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The Potential of Various Matoa Plant (*Pometia pinnata*) Extracts as Antibacterial Agents: *Systematic Literature Review*

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Abstract

Background: *Bacteria in nature can have various effects on human life, including the development of diseases. Consequently, it is necessary to regulate or inhibit the growth of harmful bacteria. One method of doing so is through the use of natural ingredients, such as Matoa (Pometia pinnata). This study aims to provide a literature review on the potential of various Matoa plant extracts as antibacterials.* **Methodology:** *The investigation was conducted using the PRISMA approach, which involved the systematic literature review method. Electronic databases, including PubMed, ScienceDirect, Scopus, and Google Scholar, were searched from 2010 to 2024. "Pometia pinnata" is a search term that encompasses " Pometia pinnata as antibacterial" and "Antibacterial Activity of Pometia pinnata." A qualitative analysis was conducted on 22 articles that satisfied the inclusion criteria following the selection process.* **Findings:** *The review results indicated that the extracts of matoa's leaves, seeds, and bark contain active compounds, including flavonoids, tannins, saponins, alkaloids, and other phenolic compounds, which exhibit antibacterial activity. Despite the large potential, the majority of the research is still exploratory and has not yet progressed to the clinical trial stage. Consequently, additional, more intensive research is required to investigate the mechanism of action, toxicity, and potential clinical applications of herbal medicines derived from indigenous Indonesian plants.* **Contribution:** *This review highlights the antibacterial potential of matoa (Pometia pinnata) and underscores the need for further studies on its mechanism, toxicity, and clinical application, thereby guiding future research on Indonesian herbal medicine*

Keywords: *Antibacterial; Matoa (Pometia pinnata); Secondary Metabolites; SLR*

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INTRODUCTION

Today and in the future, antimicrobial resistance is one of the most significant threats to global health, food security, and development. In 2019, the World Health Organization (WHO) estimated that antibiotic-resistant bacterial infections were responsible for approximately 4.95 million deaths. This figure is expected to rise if the issue is not addressed promptly (WHO, 2021; Laxminarayan, 2022). Bacterial resistance to drugs has been significantly exacerbated by the excessive and inappropriate use of antibiotics. Consequently, it is imperative to develop safe and effective alternative therapies.

The investigation of medicinal plants as a source of bioactive compounds is one of the emerging methodologies. Secondary metabolites, including flavonoids, alkaloids, saponins, tannins, and phenolics, are present in plants and have been demonstrated to possess antibacterial, antioxidant, anti-inflammatory, and anticancer properties (Ghasemzadeh & Ghasemzadeh, 2011). This potential is the primary attraction of developing natural medicinal materials based on local biodiversity. Therefore, additional efforts are required to identify novel antibacterials by utilizing bioactive compounds derived from Indonesian biodiversity. One such compound is Matoa (*Pometia pinnata*), an endemic Papuan plant. West Papua's identity flora is Matoa. People frequently refer to Matoa, a native Papuan fruit-producing tree, as "Papuan longan" due to the fruit's resemblance to longan. Bioactive compounds that can function as antioxidants, antibacterials, anti-inflammatories, and antidiabetic agents can be produced by various components of the matoa plant, including the leaves, fruit skin, bark, seeds, and fruit.

Matoa plants possess the potential to function as antibacterial agents, which could serve as an alternative solution to the escalating issue of antibiotic resistance that is currently prevalent. According to Novitasari & Wijayanti (2018), the bioactive extract of the matoa plant will demonstrate its antibacterial properties through the use of test pathogenic bacteria (Dewi, 2021). It is widely recognized that the dissemination of pathogenic bacteria can be impeded by phytochemical compounds in matoa, such as flavonoids, tannins, saponins, steroids, and alkaloids (Dewi, 2021; Novitasari & Wijayanti, 2018). Flavonoids can impede the proliferation of pathogenic bacteria, including Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, and Klebsiella pneumoniae (Novitasari & Wijayanti, 2018). Tannins are also capable of inhibiting the proliferation of bacteria, including Salmonella typhimurium, Bacillus cereus, and Staphylococcus aureus (Dewi, 2021). Saponin compounds are recognized for their capacity to impede the proliferation of numerous pathogenic bacteria, such as Staphylococcus aureus, Escherichia coli, and Bacillus cereus. In the interim, alkaloids have also been demonstrated to be effective in inhibiting the growth of Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Staphylococcus aureus, and Enterococcus faecalis (Dewi, 2021; Usman et al., 2019; Novitasari & Wijayanti, 2018). These results suggest that the utilization of matoa plants as antibacterial agents has the potential to be a promising solution, as numerous studies have demonstrated the antibacterial activity of this medicinal plant against pathogenic bacteria. Nevertheless, these findings are still incomplete, and there has not been a systematic review that comprehensively

summarizes the antibacterial potential of the Pometia pinnata plant's various components. Consequently, a thorough literature review is required to compile and evaluate scientific data concerning the antibacterial properties of various matoa plant extracts. The objective of this investigation is to establish a more thorough comprehension of the potential of Pometia pinnata as a natural antibacterial agent and to identify research gaps that can serve as the foundation for future research and the development of local plant-based phytopharmaceuticals.

METHOD

This study was a systematic literature review study that aimed to identify and narratively synthesize various scientific findings related to the potential of matoa plant extract (*Pometia pinnata*) as an antibacterial agent. The narrative synthesis approach was used to present and analyze the results of various studies descriptively and thematically, considering the heterogeneity in the types of extracts, antibacterial test methods, and target microorganisms used in each study.

Search Strategy

This systematic literature review study was conducted using a systematic and structured approach to search, evaluate, and synthesize relevant literature. The article selection guidelines were based on the PRISMA protocol (Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) (Moher et al., 2015). The literature search was conducted comprehensively by utilizing the Harzing's Publish or Perish (PoP) application on several databases, including PubMed, Scopus, and Google Scholar. In addition, there were also articles added manually. There are several keywords used in searching for articles, namely "*Pometia pinnata*," " *Pometia pinnata* as antibacterial," and "antibacterial activity of *Pometia pinnata*".

Literature Selection Criteria

The taken articles were selected based on a variety of criteria. The inclusion criteria included research articles from 2013 to 2024, articles in English and Indonesian, full text, and open access. These articles were experimental studies, both in vitro and in vivo, that conducted antibacterial activity tests on pathogenic bacterial species using various plant part extracts from Matoa (*Pometia pinnata*). The articles must also meet the PICOS framework, including Gram-positive and Gram-negative bacterial pathogens that comprised the population. The interventions were from the extracts from the matoa plant's various components (e.g., leaves, fruit, bark); the comparators were the conventional antibiotics or extracts from other plants; and the outcomes were from antibacterial activity observed through the formation of inhibition zones and NIC (non-inhibitory inhibitory concentration). The study designs were in vitro and/or in vivo tests. The articles published in the form of books, theses, literature reviews, conference proceedings, and KTI (scientific papers) were also excluded, as were studies that were not in accordance with the topic being researched, available data that did not meet standards, and articles that did not meet the desired research quality (Martignago et al., 2023).

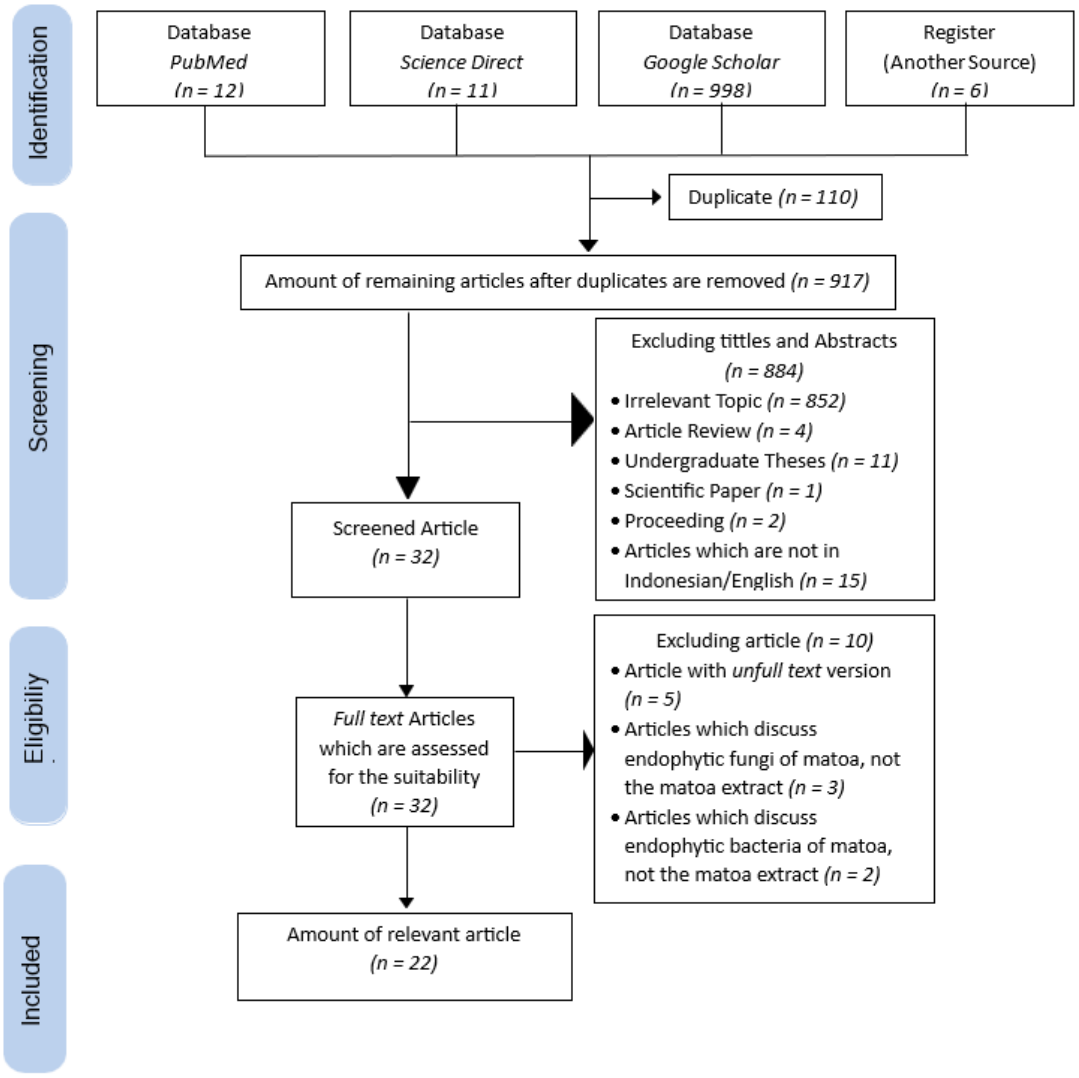

Figure 1. PRISMA Diagram Illustrating The Process of Searching For and Selecting Studies

Article Selection

Three reviewers conducted the article selection process. The articles were chosen in accordance with the PRISMA guidelines. Duplicate articles were eliminated from the database. The selection of articles was determined by the inclusion and exclusion criteria that had been previously established. Additionally, the eligibility of the selected articles was assessed by each reviewer. Eligible articles were subsequently subjected to a full-text analysis, while those that did not meet the criteria were discounted.

RESULT

Aticle Selection Results

A total of 1027 research articles were found during the database search. After removing 110 duplicates, there were 917 articles left, and after excluding the title and abstract, 884 articles were excluded for the following reasons: irrelevant topics (n = 852), review article form (n = 4), scientific papers (n = 1), proceeding articles (n = 2), and articles which are not in Indonesian/English (n = 15). After excluding the title and abstract, 33 articles were obtained. In the full-text screening of the remaining 32 articles, 11 articles were eliminated based on the following exclusion criteria: The intervention did not discuss extracts from the matoa plant but rather endophytic fungi in the matoa plant (n = 3) and endophytic bacteria in the matoa plant (n = 2). In addition, there was no antibacterial activity based on the formation of inhibition zones and/or NIC—non-inhibitory concentration (n = 1). From the first and second screenings conducted, 22 articles were selected and analyzed in this review research (Figure 2).

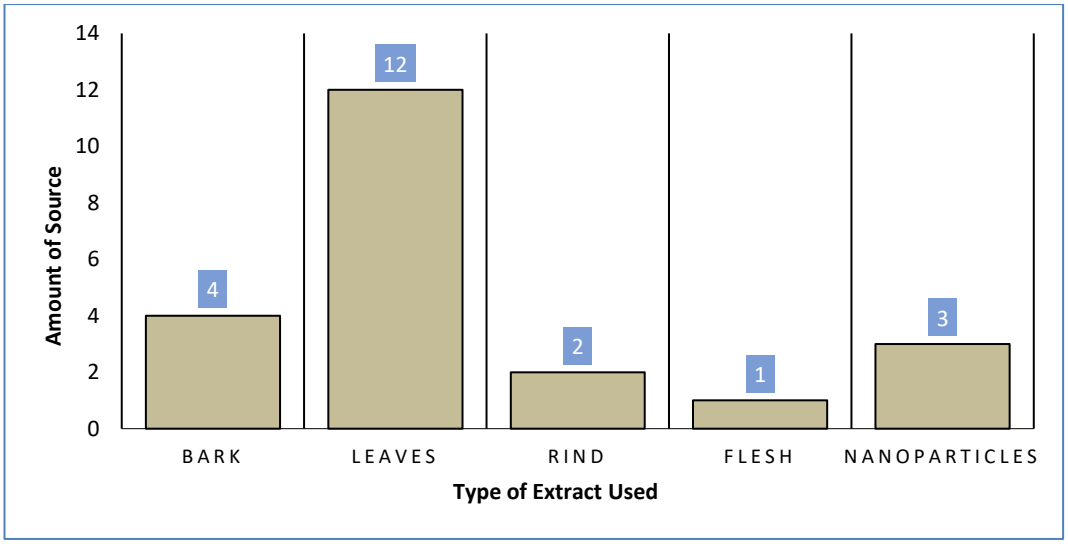

Figure 2. Amount of Literature Source Based on The Type of Extract Used

Data Search Results

There are 22 articles that have been found to meet the inclusion and exclusion indicators that have been set, and then a systematic review was carried out based on the part of the plant used. All selected articles were assessed for their quality. Antibacterial activity was observed using three test methods, namely the paper disk diffusion method (Alamsjah et al., 2024; Azlin et al., 2023; Fahira et al., 2023; Fatimah et al., 2021; Faustina & Santoso, 2017; Gultom et al., 2023; Islami et al., 2024; Litaay, 2023; Maimuna et al., 2023; Pirdina et al., 2021; Razoki, 2023; Risna, 2023; Rochaeni et al., 2021; Rossalinda et al., 2021; Sidoretno, 2021; Siregar et al., 2023; Widayani et al., 2021), the well diffusion method (Norma, 2020; Ngajow et al., 2013; Sulastri et al., 2022; Tambingon et al., 2023), and total plate counting (TPC) (Yudasari et al., 2021). The paper disk diffusion method is

a method that is often used, which is easier and faster in preparing discs for testing (Nurhayati et al., 2020).

In this method, paper discs are used to absorb bioactive compounds from sample extracts that have the potential to be antimicrobial agents, which are then placed on agar plates that have been planted with bacterial isolates. From the results of this test, a clear zone, or inhibition zone, is formed, which is an indicator of the presence or absence of the potential of the sample extract used earlier as an antimicrobial agent. The larger the clear zone formed, the greater the potential of the sample to inhibit bacterial growth. However, when compared to the well method, the inhibition zone activity formed in the paper disk method is much smaller, so the well method is more effective to use to show the antibacterial activity of a test sample (Khusuma et al., 2019; Sri et al., 2017; Nurhayati et al., 2020). This is because in the well method, the test bacteria can be active not only on the surface of the agar media but also at the bottom so that observation of the inhibition zone will be easier and the results will be wider. However, this method has a higher level of difficulty; namely, when making the well holes, one must be more careful so that the agar media is not damaged or broken and there is no remaining agar in the wells that have been made. There is 1 article that uses the TPC method to count the number of bacterial colonies living in samples by growing them on nutrient agar media.

The size of the inhibition zone formed is a determining factor in the potential antibacterial activity of the extract. Measurement of the inhibition zone using a caliper (mm). There are several criteria for grouping the antibacterial activity ability of a test sample, including the very strong category (> 20 mm), strong category (10 - 19 mm), medium category (5 - 10 mm), and low category (< 5 mm) (Sartika et al., 2020). The value of the inhibition zone formed illustrates how much an extract is able to prevent the growth of pathogenic bacteria. Analysis of 22 articles shows the potential of Matoa (Pometia pinnata), which can inhibit the growth of various pathogenic bacteria.

Antibacterial Activity Ability

Matoa Bark

Several studies have shown that matoa bark extract (Pometia pinnata) has quite significant antibacterial potential against gram-positive bacteria *Staphylococcus aureus*. Research conducted by Litaay (2023) showed that increasing extract concentration was directly proportional to the increase in the diameter of the inhibition zone against *S. aureus*. The resulting inhibition zone even approached the effectiveness of the positive control (*ampicillin*). It indicates that the active compounds in the extract had competitive antibacterial power. These results mean that the extract can be classified as having strong inhibitory power, with an inhibition zone diameter ranging from 10 to 20 mm. Similar findings were also reported by Norma (2020), who used a cream formulation based on a mixture of matoa bark extract and honey. The results showed antibacterial effectiveness, which was also relatively strong and comparable to the positive control. This finding strengthens the assumption that the bioactive compounds in matoa bark can work synergistically with other natural ingredients to increase their antibacterial power. Meanwhile, a study by Ngajow et al., (2013) also proved that the inhibitory power of the extract against *S. aureus* was relatively strong, although still

lower than the positive control ciprofloxacin, which is known to have outstanding antibacterial potential. This result confirms that although the effectiveness of matoa extract is promising, it has not yet fully matched the potential of strong synthetic antibiotics.

In contrast to previous studies, Tambingon et al., (2023) reported that matoa bark extract only showed moderate inhibition against *S. aureus* when compared to a positive control in the form of gentamicin cream. This variation is most likely due to differences in extraction methods, solvents used, extract concentrations, and test preparation formulations. In general, the range of inhibition zones of matoa bark extract against *S. aureus* is in the moderate to strong category (10 – 20 mm). This antibacterial effectiveness is thought to be closely related to the presence of active phytochemical compounds such as alkaloids, tannins, flavonoids, saponins, steroids, and terpenoids, which are known to have mechanisms of action in damaging bacterial cell walls, inhibiting protein synthesis, and reducing cell membrane permeability (Litaay, 2023; Ngajow et al., 2013). Thus, the data collected from various studies support the conclusion that matoa bark extract has the potential as a candidate for a natural antibacterial agent, especially against Staphylococcus aureus. However, to strengthen scientific evidence, further testing is needed with more homogeneous standards as well as toxicity tests and formulations that are more clinically applicable.

Matoa Leaves

Various review studies have shown that ethanol extract of *Pometia pinnata* leaves has quite broad antibacterial activity, both against Gram-negative and Gram-positive bacteria. In general, the majority of studies use ethanol solvents in the extraction process and produce strong inhibition zones, although variations in concentration and type of test bacteria also affect the strength of inhibition. In Gram-negative bacteria, such as *Neisseria gonorrhoeae*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella typhi*, and *Klebsiella pneumoniae*. Ethanol extracts of matoa leaves generally show a strong inhibition category. Research by Widayani et al., (2021) reported strong inhibition against *N. gonorrhoeae*, although still lower than levofloxacin as a positive control. Siregar et al., (2023) and Risna (2023) showed similar results in *E. coli*, with inhibition zones varying depending on the concentration of the extract, even approaching positive controls such as tetracycline and ampicillin. Interesting results were also shown by Islami et al., (2024), who reported an inhibitory ability against *K. pneumoniae* that exceeded the positive control (Ciprofloxacin), indicating the potential of this extract against resistant bacteria.

Table 1. Summary of Inhibitory Ability of Matoa (*Pometia Pinnata*) Bark Extract

No.	Author (year)	Extract	Antibacterial test	Antibacterial activity analysis results	Bioactive compounds	Comparator
1	Ngajow et al. (2013)	Ethanol extract of Matoa Bark	Well diffusion method	Inhibition zone formed • Extract *Staphylococcus aureus*: 14.61 mm (strong) • Positive control *Staphylococcus aureus*: 29.67 mm (very strong)	Tannins, flavonoids, terpenoids, and saponins	Ciprofloxacin
2	Norma (2020)	Matoa bark extract	Well diffusion method	Inhibition zone formed: • Extract *Staphylococcus aureus*: 16.44 mm (strong) • Positive control *Staphylococcus aureus*: 16.67 mm (strong)	Not tested	Cream (Mixture of Matoa Bark Extract and Honey)
3	Tambingon et al. (2023)	Matoa bark ethanol extract cream	Well diffusion method	Inhibition zone formed: • Extract *Staphylococcus aureus*: Cons. 0.5% 4.42 mm (weak) Cons. 1.5% 6.25 mm (moderate) Cons. 2.5% 7.83 mm (moderate) Cons. 3.5% 8.66 mm (strong) • Positive control *Staphylococcus aureus*: 19.58 mm (strong).	Not tested	Gentamicin Cream
4	Litaay (2023)	Ethanol extract of matoa bark	Paper disk diffusion	Inhibition zone formed • Extract *Staphylococcus aureus*: Cons. 1.5% 12.99 mm (strong) Cons. 2% 14.06 (strong) Cons. 2.5% 15.27 mm (strong) • Positive control *Staphylococcus aureus*: 16.11 mm (strong).	Alkaloids, tannins, flavonoids, saponins and steroids.	Ampicillin

Table 2. Summary of Inhibitory Ability of Matoa (*Pometia Pinnata*) Leaf Extract

No.	Author (year)	Extract	Antibacterial test	Antibacterial activity analysis results	Bioactive compounds	Comparator
1	Widayani et al. (2021)	Ethanol extract of matoa leaves	Paper disk diffusion	Inhibition zone formed • Extract *Neisseria gonorrhoeae*: 12.55 mm (strong). • Positive control *Neisseria gonorrhoeae*: 30.35 mm (very strong).	Flavonoids, tannins, saponins, and triterpenoids	Levofloxacin 500mg
2	Pirdina et al. (2021)	Ethanol extract of matoa leaves	Paper disk diffusion	Inhibition zone formed • *Salmonella typhi* extract: Cons. 25% 2.43 mm (low), Cons. 35% 3 mm (low), Cons. 45% 2.81 mm (low) Cons. 55% 2.82 mm (low) • Positive control *Salmonella typhi*: 27.38 mm (very strong)	Flavonoids, tannins and saponins	Amoxicillin
3	Rossalinda et.al. (2021)	Ethanol extract of matoa leaves	Paper disk diffusion	Inhibition zone formed • Extract: *Staphylococcus epidermidis*: 3 mm (weak) • Positive control *Staphylococcus epidermidis*: 30 mm (very strong)	Saponins, flavonoids, tannins, and alkaloids	Chloramphenicol
4	Sidoretno (2021)	Ethanol extract of matoa leaves	Paper disk diffusion	Inhibition zone formed • Extract: *Staphylococcus aureus*: Cons. 10%, 10.07-11.06 mm (strong) Cons. 20% 16.05-17.61 mm (strong) Cons. 30% 16.55-18.06 mm (strong) • Positive control *Staphylococcus aureus*: 27.44 mm (very strong)	Phenolics and flavonoids	Ciprofloxacin

No.	Author (year)	Extract	Antibacterial test	Antibacterial activity analysis results	Bioactive compounds	Comparator
5	Siregar et al. (2023)	Ethanol extract of matoa leaves	Paper disk diffusion	Inhibition zone formed • Ethanol extract of matoa leaves *Escherichia colI*: Cons. 25% 13.9 mm (strong) Cons. 50% 14.6 mm (strong) Cons. 75% 18 mm (strong) • Positive control *Escherichia colI*: 22.4 mm (very strong)	Alkaloids, flavonoids, tannins, saponins, and steroids/triterpenoids	Tetracycline 30 Mg
6	Razoki (2023)	Ethanol extract of matoa leaves	Paper disk diffusion	Inhibition zone formed • Extract: *Staphylococcus aureus*: 17.31mm (strong) *Pseudomonas aeruginosa*: 15.28 mm(strong)	Alkaloids, flavonoids, glycosides, saponins, tannins, and steroids/triterpenoids	Streptomycin
7	Risna (2023)	Ethanol extract of matoa leaves	Paper disk diffusion	Inhibition zone formed • Extract *Escherichia coli*: Cons. 1% 9.5 mm (moderate) Cons. 1.5% 10.23 mm (moderate) Cons. 2% 12.1 mm (strong) Staphylococcus aureus: Cons. 1% 12.36 mm (strong) Cons. 1.5% 13.26 (strong) Cons. 2% 13.63 mm (strong) • Positive control *Escherichia coli*: 13.66 mm (strong) *Staphylococcus aureus*: 15.61 mm (strong).	Alkaloids, flavonoids, tannins, saponins and steroids	Ampicillin

No.	Author (year)	Extract	Antibacterial test	Antibacterial activity analysis results	Bioactive compounds	Comparator
8	Gultom et al. (2023)	Ethanol extract of matoa leaves	Paper disk diffusion	Inhibition zone formed • Extract: *Salmonella typhi*: Cons. 30% 12.6 mm (strong) Cons. 40% 13.8 mm (strong) Cons. 50% 15.3 mm (strong). • Positive control: *Salmonella typhi*: 19.0 mm (strong)	Alkaloids, flavonoids, saponins, tannins, steroids and triterpenoids	Chloramphenicol 30 µg
19	Maimunaet al. (2023)	Matoa Leaf Ethyl Acetate Extract	Paper disk diffusion	Inhibition zone formed • Extract *Eschericia coli*: Cons. 10% 8.28 mm (moderate) Cons. 20% 10.33 mm (moderate) Cons. 30% 12.15 mm (strong) • Positive control: *Eschericia coli*: 27.05 mm (strong)	Not tested	Ciprofloxacin
9	Azlin et al. (2023)	Ethanol extract of matoa leaves	Paper disk diffusion	Inhibition zone formed • Extract *Staphylococcus aureus*: Cons. 10% 8.39 mm (moderate) Cons. 20% 10.64 (strong) Cons. 30% 12mm (strong) • Positive control *Staphylococcus aureus*: 23.46 mm (very strong)	Flavonoid, tannin, dan saponin	Ciprofloxacin

No.	Author (year)	Extract	Antibacterial test	Antibacterial activity analysis results	Bioactive compounds	Comparator
10	Alamsjah et al. (2024)	Ekstrak Etanol Daun Matoa	Paper disk diffusion	Inhibition zone formed • Extract: *Staphylococcus aureus*: Cons. 80% of 20.75 mm (very strong) *Pseudomonas aeruginosa*: Cons. 100% of 18.91 mm (strong) • Positive control *Staphylococcus aureus*: 26.75 mm (very strong) *Pseudomonas aeruginosa*: 31.25 mm (very strong)	Flavonoid, tannin, phenol, dan antraquinon	Chloramphenicol
11	Islami et.al. (2024)	ekstrak daun matoa dengan 3 pelarut n-heksan, etil asetat dan etanol	Paper disk diffusion	Inhibition zone formed • *Ethyl acetate* extract Cons. 70% *Stapyhlococcus aureus*: 10.63 mm (strong), *Streptococcus mutans*: 13.43 mm (strong), *Eschericia coli*: 11.23 mm(strong) *Klebsiella pneumonia*: 13.26 mm (strong). • Ethanol extract Cons. 30% *Stapyhlococcus aureus*: 13.66 mm (strong), *Streptococcus mutans*: 13.27 mm (strong), *Eschericia col*:i 10.40 mm (moderate) *Klebsiella pneumonia*: 16.63 mm (strong) • N-hexane extract Cons. 30% *Stapyhlococcus aureus*: 0 mm (none) *Streptococcus mutans*: 10.86 mm (strong) *Eschericia coli*: 10.23 mm (moderate) *Klebsiella pneumonia*: 10.16 mm (moderate) • Positive control *Stapyhlococcus aureus*: 40.1 mm (very strong) *Streptococcus mutans*: 29.43 mm (very strong) *Eschericia coli*: 45.63 mm (very strong) *Klebsiella pneumonia*: 14.63 mm (strong)	Flavonoid, terpenoid, steroid, tanin, saponin	Ciprofloxacin

In Gram-positive bacteria such as *Staphylococcus aureus*, most studies report strong to very strong inhibition (Razoki, 2023; Risna, 2023; Alamsjah et al., 2024). In fact, in some studies, the extract inhibition zone was equivalent to or close to positive controls such as *Ampicillin* and *Chloramphenicol*. Similar findings were reported against *Streptococcus* mutans, which also showed a strong category at various extract concentrations (Fahira et al., 2023; Islami et al., 2024). However, an exception was found in *Staphylococcus epidermidis*, where the extract activity was relatively low (Rossalinda et al., 2021), indicating the possibility of selectivity toward certain species within a genus.

Analysis of the use of other extraction solvents such as ethyl acetate and n-hexane showed that the type of solvent affects the antibacterial strength. Matoa leaf extract with ethyl acetate produced a strong category inhibition zone against all test bacteria, while n-hexane tended to produce moderate to inactive inhibition in several species (Islami et al., 2024). This supports the findings of Hakim & Saputri (2020), which stated that polar solvents such as ethanol are more effective in extracting bioactive compounds such as flavonoids and phenolics, which have potential as antimicrobial agents. The results of this study show that the solvent used can affect the test results obtained. This is because the solvent plays an important role in filtering bioactive compounds from the plant extracts used (Hakim & Saputri, 2020).

Overall, the ethanol extract of matoa leaves has been shown to have consistent and strong antibacterial activity, both against Gram-positive and Gram-negative bacteria. This is because ethanol solvents are very good for obtaining flavonoid compounds and phenolic compounds (Hakim & Saputri, 2020), which are known to act as antimicrobials. Variations in inhibitory strength depend on the bacterial species, extract concentration, and type of solvent used. These findings indicate that *Pometia pinnata* has the potential to be developed as a natural antibacterial agent, especially in dealing with the problem of global antibiotic resistance, although further testing of its mechanism of action and toxicity is still needed.

Several studies have shown that the skin of Pometia pinnata fruit has significant antibacterial potential. Research by Sulastri et al., (2022) reported that ethanol extract of matoa fruit skin can inhibit the growth of *Staphylococcus aureus*, one of the Gram-positive bacteria that causes various skin and systemic infections. The test was carried out with varying concentrations of the extract, and the results showed antibacterial activity at all concentrations tested. The level of effectiveness is equivalent to chloramphenicol, an amphenicol antibiotic commonly used as a positive control in antibacterial tests. This activity is categorized as moderate. It indicates that the active compounds in the ethanol extract of matoa skin have competitive abilities as natural antimicrobial agents. Furthermore, Faustina & Santoso (2017) conducted a test to determine the Non-inhibitory Concentration (NIC) of matoa skin extract using two types of solvents: ethanol and acetone. They tested its effectiveness against *Escherichia coli*, *Bacillus cereus*, and *Staphylococcus aureus*. The results showed that both extracts had strong antibacterial activity, with NIC values < 0.5 ppm against the three test bacteria. This very low NIC value indicates that the antibacterial compounds in the extracts are able to slow down bacterial growth even in minimal concentrations. In contrast, the extract with water solvent produced an NIC of 5 ppm, indicating much lower activity.

Matoa Skin

Comparative analysis of these two studies shows that the type of solvent plays an important role in extracting bioactive compounds from matoa skin. Organic solvents such as ethanol and acetone are more effective than polar water solvents because they are able to dissolve phenolic and flavonoid compounds that have antibacterial properties. Overall, these findings support that matoa skin is a plant part that has high potential as a source of natural antibacterials, especially if extracted with appropriate solvents. However, the results categorized as moderate activity indicate the need for further testing, such as identification of active compounds by chromatography and testing the mechanism of action on bacterial walls or metabolism to support its application.

Matoa Flesh

Antimicrobial activity testing on the flesh of matoa fruit was carried out by Rochaeni et al., (2021) using several different solvents, namely hexane, methanol, and ethyl acetate, against the growth of *Bacillus cereus* and *Escherichia coli* bacteria. The results of the study showed that the inhibition of hexane and ethyl acetate extracts against *Bacillus cereus* was stronger than the positive control (amoxicillin), but all extracts from matoa flesh were unable to inhibit the growth of gram-negative bacteria (*Escherichia coli*), while amoxicillin could inhibit but was also in the low category. This can be caused by the different characteristics of the cell walls of the two groups of bacteria. The gram-negative group has a complex cell wall structure consisting of an outer layer of lipopolysaccharides and proteins and an inner layer consisting of a thin layer of peptidoglycan. While the composition of the cell wall of the gram-positive group is one layer, namely thick peptidoglycan. Hamidah et al., (2019) This lipopolysaccharide part plays a role in preventing the entry of various compounds that are not needed by bacteria, which causes gram-negative bacteria to be more resistant if there are substances that are antibacterial.

Matoa Nanoparticles

Nanoparticle research is currently increasingly being carried out by researchers. The use of nanoparticles from matoa plant extract has also been reported by several researchers. Fatimah et al., (2021) conducted a study using nanoparticles from matoa leaf extract to inhibit the growth of test bacteria with an inhibition zone category in gram-positive bacteria, namely *Staphylococcus aureus* (strong) and *Streptococcus pyogenes* (strong), and gram-negative bacteria *Klebsiella pneumoniae* (strong) and *Escherichia coli* (strong). When compared to the positive control, the inhibitory ability of the matoa extract nanoparticles used was almost the same as the inhibitory ability of the positive control (Ampicillin) which was classified as strong for all test bacteria. Another study that also tested nanoparticles obtained from matoa leaf extract was Siregar et al., (2023). The ability of nanoparticles to inhibit the growth of Escherichia coli bacteria at various treatment concentrations was classified as moderate when compared to the positive control tetracycline, which has a powerful antibacterial ability. However, it

can be seen that the addition of extract concentration in this study can increase the diameter of the inhibition zone formed. The same results were also shown by a study conducted by Fahira et al., (2023). The addition of the concentration of nanoparticles of ethanol extract of matoa leaves is known to increase the diameter of the inhibition zone. The use of concentration variations can increase the diameter of the formed bland zone. So the use of nanoparticles can be used as promising research in the future because it only uses a small amount of extract concentration but already has a fairly high inhibitory ability so that in the future it can be used as a new solution in finding alternatives to overcome the problem of antibiotic resistance that is currently rampant.

DISCUSSION

The content of bioactive compounds in a plant extract is a significant factor in its antibacterial activity. The matoa plant's capacity to impede the growth of various test bacteria from the gram-positive and gram-negative groups is attributed to the presence of secondary metabolites. Flavonoids possess antibacterial properties by inhibiting the formation of nucleic acids, which in turn disrupts the functionality of bacterial cell membranes by forming complex compounds against extracellular proteins. This damage can be followed by the release of intracellular compounds. Furthermore, flavonoid compounds can also impede energy metabolism by obstructing the utilization of oxygen by bacteria (Cushnie & Lamb, 2005; Hendra et al., 2011; Nuria et al., 2009). Phenol functions as an antibacterial agent by denaturing hydrogen bonds between phenol and protein. This process disrupts the permeability of the cell wall and cytoplasmic membrane of bacteria, which can lead to the imbalance of macromolecules and ions within the cell, ultimately resulting in cell lysis (Pelczar & Chan, 2005). The formation of bacterial cells can be prevented by tannin compounds, which can inhibit the activity of DNA topoisomerase and reverse transcriptase enzymes (Nuria et al., 2009). The antibacterial properties of saponin compounds are attributed to the active substances on their surface, which are similar to the function of detergents. These substances can reduce the tension on the surface of the cell walls of bacteria, thereby damaging the permeability of the bacterial membrane and disrupting its survival (Harborne, 2006). Alkaloid compounds also function as antibacterials by disrupting the components of peptidoglycan, which causes the layers of bacterial cell walls to form imperfectly and leads to cell death (Darsana et al., 2012). The matoa leaf extract has a relatively strong ability to inhibit pathogenic bacteria, as evidenced by the analysis of 22 articles. Additionally, the resulting inhibition spectrum is quite broad. The results of in situ biosynthesis and the translocation process from leaves to other parts of the plant's organs can influence the accumulation of bioactive compounds in various parts of the plant, including leaves, stems, flowers, bark, fruit, and others. The relationship between the synthesis or transport of bioactive compounds in plant tissues can affect their concentration in different parts of the plant, and variations in these compounds may occur during the development of plant organs (Rojsanga et al., 2020).

Table 3. Summary of Inhibitory Ability of Matoa (*Pometia Pinnata*) Skin Extract

No.	Author (year)	Extract	Antibacterial test	Antibacterial activity analysis results	Bioactive compounds	Comparator
1	Faustina & Santoso (2017)	Acetone and ethanol extract of matoa fruit skin	Paper disk diffusion	Antibacterial activity was performed on all extracts and Non-Inhibitory Concentration (NIC) values were determined for all extracts. • Acetone and Ethanol Extracts *Escherichia coli*: NIC <0.5 ppm *Bacillus cereus*: NIC <0.5 ppm *Staphylococcus aureus*: NIC <0.5 ppm • Aquadest Extracts *Escherichia coli*: NIC 5 ppm *Bacillus cereus*: NIC 5 ppm *Staphylococcus aureus*: NIC 5 ppm	Tannins, saponins, and alkaloids	Matoa fruit extract with aquades solvent
2	Sulastri et al. (2022)	Ethanol extract of matoa fruit skin	Well diffusion method	Inhibition zone formed • Extract *Staphylococcus aureus*: Cons. 20% 6.6 mm (moderate) Cons. 40% 8.3 mm (moderate) Cons. 60% 7.7 mm (moderate) • Positive control *Staphylococcus aureus*: 10.1 mm (moderate)	Not tested	Amoxicillin

Table 4. Summary of Inhibitory Ability of Matoa (*Pometia Pinnata*) Nanoparticles

No.	Author (year)	Extract	Antibacterial test	Antibacterial activity analysis results	Bioactive compounds	Comparator
1	Fatimah et al. (2021)	Matoa leaf extract nanoparticles	Paper disk diffusion	Inhibition zones formed: • Extract *Klebsiella pneumoniae*: 13 mm (strong) *Escherichia coli*: 10.3 mm (strong), *Staphylococcus aureus*: 11.3 mm (strong), *Streptococcus pyogenes*: 12.3 mm (strong) • Positive control: *Klebsiella pneumoniae*: 12.3 mm (strong) *Escherichia coli*: 12.6 mm (strong) *Staphylococcus aureus*,: 13.6 mm (strong) *Streptococcus pyogenes*: 24 mm (very strong)	Not tested	Ampicillin
2	Siregar et al. (2023)	Nanoparticles of matoa leaf ethanol extract	Paper disk diffusion	Inhibition zone formed • Matoa leaf extract nanoparticles *Escherichia colI*: Cons. 2.5% 6.6 mm (moderate) Cons. 5% 7.2 mm (moderate) Cons. 7.5% 7.7 mm (moderate) • Positive control *Escherichia colI*: 22.4 mm (very strong)	Alkaloids, flavonoids, tannins, saponins, and steroids/triterpenoids	Tetracycline 30 Mg
3	Fahira et al. (2023)	Nanoparticles of Matoa Leaf Ethanol Extract	Paper disk diffusion	Inhibition zone formed • Ethanol extract *Streptococcus mutans*: Cons 25% 12.5mm (strong) Cons 25% 12 mm (strong) Cons 50% 12.5 mm (strong) Cons. 75% 12.6 mm (strong) •Ethanol extract nanoparticles *Streptococcus mutans*: Cons. 2.5% 8 mm (medium) Cons 5% 9.06 mm (medium) Cons. 7.5% 10.1 mm (medium) • Positive control *Streptococcus mutans*: 25.9 mm (very strong)	Alkaloids, flavonoids, Saponins, tannins and steroids/triterpenoids	Amoxicillin 25µg

The antibacterial activity of plant extracts, including Pometia pinnata (matoa), is greatly influenced by the presence of bioactive compounds such as flavonoids, phenols, tannins, saponins, and alkaloids. These compounds work through various mechanisms, ranging from disruption of cell wall structure and inhibition of essential enzymes to membrane damage and inhibition of nucleic acid synthesis. Flavonoids, for example, are known to be able to damage bacterial cell membranes and disrupt energy metabolism (Cushnie & Lamb, 2005), while phenols can denature proteins and cause cell lysis (Pelczar & Chan, 2005). The presence of these compounds in matoa extract has been shown to provide antibacterial activity against various Gram-positive and Gram-negative bacteria in a number of previous studies. However, when a more in-depth analysis was carried out on the 22 articles reviewed, inconsistencies were found in the results between studies, especially regarding the strength of antibacterial activity in different parts of the plant and against different target bacteria. For example, a study by Sulastri et al., (2022) showed moderate activity of the fruit peel extract against S. aureus, while Faustina & Santoso (2017) reported very low NIC values (<0.5 ppm), indicating very strong activity against the same test bacteria. These differences are most likely due to variations in extraction methods, solvent types, antibacterial testing techniques (such as disc diffusion vs. MIC/NIC determination), and extract concentrations used. These variations pose challenges in conducting direct comparisons between studies.

Furthermore, several prior investigations were identified as having methodological deficiencies. The majority of studies have relied solely on in vitro tests and have not conducted a comprehensive characterization of the active compounds in isolation. Consequently, it is uncertain which specific compounds are most effective in generating antibacterial effects. In reality, the internal validity of the study was diminished by the absence of positive control standards or adequate biological test replications in numerous studies. Moreover, the extracts employed were not subjected to toxicity tests in the majority of the literature that was examined. This situation presents the potential for an overestimation of the efficacy of the antibacterial compounds. It is uncertain whether the effective concentrations used in laboratory tests are safe for therapeutic applications in humans or animals, given the lack of toxicity data. Although tannins and saponins are antibacterially active, they are known to have toxic effects in high doses if they are not subjected to standardized and purified processes (Rojsanga et al., 2020). In addition, it is necessary to account for variations in the bioactive content of plant parts.

The accumulation of secondary metabolites is inconsistent across plant organs and can be influenced by various physiological factors, including plant age, environmental conditions, and in situ biosynthesis processes. Rojsanga et al., (2020) underscored that the internal transport processes and dynamic biosynthetic activities that occur during the development of plant organs influence the variation of bioactive compounds between plant parts. This explains why, in specific studies, the antibacterial efficacy of leaves may be greater than that of seeds or bark, and vice versa. Therefore, while the findings of this review suggest that Pometia pinnata has significant potential as a source of natural antibacterials, a more integrated and standardized approach to further research is required. This approach should include the isolation of the primary active compounds, the determination of toxicity values,

and in vivo and clinical tests to guarantee the safety and efficacy of its practical application.

CONCLUSION

Based on the results of the systematic literature review conducted, it can be concluded that various parts of the matoa plant (*Pometia pinnata*), such as leaves, bark, fruit skin, and fruit, have strong potential as sources of natural antibacterial agents. This activity is associated with the content of bioactive compounds—flavonoids, tannins, saponins, and alkaloids—which are able to inhibit the growth of Gram-positive and Gram-negative bacteria through various mechanisms of action. Extracts with ethanol solvents tend to show the highest effectiveness, and increasing extract concentrations have been shown to be positively correlated with increased bacterial inhibition. These findings have high significance in the field of herbal medicine and phytopharmaceutical development, especially as an alternative to synthetic antibiotics that are currently facing a resistance crisis. However, it should be noted that most studies are still in the early stages, with limitations such as a lack of toxicity tests, inconsistent quantitative data, and variations in methodology that have not been standardized. Therefore, to ensure its validity and clinical application, more comprehensive and evidence-based further research is needed. This study provides an important scientific basis for the use of local plants such as matoa in sustainable natural medicine innovation, while supporting the conservation of Indonesian biodiversity in the context of bioindustry and public health.

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