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The Potential of *Sonneratia caseolaris* Mangrove Plant as Functional Food and Medicine

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ABSTRACT

Mangrove forests are a unique ecosystem found extensively in tidal areas along coastal regions, including Indonesia. Apart from their environmental potential, these plants have also been proven to play a role in various functional foods with potential medicinal properties. One such plant is the *Sonneratia caseolaris* mangrove, commonly known as the mangrove apple *S. caseolaris* grows at a depth of 18-22 cm, in flooded areas directly facing the coastline. Despite its abundance, people rarely consume this plant directly due to its sour taste and the lack of knowledge about its chemical compounds, hindering its optimal utilization. This research aims to conduct an article review on studies of *S. caseolaris* mangroves to provide information that can enhance public awareness, particularly regarding its benefits and processed products. The method employed includes a review of national and international articles using search engines such as Google Scholar, Google Advanced Search, INPL database, *Citizen Medicine* (CitMed) and other publication websites. The research findings demonstrate that *S. caseolaris* contains beneficial compounds such as flavonoids, alkaloids, tannins, and phenols in its stem bark, leaves, and fruits. Its processed products can be packaged as dodol, beverages or herbal teas. Apart from food products, this plant is also used in topical preparations such as sunscreen powder, face mist, and clay masks. These results indicate that *S. caseolaris* is safe for consumption in various products, thus allowing for its maximum utilization.

Keywords: fungtional food, mangroves, natural ingredients, sonneratia caseolaris

ABSTRAK

Hutan bakau merupakan ekosistem unik yang banyak ditemukan di daerah pesisir pantai, termasuk Indonesia. Tanaman bakau terbukti berperan dalam berbagai pangan fungsional yang berpotensi berkhasiat obat, selain dari potensi lingkungannya. Salah satu tumbuhan bakau tersebut adalah *Sonneratia caseolaris* atau biasa dikenal dengan mangrove apel (*S. caseolaris*I) yang tumbuh di kedalaman 18-22 cm, pada daerah banjir yang menghadap langsung ke garis pantai. Meski melimpah, tanaman ini jarang dikonsumsi secara langsung oleh masyarakat karena rasanya yang asam dan kurangnya pengetahuan tentang senyawa kimianya sehingga menghambat pemanfaatannya secara optimal. Penelitian ini bertujuan untuk melakukan review mengenai kajian mangrove *S. caseolaris* yang dapat memberikan informasi untuk meningkatkan kesadaran masyarakat mengenai manfaat dan produk olahannya. Metode yang digunakan meliputi review artikel nasional dan internasional dengan menggunakan mesin pencari seperti Google Scholar, Google Advanced Search, database INPL, Citizen Medicine (CitMed) dan website publikasi lainnya. Hasil menunjukkan bahwa *S. caseolaris* mengandung senyawa yang bermanfaat seperti flavonoid, alkaloid, tanin, dan fenol pada kulit batang, daun, dan buahnya. Produk olahannya dapat dikemas menjadi dodol, minuman maupun teh herbal. Selain produk makanan, tanaman ini juga digunakan dalam sediaan topikal seperti bedak tabir surya, *face mist*, dan masker tanah liat. Selain itu, hasil menunjukkan bahwa *S. caseolaris* aman dikonsumsi pada berbagai produk sehingga memungkinkan pemanfaatannya secara maksimal.

Kata kunci: pangan fungsional, pohon bakau, bahasa alami, sonneratia caseolaris

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INTRODUCTION

Mangrove forests are unique and distinctive ecosystems found abundantly in Indonesia (Rajis *et al.,* 2017). These forests thrive in estuarine areas, intertidal zones, or coastal regions and play a significant role in the surrounding ecosystem (Mahmuda *et al.,* 2023). Indonesia harbors the largest mangrove area globally, accounting for approximately 23% of the global mangrove population. Apart from their crucial role in environmental preservation, these plants also act as biofilters for water pollution or bioindicators. They have the potential to accumulate important active chemical substances that can be utilized as sources of pharmaceuticals or cosmetics. Despite the high economic and ecological value of mangrove forests, insufficient conservation measures may render them vulnerable to damage, impacting human life (Rajis *et al.,* 2017). Indonesia hosts numerous species of mangrove plants, one of which is the mangrove apple or *Sonneratia caseolaris*, abundant along the Indonesian coasts (Rajis *et al.,* 2017).

S. caseolaris, also known as "*bakau apel*", "*papida putih*", *"Pedada"* or *"Pidada merah"* can grow up to 15 meters tall. It has brown-colored bark and rough, round leaves arranged in pairs on its branches, which are approximately 7 cm long. One coastal area where this plant is found is the Ketapang coastal area in Tangerang, Banten. Locally, people recognize its fruit as "kedabu." The fruit is believed to contain vitamin C, carbohydrates, fats/glycerol, proteins, minerals, and ascorbic acid (Susanto *et al.*, 2020). The stem bark and leaves contain compounds such as flavonoids, alkaloids, and tannins, while the fruit contains alkaloids, flavonoids, phenols, and tannins (Niken et al., 2019). Natural antibacterial properties are believed to be present in the stem bark, leaves, and fruit extracts. The fruit is known for its antioxidant and anticancer properties, while the leaves are proven to have antioxidant and anti-MRSA (Methicillin-Resistant *Staphylococcus Aureus*) properties (Audah *et al.,* 2022).

There haven't been many studies explaining the compounds' contents and the products that can be derived from this plant, thus people seldom consume it directly, partly due to its very sour taste. Consequently, its utilization remains suboptimal. The objective of this research is to conduct an article review of studies related to the mangrove plant *S. caseolaris* to provide information that can enhance public knowledge, particularly regarding its benefits, compound contents, and functional food products' potential as pharmaceuticals, aiming for its maximal utilization.

MATERIALS AND METHODS

This research was conducted through an article review of studies on the *Sonneratia caseolaris* plant. The method employed was a review of national and international articles using search engines such as Google Scholar, Google Advanced Search, the INPL extract library database, CitMed, and several other publication websites as empirical evidence that this plant has been extensively researched and presented in various functional food products as pharmaceuticals.

RESULT AND DISCUSSION

Research on the mangrove apple plant (Sonneratia caseolaris)

Indonesia boasts abundant mangrove forest areas along the coast from Sumatra to Papua. Many types of mangroves grow throughout the Indonesian marine regions, one of which is the *Sonneratia caseolaris* mangrove. This plant is a characteristic species of Kalimantan. Local communities utilize this plant, particularly its leaves, empirically as wound medicine and to remove scars on the skin. Meanwhile, in Central Kalimantan, locals commonly use its fruit and leaves to treat diseases like chickenpox, diarrhea, and bruises on the skin, believing that the pidada plant can act as an antibacterial agent (Sogandi *et al.,* 2017). This plant has played a significant role in the lives of communities, ranging from environmental conservation and coastal ecosystem preservation to food and medicine. This is evidenced by research findings presented in table 1.

The antibacterial compounds are compounds capable of inhibiting the growth of bacteria both inside and outside the body and can kill pathogenic bacteria (Magani *et al.* 2020). Antibacterial

compounds can be obtained from various plants through testing processes such as S. caseolaris plants. Research has shown that Sonneratia caseolaris mangrove leaves can be used as a natural preservative for fresh fish and contain antibacterial compounds that can inhibit the rate of decay in fish. Due to these properties, this plant can be packaged in hand sanitizer spray formulations. Research conducted in Kuala Tungkal, Tanjung Jabung Barat Regency, in the Pangkal Babu hamlet, showed that the concentration of hand sanitizer with pedada leaf extract affects the inhibitory zone of S. aureus growth, as indicated by the result of F Hitung (16.93) > F Table (2.87). It can be concluded that the antibacterial effect of hand sanitizer spray from pedada leaf extract on the growth of S. aureus has a good effect (Aulia *et al.* 2023).

Fitriani and Nashihah (2021) also reported that the antibacterial activity of *Sonneratia caseolaris* plants against *Propionibacterium acnes* bacteria resulted in consecutive inhibition zone diameters of 3.3 mm, 4.43 mm, 6.48 mm, and 8.45 mm, while against Staphylococcus epidermidis bacteria, they were 11.08 mm, 12.27 mm, 15.38 mm, and 16.78 mm, respectively. Rambai leaf extract has also been tested for its antibacterial activity against *Streptococcus sanguinis* by Putri *et al.* (2023), showing a good antibacterial activity in the extract. Further testing was also conducted on shrimp larvae (*Artemia Salina Leach*) using the Brine Shrimp Lethality Test (BSLT) method. The research results showed that the extract was fractionated by column chromatography and 12 fractions were obtained. Fraction F11 had an LC50 value of 46.77 µg/ml, which was higher than the other fractions. The identification results of this fraction showed the presence of steroid, flavonoid, and phenolic compound groups that could be utilized as antibacterial agents (Fitrah *et al.* 2018). Sogandi *et al.* (2017) showed a phytochemical screening of 96% ethanol extract of rambai leaves containing saponin, tannin, and flavonoid compounds suspected to have antibacterial properties. Other research also supports this, as the authors successfully proved the results of LC-MS/MS testing of this sample extract, finding phenolic compounds such as azelaic acid, aspirin, and flavonoid glycosides like isovitexin and quercitrin. These compounds significantly contribute to both antibacterial and antioxidant activities (Audah *et al.* 2022). This proves that *Sonneratia caseolaris* leaves can indeed be used as antibacterials and can be incorporated into various household products.

In addition to its antibacterial properties, this plant has also been proven to be effective as an antioxidant. Syamsul *et al.* (2020) reported the antioxidant activity of this extract using the DPPH (1,1-diphenyl-2-picrylhydrazyl) method, with the ethanol extract showing an IC_{50} value of 24.22 ppm (very strong), *n*-hexane fraction 88.18 ppm (strong), ethyl acetate fraction 15.39 ppm (very strong), and ethanol fraction 38.41 ppm (very strong). Therefore, the pidada leaf extract is formulated in topical formulations such as clay mask or masker lumpur so that the active ingredients can directly interact with the facial skin and provide long-lasting effects. The research results showed that the clay mask formulation 2 (pidada extract with 30% kaolin) is better than formula 1 (pidada extract with 25% kaolin) because it provides better spreadability and faster drying time. Besides the Clay Mask, another product that can be packaged is face mist. The research produced the best face mist formula with 70% ethanol extract of pidada leaves, with an antioxidant activity (IC50) of 3,836.01 µg/mL, moisture content of 52.35%, pH value of 4.64, and preferred by panelists especially in terms of aroma, texture, and homogeneity (Nusaibah *et al.* 2022). Mangrove leaf extract is also applied in other beauty products, such as hand and body lotion (Novita and Maruka 2022).

The red mangrove (*Sonneratia caseolaris L.*) is one of the natural ingredients traditionally used by the people of Kalimantan. Its leaves are utilized as one of the components in cold powder. Traditionally, people apply it on their faces when exposed to sunlight for an extended period. Based on research, pidada leaves exhibit antioxidant activity due to their secondary metabolites such as phenolics, flavonoids, saponins, carotenoids, and tannins. The use of antioxidants can prevent various diseases caused by UV radiation, and active antioxidant compounds like flavonoids have been reported to protect against UV radiation. Research results

demonstrate that the sunscreen profile of red mangrove leaf extract and fractions exhibits sunscreen activity as fast tanning, standard suntan, extra protection, and sunblock (Hasanah *et al.* 2015). Hasanah *et al.* (2016) also reported that leaves can be used in anti-acne products, demonstrating inhibitory effects against *Propionibacterium acnes*. Kartikaningsih *et al.* (2024) proved 3 compounds that play an important role as antioxidants in mangrove leaves via LC-HRMS, namely Tempo, Choline, and Betaine. Tempo shows higher antioxidant activity than Choline and Betaine. Mangrove leaves can also be used as an anti-inflammatory or wound-healing agent. This is proven by the coumarin compound which has successfully demonstrated potential in reducing inflammation from research conducted by Rozirwan et al. (2024).

A separate study demonstrated that the methanolic extract from the fruit of *Sonneratia caseolaris L.* in Bangladesh significantly reduced blood glucose levels in Swiss albino mice. Following the administration of the extract, a notable decrease in blood glucose levels was observed across various tested doses compared to the control group. The doses of 50 mg/kg, 100 mg/kg, 200 mg/kg, and 400 mg/kg all exhibited significant hypoglycemic activity, with mean serum glucose levels lower than those of the control. The standard drug, Glibenclamide, resulted in a more pronounced reduction in glucose levels than the plant extract. The hypoglycemic effect of the extract may be attributed to mechanisms similar to those of Glibenclamide, such as decreased intestinal glucose absorption or enhanced glucose uptake (Hasan *et al.* 2013).

Another study by Tiwari *et al.* (2010) revealed that the methanolic extract of *Sonneratia caseolaris* fruits, originating from the mangrove flora of India, exhibits intestinal α-glucosidase inhibitory activity. From this bioactive methanolic extract, three compounds were isolated and identified is *oleanolic acid, β-sitosterol-β-D-glucopyranoside*, and *luteolin*. *Oleanolic acid* demonstrated strong α-glucosidase inhibitory activity with an IC50 of 15 µM and antihyperglycemic activity. This study is the first to identify *oleanolic acid* in *S. caseolaris* fruits and establish its intestinal α-glucosidase inhibitory and antihyperglycemic activities.

In addition to leaves, mangrove fruit peel is also believed to possess antioxidant activity beneficial for the body, and research has been conducted on it. Studies on the fruit peel show that the extracts have antioxidant levels as follows: methanol extract 25.72 ppm, n-hexane fraction extract 67.48 ppm, ethyl acetate extract 109.24 ppm, and n-butanol fraction 54.29 ppm. From this data, it is evident that the mangrove fruit peel extract with methanol extract exhibits the best antioxidant results compared to other extracts, making it suitable for commercial product formulations (Putri *et al.* 2015).

Additionally, other research has discovered that the bark extract of *Sonneratia caseolaris* contains bioactive compounds such as flavonoids, steroids, and tannins that function as antioxidants (Habib *et al.* 2019). The ethanol extract (ETF) exhibited the highest antioxidant activity with an IC50 of 4.57 µg/ml, followed by the highest phenolic content in the ethyl acetate extract (EAF) at 63.00 mg GAE/g. The highest total antioxidant activity was found in the ethanol fraction (ETF) at 185 GAE/g of dry sample. This research highlights the significant potential of *S. caseolaris* as a natural source of antioxidants. These findings encourage further investigation to isolate the active compounds responsible for this antioxidant activity (Munira *et al.* 2019).

Processed products from the *mangrove apple* plant (*Sonneratia caseolaris)*

Indonesia, as a maritime country rich in biodiversity, boasts a widespread distribution of mangrove vegetation that is essential for the ecological life of its people. In 2021, the Central Statistics Agency reported that the largest expanse of mangrove vegetation in Indonesia is found in Papua, covering an area of 3.63 million hectares (ha) or 20.37% of the world's total mangrove area, followed by Sumatra and Kalimantan. This indicates the significant variety and benefits of mangroves that can be directly or indirectly experienced by local communities. One notable type of mangrove plant is the mangrove apple tree *(Sonneratia caseolaris)*, which grows abundantly

in Indonesia's mangrove forests. Compared to other mangrove species, *Sonneratia caseolaris*, particularly its fruit, is widely recognized as a food source in various countries. In Indonesia, according to the Indonesian Food and Drug Supervisory Agency (BPOM), the fruit of S. caseolaris is the only part of the mangrove plant registered as a natural food raw material (BPOM 2023). Many communities have used this fruit as a raw material for food and traditional medicine. For instance, the people of Ababiaidi Village use this plant as a source of medicinal ingredients, utilizing its leaves, fruit, and roots, which are also employed as building materials and firewood. Locally, this plant is known as "*Swai*" (Warpur et al. 2016). The pedada fruit contains phytochemicals such as steroids, terpenoids, and flavonoids. Phytochemical compounds like flavonoids act as antioxidants that neutralize free radicals attacking our body cells; these free radicals can cause cancer, heart disease, and premature aging (Wiranto *et al.* 2017). *S. caseolaris* fruit has a very sour taste, making it rarely consumed by the community, thus the second benefit of this plant part is still not optimal and requires processing into economically valuable food ingredients (Setiawan *et al.* 2016).

Table 1. Summary of Research - Studies on Leaves and Fruit Peel of *Sonneratia caseolaris*

References	Parts of the plant	Compounds	Bioactivities	Research result
Aulia *et al.* (2023)	Leaves	-	Antibacterial	Products from Sonneratia caseolaris mangrove leaves can be made into hand sanitizers.
Sogandi *et al.* (2017)	Leaves	saponin, tannin, and flavonoids	Antibacterial	The highest antibacterial activity is found at a concentration of 100%, with an average diameter of 22.48 mm.
Fitriani dan Nashihah (2021)	Leaves	-	Antibacterial	The antibacterial activity of *Sonneratia caseolaris* plant against Propionibacterium acnes bacteria is smaller compared to that against *Staphylococcus epidermidis* bacteria. However, these results prove that this plant has antibacterial activity.
Fitrah *et al.* (2018)	Leaves	-	toxicity test with BLST methode	The research findings report that ethanol extract has a higher level of toxicity compared to other extracts (*n*-hexane, ethyl acetate, and water), with an LC_{50} value of 28.18 µg/ml. Additionally, Fraction F11 exhibits a higher level of toxicity compared to other fractions, with an LC_{50} value of 46.77 µg/ml.

Putri *et al.* (2023)	Leaves	*flavonoids, tannins, phenols, triterpenoids, and steroids*	Antibacterial	The extract of rambai leaves with concentrations of 25%, 50%, 75%, and 100% exhibit antibacterial activity against Streptococcus sanguinis
Audah *et al.* (2022)	Leaves	Phenolic compounds such as azelaic acid and aspirin. Flavonoid glycosides such as isovitexin and quercitrin	Antioxidant, Antibacterial, and Anti-MRSA	The ethanol-based extract of *S. caseolaris* leaves exhibits the highest antioxidant and anti-MRSA activity. Antioxidant activity tests show comparable activity when compared to ascorbic acid, with IC50 values of 4.2499 ± 3.0506 ppm and 5.2456 ± 0.5937 ppm, respectively, classifying the extract as a super antioxidant. It also has antibacterial activity, evidenced by 12.4% of it comprising non-toxic flavonoids, with the minimum inhibitory concentration of ethanol-based S. caseolaris leaf extract being around 5000 ppm.
Syamsul *et al.* (2020)	Leaves	-	Antioxidant	The antioxidant activity test was conducted using the DPPH (1,1-diphenyl-2-picrylhydrazyl) method, and the results showed that the ethanol extract has an IC50 value of 24.22 ppm (very strong), the n-hexane fraction 88.18 ppm (strong), the ethyl acetate fraction 15.39 ppm (very strong), and the ethanol fraction 38.41 ppm (very strong).
Kumalasari *et al.* (2023)	Leaves	-	Antioxidant	One of the cosmetic products that can be formulated from the antioxidant results (24.22 ppm, very strong) is clay mask or mud mask. Research results show that if the IC50 value of the pidada leaves indicates that clay mask formulation 2 (pidada extract with 30% kaolin) is better than formula 1 (pidada extract with 25% kaolin), as it provides better spreadability and faster drying time.

Nusaibah *et al.* (2022)	Leaves	-	Antioxidant	The research yielded the best face mist formula obtained by adding 70% ethanol extract of pidada leaves with antioxidant activity (IC50) of 3,836.01 µg/mL, moisture content of 52.35%, pH value of 4.64, and preferred by panelists, especially in terms of aroma, texture, and homogeneity parameters.
Hasanah *et al.* (2015)	Leaves	fenolik, flavonoid, saponin, karotenoid dan tanin	-	The research conducted involved the development of sunscreen products using extracts and fractions of red mangrove leaves, which were proven to have sunscreen activity such as fast tanning, standard suntan, extra protection, and sunblock.
Novita dan Maruka 2022	Leaves	-	-	The research was conducted on the production of Hand and Body Lotion from Sonneratia caseolaris mangrove leaf extract, and the best extract was obtained in P1 (10 mL).
Hasanah *et al.* (2016)	Leaves	-	Antiacne	The research results indicate that the best emulgel formulae are F5, F6, F7, and F8 with thick viscosity, and anti-acne activity shows inhibition against *Propionibacterium acnes.*
Kartikaningsih *et al.* (2024)	Leaves	Tempo, Choline, and Betaine	Antioxidant	The Result compounds that play an important role as antioxidants in mangrove leaves via LC-HRMS, namely Tempo, Choline, and Betaine. Tempo shows higher antioxidant activity than Choline and Betaine.
Rozirwan et al. (2024)	Leaves	Coumarin	anti-inflammatory or wound-healing agent	Mangrove leaves can also be used as an anti-inflammatory or wound-healing agent. This is proven by the coumarin compound which has successfully demonstrated potential in reducing inflammation.
Hasan *et al.* 2013	Fruit	-	hypoglycemic activity	methanolic extract from the fruit of Sonneratia caseolaris L. significantly reduced blood glucose levels in Swiss albino mice. Following the administration of the extract, a

				notable decrease in blood glucose levels was observed across various tested doses compared to the control group. The doses of 50 mg/kg, 100 mg/kg, 200 mg/kg, and 400 mg/kg all exhibited significant hypoglycemic activity, with mean serum glucose levels lower than those of the control.
Tiwari *et al.* 2010	Fruit	-	α-glucosidase inhibitory activity	*Oleanolic acid* demonstrated strong α-glucosidase inhibitory activity with an IC50 of 15 µM and antihyperglycemic activity. This study is the first to identify *oleanolic acid* in *S. caseolaris* fruits and establish its intestinal α-glucosidase inhibitory and antihyperglycemic activities.
Putri *et al.* 2015	mangrove fruit peel	-	Antioxidant	The research shows that the methanol extract yielded results of 25.72 ppm, the n-hexane fraction extract yielded 67.48 ppm, the ethyl acetate extract yielded 109.24 ppm, and the *n*-butanol fraction yielded 54.29 ppm. From this data, it is evident that the mangrove fruit peel extract with methanol extraction has the best antioxidant results among the other extracts, thus making it suitable for commercial product formulations.
Munira *et al.* (2019)	bark		Antioxidant	The bark extract of *Sonneratia caseolaris* contains bioactive compounds such as flavonoids, steroids, and tannins that function as antioxidants. The ethanol extract (ETF) exhibited the highest antioxidant activity with an IC50 of 4.57 µg/ml, followed by the highest phenolic content in the ethyl acetate extract (EAF) at 63.00 mg GAE/g. The highest total antioxidant activity was found in the ethanol fraction (ETF) at 185 GAE/g of dry sample. This research highlights the significant potential of *S. caseolaris* as a natural source of

antioxidants. These findings encourage further investigation to isolate the active compounds responsible for this antioxidant activity.

Despite there being numerous processing methods available for this fruit, such as jenang, dodol, jam, and syrup, syrup products are preferred more due to our tropical climate, which allows people to opt for refreshing drinks over sweet foods (Rajis *et al.* 2017). This is evidenced by research summarized in Table 2. Setiawan *et al.* (2016) reported on research regarding the pedada mangrove fruit packaged as food in the form of jam. Three parameters used in making this jam fall within the Indonesian National Standard criteria, namely water content and sucrose content (sugar) in SNI 01-3746-2008, and total dissolved solids content in (SNI-01-3746-1995). The best treatment for pedada jam, with a ratio of half-ripe pedada fruit at 40% and sugar at 60%, met the requirements of SNI 01-3746-2008, SNI-01-3746-1995, descriptive sensory evaluation, and overall preference assessment. This best-treated pedada jam has a water content of 26.84%, sucrose content of 57.82%, total dissolved solids content of 66.26 ºBrix, total acid content of 15.20%, and ash content of 0.31%. Furthermore, descriptive sensory evaluation noted its light green color, slightly pedada aroma, sweet taste, slightly soft texture, and overall preference evaluation indicated that respondents liked the pedada fruit jam. Apart from being made into jam, other products made by the people of Tuban Village, Kuta District, Badung Regency, Bali, as food include fruit salad, syrup raw material, pudding, soap, and dodol (Fahreni 2016). The people of Bedono Sayung Demak commonly consume pedada fruit as food products, including syrup, jam, and dodol (Mulyatun 2018). Meanwhile, the people of Bumi Dipasena Utama Village, Tulang Bawang Regency, Lampung Province, utilize this fruit in various processed forms such as syrup, jenang, dodol, agar-agar, and others (Prasetyo *et al.* 2023).

Another utilization effort is instant drinks as conducted by Wiratno *et al.* (2017). The research results reported that instant drinks made from *Sonneratia caseolaris* mangrove fruit had a water content of 1.63-1.70%, ash content of 1.43-1.45%, and sugar content of 63.44-43.11%. These three aspects meet the instant powder quality standards (SNI 01-4320-1996). Then, sensory evaluation was selected through descriptive testing, with a color score of 2.16 (white), aroma description score of 3.27 (somewhat aromatic of pedada fruit), taste description score of 4.33 (sour), and texture description score of 2.80 (somewhat smooth). Overall hedonic assessment was liked by the panelists with a score of 4.12 (like). In addition to instant drinks, kombucha tea with pedada fruit extract variants has also been reported by Fitriyani *et al.* 2024. Testing has shown that the resulting tea has antioxidant and antibacterial activities. Antioxidant testing of kombucha and pedada variant teas showed the presence of compounds such as tannins, saponins, and flavonoids. This tea also exhibited antibacterial activity against *E. coli* and *S. typhi* bacteria, with the antibacterial activity against *E. coli* showing greater results compared to *S. typhi*.

In addition to the fruit, *Sonneratia caseolaris* mangrove leaves also have the potential to reduce lipid oxidation rates and increase antioxidant activity during the shelf life of bread, as studied by Sumartini *et al.* (2022). This preparation is formed in powder form and added directly to white bread to observe the results. The research findings indicate that the addition of leaf powder significantly improved the treatment at 2-2.5g/100g and significantly affected the volume and texture of the white bread. The addition of leaf powder was proven effective in reducing the level of peroxide accumulation and could reduce the level of peroxide accumulation during an eight-day shelf life leaf extract was also added in the production of jelly candy. The best concentration in this study was leaf extract at 58%, which had a pH value of 5.4, total dissolved solids of 13.42 ºBrix, water

content of 56.44%, texture test of 727.5 gf, antioxidant activity of 72.74%, with a reddish-yellow color description, slightly sweet taste, and an aroma approaching liking (Prima *et al.* 2023). Currently, the standardization of the leaves of *S. caseolaris* as processed food product ingredients is being conducted in cooperation with the Indonesian Food and Drug Administration (Bapan Pengawas Obat dan Makanan).

Table 2. Summary of products from the *mangrove apple* plant (*Sonneratia caseolaris)*

References	**products from the *mangrove apple* plant (*Sonneratia caseolaris)***
Setiawan *et al.* (2016)	The research involved making jam from mangrove fruits. Three parameters were utilized in the jam-making process and fall under the criteria of the Indonesian National Standards, namely water content and sucrose (sugar) content according to SNI 01-3746-2008, as well as total dissolved solids content according to (SNI-01-3746-1995). The results indicate that the samples have met all three parameters used.
Fahreni 2016	The community of Tuban Village, Kuta District, Badung Regency, Bali, commonly utilizes this pidada fruit for various food purposes such as in salads, as a raw material for syrup, pudding, soap, and dodol.
Mulyanto 2018	The community of Bedono Sayung, Demak, typically consumes pedada fruit by processing it into food products such as syrup, jam, and dodol.
Prasetyo *et al.* 2023	The community of Bumi Dipasena Utama Village, Tulang Bawang Regency, Lampung Province, utilizes Sonneratia sp. fruit to make various processed products such as syrup, porridge, dodol, agar-agar, and others.
Wiratno *et al.* (2017)	Instant drink made from Sonneratia caseolaris mangrove fruit has met the quality standards for instant powder drinks (SNI 01-4320-1996). Sensory evaluation was conducted, focusing on color, aroma, taste, and texture. Overall hedonic assessment by the panelists showed a preference score of 4.12.
Fitriyani *et al.* 2024	This study created a tea product by combining kombucha and pidada fruit. Testing has proven that the resulting tea possesses antioxidant and antibacterial activities.
Sumartini *et al.* (2022)	The research was conducted regarding the addition of Sonneratia caseolaris mangrove leaf powder to improve the texture and shelf life of white bread. The research results indicate that the addition of mangrove leaf powder significantly enhances the treatment at 2-2.5g/100g and significantly affects the volume and texture of white bread.
Prima *et al.* (2023)	The research was conducted on the addition of mangrove extract in the formulation of jelly candies. The optimal concentration in this study was 58% pedada leaf extract, which had a pH value of 5.4, total dissolved solids of 13.42 °Brix, moisture content of 56.44%, texture test of 727.5 gf, antioxidant activity of 72.74%, with a reddish-yellow color description, slightly sweet taste, and a scent resembling pedada leaves, which was well-received.
Rahim and Abu Bakar, (2018)	In India, the fruit is used in various industrial and culinary applications, such as making syrup, cakes, and pudding, and it also has potential as a source of dietary fiber.

Pattanaik *et al.* (2008)	The local community around Bhitarkanika Wildlife Sanctuary, India, frequently consumes this mangrove plant as a remedy for diarrhea, a source of fuel, and a vegetable. These benefits indicate that the plant is not only valuable in traditional medicine but also in daily life as a source of fuel and food.
Tran *et al.* (2021); Nguyen *et al.* (2021).	the Vietnamese community also extensively utilizes the *S. caseolaris* plant as a local food source. Generally, the fruit of the pedada is often used in local cuisine in various regions.
Noor *et al.* 2023	The research focus on ready-to-drink (RTD) beverages made from *Sonneratia caseolaris* fruit juice. The main findings of this study indicate that the use of *S. caseolaris* fruit puree significantly affects the organoleptic properties of RTD beverages, including color, aroma, texture, and overall preference. Cytotoxicity studies showed that RTD beverages made from *S. caseolaris* fruit are safe for consumption due to the high cell viability percentage. Additionally, the DPPH and superoxide radical scavenging activities were very high, which is beneficial for health and well-being. These RTD beverages also contain energy, protein, carbohydrates, sugars, dietary fiber, and Vitamin C, aligning with the Malaysian RNI 2017 recommendations.

In addition to Indonesia, Pidada or *Sonneratia caseolaris*, also known as mangrove apple or crabapple mangrove, is widely distributed along the coastal regions from India to the Western Pacific, including Malaysia. Pidada fruit is highly nutritious, containing carbohydrates, fats, proteins, and various phytochemical compounds such as phenolics, flavonoids, tannins, alkaloids, and saponins, which provide significant antioxidant activity. In India, the fruit is used in various industrial and culinary applications, such as making syrup, cakes, and pudding, and it also has potential as a source of dietary fiber (Rahim and Abu Bakar, 2018). The local community around Bhitarkanika Wildlife Sanctuary, India, frequently consumes this mangrove plant as a remedy for diarrhea, a source of fuel, and a vegetable. These benefits indicate that the plant is not only valuable in traditional medicine but also in daily life as a source of fuel and food (Pattanaik *et al.* 2008). Besides India, the Vietnamese community also extensively utilizes the *S. caseolaris* plant as a local food source. Generally, the fruit of the pedada is often used in local cuisine in various regions (Tran *et al.* 2021; Nguyen *et al.* 2021).

Noor *et al.* (2017) conducted research on ready-to-drink (RTD) beverages made from *Sonneratia caseolaris* fruit juice. The main findings of this study indicate that the use of *S. caseolaris* fruit puree significantly affects the organoleptic properties of RTD beverages, including color, aroma, texture, and overall preference. Cytotoxicity studies showed that RTD beverages made from *S. caseolaris* fruit are safe for consumption due to the high cell viability percentage. Additionally, the DPPH and superoxide radical scavenging activities were very high, which is beneficial for health and well-being. These RTD beverages also contain energy, protein, carbohydrates, sugars, dietary fiber, and Vitamin C, aligning with the Malaysian RNI 2017 recommendations.

CONCLUSION

Sonneratia caseolaris plant has been proven to be useful as both antibacterial and antioxidant agents and has been extensively utilized in the formulation of functional food products and medicines, ranging from leaves, fruits, to fruit peels. These findings serve as empirical evidence that the *Sonneratia caseolaris* plant is safe for consumption, enabling

its utilization to be carried out optimally and continuously by the community.

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