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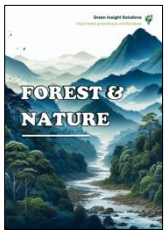

RESEARCH ARTICLE

Phytochemical Composition of *Sonneratia alba* Mangrove Leaves and Fruits: Opportunities for Functional Food, Herbal Medicine, and Forest Conservation

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ABSTRACT

Mangrove ecosystems are vital coastal habitats that provide ecological, economic, and medicinal benefits. *Sonneratia alba*, a dominant mangrove species in Muara Gembong, Indonesia, is traditionally utilized for food products and herbal remedies; however, limited studies have compared its organ-specific phytochemical profiles. This study investigates the qualitative composition of secondary metabolites in the leaves and fruits of *S. alba* using 96% ethanol extracts and standard phytochemical screening methods. The results revealed that both plant parts contained saponins, tannins, phenolics, flavonoids, and glycosides, while triterpenoids were exclusively detected in the leaves, and steroids were absent in both organs. These findings highlight distinct organ-specific variations in secondary metabolites, suggesting that leaves may possess greater therapeutic potential than fruits. The identified bioactive compounds exhibit antioxidant, anti-inflammatory, antimicrobial, and anticancer properties, underscoring their relevance for natural drug discovery and the development of functional foods. Moreover, promoting the pharmacological value of *S. alba* contributes to enhancing community awareness and participation in mangrove conservation. This study provides a scientific basis for future exploration of targeted bioactivity and sustainable utilization of *S. alba* in coastal ecosystem management.

1. Introduction

Mangroves are unique coastal ecosystems with high ecological and pharmacological importance. They are known to contain diverse secondary metabolites with significant medicinal potential (Mitra et al., 2023). Compounds such as alkaloids, flavonoids, saponins, and tannins—widely recognized for their antioxidant properties—can play a role in preventing and treating cardiovascular, neurotoxic, and neurodegenerative conditions associated with aging (Flieger et al., 2021). Previous studies have demonstrated that methanol extracts from mangrove leaves contain secondary metabolites, including alkaloids, phenols, flavonoids, tannins, and saponins (Kadek et al., 2024). For centuries, mangroves have been used in traditional medicine, and extracts from several species have exhibited strong inhibitory effects against various infections affecting plants, animals, and humans (Syahidah and Subekti, 2019).

Sonneratia alba (L.) Smith, a mangrove species from the Lythraceae family, grows abundantly along the Muara Gembong coast, Bekasi Regency, West Java. Its leaves and fruits are not only processed into products such as chips, crackers, candy, and syrup but are also believed to have medicinal value. Although several studies have investigated the biological activity of mangrove extracts, a lack of comprehensive data remains regarding the secondary metabolite profiles of different plant organs, particularly between the leaves and fruits of *S. alba*. This study addresses this gap by providing a

qualitative comparison of phytochemical content between the two organs, offering new insights that could guide targeted utilization of specific plant parts for medicinal or functional food applications.

Processed products from fruits have the potential to be developed into locally based, natural, functional products, and phytopharmaceuticals. Plant samples, including leaves, stems, fruits, flowers, seeds, and roots, possess medicinal properties and serve as raw materials in drug production (Prasetyo et al., 2023). Mangrove fruit has been successfully processed into processed food products, but studies on its phytochemicals and fruit development are still limited (Budiyanto et al., 2022). Mangrove leaf extract has anti-termite and antifungal activity (Syahidah and Subekti, 2019).

The chemical composition of plants is influenced by geographical location, temperature, climate, and soil fertility. In mangroves, various plant parts—roots, bark, stems, leaves, and fruits—are used to treat diseases ranging from infections to degenerative and digestive disorders (Syahidah and Subekti, 2019). Plant samples—whether in the form of leaves, stems, fruits, flowers, seeds, or roots—possess medicinal properties and are widely utilized as raw materials in both modern and traditional medicine. Studying these plant parts provides valuable information on their secondary metabolite content, enabling the optimal utilization of these compounds. Phytochemical screening serves as an essential method for identifying and characterizing the active compounds present in plant samples.

Phytochemical screening serves as an essential tool for identifying active compounds in these plant parts, thereby enabling their optimal use in both modern and traditional medicine. By focusing on the organ-specific variation of secondary metabolites in *S. alba*, this research contributes to the scientific understanding of these compounds while also promoting community awareness and involvement in mangrove forest conservation through the recognition of their medicinal value. Beyond their pharmacological potential, mangrove conservation provides broader ecological and social benefits. According to Salampessy et al. (2025), mangrove conservation could improve forest governance and contribute to more inclusive and sustainable resource management. Similarly, Massiri et al. (2025) highlight that a community empowerment policy—providing local communities with legal access to utilize forests within conservation areas while strengthening their economic capacity—can support the preservation of conservation ecosystems and simultaneously enhance the economic well-being of surrounding communities.

2. Materials and Methods

2.1. Research Materials

Samples of *Sonneratia alba* mangrove leaves and fruits were obtained from Muara Gembong, Bekasi Regency, West Java, in May 2025. Based on research by Martins et al. (2021), mangrove flowers are produced during the dry and rainy seasons, with the flower-to-fruit cycle generally lasting around 2.5 to 5 months (**Fig. 1**). Ethanol 96%, filter paper, distilled water, DPPH powder, and a 40-mesh sieve were used. The tools used were an Optizen brand Uv-Vis Spectrophotometer, cuvette, blender, weighing bottle, Memmert brand oven, Ohouss brand analytical balance, and spatula.

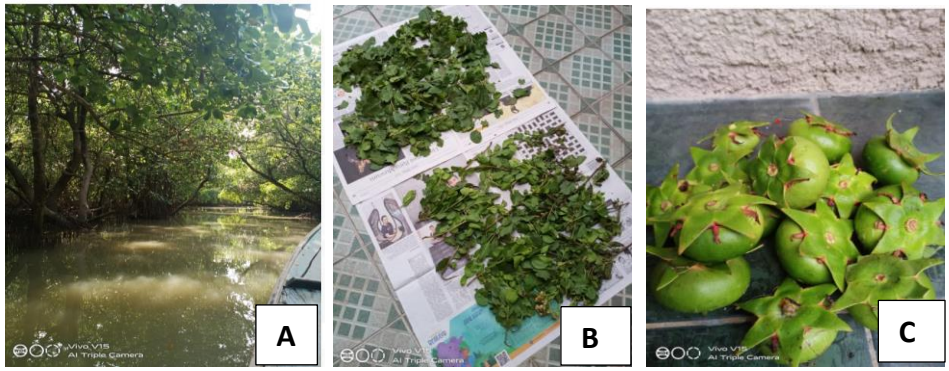

Fig. 1. (A) *Sonneratia alba* tree, (B) *S. alba* leaves, (C) *S. alba* fruit.

2.2. Preparation of Sonneratia alba Leaf and Fruit Extract

Leaves and fruits of *S. alba* were oven-dried at 60°C until completely dehydrated and subsequently ground into a fine powder. The powdered simplicia was macerated with 96% ethanol at a

ratio of 1:10 (200 g in 2 L of solvent) and extracted using a Soxhlet apparatus, following the method described by Roghini and Vijayalakshmi (2018). Qualitative phytochemical screening was performed according to the method described by Roghini and Vijayalakshmi (2018). For alkaloid detection, 2 mL of extract was mixed with 2 mL of concentrated hydrochloric acid, followed by a few drops of Mayer's reagent; the appearance of a green coloration or white precipitate indicated the presence of alkaloids.

Saponins were detected by mixing 2 mL of the extract with 2 mL of distilled water and shaking the mixture vigorously for 15 minutes. The presence of persistent foam, approximately 1 cm thick, indicated the presence of saponins. Tannins were identified by adding 2 mL of 5% ferric chloride to 1 mL of extract, resulting in a dark blue or greenish-black color, which confirmed their presence. Phenolic compounds were detected by adding 2 mL of distilled water and a few drops of 10% ferric chloride to 1 mL of extract, resulting in a blue or green coloration, which indicated the presence of phenols. Flavonoids were detected by adding 1 mL of 2N sodium hydroxide to 2 mL of the extract; a yellow coloration indicated the presence of flavonoids. The presence of triterpenoids and steroids was examined using the Libermann–Burchard test, in which a portion of the extract was treated with 0.5 mL of acetic anhydride and 0.5 mL of chloroform, followed by the gradual addition of concentrated sulfuric acid; a red–violet color indicated triterpenoids, while a bluish–green color indicated steroids. Finally, glycosides were identified by adding 3 mL of chloroform and a 10% ammonia solution to 2 mL of the extract, which resulted in a pink coloration, confirming their presence.

3. Results and Discussion

This study demonstrated that the ethanol extracts of *S. alba* leaves and fruits are rich in secondary metabolites. Qualitative phytochemical screening revealed that the leaf extract tested positive for alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, and glycosides, but negative for steroids (**Table 1**). In contrast, the fruit extract showed positive results for saponins, tannins, phenolics, flavonoids, and glycosides, while alkaloids, triterpenoids, and steroids were not detected (**Table 1**).

Table 1. Results of phytochemical analysis of leaf and fruit extracts of *S. alba*

Compound	Sample (ethanol extract 96%)	
	Leaves	Fruit
Alkaloids	+	-
Saponin	+	+
Tannin	+	+
Phenolic	+	+
Flavonoids	+	+
Triterpenoids	+	-
Steroids	-	-
Glycosides	+	+

The leaf and fruit extracts of *S. alba* contain phenolic compounds with strong antioxidant potential. Phytochemicals such as phenols, flavonoids, alkaloids, saponins, and tannins act as natural plant-derived antioxidants (Iqbal et al., 2015) that contribute to disease prevention by protecting cells from free radical damage, regulating blood sugar, and exhibiting antibacterial, anti-inflammatory, anticancer, and anti-osteoporosis properties (Roghini and Vijayalakshmi, 2018). Flavonoids, predominantly found as glycosides, function in the human body as antioxidants that can prevent cancer, protect cellular structures, enhance the efficacy of vitamin C, reduce inflammation, prevent osteoporosis, and act as natural antibiotics (Panche et al., 2016). Both flavonoids and glycosides are associated with diverse health benefits, including antioxidant, anti-inflammatory, antitumor, and antimicrobial activities (Fairulnizal et al., 2020). Steroid and triterpenoid compounds also exhibit a wide range of pharmacological properties, including antibacterial, antifungal, anthelmintic, anti-inflammatory, antitumor, antidiabetic, and therapeutic effects for menstrual disorders, malaria, and various skin conditions (Mouafi et al., 2014).

Flavonoid compounds are the most widespread group of plant parts, especially photosynthetic plant cells. Most flavonoids in nature are found in the form of glycosides (Ahmed et al., 2017; Shashank and Abhay, 2013). The presence of flavonoids has been shown to have antioxidant activity, free radical

scavenging capacity, prevention of coronary heart disease, hepatoprotective activity, anti-inflammatory and anticancer, while some flavonoids show potential anti-viral activity (Shashank and Abhay, 2013) Current trends in flavonoid research and development, mechanisms of action of flavonoids, functions and applications of flavonoids, predictions of flavonoids as potential drugs in preventing chronic diseases and future research directions (Panche et al., 2016).

Alkaloids, another important group of secondary metabolites, are recognized for their potential in biopharmaceutical development against infectious diseases. They can serve as sources of novel antimicrobials and antioxidants (Shami, 2016), and are utilized in diabetes management due to their effects on blood glucose and cholesterol levels. However, high alkaloid concentrations may impair liver and kidney function, making moderate levels more suitable for therapeutic purposes (Nimenibo-Uadia et al., 2017).

Saponins are important natural derivatives of plant triterpenoids, which are secondary metabolites of plants. Saponins, also known as glycoconjugates, are available both as natural products and synthetically (Bildziukevich et al., 2023). Plants, lower marine animals, and some bacteria produce saponins. Saponins have numerous medical uses, including as antimicrobials, antitumor agents, insecticides, hepatoprotectants, anti-inflammatory agents, and for manufacturing detergents, soaps, shampoos, and cosmetics. Saponins show hemolytic activity, taste bitter, and are toxic to fish (Moghimipour and Handali, 2015). Saponins exhibit both beneficial and detrimental properties, depending on their concentration in the sample. The biological properties of saponins suggest that they exhibit anti-carcinogenic effects through various mechanisms. Saponins have an expectorant effect and are generally used as a mild laxative and diuretic (Nimenibo-Uadia et al., 2017). Saponins and their derivatives are versatile glycoside compounds that play a crucial role in the food, agricultural, and pharmaceutical industries as natural additives in food, traditional medicine, and various pharmaceutical applications (Sharma et al., 2023).

The percentage of tannins in plants varies. Tannins are typically found in large amounts in tree bark, where they serve as a barrier to microorganisms, protecting the tree. In addition to tanning, tannins are used in dyeing, photography, beer and wine purification, and medicines. The presence of tannins in plants provides antidiabetic properties. Tannins are astringent, used to treat diarrhea and dysentery, and possess antioxidant, antimicrobial, and anticancer properties (Deivasigamani, 2018). However, tannins are known to form protein complexes, and these complexes can precipitate proteins. In addition to proteins, tannins also complex divalent metals, as well as cellulose, hemicellulose, pectin, and other carbohydrates. The best pharmacological activity of tannins is as an antibacterial because it has the same ability as phenolic compounds in precipitating bacterial proteins and is interrelated with anti-diarrheal activity caused by inflammation from bacteria (Sunani and Hendriani, 2023)

Mangrove leaves showed positive results in the presence of triterpenoid compounds. Plant Triterpenoid compounds are considered a defence against microbes, pathogens, and herbivores. The biological properties of triterpenoids include having hypoglycemic, anti-parasitic, and immunomodulatory activities as well as being an inhibitor of neutrophil elastase, which are beneficial for humans and are used in various medicinal applications, such as for antioxidants, anti-virals, anti-bacterials, anti-inflammatories, inhibition of cholesterol synthesis and anticancer agents (Flieger et al., 2021). Triterpenoid compounds exhibit significant pharmacological activity, including anti-virals, anti-bacterials, anti-inflammatory agents, and anticancer properties, which inhibit cholesterol synthesis (Bildziukevich et al., 2023).

The results of phytochemical tests of steroid compounds in both leaves and fruits were negative. This is also shown in the research results of Widiawati and Asih (2024). Plant steroid compounds play a role in regulating growth and development, as well as in controlling cell growth and differentiation processes in animals (Tarkowská, 2019). Steroids are also used to treat diseases caused by an excess or deficiency of hormones, as well as diseases such as arthritis and allergies. Steroids in plants have been shown to have cholesterol-lowering and anticancer effects. In traditional medicine, it is used to control stomach aches and as a contraceptive and for abortion (Zayed and Samling, 2016).

The presence of phenolic compounds, flavonoids, and tannins is believed to be responsible for their antioxidant activity, which acts as a potent inhibitor of free radicals. Phenolic compounds can act as antioxidants at various levels in different food systems, depending on the polarity and characteristics of the molecule. Different extractions show different activities (Benjakul et al., 2014). The presence of compounds as antioxidants offers various levels of disease prevention, protecting cells from free radical

damage, controlling blood sugar, and exhibiting antibacterial and anti-inflammatory properties, thereby reducing the risk of cancer and osteoporosis (Roghini and Vijayalakshmi, 2018).

Overall, the phenolic, flavonoid, and tannin content is likely responsible for the strong antioxidant activity of *S. alba*, acting as potent free radical scavengers and contributing to disease prevention. Variations in secondary metabolite content between leaves and fruits may be related to their distinct physiological roles. Leaves, as photosynthetic organs, are more exposed to UV radiation and environmental stress, leading to the production of specific protective metabolites. These findings suggest that *S. alba* leaves may possess greater therapeutic potential than the fruits. The absence of steroid compounds in both parts is consistent with several previous reports on the genus *Sonneratia*.

4. Conclusion

This study revealed that the leaves and fruits of *S. alba* contained various saponins, tannins, phenolics, flavonoids, and glycosides. In contrast, triterpenoids were only detected in the leaves, and steroids were not found in either plant part. This finding confirms the existence of variations in secondary metabolite content between plant organs. These variations indicate that the leaves possess a broader diversity of bioactive compounds and may offer greater pharmacological potential compared to the fruits. The identified metabolites are known for their anti-oxidant, anti-inflammatory, antimicrobial, and anticancer properties, highlighting the value of *S. alba* as a promising source for natural product development, functional foods, and phytopharmaceuticals. Furthermore, by demonstrating the medicinal potential of mangrove-derived compounds, this research supports broader community-based conservation strategies, enhancing awareness and promoting sustainable utilization of mangrove ecosystems. Future studies should focus on quantitative analyses and bioactivity assays to further validate the therapeutic potential of specific compounds identified in *S. alba*.

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