experienced the second-highest level of inhibition by most of the plant extracts. The methanol extract of *Oscimum sanctum* demonstrated comparable inhibition zones to amoxicillin, the positive control when tested against standard *S. aureus* isolates. *E. aerogenes* is the most resistant bacteria to plant extracts, with only *Eleutherine bulbosa* and *Dracaena cantleyi* extracts producing an

Table 3 MIC Values of Selected Plant Extracts Against the Tested Organisms Using Agar Well Diffusion and Microtitration Methods

Plant Species	Methods		Bacteria									
			S. aureus		*S. pyrogens*		*E. coli*		*P. aeruginosa*		*E. aerogenes*	
			Stk	Std	Stk	Std	Stk	Std	Stk	Std	Stk	Std
E. bulbosa	Agar well diffusion	W	250.00	125.00	250.00	125.00	62.50	250.00	250.00	250.00	125.00	250.00
		M	125.00	62.50	250.00	250.00	250.00	250.00	125.00	125.00	500.00	500.00
	Microtitration	W	31.25	125.00	62.50	125.00	62.50	62.50	15.63	15.63	31.25	7.81
		M	7.81	15.63	62.50	7.81	15.63	15.63	15.63	7.81	15.63	15.63
D. cantleyi	Agar well diffusion	W	125.00	62.50	250.00	62.50	250.00	250.00	250.00	125.00	250.00	62.50
		M	125.00	125.00	62.50	250.00	250.00	125.00	125.00	250.00	125.00	250.00
	Microtitration	W	62.50	62.50	31.25	125.00	62.50	62.50	15.63	62.50	31.25	15.63
		M	3.91	15.63	15.63	7.81	15.63	15.63	15.63	15.63	15.63	15.63
O. sanctum	Agar well diffusion	M	125.00	125.00	250.00	250.00	-	-	250.00	250.00	-	-
	Microtitration	M	7.81	15.63	62.50	1.95	-	-	15.63	15.63	-	-
U. gambir Roxb.	Agar well diffusion	M	125.00	-	-	250.00	-	-	125.00	250.00	-	-
	Microtitration	M	31.25	-	-	62.50	-	-	15.63	7.81	-	-

Note: measured in mg/ml, Stk: stock isolate, Std: standard (ATCC) strains, W: water extract, M: methanol extract

inhibition zone.

The MIC value of plant extracts against the tested bacteria ranged from 1.95 mg/ml (methanolic extract of *Oscimum sanctum* on standard isolate of *S. pyogens*) to 500.00 mg/ml (methanolic extract of *Eleutherine bulbosa* on stock and a standard isolate of *P. vulgaris*). The most frequent MIC value of the extracts was 250.00 mg/ml, followed by 15.63 mg/ml, 125.00 mg/ml, 62.50 mg/ml, 7.81 mg/ml, 31.25 mg/ml, 3.91 and 1.95 mg/ml (Table 3).

The MIC values of *Eleutherine bulbosa* on the microtitration method ranged from 7.81 mg/ml to 125.00 mg/ml. Its water extract had higher MIC values than its methanolic extracts except for stock isolated of *S. Pyogens*, *P. aeruginosa* (same value), and standard strains of *E. aerogenes* (smaller value). The MIC values of *Dracaena cantleyi* on the microtitration method ranged from 3.91 mg/ml to 125.00 mg/ml. Its water extract had higher MIC values than its methanolic extracts except for stock isolated of *P. aeruginosa* and standard strains of *E. aerogenes* (similar value). The MIC values of *Ocimum sanctum* (methanol extract) on the microtitration method ranged from 1.95 mg/ml to 62.50 mg/ml. The lowest MIC value was 1.95 in the ATCC S. pyogens standard isolate. There are three isolates with a similar MIC value of 15.63, on ATCC S. aureus standard isolates and both isolate stock and standard *P. aeruginosa*. The MIC values of *Uncaria gambir* Roxb. (methanol extract) on the microtitration method ranged from 7.81 mg/ml to 62.50 mg/ml. The lowest MIC value was 7.81 in ATCC *P. aeruginosa* standard isolates.

Discussion

Investigations in ethnobotany have proven valuable in discovering and advancing traditional medicinal plants for use in contemporary pharmaceuticals. The impact of this field is also evident in the present research. Methanolic and aqueous extracts of *Eleutherine bulbosa* bulbs and *Dracaena cantleyi* leaves showed potent antibacterial activity against ten bacterial strains.

Prior studies have indicated that initial phytochemical analysis of *Eleutherine bulbosa* (*bawang dayak*) ethanol extracts revealed the presence of metabolites such as flavonoids, saponins, alkaloids, and tannins.[22] Flavonoids demonstrate strong antibacterial properties against a range of bacteria. They exhibit antibacterial action through three primary processes: hindering energy metabolism, obstructing nucleic acid synthesis, and causing harm to the cytoplasmic membrane.[23,24] Additional antimicrobial properties of *bawang dayak* are under investigation, including eleutherol A, a flavonoid derived from *bawang dayak*, recognized for its ability to hinder bacterial cell wall formation.[25] Alkaloids typically exhibit antibacterial properties by inhibiting efflux pump activity. They are more commonly bactericidal rather than bacteriostatic.[26,27] One way saponins exhibit antibacterial properties is by reducing

the effectiveness of glucose usage in bacteria, which in turn influences their reproduction or expansion, ultimately leading to an antibacterial impact. Additionally, numerous research findings indicate that tannins possess antibacterial characteristics, affecting both Gram-negative and Gram-positive bacteria.[28]

Tewukak (*Dracaena cantleyi*) is one of the plants used by the Dayak tribe, the leaves are often used when the body feels sore or has muscle pain (cramps) by 'pulling it with water' and then sticking it where it hurts. *Tewukak* leaves have also been proven empirically to be used by orangutans (*Pongo pygmaeus*) by chewing them and then sticking them to the body/or parts of the body that are thought to be experiencing pain. The results of research on the *Dracaena cantleyi* plant used by orangutans showed an inhibitory effect of *tewukak* leaf extract on TNFα which induces inflammatory cytokines (E-selectin, ICAM1, VCAM-1, and IL-6) resulting in decreased expression of E-selectin, ICAM1, VCAM-1, and IL-6. *Tewukak* leaf extract is proven to contain saponins E-selectin, ICAM1, VCAM-1, and IL-6. *Tewukak* leaf extract is proven to contain saponins.[29] Saponins are compounds that have been studied to have antibacterial activity against *E. coli*,[30] and methicillin-resistant *Staphylococcus aureus* (MRSA).[31]

Most of the MBC and MIC values for all plant extracts were nearly identical, or the MBC was one dilution factor lower than the MIC value of the extract. This resemblance or proximity of the MBC and MIC values in plant extracts might result from the microtitration method's sensitivity in identifying the minimal turbidity level, which served as a growth indicator for the test organisms instead of a visual examination.

Methanolic plant extracts exhibit more potent antibacterial activity than water extracts, suggesting that the compounds responsible for inhibiting bacterial growth may dissolve more effectively in methanol than in water.[32]

Methanolic extract of *Oscimum sanctum* on a microtitration method showed antibacterial activity at the lowest concentration compared to all other plant extracts. The lowest MIC value was 1.95 in the ATCC *S. pyogens* standard isolate. Tulsi, an aromatic shrub belonging to the Lamiaceae family and the Ocimeae tribe, is a well-known plant in the basil family. In Ayurveda, it is referred to as "the Incomparable One," "Mother Medicine of Nature," and "the Queen of Herbs." It is highly regarded as a unique "elixir of life" for its unparalleled medicinal and spiritual attributes.[33] Numerous scientific studies, encompassing in vitro, animal, and human experiments, have investigated the medicinal properties of *Oscimum sanctum*. Research has revealed that this plant possesses a distinct array of therapeutic actions, including antimicrobial (antibacterial, antiviral, antifungal, antiprotozoal, antimalarial, and anthelmintic). *Oscimum sanctum* chemical makeup is highly intricate, consisting of numerous nutrients and other biologically active substances, with the ratios varying significantly among strains and even among plants within the same field. Additionally, the amounts of several constituents are influenced by diverse growing, harvesting, processing, and storage conditions, still being studied. Eugenol (l-hydroxy-2-methoxy-4-allylbenzene), a key component found in *Oscimum sanctum*, is likely the main contributor to plants therapeutic properties. Other significant constituents are ursolic acid and carvacrol, which are responsible for the antimicrobial effects of *Oscimum sanctum*.[34]

The methanol extract of *Uncaria gambir* Roxb. showed antibacterial activity against stock and standard *P. aeruginosa* isolates, *S. pyogens* standard isolates, and *S. aureus* stock isolates. Research states that *Uncaria gambir* can fight infections caused by *S. aureus* and *P. aeruginosa*.[35] With the increasing medicinal applications of Uncaria species, numerous investigations have been conducted on the phytochemistry and pharmacology of *Uncaria*. Over 200 chemical components, such as indole alkaloids, triterpenes, flavonoids, and phenylpropanoids, have been extracted from the *Uncaria* genus.[36] *Uncaria* is commonly used in traditional medicine to treat wounds and ulcers, alleviate fevers and headaches, treat gastrointestinal issues, and combat bacterial and fungal infections. Over the last ten years, researchers have studied the metabolites of bioactive indole alkaloids found in *Uncaria* species. It is believed that these alkaloids can be metabolized into their 10- and 11- 11-hydroxyl derivatives, including compounds like rhynchophylline, isorhynchophylline, corynoxeine, and isocorynoxeine.[37]

Most plant extracts demonstrated the most significant inhibitory effect on the Gram-positive *S. pyogens*. At the same time, Gram-negative *E. aerogenes* strains showed the most resistance, only inhibited by the water-based and

methanolic extracts of *Eleutherine bulbous* bulb and *Dracaena cantleyi* leaf. *E. aerogenes*, which is called *Klebsiella aerogenes*, is a rod-shaped bacterium that is Gram-negative, oxidase-negative, catalase-positive, citrate-positive, and indole-negative. This nosocomial and pathogenic bacterium leads to various opportunistic infections. While many strains of this bacteria are initially sensitive to most antibiotics in its class, they can develop resistance quickly due to inducible resistance mechanisms, such as lactamase production. It necessitates a change in antibiotic treatment to prevent the exacerbation of sepsis.[38]

Conclusions

Most plant extracts demonstrated the most significant inhibitory effect on the Gram-positive *S. pyogens*. At the same time, Gram-negative *E. aerogenes* strains showed the most resistance, only inhibited by the water-based and methanolic extracts of *Eleutherine bulbosa* bulb and *Dracaena cantleyi* leaf. Overall, most methanolic extracts and a portion of aqueous extracts from plants exhibited antibacterial properties, suggesting their potential as antibacterial agents against pathogenic infections. To effectively utilize these plants for drug development against diseases and other harmful bacteria, additional research should be conducted using various extraction solvents, toxicity, and phytochemical evaluations.

Conflict of Interest

The authors state that there is no conflict of interest in this article.

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