Analysis of Differences in the Function Groups of Bioactive Compounds of Noni and Papaya Leaf Extracts as Antibacterial Agents Using FTIR Spectrophotometer

R. M. Pradikalisatryo Rizqiravendra Al-Hakiim[1], Putri Maulidyah[2], Funsu Andiarna[3], Eva Agustina[4], Risa Purnamasari[5], Nova Lusiana[6], Irul Hidayat[7]
[12457]Fakultas Sains dan Teknologi, UIN Sunan Ampel Surabaya
eva_agustina@uinsby.ac.id

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Abstract: Noni (Morinda citrifolia) and papaya (Carica papaya) are plants that are abundant in Indonesia and have traditionally been used as medicine. This study aims to analyze the differences in functional groups of noni and papaya leaf extracts as antibacterial agents. The extracts were obtained through maceration using 96% ethanol as the solvent. Fourier Transform Infrared Spectroscopy (FTIR) was used in this study to identify the functional groups of bioactive compounds in each extract. The FTIR spectrum of noni leaves showed the presence of alkaloid functional groups due to the characteristic absorption of the -NH functional group of alkaloids at a wavelength of 3335.96736 cm-1, while papaya leaves showed the presence of saponin functional groups due to the characteristic absorption of the -OH functional group of saponins at 3337.83103 cm-1. Both compounds exhibit broad biological activity, including as antibacterial agents. Alkaloids from noni leaves have been proven effective against Staphylococcus aureus bacteria (causing acne), while saponins from papaya leaves are effective against Escherichia coli (the cause of diarrhea). Extracts from noni and papaya leaves show significant potential as natural antibacterial agents, supported by the identification of alkaloid and saponin functional groups through FTIR analysis

1 INTRODUCTION

Nature holds many potential biological resources that can be utilized by humans, one of which is plants that have potential as medicines. Forests with their biodiversity are one of the main sources of traditional medicinal plants whose utilization has been going on for a long time even for hundreds of years (Nugroho, 2017). In the last three years, acne (*Acne vulgaris*) remains one of the most widespread skin problems globally. From 1990 to 2021, the prevalence and incidence of acne in adolescents and young adults (aged 10-24 years) increased with an average annual percentage change (AAPC) of 0.43% and in 2021 there were approximately 9,790 cases per 100,000 population (Zhu et al., 2025).

Meanwhile, diarrhea remains one of the leading causes of global morbidity and mortality. In 2021, it is estimated that there will be 1.2

million deaths from diarrheal diseases, including approximately 340 000 deaths in children under the age of five (Zhao *et al*., 2025). Clinically, acne is usually treated with topical medications such as benzoyl peroxide, which is effective in killing *Staphylococcus aureus* without causing resistance, and the combination of *Benzoyl peroxide* with adapalene, which is more effective than single use (Thiboutot *et al*., 2007). For diarrhea, the main treatments include the use of oral rehydration salts (ORS), zinc supplementation, and vaccinations such as rotavirus which has been shown to reduce mortality (Bhatnagar *et al*., 2004). In general, people are less aware that consuming drugs containing BKOs (Medicinal Chemicals) continuously can have side effects in the long term (Rizki *et al*., 2023). Therefore, the need for herbal medicines by the pharmaceutical industry and for their own needs is also increasing (Nuraini, 2021).

The use of traditional medicine in Indonesia has been around for a long time and has become a community culture that is passed down from generation to generation. Although in terms of healing, medicinal plants are generally slower in treatment than using chemical drugs, traditional medicine using plants is believed to be much safer because it does not have major side effects, is toxic-free, easily obtained, and easily produced (Nugroho, 2017). The content of compounds contained in plants has various benefits for health. Plants have parts to be used as medicine such as roots, stems, leaves, fruits, seeds, flowers, and skin. The part of the plant that is most often used as medicine is the leaves, because the leaves are easily obtained in large quantities and are available all the time without depending on the season (Nuraini, 2021).

One type of natural material that has potential as an antibacterial is the noni plant (*Morinda citrifolia* L.) and papaya plant (*Carica papaya*). Antibacterials are compounds that can inhibit the growth or kill disease-causing bacteria. The mechanism of antibacterial action can vary, ranging from damaging the cell wall, disrupting membrane permeability, to inhibiting protein synthesis and bacterial DNA (Magani *et al*., 2020). Currently, the use of natural antibacterial ingredients from plants is increasingly being researched because it is considered safer, environmentally friendly, and has the potential to be an alternative to synthetic antibiotics, especially to overcome the increasing problem of bacterial resistance (AlSheikh *et al*., 2020).

Almost all parts of the two plants are medicinal, especially the leaves. Noni and papaya plants are versatile plants because they have beneficial properties for health, one of which is as an antibacterial agent. The phytochemical components of noni plants are mostly alkaloid compounds (Geofani *et al*., 2022). While the phytochemical components of papaya leaves contain saponin compounds (Nor *et al*., 2018). The purpose of this study was to analyze the differences in the functional groups of noni and papaya leaf extracts as antibacterial agents.

Analysis of the compound's functional groups was carried out using FTIR spectrophotometry. *Fourier transform infrared spectrophotometer* (FTIR) is a tool used to identify the type of chemical bonds (functional groups) that are in the compound (Sumantri *et al.*, 2020). Identification can determine the primary and secondary metabolites present in plant samples. Plant samples are enhanced by FTIR spectrophotometric analysis (Nurfirzatulloh *et al.*, 2023). FTIR spectra involve interactions between chemical compounds in the matrix. Samples in FTIR spectrophotometric testing can be carried out directly without any prior separation stages. (Rafi *et al.*, 2016).

Analysis of the functional groups of compounds in plant extracts is important to determine the content of secondary metabolites that play a role in their biological activity, including as antibacterials. Identification of the compound's functional groups can provide information about the presence of certain chemical bonds related to antibacterial activity. By knowing the dominant functional groups, the antibacterial potential of plant extracts can be linked to the mechanism of action of its bioactive compounds. This is important in efforts to develop herbal medicines based on natural ingredients that are more effective and scientific (Megawati *et al.*, 2023).

2 METHOD

Tools and Materials

- Materials

The materials used in this study were dried papaya and noni leaves, 96% ethanol, labels, and extracts of noni leaves and papaya leaf extracts.

- Tools

The tools used were analytical scales, scissors/knife, dry blender, jar, stirrer, filter paper, funnel, filter cloth, water bath (hot water), rotary evaporator, oven, drying rack, thermometer, measuring cup, measuring pipette, latex, and FTIR spectrophotometry.

Research Procedure

- **Preparation of noni leaf and papaya leaf extracts**

a. Preparation of Materials

Noni leaves (*Morinda citrifolia*) and papaya leaves (*Carica papaya*) are picked and washed with running water to remove dirt and dust. The leaves are dried by airing them in a shaded place (not exposed to direct sunlight) until dry (simplisia).

b. Grinding

The dried leaves are cut into small pieces and then blended or pounded using a mortar and pestle until they become a *coarse* powder. The powder is weighed as needed (e.g., 100 g).

c. Extraction Process (Maceration)

The powder is placed in a *sealed* glass container/jar. Add 70% ethanol solvent at a ratio of 1:10 (100 g powder + 1000 mL ethanol). Soak for 3 × 24 hours at room temperature, stirring occasionally with a shaker for optimal extraction.

d. Filtration

After 3 days, filter the mixture using filter paper/flannel cloth. Collect the filtrate (filtered liquid) in a dark glass container. The leaf *residue* can be re-extracted with fresh solvent to increase the yield.

e. Solvent Evaporation

The filtrate is concentrated by *evaporation* using a rotary evaporator at a temperature of ±40–50 °C (or with a water bath at a low temperature; avoid excessive heat to prevent damage to the compounds). Continue until a thick extract (concentrated extract) is obtained.

f. Storage

The thick extract is placed in a tightly sealed dark glass bottle. Store in a refrigerator or cool place, protected from direct light.

- **Analysis using FTIR spectrophotometry**

Before conducting the experiment, turn on the FTIR spectrophotometry testing device and the computer connected to the software used for analysis, then place the sample in the sample holder. Operate the FTIR device to produce the FTIR spectrum of the sample, then read the FTIR spectrum by comparing it with the FTIR table.

Data Analysis

This study is a laboratory experimental study with a qualitative-quantitative approach. The analysis was conducted through the identification of bioactive compound functional groups in noni leaf extract (*Morinda citrifolia*) and papaya leaf extract (*Carica papaya*) using FTIR spectrophotometer instruments, and was related to their antibacterial activity potential based on literature and supporting tests.

Literature Study

The literature study in this research focused on researching and searching for various journals relevant to the analysis of functional groups of bioactive compounds in noni leaves (*Morinda citrifolia*) and papaya leaves (*Carica papaya*) using FTIR spectrophotometry. This literature review included the identification of dominant secondary metabolites in both plants, such as alkaloids in noni leaves and saponins in papaya leaves. In addition, the literature study was also used to find the role of bioactive compounds in antibacterial activity. Thus, this literature review serves as the basis for determining the FTIR bands to be observed, comparing the research results with previous data, and linking the differences in functional groups with the antibacterial mechanisms of each extract

3 RESULT

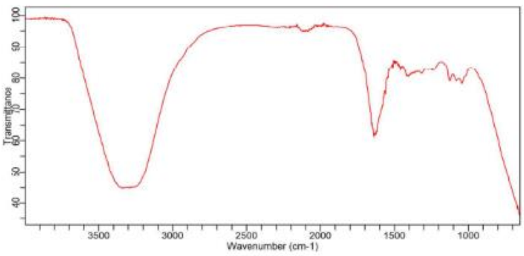

Figure 1. FTIR curve of mangosteen leaf extract

The results of FTIR spectrophotometry analysis of noni leaf extract (Figure 1) show characteristic absorption at several wavelengths. There is a broad absorption band in the region around 3400 cm⁻¹, indicating the presence of –OH groups from phenolic compounds or alcohols. In addition, absorption in the region around 1635 cm⁻¹ indicates the presence of C=O groups from carbonyl compounds, which are commonly found in alkaloids or flavonoids. Absorption in the region around 2920 cm⁻¹ also indicates C-H groups from aliphatic compounds. This pattern confirms that noni leaf extract contains bioactive alkaloid compounds known to have antibacterial activity (Zhang *et al*., 2016).

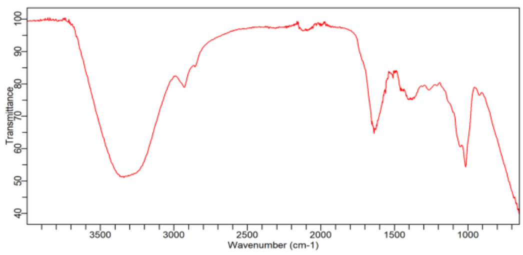

Figure 2. FTIR curve of papaya leaf extract

Meanwhile, FTIR results on papaya leaf extract (Figure 2) show several peaks that differ from those of mengkudu leaves. Strong absorption in the 3400 cm⁻¹ region also indicates hydroxyl groups (–OH), but it appears more intense than in mengkudu extract, indicating the dominance of polar compounds such as saponins. In addition, the absorption band at 1050–1150 cm⁻¹ is characteristic of C–O–C glycoside bonds, which supports the presence of saponin compounds. The peak at around 2925 cm⁻¹ also indicates aliphatic C-H groups, while the absorption at 1637 cm⁻¹ indicates the presence of aromatic C=C groups. The presence of saponins as the dominant compounds in papaya leaf extract is known to have antibacterial activity (Soranta, 2009).

The main difference between the two extracts is seen in the dominance of their bioactive compounds. Moringa leaves are more prominent in their alkaloid content, as indicated by the absorption at the characteristic carbonyl (C=O) and amine (N–H) groups. In contrast, papaya leaves are prominent in the presence of saponins, as indicated by intense absorption of glycoside (C–O–C) and hydroxyl (–OH) groups. Both compounds contribute to the antibacterial properties of the extract, albeit through different mechanisms, so that the use of both has the potential to complement each other in phytopharmaceutical applications.

4 DISCUSSION

Samples in the FTIR spectrophotometry practicum were extracted using the maceration method. The maceration process was carried out by soaking the samples in an organic solvent, namely ethanol. Ethanol was used as a solvent because it can dissolve compounds with various levels of polarity, ranging from polar to nonpolar. In addition, ethanol is considered safer than other organic solvents (Muis, 2017). In this study, the samples used were from moringa leaves and papaya leaves. The samples were tested using FTIR spectrophotometry with the following results:

Morinda citrifolia leaf extract

FTIR spectrophotometry analysis of *Morinda citrifolia* leaf extract (Figure 1) shows several characteristic absorptions, namely amine and amide groups (N–H) at a wavelength of 3335.97 cm^{-1}, ether groups (C–O) at 1045.52 cm^{-1} and 1082.79 cm^{-1}, and ether groups (C=O) at 1125.66 cm^{-1}. In addition, amine and amide groups (C–N) were also detected at 1313.89 cm^{-1}, as well as alkene groups (C=C) at 1638.16 cm^{-1}. The presence of absorption at the alkene number (C=C) indicates the presence of alkaloid compounds in noni leaf extract.

Table 1. Results of functional group analysis of noni leaf extract

No	Wave Number	Function Group	Intensity
1	1045,518 26	Eters (C-O)	strong
2	1082,791 64	Alchohol, ethers, carboxylc acids, esters (C-O)	strong
3	1125,656 03	Alchohol, ethers, carboxylc acids, esters (C=O)	strong
4	1313,886 59	Amines, Amides (C-N)	strong
5	1638,164 98	Alkenes (C=C)	Variabel
6	2107,809 55	Alkynes (C≡C)	Variabel
7	3335,967 36	Amines, Amides (N-H)	Variabel

Morinda citrifolia contains alkaloids, flavonoids, saponins, and tannins (Priamsari *et al.,* 2019). However, the most prominent compound in mengkudu leaves is alkaloids. This is evidenced by the data in Table 1, where the wavelength number 3335.96736 cm^{-1} indicates the presence of an N-H functional group with an absorption band, and the wavelength number 1313.88659 cm^{-1} indicates the presence of a C-N bond, which is characteristic of alkaloids. In addition, a carbonyl group (C=O) with a sharp but weak absorption at 1125.65603 cm^{-1} was also detected, as well as vibrations in the double bond of alkenes (C=C) (Aksara *et al.*, 2013).

Alkaloids are one of the most commonly found types of secondary metabolites and contain nitrogen atoms (Gusmiarni & Des, 2021). Alkaloids are secondary metabolites that have basic properties and contain one or more nitrogen atoms, usually bound in a ring or cyclic system (Wink, 2008). Alkaloids can be found in various parts of plants, including flowers, seeds, leaves, twigs, roots, and bark. Alkaloid compounds are usually found in relatively small amounts and need to be separated from the complex mixture of other compounds present in plant tissues (Ningrum *et al*., 2016).

Alkaloid compounds are known to have various biological activities, one of which is their role as antibacterial agents (Rukmana *et al*., 2024). Based on several studies, one of the biological activities that is often tested is the antibacterial activity of alkaloids against Staphylococcus aureus bacteria. *Staphylococcus aureus* is one of the most common infectious disease-causing bacteria worldwide. This bacterium is invasive and belongs to the gram-positive pathogen group (Widiastuti *et al*., 2019). The presence of S. aureus is known to be the main trigger of various health disorders, ranging from abscesses, pneumonia, endocarditis, meningitis, sepsis, to problems such as acne (Novianti & Wirnawati, 2024).

Staphylococcus aureus bacteria are Gram-positive bacteria that cause inflammation and are involved in the pathogenesis of acne. *Staphylococcus aureus* can trigger a significant inflammatory response in clogged hair follicles, causing inflammatory symptoms such as redness, swelling, and pain. In existing acne lesions or damaged skin, *Staphylococcus aureus* can cause secondary infections, which worsen the condition of acne and potentially lead to the formation of more severe lesions such as pustules or nodules. In addition, the ability of *Staphylococcus aureus* to form biofilms can make acne more persistent (Novianti & Wirnawati, 2024). Alkaloids are a class of compounds that exhibit antibacterial activity against Staphylococcus aureus (Sasebohe *et al*., 2024)

Based on research conducted by Mabhiza *et al.* (2016), alkaloids do indeed exhibit antibacterial activity against *Staphylococcus aureus*. Alkaloids from *Callistemon citrinus* and *Vernonia adoensis* showed significant ability to inhibit the growth of *Staphylococcus aureus*. At a concentration of 1.67 mg/mL, alkaloids were able to inhibit bacterial growth with an effect comparable to ampicillin, a standard antibiotic. Alkaloids from *C. citrinus* proved to be the most effective against *S. aureus*, with a Minimum Inhibitory Concentration (MIC) of 0.0025 mg/mL and a Minimum Bactericidal Concentration (MBC) of 0.835 mg/mL, indicating a bactericidal effect or the ability to kill bacteria directly. Meanwhile, alkaloids from V. adoensis also showed antibacterial activity against S. aureus with an MIC of 0.21 mg/mL, but the effect was bacteriostatic or the ability to inhibit the growth and reproduction of bacteria, but not kill the bacteria directly.

Research conducted by Sasebohe *et al.* (2024) using Binahong (*Anredera cordifolia*) leaf extract containing alkaloids, steroids, flavonoids, and phenols showed effectiveness in inhibiting the growth (bacteriostatic) of *Staphylococcus aureus* bacteria. The effective concentration of Binahong leaf extract varies depending on the testing method. When tested using the diffusion method, inhibition zones were observed at concentrations of 10% (1.7 mm), 15% (2.0 mm), and 20% (2.6 mm), indicating that increasing concentrations resulted in larger inhibition zones. Meanwhile, using the dilution method, a concentration of 25% proved to be effective. Furthermore, Binahong leaf fraction has a Minimum Inhibitory Concentration (MIC) value of 512 mg/ml against *Staphylococcus aureus*, indicating significant antibacterial potential.

The mechanism of antibacterial activity of alkaloids in *Staphylococcus aureus* is by disrupting the function of topoisomerase enzymes in bacterial cells. Topoisomerase enzymes are crucial in the processes of bacterial DNA replication, transcription, and recombination. Therefore, by disrupting these enzymes, alkaloids inhibit the bacteria's ability to multiply and perform their essential genetic functions. Alkaloids can also intercalate with bacterial DNA. Intercalation means that alkaloids insert themselves between DNA base pairs, causing changes in the structure of the DNA double helix. These changes can disrupt DNA replication and transcription, thereby inhibiting bacterial growth and survival (Sasebohe *et al.*, 2024). Alkaloids damage the part that forms the peptidoglycan of bacterial cells. Peptidoglycan is the main component of the cell wall of Gram-positive bacteria such as *Staphylococcus aureus*, which provides structural strength and protects the cell from osmotic pressure. Damage to peptidoglycan formation results in the bacterial cell wall not being perfectly structured (Ningsih & Zusfahair, 2016).

In addition to damaging its formation, alkaloids also interfere with peptidoglycan synthesis itself. This means that the process of bacterial cell wall formation is inhibited or does not proceed properly. As a result of interference with peptidoglycan formation and synthesis, the bacterial cell wall becomes incomplete or does not function optimally. The bacterial cell becomes incomplete because its cell wall is only composed of a cell membrane without complete peptidoglycan. This condition causes the bacterial cell to not function properly and eventually die (Retnowati *et al.*, 2011). Based on several studies that have been conducted, it can be concluded that alkaloids can be an alternative solution for treating acne through their antibacterial activity against one of the bacteria that plays a role in the formation of acne, namely Staphylococcus aureus.

Papaya Leaf Extract

The results of FTIR spectrophotometry analysis of papaya leaf extract (Figure 6) show the absorption of ether groups (C–O) at wavelengths of 1015.69956 cm^{-1} and 1051.10927 cm^{-1}. In addition, absorption of alkane groups (C–H) was also detected at 1399.61536 cm^{-1} and 2927.82387 cm^{-1}. Absorption from alkena groups (C=C) was observed at wavelengths of 1638.16498 cm^{-1}, while hydroxyl groups (O–H) were identified at 3337.83103 cm^{-1}, indicating that these groups are included in saponin compounds. Details of the absorption of functional groups related to saponins can be seen in Table 6.

Table 6. Results of the analysis of the functional groups of papaya leaf extract

No	Wave Number	Functio Group	Intensity
1	1015,699 56	Eters (C-O)	strong
2	1051,109 27	eters (C-O)	Strong
3	1399,615 36	Alkanes (C-H)	strong
4	1638,164 98	Alkenes (C=C)	Variabel
5	2927,823 87	Alkanes (C-H)	strong
6	3337,831 03	Alkohol (O-H)	Variabel sometimes broad

Papaya leaves are known to contain bioactive compounds such as alkaloids, flavonoids, glycosides, saponins, tannins, and steroids or triterpenoids (Kurniasari *et al.*, 2019). However, the most prominent compound in papaya leaf extract is saponin. This can be seen in Table 6, where papaya leaf ethanol extract shows a fairly broad absorption at a wavelength of 3337.83103 cm^{-1}, indicating the presence of an O-H group. In addition, there is an aliphatic C-H stretching vibration at a wavelength of 2927.82387 cm^{-1}, which is then reinforced by the presence of an alkane C-H bending vibration at 1399.61536 cm^{-1}. The characteristic indicators of saponins are also evident with the discovery of C-O groups at wavelengths of 1015.69956 cm^{-1} and 1051.10927 cm^{-1}. Therefore, the presence of C-O, C-H, and O-H groups is a key indicator that saponin compounds are indeed contained in papaya leaf extract.

Saponins are a type of glycoside commonly found in various types of plants. Saponins belong to a complex group of secondary metabolites with relatively large molecular masses (Gunawan, 2018). Chemically, saponins are classified as complex glycosides formed from bonds between sugar molecules and organic compounds that have hydroxyl groups. This distinctive structure gives saponins soap- or detergent-like properties, making them known as natural surfactants (Bintoro *et al.*, 2017). Saponin compounds are known to have various properties, such as anti-inflammatory and antimicrobial (Melina *et al*., 2022). Saponin can also play a role in inhibiting bacterial growth (Medika, 2024).

One of the bacteria commonly used to test the antibacterial activity of saponins, according to several studies, is *Escherichia coli*. *Escherichia coli* bacteria live naturally in the intestines of humans and animals and are generally excreted in feces (Zikra *et al*., 2018). The presence of *E. coli* also plays a role in helping the process of removing metabolic waste in the digestive tract (Puteri & Milanda, 2016). *Escherichia coli* is also one of the bacteria that cause infections commonly found in our environment (Magani *et al*., 2020).

Escherichia coli (E. coli) is one of the most common microorganisms that cause diarrhea. Research conducted by Hutasoit (2020) shows that *Escherichia coli* can become pathogenic and cause diarrhea if its numbers increase in the digestive tract or if it is outside the intestine. There are four main types of E. coli that cause diarrhea in humans: Enterotoxigenic *E. coli* (ETEC), which produces enterotoxins that affect intestinal fluid secretion; Enteroinvasive E. coli (EIEC), which invades intestinal cells; Enteropathogenic *E. coli* (EPEC), which causes intestinal atrophy and necrosis, especially in children; and Enterohemorrhagic *E. coli* (EHEC), which forms colonies and causes atrophy in intestinal epithelial cells. E. coli contamination can occur through direct contact, cross-contamination, or recontamination. These bacteria can also cause various digestive problems such as cholera and gastroenteritis, with most studies showing that *E. coli* contamination plays a role in diarrheal diseases.

According to several studies, saponins are known to have antibacterial activity against *Escherichia coli*. Based on research conducted by Hidayati *et al*. (2023), saponin compounds contained in ethanol extracts of Hibiscus tiliaceus L. leaves were proven to have antibacterial activity against Escherichia coli. The presence of saponins was confirmed through phytochemical screening in all extraction methods used, and the results of antibacterial activity tests showed an inhibition zone against E. coli. This study tested ethanol extracts of *Hibiscus tiliaceus* L. leaves at concentrations of 1%, 2%, 3%, 4%, and 5%. The results showed that all concentrations were effective in inhibiting the growth of *E. coli*, with the diameter of the inhibition zone tending to increase with increasing concentration. For example, extracts produced by the maceration method showed an average inhibition zone diameter of 9.82 pm ± 0.70 mm at a concentration of 1% and 12.72 pm ± 1.60 mm at a concentration of 5% against *E. coli*. Based on research conducted by Khan et al. (2018), saponins isolated from green tea seeds showed significant antibacterial activity against Escherichia coli. Saponins were found to inhibit the growth of *E. coli* at a dose of 100 mg/ml. The minimum inhibitory concentration (MIC) for saponins against Escherichia coli was 0.20 mg/mL. The measured inhibition zone (IZ) for saponins was 10 ± 1.33 mm.

The main mechanism of saponins as effective antimicrobial agents is by inhibiting bacterial growth. Saponins inhibit bacterial growth by reducing the surface tension of bacterial cell walls. This reduction in surface tension can disrupt the structural integrity of bacterial cell walls, making them more susceptible to damage (Hidayati *et al.*, 2023). The antibacterial mechanism of saponins involves damage to the cell walls and membranes of bacteria, as evidenced by an increase in alkaline phosphatase (AKP) and soluble protein levels after exposure to saponins. The increase in AKP indicates leakage due to cell wall damage, while the increase in soluble protein indicates membrane damage that causes the release of cell contents (Khan *et al.*, 2018).

5 CONCLUSIONS

Based on the results of FTIR spectrophotometry analysis, noni leaf extract (Morinda citrifolia) was identified as containing alkaloid compounds with dominant functional groups of N–H, C–N, and C=C that play a role in antibacterial activity, particularly against Staphylococcus aureus bacteria, which is known as one of the main causes of skin infections such as acne. Meanwhile, papaya leaf extract (Carica papaya) showed the presence of saponin compounds with O–H, C–H, and C–O functional groups that act as antibacterial agents against Escherichia coli, a pathogenic bacterium often associated with diarrhea. These findings confirm that both plants have the potential as sources of bioactive compounds with different mechanisms of action, making them natural alternatives in the development of antibacterial agents.

6 SUGGESTIONS

Further research should be conducted using in vitro and in vivo antibacterial testing methods to confirm the antibacterial activity of moringa and papaya leaf extracts. In addition, isolation and purification of the main active compounds need to be carried out to determine their specific effectiveness and to determine the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC). Exploring combinations of noni and papaya extracts is also important to determine their synergistic potential in inhibiting the growth of various types of pathogenic bacteria. In terms of application, the results of this study can be used as a basis for the development of phytopharmaceuticals or herbal antibacterial products that are safe, inexpensive, and environmentally friendly.

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