Available online at Portal Jurnal UNSRAT

Jurnal Ilmiah PLATAX

Journal homepage: https://ejournal.unsrat.ac.id/v3/index.php/platax

ARTIKEL PENELITIAN / RESEARCH ARTICLE

e-ISSN 2302-3589

Karakterisasi Gugus Fungsional Senyawa Bioaktif yang Diekstrak dari Buah Mangrove *Rhizophora apiculata*

Characterization of Functional Groups of Bioactive Compounds Extracted from Rhizophora apiculata Mangrove Fruit

Running title: Functional Groups of Bioactive Compounds in *R. apiculata*

Darus Sa'adah J. Paransa[1*], Kurniati Kemer[1], Rignolda Djamaludin[1], Desy Maria Helena Mantiri[1], Rene Charles Kepel[2], Dininurilmi Putri Suleman[3]

[1]*Marine Science Study Program, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Manado 95115, Indonesia*

[2]*Aquatic Resources Management Study Program, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Manado 95115, Indonesia*

[3]*Agricultural Product Technology Study Program, Vocational School, Sebelas Maret University, Surakarta 57126, Indonesia*

Abstract

The mangrove fruit *Rhizophora apiculata* is known to contain various potential bioactive compounds, but information about the characterization of its chemical functional groups is still limited. This study aimed to identify the main functional groups in *R. apiculata* fruit extracts using Fourier Transform Infrared Spectroscopy (FTIR). The analysis was carried out using two types of extracts, namely ethanol extract and base–acid extract (NaOH + CH_3COOH), using a Bruker Alpha II ATR-based FTIR instrument in the range of 4,000–600 cm-1 with a resolution of 4 cm-1 and 32 scans. The FTIR spectrum of the ethanol extract showed dominant absorption bands of O–H (3100–2500 cm-1), C=O (1,725–1,700 cm-1), and C–O (1,320–1,211 cm-1) indicating the presence of carboxylic acids, esters, and ketones. In the base–acid extract, the spectrum profile became more complex with the detection of additional bands of N–H (3,360–3,100 cm-1) and amide II (1,570–1,515 cm-1), suggesting the presence of nitrogen-based compounds as well as the Si–O/Si–OH band (1,040–830 cm-1) from silica minerals. The differences in the spectral profiles indicate that the extraction method significantly affects the types of metabolites detected, with acid–base extracts being more effective at extracting polar compounds. These results reinforce the potential of *R. apiculata* fruit as a source of functional food materials rich in bioactive compounds, but further studies are still needed for definitive molecular identification.

Keywords: Mangrove, *Rhizophora apiculata*, mangrove fruit, FTIR, functional groups, bioactive compounds

Abstrak

Buah mangrove *Rhizophora apiculata* diketahui mengandung berbagai senyawa bioaktif yang berpotensi dimanfaatkan, tetapi informasi mengenai karakterisasi gugus fungsional kimianya masih terbatas. Penelitian ini bertujuan mengidentifikasi gugus fungsional utama pada ekstrak buah *R. apiculata* menggunakan Fourier Transform Infrared Spectroscopy (FTIR). Analisis dilakukan pada dua jenis ekstrak, yaitu ekstrak etanol dan ekstrak basa–asam (NaOH + CH_3COOH), menggunakan instrumen FTIR Bruker Alpha II berbasis ATR pada rentang 4,000–600 cm-1 dengan resolusi 4 cm-1 dan 32 pemindaian. Spektrum FTIR ekstrak etanol menunjukkan pita serapan dominan O–H (3.100–2.500 cm-1), C=O (1.725–1.700 cm-1), dan C–O (1.320–1.211 cm-1) yang mengindikasikan keberadaan asam karboksilat, ester, dan keton. Pada ekstrak basa–asam, profil spektrum menjadi lebih kompleks dengan munculnya pita tambahan N–H (3.360–3.100 cm-1) dan amida II (1.570–1.515 cm-1), yang menunjukkan keberadaan senyawa berbasis nitrogen serta pita Si–O/Si–OH (1.040–830 cm-1) dari mineral silika. Perbedaan profil spektrum menunjukkan bahwa metode ekstraksi berpengaruh terhadap jenis metabolit yang terdeteksi, dengan ekstrak basa–asam lebih efektif mengekstraksi senyawa polar. Hasil ini memperkuat potensi buah *R. apiculata* sebagai bahan pangan fungsional yang kaya senyawa bioaktif, tetapi penelitian lanjutan masih diperlukan untuk identifikasi molekuler yang lebih definitif.

Kata kunci: Mangrove, Rhizophora apiculata, buah mangrove, FTIR, gugus fungsi, senyawa bioaktif

1. Introduction

Mangroves are a group of coastal plants that have a high ability to adapt to extreme environments, such as high salinity, temperature fluctuations, and low oxygen conditions. This adaptability is related to the production of various secondary metabolites, including phenolic compounds, flavonoids, terpenoids, sterols, and pigments, which are known to have potential biological activities (Gao & Xiao, 2012; Abdel-Aziz et al., 2016; Dahibhate et al., 2018). In R. apiculata, experimental studies have reported phenolic-rich extracts and antioxidant, antimicrobial, and related biological activities, supporting the need for chemical characterization of this species (Ramalingam & Rajaram, 2018; Acharya et al., 2023). Mangrove fruits also contain diverse secondary metabolites; for example, phytochemical

Received: 2 September 2026 Revised: 6 September 2026 Accepted: 8 September 2026

***Corresponding author: Darus Sa'adah J. Paransa**

Marine Science Study Program, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Manado 95115, Indonesia

Tel: +62-82187654321, E-mail: darusparansa@unsrat.ac.id

https://doi.org/ 10.35800/jip.v14i2.69815

screening has detected phenolics, flavonoids, tannins, saponins, and alkaloids in Sonneratia alba fruit material (Tahulending et al., 2023). Subcritical water extraction of S. alba mangrove fruit has potential as a functional food with antioxidant activity from the flavonoid and tannin content (Wonggo et al., 2024). Mangrove fruits from the species Rhizophora apiculata have begun to be used for functional foods, for processing into mangrove coffee (Abubakar et al., 2023).

The fruit of the mangrove *R. mucronata* has been made into functional food in the form of mangrove coffee (Prihatiningsih et al., 2024). The use of *R. apiculata* mangrove fruit as a functional food has potential as a high-value raw material. In addition, some previous studies have also reported that various mangrove species contain bioactive compounds that are interesting to explore further. However, information on the chemical characterization of *R. apiculata* fruit, especially through functional group analysis using Fourier Transform Infrared Spectroscopy (FTIR), is still limited. According to Smith (2011), FTIR is one of the analytical methods used to identify functional groups based on the vibration of chemical bonds in a compound. This technique provides preliminary information about the chemical components in a sample, although it cannot yet be used to specifically identify molecular structures. Therefore, this study was conducted to analyze the functional group characteristics of the mangrove fruit extract *R. apiculata* as a basis for understanding its chemical characteristics and the potential compounds it contains.

The success of identifying bioactive compounds does not depend on the potential of the natural materials themselves, but is also heavily influenced by the extraction methods used. A comprehensive review by Gil-Martín et al. (2022) points out that factors such as the type of solvent, pH, and temperature are crucial variables that affect the release and stability of phytochemicals, especially phenolic compounds. Experimental studies on *R. apiculata* have also demonstrated that extraction conditions can influence the composition and biological properties of the resulting extracts (Kannappan et al., 2018). Therefore, this study not only identifies functional groups but also compares two different extraction methods to examine their impact on the metabolite profile.

2. Materials and Methods

2.1. Study period and location

This study was conducted in 2025, with samples taken from *Rhizophora apiculata* mangrove fruit in a tourist village in Wori Sub-district, North Minahasa Regency, North Sulawesi (1.589–1.591° N and 124.837–124.839° E). Fourier Transform Infrared (FTIR) spectroscopic analysis, using an ATR-based Bruker Alpha II FTIR instrument, was carried out at the North Sulawesi Regional Police Forensic Laboratory.

2.2. Data collection

The fruits of the mangrove *R. apiculata*, which are brownish in color, were air-dried at room temperature for 7 days and then ground into a fine powder. Next, 10 grams of this fine mangrove R. apiculata fruit powder were macerated with 25 ml of PA ethanol for 3 days. Each day, the extract was filtered, collected, and stored in the refrigerator. The filtered extract was then mixed with PA hexane solution, evaporated, and dissolved in PA ethanol, resulting in a polar ethanol extract of mangrove *R. apiculata*. The ethanol extracts were then treated by adding a base-acid solution (10 mL of 1 M NaOH for 30 min, followed by neutralization with 1 M CH_3COOH), and this became the second extract. Both extracts were then taken for FTIR analysis. The difference in treatment was based on the consideration that modifying the extraction conditions, referring to (Gil-Martín et al., 2022), especially adjusting the pH and choosing the solvent, proves to be a strategic way to promote the desorption and solubilization of target compounds from the sample matrix.

2.2.1. Laboratory analysis

Functional-group characterization was performed using Fourier Transform Infrared (FTIR) spectroscopy with Attenuated Total Reflectance (ATR) mode. In this technique, the extract was placed directly on the ATR crystal (diamond), and infrared radiation was directed through the crystal at a controlled angle, allowing evanescent-wave interaction with the sample surface without requiring additional sample preparation such as pellet formation or thin-film deposition. The spectra were processed using the spectrometer software, including background correction, normalization, smoothing, and interpretation. The use of infrared spectroscopy for chemical characterization was supported by established spectrochemical methodology (Bhargava & Levin, 2005).

Measurements were performed using a Bruker Alpha II FTIR spectrometer in Attenuated Total Reflectance (ATR) mode over 4,000–600 cm^{-1}, with a resolution of 4 cm^{-1} and 32 scans. These settings were selected to provide adequate spectral quality and reproducibility. The absorption bands were interpreted by comparison with established infrared spectral assignments, particularly in the characteristic and fingerprint regions (Ferraro & Basile, 1978).

2.3. Data analysis

All measurements were performed in triplicate (n = 3), and the reported spectra represent the average of three replicate scans. Spectral data processing was carried out using the OPUS software (Bruker Optik GmbH, Ettlingen, Germany), and included background subtraction (atmospheric CO_2 and H_2O correction), baseline correction, normalization to the highest-intensity band, smoothing with a Savitzky–Golay function (9-point window), and peak-picking at minima in the second-derivative spectrum. Each identified absorption peak was assigned to a functional group based on its wavenumber position, and the assignments were validated against established infrared spectral reference data for functional groups such as O–H, C=O, C–O, C–N, and N–H (Ferraro & Basile, 1978; Smith, 2011).

3. Results

The FTIR spectrum of the ethanol extract (Figure 1) showed dominant absorption bands associated with polar organic compounds, particularly hydroxyl, carbonyl, and C–O-containing structures. The interpretation was based on the characteristic wavenumber regions of the detected vibrations, as summarized in Table 1.

Figure 1. FTIR spectrum of *R. apiculata* mangrove extract in ethanol

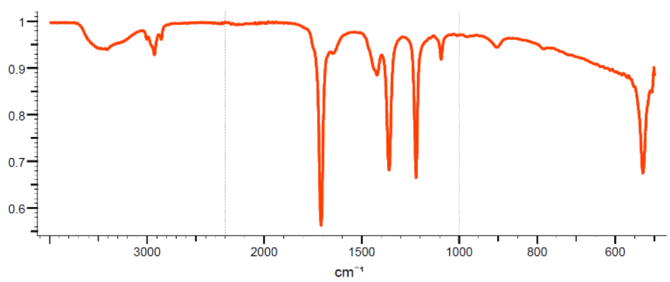

Table 1. Identification of functional groups absorbed in FTIR of R. apiculata mangrove fruit extract in ethanol

No	Wave number (cm^{-1})	Intensity	Functional group interpretation	Interpretation of molecular meaning
1	3,100–2,500	wide	O–H stretching	carboxylic acid
2	1,725–1,700	strong	C=O stretching	carbonyl, carboxylate, ketone
3	1,740–1,715	strong	C=O stretching	unsaturated ester
4	1,700–1,680	strong	C=O stretching	aryl ketone
5	1,320–1,211	strong	C–O stretching	carboxylate, ester
6	1,440–1,395	strong	O–H deformation	carboxylate
7	960–875	medium	O–H deformation	H-bonding

The broad band at 3,100–2,500 cm^{-1} was assigned to O–H stretching associated with hydrogen-bonded hydroxyl groups, including those occurring in carboxylic acids and phenols. The sharp absorption at 1,725–1,700 cm^{-1} corresponded to C=O stretching, which may occur in carboxylic acids, esters, or ketones. The simultaneous presence of hydroxyl and carbonyl absorptions indicates a chemically diverse polar extract and is consistent with the occurrence of phenolic constituents previously reported for R. apiculata.

Additional bands at 1,740–1,715 cm^{-1} and 1,700–1,680 cm^{-1} further indicated carbonyl-containing structures, while the strong absorption at 1,320–1,211 cm^{-1} was assigned to C–O stretching. Taken together, these bands suggest that the ethanol extract contains oxygenated organic compounds, including acid, ester, alcohol, and related carbonyl structures.

The absorption pattern was comparable with FTIR observations reported for other mangrove extracts, in which O–H, C=O, and C–O bands were prominent in the spectra of natural-product fractions (Pancapalaga et al., 2023).

The FTIR profile of the *R. apiculata* extract treated with base-acid is presented in Figure 2 and is more complex than the pure ethanol extract. The difference in profiles is a direct result of the increased diversity of chemical components extracted, which also highlights the analytical power of FTIR in detecting multicomponent mixtures. The base treatment (NaOH) followed by acid neutralization (CH_3COOH) aims to break ester bonds and improve the solubility of polar compounds, so that bound phenolic compounds and nitrogen-based compounds (amides, alkaloids) can be identified (Table 2).

Figure 2. FTIR spectrum of *R. apiculata* fruit extract in acid-base

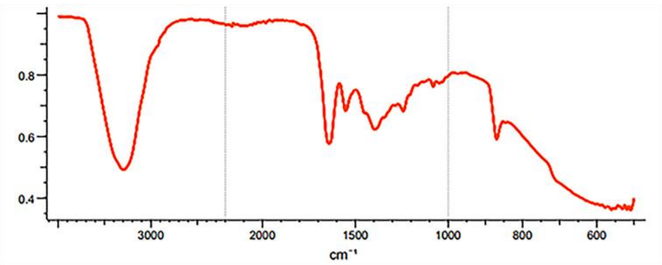

Table 2. Identification of functional groups absorbed in FTIR of *R. apiculata* fruit extract in acid-base

No	Wave number (cm^{-1})	Intensity	Functional group interpretation	Interpretation of molecular meaning
1	3,360–3,100	medium	N–H stretching	Amide/thioamide (protein/peptide derivatives)
2	3,350–3,200	variable	O–H stretching	Phenol, as an antioxidant agent
3	3,100–2,900	variable	O–H stretching	Carboxylic acid (appears)
4	1,750–1,650	Strong	C=O (Amida I)	The carbonyl in amide, ketone, or acid structures
5	1,670–1,650	Strong	C=O (H-bond)	Carbonyl with internal hydrogen bonding
6	1,570–1,515	medium–strong	Amida II	Combined vibration (C–N stretching + N–H bending)
7	1,320–1,211	Strong	C–O stretching	Carboxylate, ester, phenol
8	1,260–1,180	Strong	C–O stretching	Specifically for phenolic alcohol
9	1,040–830	Strong	Si–O / Si–OH	Natural silica (mineral from the sea)
10	960–875	medium	O–H deformation	Carboxylate deformation

The N–H stretching band at 3,360–3,100 cm^{-1} indicates the presence of secondary amide groups from amides or thioamides, which are derivatives of proteins or peptides. A strong peak at 1,750–1,650 cm^{-1} shows C=O vibration (Amide I) from the carbonyl group in amide, ketone, or acid structures. The band at 1,570–1,515 cm^{-1} is a combined C–N stretching and N–H bending vibration (Amide II). The appearance of these N–H and Amide II bands suggests the presence of nitrogen-based compounds like alkaloids or proteins/peptides.

The O–H band at 3,350–3,200 cm^{-1} is consistent with hydrogen-bonded hydroxyl groups commonly associated with phenolic constituents. Phenolic functional groups are important in plant extracts because they may contribute to antioxidant properties; FTIR profiling is therefore useful as a preliminary qualitative tool for recognizing such chemical features (Dev & Mukadam, 2025).

The Si–O/Si–OH band in the 1,040–830 cm^{-1} region suggests the possible presence of silicate-containing mineral material in the extract. Because FTIR spectra of biological samples may contain overlapping organic and inorganic signals, this assignment should be treated as a preliminary indication rather than definitive mineral identification.

The possible mineral-related signal is also compatible with the observation that mangrove tissues can contain inorganic elements in addition to organic secondary metabolites. Previous work on R. apiculata has demonstrated that FTIR spectra can contain multiple oxygen-, nitrogen-, and other heteroatom-containing functional groups, illustrating the multicomponent nature of mangrove extracts (Wen et al., 2020).

4. Discussion

The difference between the two extraction profiles indicates that extraction conditions influence the chemical functionalities detected by FTIR. The ethanol extract was characterized mainly by O–H, C=O, and C–O absorptions, whereas the acid–base treatment produced additional N–H/amide-related and mineral-associated bands. This supports the use of complementary extraction conditions when the objective is to obtain a broader preliminary chemical profile. Importantly, the FTIR results should be interpreted as functional-group evidence rather than definitive compound identification. For R. apiculata, previous work has demonstrated that extraction fractions contain different functional groups and phenolic acids, while more recent FTIR-based studies have reported hydroxyl, amino, carbonyl, and carboxyl-related groups in its extracts (Othman et al., 2020; Santhosh et al., 2025).

The broader profile observed after acid–base treatment is consistent with the known chemical complexity of R. apiculata extracts, which may contain phenolic, tannin, nitrogen-containing, and other bioactive constituents. Recent studies combining FTIR with phytochemical or chromatographic approaches have similarly demonstrated that several functional groups can coexist in R. apiculata extracts. Therefore, the present findings provide a useful preliminary chemical characterization, while targeted techniques such as GC–MS, LC–MS, or NMR would be required to confirm individual molecular structures. Environmental and physiological conditions can also influence antioxidant responses in mangrove species, reinforcing the need to interpret chemical profiles in relation to sample and extraction conditions (Chan-Keb et al., 2025).

5. Conclusion

FTIR analysis of *R. apiculata* extract successfully identified the main functional groups, namely O–H, C=O, C–O, N–H, and C–N, which represent the presence of phenolic compounds, organic acids, esters, ketones, as well as nitrogen-based compounds. The ethanol extract was dominated by carboxyl and ester groups, while the acid–base extract showed a more complex profile with the appearance of amine and amide bands, indicating increased efficiency in extracting polar compounds.

Competing interests

The authors declare no competing interests relevant to this article.

Funding sources

The study was funded by Sam Ratulangi University through the 2025 DIPA No. 806/UN12.27/LT/2025 via RDUU_K1 2025.

Acknowledgements

The authors thank the Head of the Forensic Laboratory of the North Sulawesi Regional Police for granting access to the Bruker Alpha II FTIR instrument used in this study, and all field assistants who supported sample collection in Wori Sub-district.

Author Contributions (CRediT)

DSP: Conceptualization, Methodology, Formal analysis, Investigation, Writing — original draft, Writing — review & editing, Project administration. KK: Investigation, Data curation, Writing — review & editing. RD: Investigation, Supervision, Writing — review & editing. DMHM: Investigation, Formal analysis, Writing — review & editing. RCK: Supervision, Validation, Writing — review & editing. DNS: Formal analysis, Visualization, Writing — review & editing.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

Ethical approval was not required because the study used plant material and computational analyses and did not involve humans or experimental animals.

ORCID

Darus Sa'adah J. Paransa: https://orcid.org/0000-0002-1147-5007
Kurniati Kemer : https://orcid.org/0000-0001-7814-1688
Rignolda Djamaludin: https://orcid.org/0000-0002-6981-6636
Desy Maria Helena Mantiri: https://orcid.org/0000-0003-2606-2229
Rene Charles Kepel: https://orcid.org/0000-0001-5003-9462
Dininurilmi Putri Suleman: https://orcid.org/0000-0002-1381-3444

References

Abdel-Aziz, S.M., Mouafi, F.E., Moustafa, Y.A., & Abdelwahed, N.A.M. (2016). Medicinal importance of mangrove plants. In S.M. Abdel-Aziz (Ed.), Mangrove Ecosystems: Ecology and Function (pp. 77–96). Springer. https://doi.org/10.1007/978-3-319- 25277-3 5

Abubakar, S., Kadir, M.A., Subur, R., Rina, A.H., Fadel, M.S., Al Hadad, W., Susanto, A.N., Salim, F.D., & Muksin, D. (2023). Pemanfaatan buah mangrove *Rhizophora apiculata* sebagai olahan kopi mangrove dalam upaya peningkatan ekonomi masyarakat di Desa Maitara Utara Kecamatan Tidore Utara. *Jurnal Pengabdian Magister Pendidikan IPA*, 6(2), 368-377. https://doi.org/10.29303/jpmpi.v6i2.4476

Acharya, S., Jali, P., Pradhan, M., Pradhan, C. & Mohapatra, P.K. (2023). Antimicrobial and Antioxidant Property of a True Mangrove Rhizophora apiculata Bl. Chemistry & Biodiversity, 20(9), e202201144. https://doi.org/10.1002/cbdv.202201144

Bhargava, R., & Levin, I.W. (Eds.). (2005). Spectrochemical Analysis Using Infrared Multichannel Detectors. Blackwell Publishing Ltd., Oxford, 308 p. https://doi.org/10.1002/9780470988541

Chan-Keb, C.A., Aragon-Gastelum, J.L., Agraz-Hernandez, C.M., Perez-Balan, R.A.' Gutierrez-Alcantara, E.J., Popoca-Cuaya, M.A., Guillen-Poot, M.A., Nunez, E.H. &. Aguirre-Crespo, F.J. (2025). Salinity as an inducer of antioxidant activity exerted by mangrove species from Campeche, Mexico. *Plants*, 14(5), 800-814, https://doi.org/10.3390/plants14050800

Dahibhate, N.L., Saddhe, A.A. & Kumar, K. (2018). Mangrove plants as a source of bioactive compounds: a review. *The Natural Products Journal*, 9(2), 86-97, https://doi.org/10.2174/2210315508666180910125328

Dev, P., & Mukadam, D. (2025). Functional group profiling of medicinal plants using FTIR Spectroscopy. *World Journal of Basic and Pharmaceutical Health Sciences*, 9(2), 110–120. https://doi.org/10.33545/27069532.2025.v9.i2b.1052

Ferraro, J.R., & Basile, L.J. (1978). Fourier transform infrared spectroscopy: Applications to chemical systems (Vol. 1). Academic Press.

Gao, M., & Xiao, H. (2012). Activity-Guided Isolation of Antioxidant Compounds from Rhizophora apiculata. Molecules, 17(9), 10675–10682. https://doi.org/10.3390/molecules170910675

Gil-Martin, E., Forbes-Hernandez, T., Romero, A., Cianciosi, D., Giampieri, F. & Battino, M. (2022). Influence of the extraction method on the recovery of bioactive phenolic compounds from food industry by-products. *Food Chemistry*, 378(131918), 1-39. https://doi.org/10.1016/j.foodchem.2021.131918

Kannappan, S., Sivakumar, K. & Sethi, S. (2018). Protective effect of mangrove (Rhizophora apiculata) leaves extract in shrimp (Penaeus monodon) larvae against bio-luminescent disease-causing Vibrio harveyi bacteria. Spanish Journal of Agricultural Research, 16(1), e0501. https://doi.org/10.5424/sjar/2018161-11675.

Othman, R., Ramya, R., Mohd Hassan, N. & Kamoona, S. (2020). Functional Groups and Individual Phenolic Compounds in Different Fractional Polarities Extracts of Rhizophora apiculata. Journal of Pharmacy and Nutrition Sciences, 10(1). https://doi.org/10.29169/1927-5951.2020.10.01.3.

Pancapalaga, W., Ishartati, E. & Ambarwati ,T. (2023). Production and haracterization of natural dyes for ecoprinting leather from the extracts of three mangrove species. *Jurnal Sylva Lestari*, 11(1), 98-106, https://doi.org/10.23960/jsl.v11i1.634

Prihatiningsih, I., Riyanti, R.R., Hidayat, M., Trenggono & Pamungkas, S. (2024). Pengembangan produk kopi mangrove masyarakat pesisir Cilacap. *Jurnal Pengabdian Magister Pendidikan IPA*, 7(1), 34-39. https://doi.org/10.29303/jpmpi.v7i1.6305

Ramalingam, V., & Rajaram, R. (2018). Enhanced antimicrobial, antioxidant and anticancer activity of *Rhizophora apiculata*: an experimental report. *3 Biotech*, *8*(4), 200.. https://doi.org/10.1007/s13205-018-1222-2

Santhosh, K., Gunasekaran, R., Kannan, K. & Pitchiah, S. (2025). Bioactive potential of Rhizophora apiculata: phytochemical profiling, antibacterial activity, and toxicity evaluation on zebrafish (Danio rerio) larvae. Natural Product Research. https://doi.org/10.1080/14786419.2025.2602911.

Smith, C.B. (2011). Fundamentals of Fourier Transform Infrared Spectroscopy. CRC Press, by Taylor and Francis Group. pp 1-198.

Tahulending, C., Dotulong, V., Mentang, F., Damongilala, L., Harikedua, S. D., Pongoh, J., & Salindeho, N. (2023). Metabolit sekunder ekstrak air mendidih tepung buah mangrove Sonneratia alba. Media Teknologi Hasil Perikanan, 11(1), 59–63. https://doi.org/10.35800/mthp.11.1.2023.34511.

Wen, X., Wang, Q., Dai, T., Shao, J., Wu, X., Jiang, Z., Jacob, J.A. & Jiang, C. (2020). Identification of possible reductants in the aqueous leaf extract of mangrove plant Rhizophora apiculata for the fabrication and cytotoxicity of silver nanoparticles against human osteosarcoma MG-63 cells. Materials Science and Engineering C, 116, 111252. https://doi.org/10.1016/j.msec.2020.111252.

Wonggo, D., Anwar, C., Dotulong, V., Reo, A., Taher, N., Syahputra, R.A., Nurkolis, F., Tallei, T.E., Kim, B. & Tsopmo A. (2024). Subcritical water extraction of mangrove fruit extract (*Sonneratia alba*) and its antioxidant activity, network pharmacology, and molecular connectivity studies. *Journal of Agriculture and Food Research*, 1-13, https://doi.org/10.1016/j.jafr.2024.101334