Acta. Chim. Asiana., 2025, 8(1), 623 –632
e-ISSN/p-ISSN 2550-0503/2550-049x

RESEARCH PAPER

Exploration of secondary metabolite profile in the n-hexane fraction of *Rhizophora mucronata*, *Avicennia marina*, and *Sonneratia alba*

Raehanul Maziya, Lina Permatasari*, Rizqa Fersiyana Deccati, Handa Muliasari, Fania Rahman, Zulfiana Fatianingrum Annas, and Rahula Vijja Sammanta

[a] Study Program of Pharmacy, Faculty of Medicine and Health Sciences, Mataram University, Mataram, Indonesia
E-mail: lina.permatasari@unram.ac.id

DOI: 10.29303/aca.v7i2.211

Article info:

Received 07/01/2025

Revised 11/03/2025

Accepted 13/03/2025

Available online 30/05/2025

Abstract: Indonesia is a maritime and archipelagic country with an ocean area of almost two-thirds of its total area, with a coastline stretching 99.123 km from Sabang to Merauke. According to Indonesian Law Number 1 of 2014, it is mentioned that one of the most important biological resources of the coast is mangroves. Some mangrove species commonly found on Lombok Island are Rhizophora mucronata, Sonneratia alba, and Avicennia marina. However, there has not been much exploration of the compound content in these mangroves. Therefore, this study aimed to identify the secondary metabolites of the n-hexane fraction of the three mangrove species using Gas Chromatography-Mass Spectrometry (GC-MS). The leaves of each mangrove species were extracted by sonication method using 96% ethanol solvent, followed by multistage fractionation using n-hexane and water. GC-MS analyzed the n-hexane fraction of each mangrove species. The GC-MS analysis revealed that in the n-hexane fraction of mangrove leaves Rhizophora mucronata and Avicennia marina there were 10 compounds, while Sonneratia alba obtained five compounds. The compounds with the highest intensity in the n-hexane fraction of mangrove leaves of Rhizophora mucronata, Sonneratia alba, and Avicennia marina were squalene (41.71%), ethyl oleate (87.53%), and ethyl oleate (44.02%), respectively. Squalene was reported to have antioxidant and anticancer activities. The ethyl oleate was reported to have bactericidal activity on gram-positive and negative bacteria. The three types of mangrove leaves can be an alternative source of medicine.

Keywords: Rhizophora mucronata, Sonneratia alba, Avicennia marina, mangrove leaves, Gas Chromatography-Mass

Citation: Maziya, R, Permatasari, L., Deccati, R. F., Muliasari, H., Rahman, F., Annas, Z. F., & Sammanta, R. V. (2025). Exploration of secondary metabolite profile in the n-hexane fraction of Rhizophora mucronata, Avicennia marina, and Sonneratia alba. Acta Chimica Asiana, 8(1), 623–632. https://doi.org/10.29303/aca.v7i2.211

INTRODUCTION

Indonesia is a maritime and archipelagic country with water territories covering two-thirds of its area. This condition has positioned Indonesia with the second-longest coastline in the world after Canada, stretching 99,123 km from Sabang to Merauke [1]. According to Indonesian Law No. 1 of 2014, mangroves are one of the most critical coastal biological resources [2].

The length of the coastline in Indonesia directly correlates to the extent of mangrove forests in Indonesia. Of the total 16,530,000 hectares of mangrove forest area worldwide, Indonesia contributed 3,735,250 hectares of mangrove forest area [3]. According to data from the West Nusa Tenggara Provincial Government in 2017, the mangrove forest area on Lombok Island was recorded at 2,514.4 hectares [4]. *Rhizophora mucronata*, *Sonneratia alba*, and

Avicennia marina are three mangrove species commonly found on Lombok Island [5].

The three types of mangroves are widely utilized in traditional medicine, particularly their leaves. The leaves of *Rhizophora mucronata* are traditionally used to treat diarrhea and gastric dysmotility, reduce fever, and facilitate childbirth [6], [7]. Meanwhile, the leaves of *Sonneratia alba* are used to treat oral thrush and chickenpox and as a laxative for infants [8], [9]. *Avicennia marina* leaves are traditionally used for treating skin diseases, rheumatism, smallpox, and ulcers and as an alternative contraceptive agent [10], [11].

Research related to the pharmacological activities of these three mangrove species has been widely conducted. From several studies, it is known that *Rhizophora mucronata* has pharmacological activities, such as anti-inflammatory, analgesic, antioxidant, antimicrobial, anti-cholinesterase, antidiabetic, and so on [12], [13], [14], [15], [16], [17], [18], [19]. *Sonneratia alba* leaves are also reported to have various pharmacological effects such as cardiovascular protection, antidiabetes, antioxidant, antibacterial, anti-cholesterol, anti-inflammatory, and antifungal [20], [21], [22], [23]. Like the previous two mangrove species, Avicennia marina has pharmacological activities such as antioxidant, antiviral, and antibacterial [24].

The pharmacology activities of plants were influenced by their compounds. Flavonoids are compounds that play a role in some plant's pharmacological activity [25]. These three mangrove species extract and (n-hexane, ethyl acetate, and water) fractions were identified. The n-hexane fraction of *Rhizopora mucronata, Avicennia marina, and Sonneratia alba* leaves showed the highest total flavonoid content [26], [27], [28]. However, exploring the compound content in these n-hexane fractions of three mangrove species has not been extensively conducted. Therefore, this study aims to explore the secondary metabolites of the n-hexane fraction of these three mangrove species using Gas Chromatography-Mass Spectrometry (GC-MS).

MATERIALS AND METHODS

Materials

Mangrove leaves (*Rhizophora mucronata*, *Sonneratia alba*, *Avicennia marina*) were obtained from Buwun Mas Village, West Lombok District, West Nusa Tenggara, Indonesia. The technical grade was the ethanol 96%, n-hexane, and distilled water (aquadest).

Extraction and Fractionation

Each fresh mangrove leaf (*Rhizophora mucronata*, *Sonneratia alba*, *Avicennia marina*) was harvested and wet sorted to separate mangrove leaves with impurities and damaged leaves. The sorted leaves were then washed and dried in the sun. The dried leaves are then mashed so that the dry powder of each mangrove leaf is obtained. The sonication method extracted each dry powder in a separate container using 96% ethanol as a solvent (1:5). Resonication was done twice, and liquid extracts were used for each sample. Each extract was then evaporated with a rotary evaporator to remove the solvent and concentrated with a water bath to obtain a thick extract. Each thick extract was subsequently fractionated using the liquid-liquid fractionation method with a separatory funnel. This fractionation was carried out using n-hexane solvent with two repetitions. The flow of the fractionation process of each sample can be seen in Figure 1. The obtained fractions were then evaporated using a rotary evaporator to remove the solvent and concentrated with a water bath to obtain a thick fraction.

Sample Analysis by GC-MS

The n-hexane fraction of each mangrove leaf was analyzed for compounds by Shimadzu Gas Chromatography-Mass Spectroscopy (GC-MS QP2010 Ultra) with Rtx® 5MS Column. The injection volume used was 1µL.

Statistical Analysis

The compounds detected in three mangrove leaf species were analyzed using Minitab (version 17) with Principal component analysis (PCA) and hierarchical clustering analysis method (HCA).

RESULTS AND DISCUSSION

Rhizophora mucronata

The gas chromatogram showed *R. mucronata* leaves to have 10 peak compounds, as seen in Figure 2. Table 1 showed squalene was the major compound in the n-hexane fraction of Rhizophora mucronata leaves.

Five of the eight compounds contained in this fraction have pharmacological activity as antioxidants. The most dominant compound in this fraction is the compound 2,6,10,14,18,22 Tetracosahexaene, better known as squalen [40].

Based on research by Zhang et al. [41], squalene has an antioxidant activity that can ward off free radicals by 32%, as tested with the DPPH method. Squalene is an antioxidant that works by inhibiting oxidative stress in several organs. Squalene inhibits oxidative stress in the skin by forming superoxide anions in radical-exposed keratinocytes. In the heart organ, this antioxidant activity of squalene confers cardioprotective properties. Squalene stimulates Nrf2, resulting in transcriptional activation of antioxidant enzymes, possibly reducing myocardial injury [42].

Table 1. Compounds in the n-hexane fraction of *Rhizophora mucronata* leaves detected by GC-MS analysis.

Peak	R. Time	Senyawa	% Area	Aktivitas
1	13.483	1-Hexadecanol	6.66	Antioxidant [29]
2	14.385	Lanol	2.67	Antifungal, antibacterial, antioxidant [30], [31]
3	15.007	1-nonadecane	8.95	Antioxidant, Anti-inflammatory, Antibacterial, Cytotoxic, Antinociceptive, Antimutagenic, Antiteratogenic, Anxiolytic, Antidepressant, Immunoadjuvant [32]
4	15.251	Ethyl oleate	19.04	Antimicrobial [33], [34]
5	15.450	Behenic alcohol	2.61	Antiviral [35]
6	17.861	Squalene	41.71	Antioxidant, antitumor [36], [37]
7	19.236	Vitamin E	2.01	Antioxidant [38]
8	20.614	Cholest-5-en-3-ol (3.beta.)-, tetradecanoate	2.06	Imunomodulator [39]
9	20.855	(-)-Caryophyllen	10.54	-
10	20.985	Unknown compound	3.75	-

Apart from being an antioxidant, several other studies have shown that squalene has anti-inflammatory, anticancer, antibacterial, and anti-candidiasis activities [41], [43]. Squalen as an anti-inflammatory works by suppressing the synthesis of pro-inflammatory mediators such as nitrates, pro-inflammatory enzymes ((iNOS, COX-2, and MPO), cytokines (TNF-α, IL-1β, IL-6, and IFN-γ), and increasing the secretion of anti-inflammatory enzyme (H)-1) [44]. These anti-inflammatory activities of squalen contribute to the traditional use of *Rhizophora mucronata* to treat fever.

This fraction also contains the compound Ethyl octadec-9-enoate, an ester oleic acid compound. This compound is known to increase the production of prostaglandin PGE2 [45]. Prostaglandins affect gastric motility and trigger uterine contractions [46]. It is the presence of this compound that may be involved in treating gastric dysmotility and facilitating labor by triggering uterine contractions, as it is used empirically.

Sonneratia alba

The gas chromatogram showed that 5 peak compounds were detected in the n-hexane fraction of *Sonneratia* (Figure 3).

Table 2. Compounds in the n-hexane fraction of *Sonneratia alba* leaves detected by GC-MS analysis.

Peak	R. Time	Senyawa	% Area	Aktivitas
1	14.304	Ethyl palmitate	7.37	Anticancer, antimicrobial, antifungal, antiviral [51], [52]
2	15.258	Ethyl oleate	87.53	Antimicrobial [53], antioxidant [50]
3	15.383	Ethyl stearate	1.70	-
4	15.455	Linoleic acid	2.02	-
5	15.616	Ethyl linoleate	1.38	Antibacterial, anti-inflammatory [54]

Based on Table 2, the most dominant compound in this fraction is the ethyl oleate compound. Based on the research of Krishnaveni et al. (2014), it is known that this compound has antimicrobial activity [47]. Ethyl oleate has antibacterial activity, both gram-positive and negative bacteria. Ethyl oleate was antibacterial by damaging the bacterial cell membrane, causing oxidative stress in bacteria, and inhibiting the FabI enzyme that inhibits bacterial fatty acid synthesis [48], [49]. In addition, ethyl oleate increased the antioxidant activity of blueberries [50].

Ethyl oleate and ethyl linoleate are unsaturated fatty acids that can act as emollient laxatives. This emollient laxative acted as a laxative by working as an anionic surfactant that softens the fecal mass and increased fluid secretion and permeability of the intestinal mucosa [55]. Ethyl palmitate compounds have pharmacological activity as antifungal and antiviral, so the presence of these compounds was directly correlated with the efficacy of *Sonneratia alba* leaves as smallpox and manger

Acta. Chim. Asiana., 2025, 8(1), 623 –632

medicine. Ethyl palmitate, an antiviral, inhibited viral fusion by forming a strong bond to the viral envelope E1 protein [51].

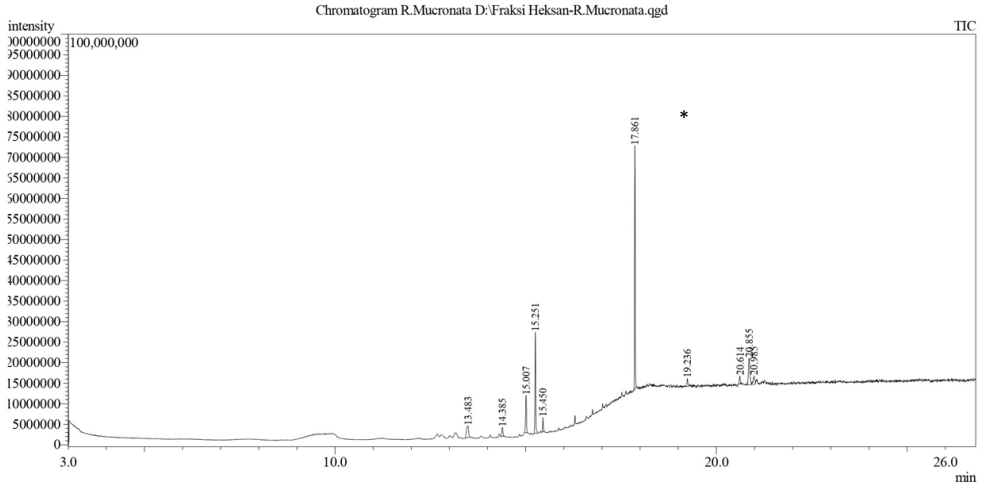

Figure 1. GC-MS chromatogram of n-hexane fraction of *Rhizophora mucronata* leaves. *Major compound

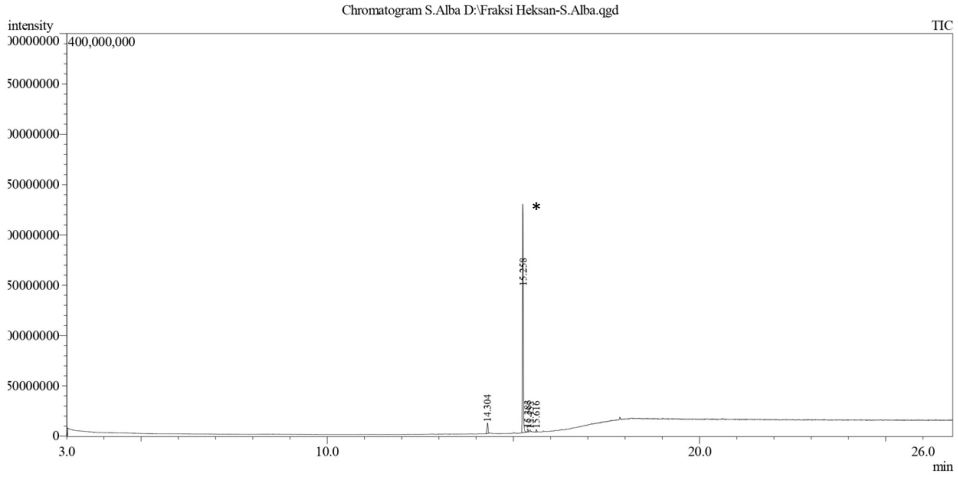

Figure 2. GC-MS chromatogram of n-hexane fraction of *Sonneratia alba* leaves. *Major compound

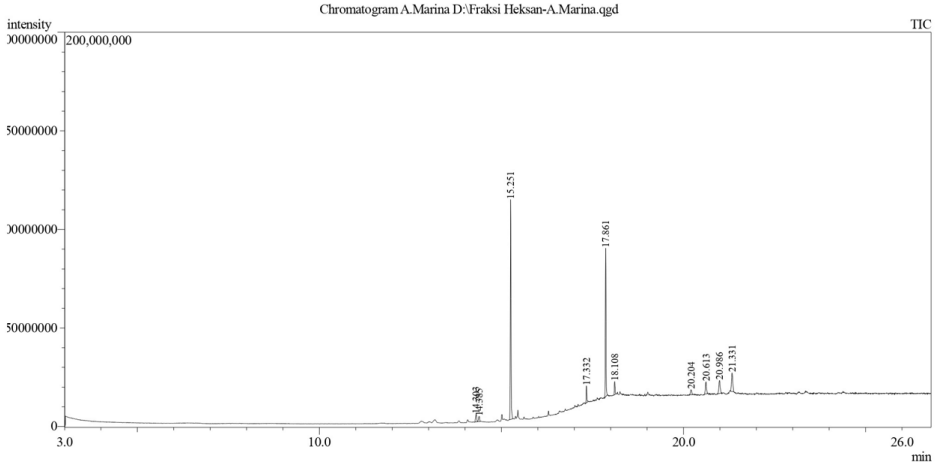

Figure 4. GC-MS chromatogram of n-hexane fraction of *Avicennia marina* leaves. *Major compound

Acta. Chim. Asiana., 2025, 8(1), 623 –632

Avicennia marina

Table 3. Phytochemical components identified in the n-hexane fraction of *Avicennia marina* leaves by GC-MS analysis

Peak	R. Time	Senyawa	% Area	Aktivitas
1	14.303	Ethyl palmitate	2.57	Anticancer, antimicrobial, antifungal, antiviral [51], [52]
2	14.385	Behenic alcohol	1.82	Antiviral [35]
3	15.251	Ethyl oleate	44.02	Antimicrobial [53], antioxidant [50]
4	17.332	lanol	3.44	-
5	17.861	1,6,10,14,18,22-tetracosahexane -3-ol	27.69	Anti-inflammatory, antiarthritic, antimicrobial, antitumorigenic, anti-protozoal, and chemopreventive [56]
6	18.108	lanol	2.73	-
7	20.204	Silane	1.74	-
8	20.613	Stigmast-5-en-3-ol, (3.beta.,24S)- (CAS) Clionastern	3.96	anti-inflammatory, anticancer, hepatoprotective, antioxidant, cardioprotective, and antidiabetic [57]
9	20.986	4,4,6a,6b,8a,11, 11,14b-octamethyl	5.00	Antidiabetic, anti-inflammatory [58], [59]
10	21.331	Methyl commate d	7.03	Antibacterial, antioxidant, anti-inflammatory [60], [61], [62]

The GC-MS analysis showed that the n-hexane fraction has 10 peak compounds, as shown in Figure 4. The components of the compounds that make up* this fraction can be seen in Table 3. Based on Table 3, the dominant compound in this fraction was ethyl oleate, which was the same as the *Sonneratia alba* n-hexane fraction. Most of the compounds contained in this fraction have anti-inflammatory and antimicrobial activities. These compounds then contribute to the healing of skin diseases and ulcers by suppressing inflammatory reactions in the disease and killing existing pathogenic bacteria. In addition, the compound 1,6,10,14,18,22-tetracosahexaen-3-ol reportedly has antiathritic activity [56]. However, the mechanism of action of these compounds in suppressing joint inflammation remains unknown.

The analysis found that the metabolite compound profiles of the three mangrove species on Lombok Island were quite different. Most of the compound components in the n-hexane fraction of *Rhizophora mucronata* have antioxidant activity. Meanwhile, the compound components in the *Sonneratia alba* n-hexane fraction mostly have antibacterial activity. Just like *Sonneratia alba*, the compound components in the n-hexane fraction of *Avicennia marina* mostly have antibacterial activity.

The metabolites in mangroves have an ecological role, such as for food ingredients. The antioxidant activity from the mangrove's metabolites was utilized as traditional medicine [63]. Squalene and ethyl oleate, major compounds in each mangrove species, have potential antioxidant activity [36, 50]. In addition, these antioxidant metabolites contributed to climate resilience and environmental adaptation of mangroves from various stressful conditions [64], [65]. The stressful condition will produce reactive oxygen species (ROS), so the antioxidant role of the mangrove's metabolites can prevent it [66].

The mass spectrum for each peak in GC-MS chromatography has a similarity index (SI) in the 82-94% range. These data showed that the identity of the detected compounds in three species of mangrove leaves was highly similar to the mass spectrum of database compounds in NIST library matching software. This software will display the mass spectrum that best matches the mass spectrum of the detected compound. NIST library matching has the disadvantage that if there is no mass spectrum in the software database that matches the mass spectrum of the compound in the sample, then the compound becomes an unknown compound [67].

The compounds in three species of mangrove leaves were detected using GC-MS, which mostly contained fatty acid and nonpolar compounds. The polar or semipolar compounds such as phenolic and flavonoid can not detected using GC-MS because these compounds were difficult to pavorize. The sample must be derivatized with trimethylsilyl to cap the polar functional group, such as -OH, -NH, -COOH, and -SH. However, the procedure can modify the compounds. So, the other biotechnology to metabolomic the compounds in these three species of mangrove leaves was Liquid Chromatography-Mass Spectrometry (LC-MS). LC-MS can detect secondary metabolites in a wide range and has a high sensitivity. LC-MS can detect polar compounds like phenolic and flavonoids without derivatization [68].

Meanwhile, Fourier transform–ion cyclotron resonance–MS (FT–ICR–MS) and Nuclear Magnetic Resonance (NMR) were the other biotechnology for plant metabolomic compounds. NMR, especially ^{1}H-NMR, can identify and quantify metabolites widely, but the sensitivity was low [69]. Meanwhile, the FT-ICR-MS can identify thousands of metabolites simultaneously quickly and identify the phosphorylated and hydrophilic ionic

compounds. However, FT-ICR-MS needs an operator with skill and experience [70].

Principal Component Analysis (PCA)

PCA is a multivariate method for the analysis sample with more than two variables. The variables in this study were the compounds detected in three n-hexane fractions of mangrove leaf species. The PCA was used to identify similar compounds in the three mangrove species [71]. The PC1 and PC2 contributed to all variables was 77.8% and 22.2%, respectively. The accumulation of two PC was 100%. It showed that the PC can represent all the variables. The ethyl oleate (d), squalene (f), and 1,6,10,14,18,22-tetracosahexane-3-ol (n) were the gave the highest contribution to PC1 and PC2 (Figure 5) [71]. So, these compounds can differentiate the three species of mangrove. These three compounds have a high abundance percentage in the three mangrove species.

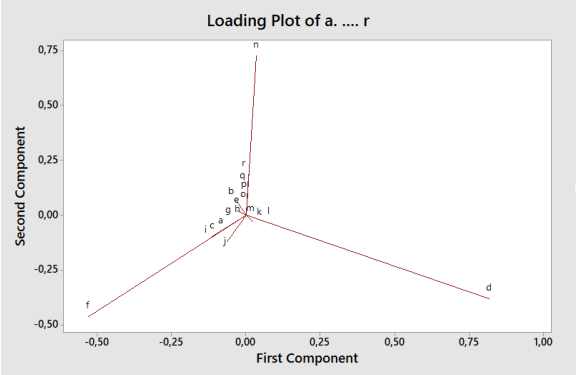

Figure 5. Loading Plot of Detected Cmpounds in the Three Mangrove Species. 1-Hexadecanol (a), lanol (b), 1-nonadecene (c), Ethyl oleate (d), Behenic alcohol (e), Squalene (f), Vitamin E (g), Cholest-5-en-3-ol (h), (-)-caryophyllene (i), Ethyl palmitate (j), Ethyl stearate (k), Linoleic acid (l), Ethyl linoleate (m), 1,6,10,14,18,22-tetracosahexane-3-ol (n), silane (o), Stigmast-5-en-3-ol (p), 4,4,6a,6b,8a,11,11,14b-octamethyl (q), Methyl commate d (r).

Hierarchical Clustering Analysis (HCA)

HCA is a statistical analysis method that organizes many variables into one tree. The result of HCA is a dendrogram that can provide an overview of the analyzed samples from the similarity value [72]. The dendrogram in Figure 6 reported that *Sonneratia alba* and *Avicennia marina* have a similarity of 33.33%. Meanwhile, *Rhizopora mucronata* did not have similarities with *Sonneratia alba* and *Avicennia marina.*

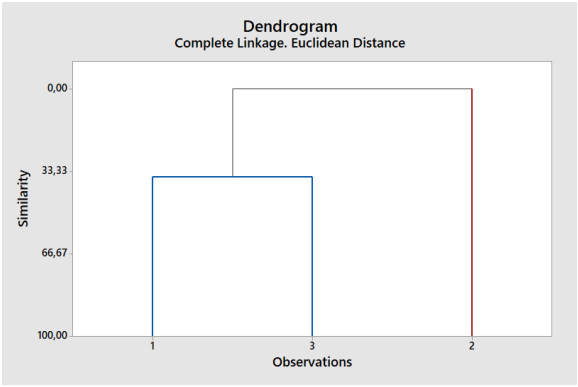

Figure 6. Dendogram of Detected Cmpounds in the Three Mangrove Species. *Sonneratia alba* (1), *Rhizopora mucronata* (2), *Avicennia marina* (3).

CONCLUSION

Based on the results of GC-MS analysis, the main components identified in the n-hexane fraction of the mangrove leaves *Rhizophora mucronata*, *Sonneratia alba*, and *Avicennia marina* are squalene and ethyl oleate, respectively. These two compounds exhibit antioxidant and antibacterial activities, making these three types of mangrove leaves potential alternative sources for medicinal purposes. Based on the compounds, HCA revealed that *R. mucronata* leaves did not have similarities to *S. alba* and *A. marina.*

REFERENCES

[1] Maulana, M., Moehammad, A., & Janu, F. A. (2017). Analisis Pengaruh Perubahan Garis Pantai Terhadap Batas Pengelolaan Wilayah Laut Provinsi Jawa Timur Dan Provinsi Bali Di Selat Bali. Jurnal Geodesi Undip, 55(4), 233–242.

[2] Pemerintah Republik Indonesia. (2014). Undang-Undang RI Nomor 1 Tahun 2014 Tentang Perubahan Atas Undang-Undang Nomor 27 Tahun 2007 Tentang Pengelolaan Wilayah Pesisir Dan Pulau-Pulau Kecil. Lembaran Negara Republik Indonesia, 8.

[3] Husuna, R., Wantasen, A. S., & Rondonuwu, A. B. (2019). Struktur Komunitas Mangrove di Pantai Tabulo Selatan Kabupaten Boalemo. Jurnal Ilmiah Platax, 7(1), 309–319.

[4] Rahmani, A. V., Idrus, A. Al, & Mertha, I. G. (2023). The Structure of Mangrove Community in Regional Marine Conservation Area Gili Sulat West Nusa

Tenggara. Jurnal Biologi Tropis, 23(1), 42–51.

[5] Rahman, F. A. (2022). Ekologi mangrove Pulau Lombok (Mu. L. Irrubai (ed.); 1st ed.). UIN Mataram Press.

[6] Pambudi, D. B., & Haryoto. (2022). Efektivitas Farmakologi Senyawa Aktif Tumbuhan Mangrove Yang Hidup Di Indonesia. Jurnal Ilmiah Kesehatan, 15(1), 39–57.

[7] Setyawan, A. D., Ragavan, P., Basyuni, M., & Sarno, S. (2022). Review: Rhizophora mucronata as source of foods and medicines. International Journal of Bonorowo Wetlands, 9(1), 42–55.

[8] Abubakar, S., Kadir, asykhur A., Wibowo, E. S., & Nebuchadnezzar Akbar. (2019). Manfaat Mangrove Bagi Peruntukan Sediaan Farmasitika Di Desa Mamuya Kecamatan Galela Timur Kabupaten Halmahera Timur (Tinjauan Etnofarmakologis). Jurnal Enggano, 4(1), 12–25.

[9] Putri, R. R., Hasanah, R., & Kusimaningrum, I. (2016). Uji Aktivitas Antibakteri dan Uji Fitokimia Ekstrak Daun Mangrove Sonneratia alba Anti-bacterial. Aquawarman Jurnal Sains Dan Teknologi Akuakultur, 2(1), 43–50.

[10] Fitri, A., & Usman. (2021). Aktivitas Antioksidan Ekstrak Metanol Daun Mangrove (Avicennia Marina). Prosiding Seminar Nasional Kimia, 1, 12–17.

[11] Rodiani, D., Maryono, T., & Ramdini, D. A. (2023). Avicennia marina: a natural resource for male anti-fertility in family planning. International Journal of Design & Nature and Ecodynamics, 18(5), 1077-1085.

[12] Adhikari, A., Ray, M., Das, A. K., & Sur, T. K. (2016). Antidiabetic and antioxidant activity of Rhizophora mucronata leaves (Indian sundarban mangrove): An in vitro and in vivo study. AYU (An International Quarterly Journal of Research in Ayurveda), 37(1), 76.

[13] Karundeng, E. D. B., Hanizar, E., & Sari, D. N. R. (2022). Potensi Ekst 659 n Rhizophora mucronata i Antibakteri Pada Staphylococcu . BIOSAPPHIRE: Jurnal Biologi Dan Diversitas, 1(1), 10–18.

[14] Kaur, S., Syed Ali, M., Anuradha, V., Suganya, V., Ashashalini, A., & Bhuvana, P. (2018). In vitro anti-inflammatory activity of mangrove plant Rhizophora mucronata Lam. (Malpighiales: Rhizophoraceae). Brazilian Journal of Biological Sciences, 5(10), 417–426.

[15] Mulyani, Y., Syaputra, N. D., Dewi, K. C., Lili, W., & Agung, M. U. K. (2019). Total phenolic , flavonoid content and antioxidant capacity of stem bark , root , and leaves methanolic extract of Rhizophora mucronata Lam . World News of Natural Science, 26(August), 118–127.

[16] Pertiwi, R., Yudha, S. S., Wibowo, R. H., Notriawan, D., Nasution, R. P., & Azhar, A. W. (2024). Aktivitas Antibakteri Ekstrak Daun Mangrove (Rhizophora mucronata) pada Bakteri Helicobacter pylori Penyebab Tukak Lambung. Bioscientist: Jurnal Ilmiah Biologi, 12(1), 202–209.

[17] Ridlo, A., Pramesti, R., Koesoemadji, K., Supriyantini, E., & Soenardjo, N. (2017). Aktivitas Antioksidan Ekstrak Daun Mangrove Rhizopora mucronata. Buletin Oseanografi Marina, 6(2), 110.

[18] Suganthy, N., & Devi, K. P. (2016). In vitro antioxidant and anti-cholinesterase activities of Rhizophora mucronata. Pharmaceutical Biology, 54(1), 118–129.

[19] Usman, U., Masruhim, M. A., Kusumaningtiyas, P., Erwin, E., & Bulan, D. E. (2023). Antioxidant and Antidiabetic from Rhizophora mucronata Derived from Sambera. Tropical Journal of Natural Product Research, 7(10), 4921–4926.

[20] Binuni, R., Maarisit, W., Hariyadi, H., & Saroinsong, Y. (2020). Uji Aktivitas Antioksidan Ekstrak Daun Mangrove Sonneratia alba Dari Kecamatan Tagulandang, Sulawesi Utara Menggunakan Metode DPPH. Biofarmasetikal Tropis, 3(1), 79–85.

[21] Musa, W. J. ., Bialangi, N., Situmeang, B., & Silaban, S. (2019). Triterpenoid compound from metanol extract of mangrove leaves (Sonneratia alba) and anti-cholesterol activity test. Jurnal Pendidikan Kimia, 11(1), 18–23.

[22] Asad, S., Nesa, L., Deepa, K. N., Sohel, D., & Kawsar. (2017). Analgesic, Anti-Inflammatory and CNS Depressant Activities of Methanolic Extract of Sonneratia alba Leaves in Mice. Natural Products Chemistry & Research, 05(05), 1–7.

[23] Thu, N. T. H., Khanh, L. P., Duy, N. T., Chanh, N. K., Phung, N. K. P., & Hansen, P. E. (2011). Chemical Constituents From Leaves of Sonneratia Alba J.E. Smith (Sonneratiaceae). Science and

Technology Development Journal, 14(4), 11–17.
[24] Annas, Z. F., Deccati, R. F., Permatasari, L., & Mukhlishah, N. R. I. (2023). Penentuan Kadar Flavonoid Total Ekstrak dan Fraksi-Fraksi Daun Mangrove (Avicennia marina). Program Studi Farmasi Fakultas Kedokteran Dan Ilmu Kesehatan Universitas Mataram.
[25] Roy, A., Das, S., Chatterjee, I., Roy, S., & Chakraborty, R. (2022). Anti-inflammatory Effects of Different Dietary Antioxidants BT - Plant Antioxidants and Health (H. M. Ekiert, K. G. Ramawat, & J. Arora (eds.); pp. 573–597). Springer International Publishing.
[26] Sammanta, R. V., Muliasari, H., & Mukhlishah, N. R. I. (2023). Penentuan Kadar Flavonoid Total Ekstrak dan Fraksi-Fraksi Daun Mangrove (Rhizopora mucronata). Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology, 1(1), 1–25.
[27] Annas, Z. F., Deccati, R. F., Permatasari, L., & Mukhlishah, N. R. I. (2023). Penentuan Kadar Flavonoid Total Ekstrak dan Fraksi-Fraksi Daun Mangrove (Avicennia marina). Program Studi Farmasi Fakultas Kedokteran Dan Ilmu Kesehatan Universitas Mataram.
[28] Rahman, F. (2023). Penentuan Kadar Flavonoid Total Ekstrak dan Fraksi-fraksi Daun Mangrove (Sonneratia alba). Universitas Mataram.
[29] Sianturi, G. L. R., Trisnawati, E. W., Koketsu, M., & Suryanti, V. (2023). Chemical constituents and antioxidant activity of Britton's wild petunia (Ruellia brittoniana) flower. Biodiversitas, 24(7), 3665–3672.
[30] Amudha, P., Jayalakshmi, M., Pushpabharathi, N., & Vanitha, V. (2018). Identification of bioactive components in enhalus acoroides seagrass extract by gas chromatography–mass spectrometry. Asian Journal of Pharmaceutical and Clinical Research, 11(10), 313–317.
[31] Heng, Y. W., Ban, J. J., Khoo, K. S., & Sit, N. W. (2020). Biological activities and phytochemical content of the rhizome hairs of Cibotium barometz (Cibotiaceae). Industrial Crops and Products, 153(April), 112612.
[32] Alencar, M. V. O. B., Islam, M. T., Ali, E. S., Santos, J. V. O., Paz, M. F. C. J., Sousa, J. M. C., Dantas, S. M. M. M., Mishra, S. K., & Cavalcante, A. A. C. M. (2018). Association of Phytol with Toxic and Cytotoxic Activities in an Antitumoral Perspective: A Meta-Analysis and Systemic Review. Anti-Cancer Agents in Medicinal Chemistry, 18(13), 1828–1837.
[33] Al-Mohammadi, A.-R., Ibrahim, R. A., Mustofa, A. H., Ismaiel, A. A., Zeid, A. A., & Gamal, E. (2021). Chemical Constitution and Antimicrobial Activity of Kefir Fermented Beverage. Molecules, 26(9), 1–19.
[34] Zhao, J., Shan, T., Huang, Y., Liu, X., Gao, X., Wang, M., Jiang, W., & Zhou, L. (2010). Chemical Composition and In Vitro Antimicrobial Activity of the Volatile Oils from Gliomastix murorum and Pichia guilliermondii, Two Endophytic Fungi in Paris polyphylla var. yunnanensis Jianglinural Product Communications. NPC Natural Product Communications, 4(11), 1491–1496.
[35] Katz, D. H., Marcelletti, J. F., Khalil, M. H., Pope, L. E., & Katz, L. R. (1991). Antiviral activity of 1-docosanol, an inhibitor of lipid-enveloped viruses including herpes simplexfile. Proceedings of the National Academy of Sciences of the United States of America, 88(23), 10825–10829.
[36] Dhankhar, S., Dhankhar, S., Ruhil, S., Balhara, M., Malik, V., & Chhillar, A. K. (2014). Isolation and biological evaluation of novel Tetracosahexaene hexamethyl, an acyclic triterpenoids derivatives and antioxidant from Justicia adhatoda. Combinatorial Chemistry & High Throughput Screening, 17(8), 723–732.
[37] Gautam, V., Kohli, S. K., Arora, S., Bhardwaj, R., Kazi, M., Ahmad, A., Raish, M., Ganaie, M. A., & Ahmad, P. (2018). Antioxidant and antimutagenic activities of different fractions from the leaves of rhododendron arboreum sm. And their gc-ms profiling. Molecules, 23(9), 1–12.
[38] Rizvi, S., Raza, S. T., Ahmed, F., Ahmad, A., Abbas, S., & Mahdi, F. (2014). The role of Vitamin E in human health and some diseases. Sultan Qaboos University Medical Journal, 14(2), 157–165.
[39] Chen, D. F., Zhang, H. L., Du, S. H., Li, H., Zhou, J. H., Li, Y. W., Zeng, H. P., & Hua, Z. C. (2010). Cholesterol myristate suppresses the apoptosis of mesenchymal stem cells via upregulation of inhibitor of differentiation. Steroids, 75(13–14), 1119–1126.
[40] National Center for Biotechnology Information. (2024). Squalene. PubChem

Compound Summary for CID 638072. https://pubchem.ncbi.nlm.nih.gov/compound/Squalene

[41] Zhang, P., Liu, N., Xue, M., Zhang, M., Xiao, Z., Xu, C., Fan, Y., Liu, W., Qiu, J., Zhang, Q., & Zhou, Y. (2023). Anti-Inflammatory and Antioxidant Properties of Squalene in Copper Sulfate-Induced Inflammation in Zebrafish (Danio rerio). International Journal of Molecular Sciences, 24(10).

[42] Micera, M., Botto, A., Geddo, F., Antoniotti, S., Bertea, C. M., Levi, R., Gallo, M. P., & Querio, G. (2020). Squalene: More than a step toward sterols. Antioxidants, 9(8), 1–14.

[43] Bhat, M. P., Rudrappa, M., Hugar, A., Gunagambhire, P. V., Suresh Kumar, R., Nayaka, S., Almansour, A. I., & Perumal, K. (2023). In-vitro investigation on the biological activities of squalene derived from the soil fungus Talaromyces pinophilus. Heliyon, 9(11), e21461.

[44] Cárdeno, A., Aparicio-Soto, M., Montserrat-de la Paz, S., Bermudez, B., Muriana, F. J. G., & Alarcón-de-la-Lastra, C. (2015). Squalene targets pro- and anti-inflammatory mediators and pathways to modulate over-activation of neutrophils, monocytes and macrophages. Journal of Functional Foods, 14, 779–790.

[45] Cheng, Z., Abayasekara, D. R. E., Elmes, M., Kirkup, S., & Wathes, D. C. (2015). Effect of oleic acid supplementation on prostaglandin production in maternal endometrial and fetal allantochorion cells isolated from late gestation ewes. Placenta, 36(9), 1011–1017.

[46] Jesica, F., & Friadi, A. (2019). Hubungan Kadar Kortisol Dan Prostaglandin Maternal Dengan Persalinan Preterm Dan Aterm. Jurnal Ilmu Keperawatan Dan Kebidanan, 10(1),

[47] Krishnaveni, M., Banu, C. R., Kalaivani, M., & Krishnakumari, G. (2015). GC-MS Analysis of Phytochemicals in Muntingia Calabura L, Antimicrobiasl Assay. SJIF Journal, 4(4), 1855–1859.

[48] Akin-Osanaiye, C. B., Gabriel, A. F., & Alebiosu, R. A. (2011). Characterization and Antimicrobial Screening of Ethyl Oleat Isolated from Phyllanthus Amarus (Sehum and Thonn). Annals of Biological Research, 2(2), 298–305.

[49] Zheng, C. J., Yoo, J. S., Lee, T. G., Cho, H. Y., Kim, Y. H., & Kim, W. G. (2005). Fatty acid synthesis is a target for antibacterial activity of unsaturated fatty acids. FEBS Letters, 579(23), 5157–5162.

[50] An, K., Fu, M., Zhang, H., Tang, D., Xu, Y., & Xiao, G. (2019). Effect of ethyl oleate pretreatment on blueberry (Vaccinium corymbosum L.): drying kinetics, antioxidant activity, and structure of wax layer. Journal of Food Science and Technology, 56(2), 783–791.

[51] Sagna, A., Nair, R. V. R., Hulyalkar, N., Rajasekharan, S., Nair, V. T. G., Sivakumar, K. C., Suja, S. R., Baby, S., & Sreekumar, E. (2023). Ethyl palmitate, an anti-chikungunya virus principle from Sauropus androgynus, a medicinal plant used to alleviate fever in ethnomedicine. Journal of Ethnopharmacology, 309, 116366.

[52] Saeed, N. M., El-Demerdash, E., Abdel-Rahman, H. M., Algandaby, M. M., Al-Abbasi, F. A., & Abdel-Naim, A. B. (2012). Anti-inflammatory activity of methyl palmitate and ethyl palmitate in different experimental rat models. Toxicology and Applied Pharmacology, 264(1), 84–93.

[53] Muflihunna, A., Mu'Nisa, A., Hala, Y., & Hasri. (2021). Gas Chromatography-Mass Spectrometry (GC-MS) Analysis and Antioxidant Activity of Sea-Cucumber (Holothurian atra and Holothurian edulis) from Selayar Island. Journal of Physics: Conference Series, 1752(1).

[54] Park, S. Y., Seetharaman, R., Ko, M. J., Kim, D. Y., Kim, T. H., Yoon, M. K., Kwak, J. H., Lee, S. J., Bae, Y. S., & Choi, Y. W. (2014). Ethyl linoleate from garlic attenuates lipopolysaccharide-induced pro-inflammatory cytokine production by inducing heme oxygenase-1 in RAW264.7 cells. International Immunopharmacology, 19(2), 253–261.

[55] Arriza, N. (2022). Pengaruh Teh Lidah Buaya (Aloe Vera) Terhadap Penanganan Konstipasi Dan Keamanan Pertumbuhan Fetus Pada Mencit Bunting. In Sekolah Pascasarjana Program Studi Magister Kebidanan Universitas Hasanuddin Makasar.

[56] Jenecius, A., Uthayakumari, F., & Mohan, V. (2012). Gc-Ms Determination of Bioactive Components of Sauropus Bacciformis Blume (Euphorbiaceae). Journal of Current Chemical and Pharmaceutical Science, 2(January 2012), 347–358.

[57] Khan, Z., Nath, N., Rauf, A., Emran, T. Bin, Mitra, S., Islam, F., Chandran, D.,

Barua, J., Khandaker, M. U., Idris, A. M., Wilairatana, P., & Thiruvengadam, M. (2022). Multifunctional roles and pharmacological potential of β-sitosterol: Emerging evidence toward clinical applications. Chemico-Biological Interactions, 365, 110117.

[58] De Almeida, P. D. O., Boleti, A. P. D. A., Rüdiger, A. L., Lourenço, G. A., Da Veiga Junior, V. F., & Lima, E. S. (2015). Anti-inflammatory activity of triterpenes isolated from Protium paniculatum oil-resins. Evidence-Based Complementary and Alternative Medicine, 2015, 1–10.

[59] Ferreira, R. G. S., Silva, W. F., Veiga, V. F., Lima, Á. A. N., & Lima, E. S. (2017). Physicochemical characterization and biological activities of the triterpenic mixture α,β-amyrenone. Molecules, 22(2), 1–9.

[60] Raman, V. B., Samuel, L. A., Saradhi, P. M., Rao, N. B., Krishna, N. V. A., Sudhakar, M., & Radhakrishnan, T. M. (2012). Academic Sciences Asian Journal of Pharmaceutical and Clinical Research. Asian Journal of Pharmaceutical and Clinical Research, 5(2), 99–106.

[61] Gairola, K., Gururani, S., Kumar, R., Prakash, O., Agrawal, S., & Dubey, S. K. (2022). Composition, Antioxidant and Anti-inflammatory activities of Hexane and Methanol extracts of Acmella uliginosa from Terai region of Uttarakhand. Brazilian Journal of Pharmaceutical Sciences, 58.

[62] Saddiq, A. A., Tag, H. M., Doleib, N. M., Salman, A. S., & Hagagy, N. (2022). Antimicrobial, Antigenotoxicity, and Characterization of Calotropis procera and Its Rhizosphere-Inhabiting Actinobacteria: In Vitro and In Vivo Studies. Molecules, 27(10), 1–19.

[63] Paputungan, Z., Wonggo, D., & Kaseger, B. E. (2017). Uji Fitokimia dan Aktivitas Antioksidan Buah Mangrove Sonneratia alba di Desa Nunuk Kecamatan Pinolosian Kabupaten Bolaang Mongondow Selatan. Media Teknologi Hasil Perikanan, 5(3), 96.

[64] Sharma, P., Jha, A. B., Dubey, R. S., & Pessarakli, M. (2012). Reactive Oxygen Species, Oxidative Damage, and Antioxidative Defense Mechanism in Plants under Stressful Conditions. Journal of Botany, 2012, 1–26.

[65] Nizam, A., Meera, S. P. , & Kumar, A. (2022). Genetic and molecular mechanisms underlying mangrove adaptations to intertidal environments. IScience, 25(1), 103547.

[66] Jithesh, M. N., Prashanth, S. R., Sivaprakash, K. R., & Parida, A. (2006). Monitoring expression profiles of antioxidant genes to salinity, iron, oxidative, light and hyperosmotic stresses in the highly salt tolerant grey mangrove, Avicennia marina (Forsk.) Vierh. by mRNA analysis. Plant Cell Reports, 25(8), 865–876.

[67] Wallace, W. E., & Moorthy, A. S. (2023). NIST Mass Spectrometry Data Center standard reference libraries and software tools: Application to seized drug analysis. Journal of Forensic Sciences, 68(5), 1484–1493.

[68] Oh, S.-W., Imran, M., Kim, E.-H., Park, S.-Y., Lee, S.-G., Park, H.-M., Jung, J.-W., & Ryu, T.-H. (2023). Approach strategies and application of metabolomics to biotechnology in plants. Frontiers in Plant Science, 14, 1192235.

[69] Deborde, C., Moing, A., Roch, L., Jacob, D., Rolin, D., & Giraudeau, P. (2017). Plant metabolism as studied by NMR spectroscopy. Progress in Nuclear Magnetic Resonance Spectroscopy, 102–103, 61–97.

[70] Ren, J.-L., Zhang, A.-H., Kong, L., & Wang, X.-J. (2018). Advances in mass spectrometry-based metabolomics for investigation of metabolites. RSC Advances, 8(40), 22335–22350.

[71] Saputri, L. O., Nurhidayati, Nurhidayati, Harahap, H. S., Zubaidi, F. F., Rivarti, A. W., & Permatasari, L. (2024). Principal compounds and antioxidant activity of various sample particle sizes of sea urchin shells from coastal area of Lombok Island. Research Journal of Pharmacy and Technology, 17(12).

[72] Caesar, L. K., Kvalheim, O. M., & Cech, N. B. (2018). Hierarchical cluster analysis of technical replicates to identify interferents in untargeted mass spectrometry metabolomics. Analytica Chimica Acta, 1021, 69–77.