Antibacterial Evaluation of the Rutaceae and Rosaceae Plant Collection from Cibodas Botanical Garden, Indonesia

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Abstract: Plants produce a variety of bioactive compounds with numerous biological activities, including antibacterial properties. The potential of plant extracts possessing antibacterial properties can be further developed as raw materials for drugs and cosmetics. In this study, antibacterial screening was conducted on three species of plants (*Rubus fraxinifolius*, *R. rosifolius*, and *Prunus cerasoides*) from the Rosaceae family and two species of plants (*Acronychia pedunculata* and *Zanthoxylum acanthopodium*) from the Rutaceae family, sourced from the Cibodas Botanic Gardens collection in West Java. The antibacterial assay was carried out utilizing the disc diffusion method. The bacterial isolates tested included *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *S. epidermidis*. The findings demonstrated that the leaf ethanolic extract of *A. pedunculata* (Rutaceae) exhibited the highest antibacterial activity compared to other species, followed by *R. rosifolius* (Rosaceae). Conversely, *R. fraxinifolius* leaf shoot extract demonstrated the lowest antibacterial activity based on tests against the three bacteria. Overall, all extracts produced the largest inhibition zone diameter against *S. epidermidis*. Further research is necessary to develop plant bioprospecting with antibacterial properties for pharmaceutical raw materials.

1 INTRODUCTION

Herbal medicines have been used for many generations to treat various medical conditions, including infectious diseases. Several natural chemical compounds have been clinically proven to function as medicinal raw materials, and many studies have been conducted on their use as antimicrobial agents (Mahady et al., 2008). Antibiotics from natural ingredients, although historically important, have not received the same level of investment in research and development, standardization, and marketing as synthetic antibiotics. Synthetic antibacterial agents have also been widely used in cosmetics to prevent microbial contamination and ensure product safety (Halla et al., 2018). Conversely, there has been a major trend toward the application of natural resources for therapeutic purposes. This shift is driven by consumer concerns about the safety of synthetic ingredients and preference for natural alternatives (Varvaresou et al., 2009). Regulatory aspects and consumer safety remain paramount, as evidenced by the presence of hazardous ingredients in cosmetics in some markets and strict laws regulating cosmetic ingredients (Manent and Abellán, 2007).

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The Rosaceae and Rutaceae plant families exhibit significant antibacterial activity as demonstrated in various studies. Extracts from Rosaceae fruits like hawthorn and dog rose show potent antibacterial properties against uropathogenic *Escherichia coli* strains, reducing bacterial adhesion and biofilm formation (Andrzej et al., 2020). Additionally, the essential oil from rose, a member of the Rosaceae family, exhibits antimicrobial activity against various microorganisms, with notable effectiveness against *Staphylococcus aureus*, *E. coli*, and *Candida albicans*, showcasing its potential as a natural antibacterial agent (Li et al., 2009). In contrast, the ethanolic extracts from Rutaceae leaves such as *Acronychia pedunculata* and *Glycosmis pentaphylla*, display antibacterial effects against a range of bacterial strains, including *E. coli*, *S. aureus*, and *P. aeruginosa*, indicating their potential medicinal applications (Hong et al., 2020).

Discovering potent antibacterial substances from sources of nature, such as the Rutaceae and Rosaceae plant families, holds immense promise for various applications in healthcare and pharmaceutical industries. These plant-derived compounds may serve as valuable alternatives or complementary treatments to conventional antibiotics, potentially addressing the growing challenge of antimicrobial resistance (Barbieri et al., 2017).

A key area of interest is the development of novel antimicrobial therapies for treating various bacterial infections, especially skin infections. *Pseudomonas aeruginosa* InaCC B52 and *Staphylococcus epidermidis* FNCC 0048 were used as gram-negative bacteria and *Staphylococcus aureus* ATCC 25923 was used as gram-positive bacteria. These three bacterias were common bacteria causing chronic skin wound infections. The identification of potent antibacterial compounds from Rutaceae and Rosaceae plants could lead to the creation of new drug candidates or the enhancement of existing antimicrobial formulations (Chintaluri et al., 2015; Zazharsky et al., 2020; Garcia-Oliviera et al., 2020). These natural-based solutions may offer unique mechanisms of action, reduced side effects, and improved efficacy compared to synthetic antibiotics, making them attractive options for clinicians and patients (Fadilah et al., 2020; Mota et al., 2020).

Furthermore, the exploration of plant-derived antibacterial agents from Rutaceae and Rosaceae could have broader applications in the fields of food preservation, personal care, and environmental remediation. The antimicrobial properties of these plant compounds could be harnessed to develop natural preservatives for food and cosmetic products, thereby reducing their reliance on synthetic antimicrobials. Additionally, plant-based antimicrobials could be explored for their potential in water treatment and soil remediation, contributing to more sustainable and eco-friendly solutions to environmental challenges (van Vuuren & Viljoen, 2011; Vaou et al., 2021).

This study aimed to identify and analyze three species of Rosaceae and two species of Rutaceae with antibacterial activity from a collection of Cibodas Botanic Gardens, West Java, Indonesia. Thus, it can provide information on new antibacterial sources, which can aid in the development of more effective and safer medicines for treating bacterial infections based on local natural resources. The discovery of effective antibacterial compounds in these plant sources could lead to the creation of new antimicrobial medications, food preservatives, and environmental remediation strategies, ultimately contributing to the global efforts to combat the threat of antimicrobial resistance.

2 METHODS

2.1 Sample Preparation

Samples from 5 plant species were acquired from Cibodas Botanic Garden plant collections in simplisia forms. All samples were the leaves of the plants unless otherwise stated (fruits). They are *Rubus fraxinifolius*, *R. rosifolius,* and *Prunus cerasoides* from the Rosaceae family and *Acronychia pedunculata* and *Zanthoxylum acanthopodium* from the Rutaceae family. Five grams of each sample were macerated in 70% ethanol solution at ratio of 1:5 (v/v). The sample was shaken using an incubator shaker (Taitec BR-43FL) at 25°C, 170 rpm for 24 h. After that, the sample was centrifuged (Tomy KITMAN-T24) at 4°C, 5000 ×g, for 10 min to separate the supernatant from the unsoluble substances. Subsequently, the sample was re-extracted twice with the same procedure and then the filtrate was collected. Afterward, the extract was evaporated by a rotary evaporator (IKA RV 10 Digital) to remove the solvent, followed by lyophilization (Alpha 1-2 LD Plus Christ). The lyophilized ethanol extract was dissolved in a 10% dimethyl sulfoxide - phosphate-buffered saline (DMSO-PBS) solution for antibacterial evaluation.

2.2 Bacterial Isolate

The bacterial cultures used in this research were *Pseudomonas aeruginosa* InaCC B52 and *Staphylococcus epidermidis* FNCC 0048 as gram-negative bacteria and *Staphylococcus aureus* ATCC 25923 as gram-positive bacteria. Mueller-Hinton Agar (MHA) and Mueller-Hinton Broth (MHB) (HiMedia, Mumbai, India) were used as culture media and prepared according to the manufacturer's instructions.

2.3 Antibacterial Assay

The clear zone method was employed for a semi-quantitative antibacterial activity test. The suspension of each bacterial isolate of *P. aeruginosa*, *S. aureus*, or *S. epidermidis* was poured and spread on Mueller-Hinton Agar (MHA) in petri dishes. A 0.5 cm diameter Whatman filter paper (paper disk) was then positioned on the agar plate, followed by adding 10 µL of sample (lyophilized ethanol extract dissolved in 10% DMSO-PBS) onto the paper disk. Each sample was prepared at a concentration of 1000 µg/mL. Additionally, the positive and negative controls used were 12.5 µg/mL of commercial chloramphenicol (Novapharin, Gresik, Indonesia) and 10% DMSO-PBS, respectively. After incubating bacterial cultures at 37°C for 24 hours, the zone of inhibition diameter was measured using a caliper. Triplication was performed for each sample tested. The inhibition zones formed in each test were observed and measured as the appearance of antibacterial activity.

2.4 Data Analysis

The statistical significance of the difference was tested by the one-way ANOVA method completed by the Tukey-Kramer test. Values with $*p < 0.05$ or $**p < 0.01$ were considered statistically significant against negative control (10% DMSO-PBS). In addition, plant descriptions were explained by works of literature. Plant origin was based on the Cibodas Botanic Gardens data collection database, plant distribution by POWO database, and antibacterial compounds were collected from related journal articles.

3 RESULTS AND DISCUSSION

3.1 Plant Characteristics of Rutaceae and Rosaceae

The Rutaceae and Rosaceae families are well-known for their diverse and often economically important plant species. The Rutaceae family, commonly known as the rue or citrus family, encompasses various plants, including familiar citrus fruits, such as oranges, lemons, and limes. These plants are renowned for their aromatic compounds and have long been used in traditional medicine because of their medicinal properties. On the other hand, often called the "rose family", the Rosaceae family is a broad group of plants that includes a range of fruits, including strawberries, pears, and apples, as well as ornamental species like roses. Like the Rutaceae family, Rosaceae plants have a rich history of traditional medicinal use, with many species exhibiting a range of bioactivities, including antimicrobial properties. Plant descriptions with antibacterial properties from Rutaceae and Rosaceae species from the Cibodas Botanic Gardens collection were described in Table 1.

Approximately 1800 species and 156 genera belong to the Rutaceae family, which is widely distributed throughout tropical and subtropical climates, especially Southeast Asia. Many species of Rutaceae, such as *A. pedunculata* and *Z. acanthopodium*, have many biologically active compounds. Numerous beneficial goods, including medicines, food, spices, and essential oils, are made from those natural resources (Van et al., 2020).

Often referred to as claw-flowered Laural or Lake, Kayu Semidra, or Jejerukan (in Indonesia), *Acronychia pedunculata* L. (Rutaceae) is a tiny tree with glabrous branches and pale, smooth bark. This plant's leaves are oval, 7.5-12.5 cm long, and can be placed simply, oppositely, or alternately. The flowers are arranged loosely in pyramidal or divaricate patterns on long, straight axillary peduncles and are small, regular, polygamous, and pale yellowish green in color. Usually, flowering takes place from February to April. The spherical, indehiscent fruits measure between 1.2 and 1.8 centimeters in length. It's interesting to note that fruits have four chambers, with one seed in each chamber (Jayaweera, 1982). One species of the Rutaceae family that is widespread in Indonesia is *A. pedunculata* (Figure 1a). Traditional medicine has utilized stem bark to treat rheumatism, diarrhea, fever, and asthma (Tanjung et al., 2018).

Table 1: Plant descriptions with antibacterial properties.

Scientific names	Family	Origin*	Distribution**	Antibacterial activity	Compounds	References
Rubus fraxinifolius Poir.	Rosaceae	West Java	Lesser Sunda Is., Taiwan, Mauritius, Rodrigues, Réunion	Leaf extract from *R. fraxinifolius* had antibacterial potency against *B. subtilis, S. aureus,* and *E. coli*	Flavonoids, quercetin, naringenin	Dewi et al. (2019)
Rubus rosifolius Sm.	Rosaceae	West Java	Central & S. China to Tropical Asia	The fruit crude extract of *R. rosifolius* had antimicrobial activity against a wide range of microorganisms, including *S. aureus* and *E. coli*	The phenolic compounds, alkaloids, anthraquinones, and alcohols	Alvares et al. (2013)
Prunus cerasoides Buch.-Ham. ex D.Don	Rosaceae	Himalaya	NE. Pakistan to Indo-China Assam, Myanmar, East Himalaya, Pakistan, Laos, Nepal, Vietnam, Sri Lanka, West Himalaya, Thailand	Ethyl acetate stem bark extract *P. cerasoides* inhibits the growth of *Staphylococcus aureus* and *Klebsiella pneumoniae*	Phytoconstituent, flavonoids, diterpenes, and cardiac glycosides	Mahajan & Arora (2019)
Acronychia pedunculata (L.) Miq.	Rutaceae	Java	Tropical & Subtropical Asia	Methanol extract from a root, seed, flower, leaves, and stem bark extract gave the maximum inhibition on test pathogenic bacteria (*S. typhi, E. coli, B. subtilis*, and *S. aureus*). It has been demonstrated that the essential oil extracted from the plant's aerial parts has a wide range of antibacterial activity against different microorganisms., particularly *Staphylococcus epidermidis* and *Salmonella enterica*	Sterols, flavonoids, terpenoids, resins, saponins, carbohydrates, tannins, and glycosides	Lesueur et al. (2008), Gireesha & Raju (2016), Ratnasooriya et al. (2016), Muthukuda & Jayakody (2021)
Zanthoxylum acanthopodium DC.	Rutaceae	North Sumatera	Himalaya to S. China and W. Malesia	The antibacterial activity of the Andaliman fruit's ethyl acetate extract was stronger response *S. aureus* and *S. typhimurium* than *E. Coli*. 50 - 75% extracts fruits also against *Salmonella typhi*, although did not against all aquaculture pathogens	Alkaloids, steroids, tannins and saponins	Muzafri et al. (2018), Sihombing et al. (2019), Sibero et al. (2021), Adrian et al. (2023)

In North Sumatera Utara, Indonesia, andaliman (*Zanthoxylum acanthopodium* DC.) is a common wild plant. Many members of the Batak ethnic group use Andaliman for food processing, particularly fish and meat. It is known as "Batak pepper" for its hot flavor and peculiar scent. Andaliman is used by the Batak population as a traditional medicine in addition to being used in food preparation (Adrian et al., 2023).

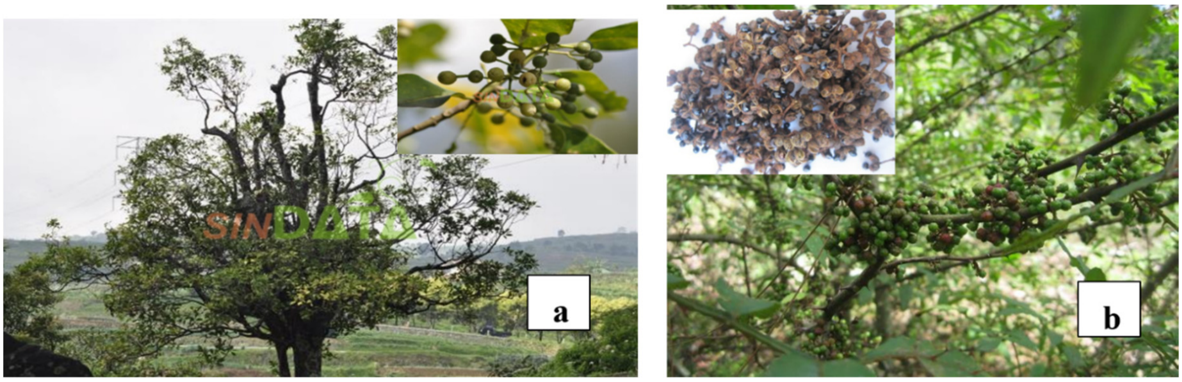

Figure 1: a) *A. pedunculata*, b) *Z. acanthopodium.*

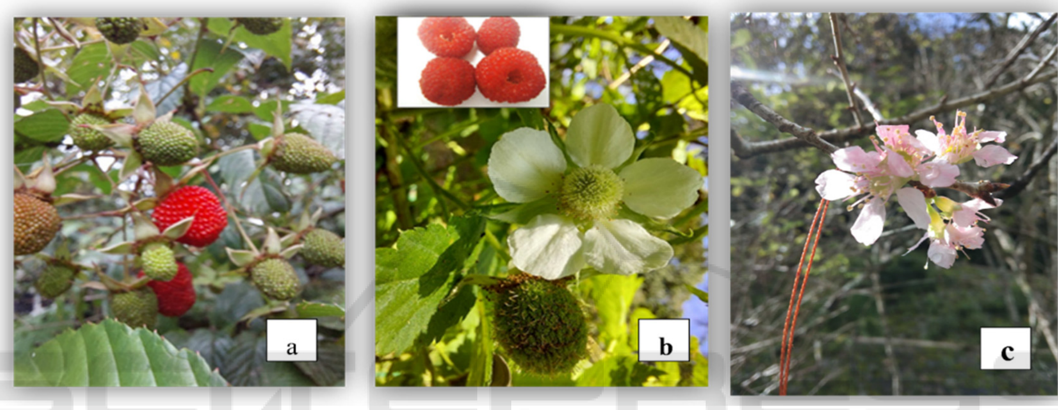

Figure 2: a) *R. fraxinifolius*, b) *R. rosifolius*, and c) *P. cerasoides.*

With low, prickly branches, trunks, and twigs, the Andaliman is a shrub or small tree that can grow up to 6 meters in height. Its odd-pinnate, dispersed, stemmed compound leaves, which are 5–20 cm long and 3–15 cm broad, contain oil glands. Three to eleven thorny, oblong-shaped leaflets with tapering ends and coarsely serrated edges, reaching 1 to 7 cm in length and 0.5 to 2.0 cm in width, are affixed to the winged rachis. Some leaves have a green top surface and a reddish-green underside, while young or light leaves have a sparkling green top surface and a green bottom. The petals are pale yellow, androgynous, and measure 5-7 cm long (1-2 cm). The flower has three to four pistils, an apocarpous ovule, reddish anthers, and around five to six stamens at the base. Andaliman produces actual box fruits or capsules that are round, 2-3 mm in diameter, shiny black, contain one seed, have a hard skin, and are brilliant green when young or dark red when old. After ten days at room temperature, the black seeds will sprout from the old fruit (Rahmawaty et al., 2019; Sonangda et al., 2019). The Andaliman plant is presented in Figure 1b.

Genus *Rubus* belongs to the Rosaceae family, Rosoideae subfamily. With more than 1,350 species, it is a sizable and varied genus. In high-altitude woods, such as those in the Himalayas and the Nilgiris, rubus is extensively distributed (Schulz and Chim, 2019; Sharma et al., 2021). The ragimot berry (*Rubus spp*.) is an erect shrub that grows to a height of 2-3 meters and has stems with up to 6 mm prickles. Its pinnate leaves have a terminal leaflet and four pairs of opposing leaflets. These elliptic leaflets are 2-9 × 1.4 cm, with 7-10(-15) vein pairs, scant hair coating, and serrated edges (Lamb, 2019). Grayish yellow-green flowers with bulging shapes grow on inflorescence panicles that measure 6-20 cm long (Normasiwi et al., 2021).

R. rosifolius J. Sm. and *Rubus fraxinifolius* Poir. are Indonesian Raspberry species native to Indonesia (Figure 2a dan 2b). In West Java (Sundanese), the fruit of *R. rosifolius* and *R. fraxinifolius* is known as "Beberetean" or "Arben". Both fruits are edible, have a similar appearance (small, red), and possess a sweet instead of sour taste (Desmiaty et al., 2018).

Prunus is a member of the Rosaceae, specifically the Amygdalaceae subfamily. It consists of around 430 deciduous and evergreen shrub and tree species that are mostly found in the northern hemisphere and temperate zones (Agrawal et al., 2024). *Prunus* has simple, alternate, generally lanceolate, unlobed leaves with nectarines on the stem. These flowers have five petals, five sepals, and many stamens. They are often white to pink but can also be crimson. Flowers bloom singly, in umbels of two to six, or even more, on racemes. Fruits are fleshy drupes with a single rather big, hard-coated seed, popularly called the stone fruit (Joseph et al., 2018). In India, *Prunus* grows widely, and the majority of them have significant therapeutic and commercial value, one of which is *P. cerasoides* or Himalayan Cherry Blossom (Agrawal et al., 2024), see Figure 2.

3.1 Antibacterial Activity

The diameter of the inhibition zones against different bacteria was used to measure the antibacterial activity of ethanolic extracts from the leaves and fruits of Rosaceae and Rutaceae species (see Figure 3, 4, and 5). The ethanol extracts of the leaves of *R. rosifolius, A. pedunculata*, and *R. fraxinifolius* (young leaves) were considered as the top three that significantly inhibited the growth of all three bacterial strains, i.e: *P. aeruginosa*, *S. aureus*, and *S. epidermidis*. However, results revealed that ethanol extract of *A. pedunculata* leaves (from the Rutaceae family) exhibited the highest antibacterial activity compared to other species, followed by *R. rosifolius* (Rosaceae). Conversely, *R. fraxinifolius* (p) leaf bud extract demonstrated the lowest antibacterial activity based on tests against the three bacteria. Overall, all extracts produced the largest inhibition zone diameter against *S. epidermidis*.

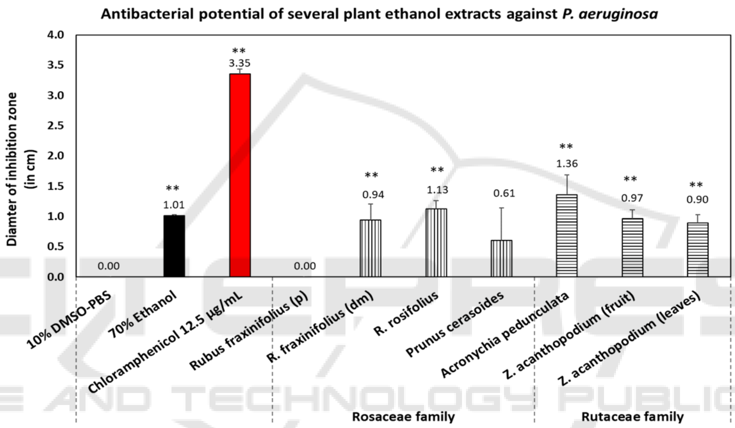

Figure 3: Antibacterial activity of plant collections from the families of Rutaceae and Rosaceae against *Pseudomonas aeruginosa*. Values with $*p < 0.05$ or $**p < 0.01$ were considered statistically significant against negative control (10% DMSO-PBS). Data were represented as mean ± SD. All samples were the leaves of the plants unless otherwise stated (fruits). Notes: p: leaf bud, dm: young leaf.

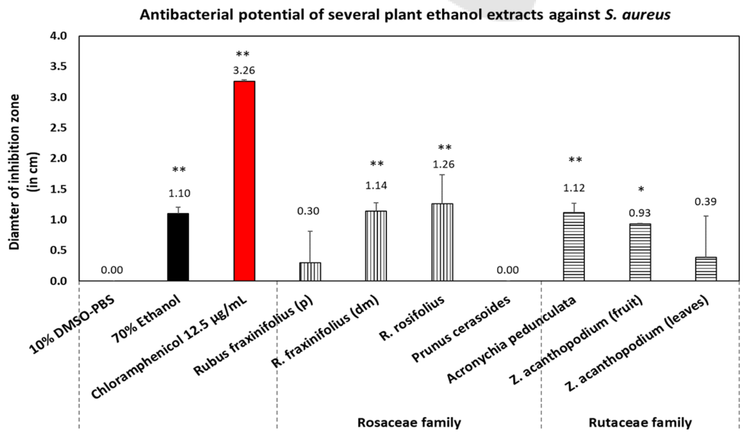

Figure 4: Antibacterial activity of plant collections from the families of Rutaceae and Rosaceae against *Staphylococcus aureus*. Values with $*p < 0.05$ or $**p < 0.01$ were considered statistically significant against negative control (10% DMSO-PBS). Data were represented as mean ± SD. All samples were the leaves of the plants unless otherwise stated (fruits). Notes: p: leaf bud, dm: young leaf.

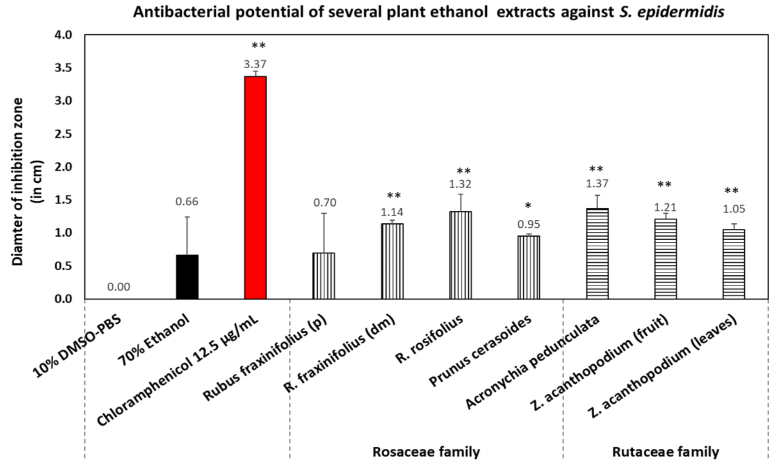

Figure 5: Antibacterial activity of plant collections from the families of Rutaceae and Rosaceae against *Staphylococcus epidermidis* FNCC 0048. Values with **p* < 0.05 or ***p* < 0.01 were considered statistically significant against negative control (10% DMSO-PBS). Data were represented as mean ± SD. All samples were the leaves of the plants unless otherwise stated (fruits). Notes: p: leaf bud, dm: young leaf.

The once-considered harmless bacterium *S. epidermidis*, which thrives on human skin, has developed into a significant opportunistic pathogen. Numerous infections have been linked to these bacteria, and treatment has been impeded by its resistance to several drugs. New strains of multidrug-resistant bacteria may arise as a result of *S. epidermidis* acting as a reservoir for antibiotic resistance genes that can be passed from one *Staphylococci* species to another, including *S. aureus* (Ahmadunissah et al., 2022).

In this study, *A. pedunculata* had the highest antibacterial activity against the three test bacteria. This is in line with the research of Van et al. (2020) that all six bacterial strains—*Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella enteritidis*, and *Salmonella typhimurium*—were able to withstand the ethanolic extracts made from A. pedunculata leaves.

Further, the extract of *Acronychia pedunculata* contained polyphenols, triterpene alcohols, and acetophenones, which were effective in inhibiting the activity of *Staphylococcus epidermidis* and *Salmonella enterica* (Kumar et al., 1989; Su et al., 2003).

In addition, as shown in Figure 3, 4, and 5, the ethanol extract of the fruit of *Z. acanthopodium* slightly exhibited a wider inhibition zone compared to that of its leaf ethanol extract. Majumder et al. (2014) reported that traditionally the fruits of Andaliman have been used as a spice, to treat fish poisoning, to alleviate toothaches, and to treat stomach colic, etc. The essential oil analysis of Andaliman fruit identified 21 components, with major components i.e. δ-3-carene (13.525%), Limonine (16.903%), Eucalyptol (36.563%), and Methyl-cinnamate (9.366%). With a broader zone of inhibition, andaliman exhibits encouraging antibacterial action, particularly against *S. aureus*.

Furthermore, the ethanol extract of the young leaf of *R. fraxinifolius* showed higher antibacterial activity than that of its leaf bud. Based on Shamsudin et al. (2019), In addition to other phytochemicals including alkaloids, phytosterols, tannins, and terpenoids, *R. fraxinifolius* has been shown to possess flavonoids and phenolic compounds. Free radical-related illnesses have been treated and prevented with these chemical substances. These substances exhibit promise for use as natural antioxidants for human well-being.

4 CONCLUSIONS

Natural materials have become increasingly popular as traditional remedies in Indonesia. Traditional treatments have been reported to have fewer negative effects than chemical-based therapies. Many plant species are widely used by the community as traditional medicinal ingredients in daily life and have antibacterial properties. Hence, according to our results, plants from the Rutaceae and Rosaceae families, especially the ethanol extracts of the leaves of *R. rosifolius* (Indonesian Raspberry) and *A. pedunculata* (Kayu Semidra) have the potential to be further utilized as an active ingredient for antibacterial products, especially against skin bacteria

(*Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *S. epidermidis*) which are safer and more comfortable. However, a more specific antibacterial mechanism needs further investigation.

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