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POTENTIAL UTILIZATION OF MANGROVE LEAVES (*Rhizophora* sp.) AS RAW MATERIAL FOR FUNCTIONAL HERBAL TEA DRINKS BASED ON PHYTOCHEMICAL ANALYSIS AND LEVEL OF PREFERENCE

Potensi Pemanfaatan Daun Mangrove (*Rhizophora* sp.) Sebagai Bahan Baku Minuman Teh Herbal Fungsional Berdasarkan Analisis Kandungan Fitokimia dan Tingkat Kesukaan

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ABSTRACT

Rhizophora sp. mangrove leaves contain bioactive compounds such as phenolics, flavonoids, tannins, and saponins that have antioxidant properties. This potential can be utilized to develop herbal tea as a natural and healthy functional beverage, which can support the preservation of mangrove ecosystems and contribute to improving the economy of coastal communities. This study aims to determine the potential use of *Rhizophora* sp. mangrove leaves as raw materials for functional herbal tea through analysis of phytochemical content and panelist preference levels. The research method used is an exploratory and experimental approach quantitatively to three types of mangrove leaves as test treatments, namely *Rhizophora* apiculata, *Rhizophora* mucronata, and *Rhizophora* stylosa. The parameters analyzed include phenolic content, flavonoids, antioxidant activity, and hedonic tests. The results showed that the three types of mangrove leaves, namely R. apiculata, R. mucronata, and R. stylosa, have potential as raw materials for functional herbal tea drinks. The three types of *Rhizophora* leaves contain phenolic compounds of 39,716–84,645 mg GAE/g, flavonoids of 61,075–89,508 mg CAE/g, antioxidants with IC_{50} values of 72,339–76,626 ppm. The mangrove leaf type *Rhizophora* stylosa showed the best results in all test parameters. The results of the panelists' preference level through the hedonic test, the herbal tea of the three types of *Rhizophora* leaves was positively received by the panelists, with color attribute scores of 7,00–7,64, aroma of 6,44–6,60, and taste of 7,00–7,16. *Rhizophora* stylosa herbal leaf tea obtained the highest alternative value based on the results of the *Bayes* method decision making of 7,27. *Rhizophora* sp. mangrove leaf herbal tea has the potential to be developed as a functional drink based on natural and local ingredients and supports the sustainable use of mangrove plants.

Keywords: Mangrove Leaves, *Rhizophora* sp., Phytochemicals, Herbal Tea, Functional Drinks

ABSTRAK

Daun mangrove *Rhizophora* sp. mengandung senyawa bioaktif seperti fenolik, flavonoid, tanin, dan saponin yang memiliki sifat antioksidan. Potensi ini dapat dimanfaatkan untuk mengembangkan teh herbal sebagai minuman fungsional alami dan sehat, yang dapat mendukung pelestarian ekosistem mangrove serta berkontribusi pada peningkatan ekonomi masyarakat pesisir. Penelitian ini bertujuan untuk mengetahui potensi pemanfaatan daun mangrove *Rhizophora* sp. sebagai bahan baku teh herbal fungsional melalui analisis kandungan fitokimia dan tingkat kesukaan panelis. Metode penelitian yang digunakan yaitu metode pendekatan eksploratif dan eksperimental secara kuantitatif terhadap tiga jenis daun mangrove sebagai perlakuan uji, diantaranya *Rhizophora apiculata, Rhizophora mucronata,* dan *Rhizophora stylosa.* Parameter yang dianalisis meliputi kandungan fenolik, flavonoid, aktivitas antioksidan, dan uji hedonik. Hasil penelitian menunjukkan bahwa, ketiga jenis daun mangrove meliputi *R. apiculata, R. mucronata,* dan *R. stylosa* memiliki potensi sebagai bahan baku minuman teh herbal fungsional. Ketiga jenis daun *Rhizophora* mengandung senyawa fenolik sebesar 39,716–84,645 mg GAE/g, flavonoid sebesar 61,075–89,508 mg CAE/g, antioksidan dengan nilai IC_{50} sebesar 72,339–76,626 ppm. Jenis daun mangrove *Rhizophora stylosa* menunjukkan hasil yang terbaik pada seluruh parameter uji. Hasil tingkat kesukaan panelis melalui uji hedonik, teh herbal ketiga jenis daun *Rhizophora* diterima secara positif oleh panelis, dengan skor atribut warna sebesar 7,00–7,64, aroma sebesar 6,44–6,60, dan rasa sebesar 7,00–7,16. Teh herbal daun *Rhizophora stylosa* memperoleh nilai alternatif tertinggi berdasarkan hasil pengambilan keputusan metode *Bayes* sebesar 7,27. Teh herbal daun mangrove *Rhizophora* sp. berpotensi dikembangkan sebagai minuman fungsional berbasis bahan alami dan lokal serta mendukung pemanfaatan tumbuhan mangrove secara berkelanjutan.

Kata Kunci: Daun Mangrove, *Rhizophora* sp., Fitokimia, Teh Herbal, Minuman Fungsional

INTRODUCTION

Mangroves have a wealth of potential and benefits that can be exploited, with various products produced from their roots, stems, fruits, and leaves, including medicines, natural food colorings, food additives, natural food preservatives, fuel, and more (Baswantara *et al.*, 2023). However, this enormous potential has not been fully utilized by local communities. Coastal communities still view mangroves as a resource with little economic or health potential, leading to plant parts such as leaves, fruits, and flowers often being thrown away (Safitri *et al.,*, 2018). Based on questionnaire data from Prasetyo *et al.,* (2023), the level of trust in the use of mangrove plants for food and medicinal purposes by coastal communities remains relatively low at 31%. To date, communities are unaware of the direct economic and health benefits of the mangrove ecosystem, thus deeming it unsuitable, given the lack of education regarding its use. One part of the mangrove plant with potential for use as a herbal product is its leaves, which are known to contain various bioactive compounds such as phenolics, flavonoids, tannins, and saponins, which have antioxidant properties beneficial for human health (Andari *et al.*, 2024). Besides containing various bioactive compounds, mangrove leaves are also readily available and abundant, compared to fruit and flowers, which are seasonal (Analuddin *et al.*, 2018). This supports the use of mangrove leaves as an herbal product.

One popular herbal product is herbal tea. Herbal tea is a beverage made from spices or plants derived from dried flowers, seeds, leaves, or roots. It is prepared by boiling or adding hot water for consumption (Dandi *et al.,* 2022). Herbal tea is a beverage made from herbal ingredients with health benefits, containing caffeine, theophylline, and fat, carbohydrates, and protein levels of almost 0% (Pandiangan *et al.,* 2022). Herbal tea is categorized as a functional beverage due to its various health benefits, including its polyphenol content, which acts as an

antioxidant, anti-inflammatory, or aids the body's detoxification process (Batubara *et al.,* 2018).

The *Rhizophora*ceae family is the dominant mangrove species found in Indonesia. Among the widespread mangrove species, 15 genera and 157 species have been identified and thrive in Indonesia (Plants of the World Online, 2024). *Rhizophora* is a genus of tropical mangrove trees, sometimes collectively referred to as true mangroves. The *Rhizophora* genus comprises three species: *Rhizophora* mucronata (black mangrove), *Rhizophora* apiculata (oil mangrove), and *Rhizophora* stylosa (red mangrove). *Rhizophora* sp. is the best mangrove species and has very dense leaves (Kamal, 2011). *Rhizophora* sp. leaves. It is rich in phytochemical compounds such as alkaloids, flavonoids, phenols, terpenoids, steroids, and saponins compared to other mangrove species such as *Sonneratia* sp. and *Avicennia* sp. These compounds are found in medicinal ingredients and have been shown to inhibit bacteria (Akasia *et al.*, 2021). According to Ridlo *et al.,* (2017), empirically, *Rhizophora* sp. mangrove leaves can be effective as an aphrodisiac (libido stimulant), and can be used to treat asthma, diabetes, diuretics, hepatitis, leprosy, neuralgia, roundworms, rheumatism, skin diseases, tumors, ulcers (resin), and antifertility.

Rhizophora sp. has been shown to contain phytochemical compounds and possess antioxidant activity. However, the use of the three types of *Rhizophora* mangrove leaves—*Rhizophora* apiculata, *Rhizophora* mucronata, and *Rhizophora* stylosa—as herbal drinks is still very limited. To date, there has been no comprehensive study comparing the three *Rhizophora* species in herbal tea, either in terms of phytochemical content, antioxidant activity, or panelist preference through hedonic testing. The use of mangrove plants, particularly the leaves, needs further exploration to uncover potential and new information that could benefit the community, including as a food ingredient and herbal medicine. This could open up opportunities for development as a food and medicine ingredient, as well as providing a more affordable and sustainable natural alternative.

This research is important to strengthen the scientific basis for the development of functional herbal teas sourced from Indonesia's local biodiversity. Therefore, to determine and evaluate the potential use of three types of *Rhizophora* mangrove leaves (*Rhizophora* apiculata, *Rhizophora* mucronata, and *Rhizophora* stylosa) as herbal tea, a phytochemical analysis is necessary to identify and determine the extent of bioactive compounds that play a role in determining the tea's efficacy. *Rhizophora* sp. mangrove leaves processed into herbal tea bags were then subjected to a hedonic test to assess the panelists' level of preference for the color, aroma, and taste of the resulting product. The results of this hedonic test can be used as a reference for product feasibility and improvement, as well as to ensure market appeal.

RESEARCH METHODS

Place and Time

The sampling location was in the coastal mangrove area of Pangandaran, West Java. Testing of *Rhizophora* sp. mangrove leaf samples, consisting of phytochemical tests, yield tests, and solubility tests, was conducted at the Marine BioGeoChemistry Research Laboratory, Faculty of Fisheries and Marine Sciences, Padjadjaran University. Testing of water content and hedonic properties of *Rhizophora* sp. mangrove leaf herbal tea was conducted at the Fisheries Product Processing Laboratory, Faculty of Fisheries and Marine Sciences, Padjadjaran University. The research was conducted from May to June 2025.

Tools and Materials

The tools used in this study include a Cary 60 UV-Vis Spectrophotometer, analytical balance, micropipette, measuring cup, beaker glass, cuvette, amber bottle, hot plate stirrer, glass laboratory thermometer, grinder machine, test sieve with mesh size 20 and 40, digital

laboratory precision scales, and blower drying oven. The materials used in this study include young mangrove leaves of *Rhizophora* apiculata, *Rhizophora* mucronata, and *Rhizophora* stylosa species, 10% folin reagent, Na2CO3, NaNO2, AlCl3, 1M NaOH, DPPH solution, Whatman paper no. 1, gallic acid, catechin standard, water, distilled water, methanol, commercial herbal leaf tea bags, paper tea bags (5.5x7 cm), cling wrap, aluminum foil, and paper cups (4 oz (120 ml) size).

Research Methods and Design

The research methods used are exploratory and experimental. Exploratory research aims to explore new things that are not widely known and examine contemporary phenomena (Sugiyono, 2017). Meanwhile, experimental research is used to gather information through observation with controlled treatments (Sugiyono, 2019). The use of this approach method allows researchers to find initial potential while testing and comparing results as a basis for further research or broader product development. The experimental method in this study was used to systematically test the treatments given, namely on three types of *Rhizophora* mangrove leaves: *Rhizophora* apiculata, *Rhizophora* mucronata, and *Rhizophora* stylosa, which was carried out with 3 repetitions for each test parameter. Determination of treatment differences in this study was based on the Completely Randomized Design (CRD) principle with repetitions to minimize experimental errors and further testing using analysis of variance (ANOVA) to determine significant differences between treatments (Walpole, 1993). Test parameters used included phenolic and flavonoid phytochemical content, the antioxidant 2,2-diphenyl-1 picrylhydrazyl (DPPH) method, and panelists' preference levels for the color, aroma, and flavor of the resulting tea through a hedonic test.

The principle of phenolic content testing is based on changes in absorbance at a wavelength of 765 nm due to the reduction of Folin–Ciocalteu reagent in the presence of phenolics in an alkaline environment, resulting in the production of a molybdenum–tungsten blue complex, resulting in a color change from yellow to blue. Flavonoid content testing is based on changes in absorbance at a wavelength of 510 nm because aluminum chloride forms a stable acid complex with the C-4 keto group and the C-3 or C-5 hydroxyl group of flavones and flavonols, resulting in a color change of red/pink/orange/yellow. The DPPH method for antioxidant testing is based on changes in absorbance at a wavelength of 517 nm due to the reduction of the free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) in the presence of antioxidants, resulting in a color change from purple to yellow.

Phytochemical testing and antioxidant activity are measured based on changes in the absorbance of the solution on a Cary 60 UV-Vis Spectrophotometer, which operates at ultraviolet (UV) wavelengths (absorbance is measured three times for each sample). The absorbance change was measured based on a linear regression equation against the calibration curve of standard gallic acid, catechin acid, and DPPH solutions, with the equation (x, y) being $y = ax + b$ (where x = regression result (content) and y = absorbance value) and a coefficient of determination (R2) ≤ 1. The results were expressed in mg Acid Equivalent (AE) per 1 gram of dry matter for phytochemical content and IC50 (Inhibition Concentration 50%) in ppm (parts per million) for antioxidants.

The preference level test was analyzed based on panelist assessments referring to SNI 4324 of 2014 concerning the organoleptic quality requirements for green tea bags in sensory aspects, such as color, aroma, and taste of *Rhizophora* sp. mangrove leaf herbal tea, to determine consumer appeal to the mangrove leaf herbal tea product. Panelists were used as the research instrument for the hedonic test. The panelists selected were 25 semi-trained panelists, the number of samples served to the panelists was 4 samples as a treatment consisting of 1 type of commercial herbal tea sample as a comparison product (A), and 3 of them were samples of mangrove leaf tea bags of the species *Rhizophora* apiculata (B), *Rhizophora* mucronata (C),

and Rhizophoa stylosa (D). The assessment of the level of preference by the panelists for the product used a scoring method with a 5-point hedonic scale (1-9).

Tea Making and Extraction of *Rhizophora* sp. Mangrove Leaves

The production of *Rhizophora* sp. mangrove leaf tea powder involves several stages: withering using a blower drying oven for 30 minutes at 60°C, grinding the leaves using a grinder machine with a fine and semi-coarse grind with particle sizes of approximately 425 µm (fine) and 850 µm (semi-coarse), sieving the fine and semi-coarse leaf powder using a 40-mesh (fine) and 20-mesh (semi-coarse) test sieve, and drying the leaf powder using a blower drying oven for 3 hours at 60°C. The moisture content of the leaf powder is measured before extraction (maceration) and packaging into tea bags, to ensure that the moisture content of the tea leaf powder meets the quality requirements for green tea bags according to SNI 4324:2014, which is a moisture content of ≤ 10%.

The extraction process for a sample of fine powder (40 mesh) of Rhizophora sp. mangrove leaves. The extraction was carried out using a maceration method with a sample to solvent ratio of 1:10 (10 g sample and 100 ml solvent). The extraction solvent used was 96% methanol. Maceration was carried out for 72 hours at room temperature (20°-25°C) in the dark using an amber bottle to ensure the bioactive compounds in the leaves were dissolved in the solvent and properly extracted. The extraction sample was filtered using a funnel and Whatman No. 1 filter paper, separating the filtrate (extract) from the residue (remaining mangrove leaves). The extraction results were transferred into an amber bottle, and the mangrove extract was ready for use in further research.

Mangrove leaf tea powder in the form of semi-coarse powder (fanning) (20 mesh) was weighed at 1 g per bag and packaged into each 5.5 x 7 cm tea bag as a product sample to be tested on panelists. The product samples presented to the panelists were tea bags brewed using 100 ml of water at 80ºC in 120 ml paper cups marked with a 3-digit random code for each of the 4 different sample types. The panelists' hedonic test assessment form was used as an instrument in the hedonic testing of the herbal tea product.

Data Analysis

The data from phytochemical measurements and antioxidant activity were analyzed using the One-Way ANOVA (Analysis of Variance) test and a further test, namely the Duncan test, to test for significant differences between the average values of the samples and to test the homogeneity of the data between samples with a significance level of 5%. The data from the hedonic test were analyzed using the Friedman test with a significance level of 5%. The decision-making of the panelists' assessment of the level of preference for *Rhizophora* mangrove leaf herbal tea was carried out using multiple comparisons, then to determine the best treatment, the Bayes method was used to provide differences in each treatment and to determine the comparison of determining criteria in a product.

RESULT

Total Phenolic Content (TPC)

Total Phenolic Content (TPC) is expressed in milligrams of gallic acid equivalent per gram of sample (mg GAE/g), which is a common measurement standard for phenolic compounds. The results of the Total Phenolic Content (TPC) statistical test on the three types of *Rhizophora* mangrove leaves showed that there were significant differences in the phenolic content values between the three types of *Rhizophora* sp. mangrove leaves. The following are the results of the Total Phenolic Content (TPC) in *Rhizophora* sp. mangrove leaf extracts presented in Figure 1.

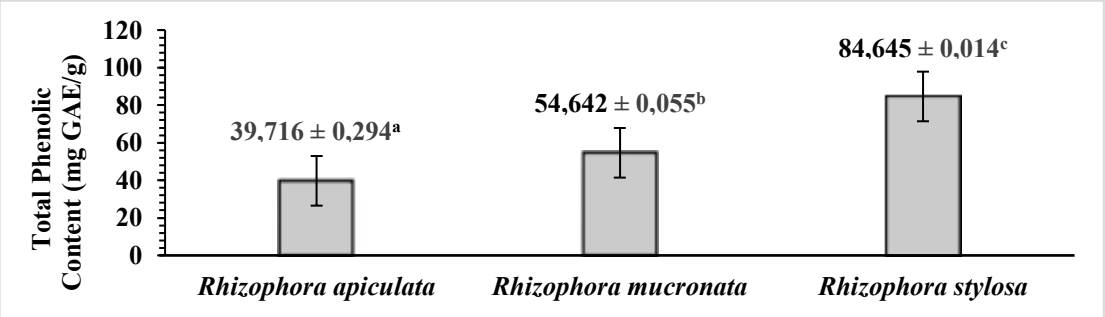

Figure 1. Total Phenolic Content (TPC) of *Rhizophora* sp. Mangrove Leaf Extract
Description: The average sample figures followed by the same letter show no significant difference based on Duncan's test at a significance level of 5%

Total Flavonoid Content (TFC)

The total flavonoid results are expressed in milligrams of catechin acid equivalent per gram of sample (mg CAE/g). The results of the Total Flavonoid Content (TFC) statistical test on the three types of *Rhizophora* mangrove leaves showed that there were significant differences in the flavonoid content values between the three types of *Rhizophora* sp. mangrove leaves. The following are the results of the Total Flavonoid Content (TFC) in *Rhizophora* sp. mangrove leaf extracts, presented in Figure 2.

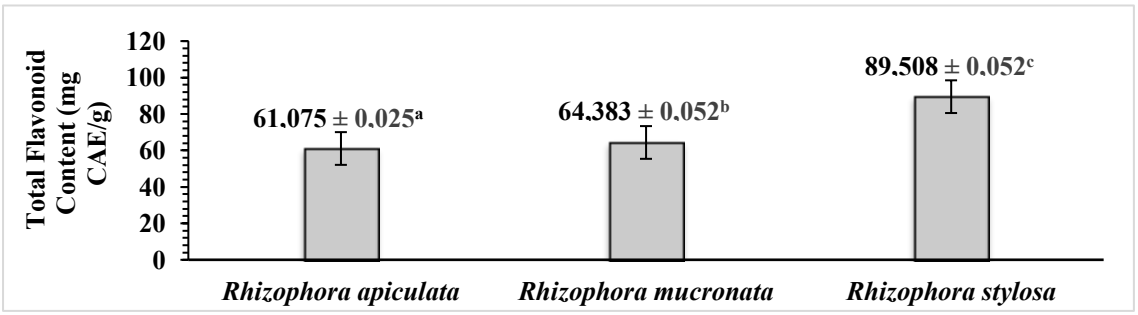

Figure 2. Total Flavonoid Content (TFC) of *Rhizophora* sp. Mangrove Leaf Extract
Description: The average sample figures followed by the same letter show no significant difference based on Duncan's test at a significance level of 5%

DPPH Antioxidant

The antioxidant activity value of the DPPH method is seen from the Inhibition Concentration (IC50) value, namely the concentration/level of the extract of the material needed to ward off the free radical 2,2-diphenyl-1 picrylhydrazyl (DPPH) by 50% which is expressed in parts per million (ppm). The results of the statistical test of the DPPH antioxidant activity on the three types of *Rhizophora* sp. mangrove leaves show that there is a significant difference in the IC50 value of the DPPH antioxidant activity between the three types of *Rhizophora* sp. mangrove leaves. The following are the results of the IC50 value of the DPPH method antioxidant activity on *Rhizophora* sp. mangrove leaves which are presented in Figure 3.

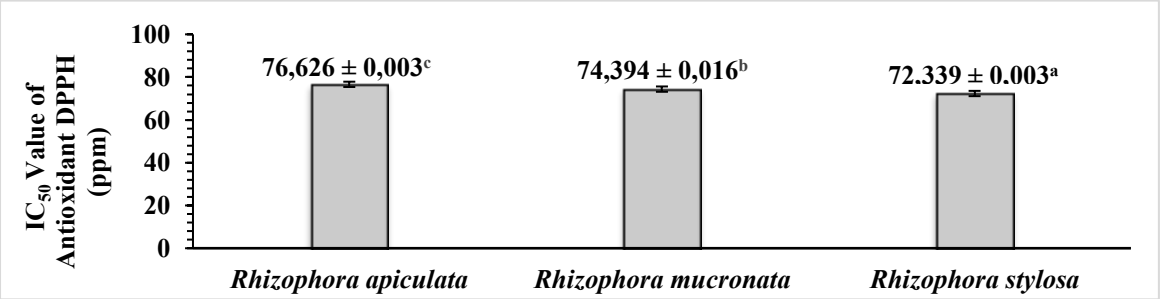

Figure 3. IC50 Value of DPPH Antioxidant of *Rhizophora* sp. Mangrove Leaf Extract
Description: The average sample figures followed by the same letter show no significant difference based on Duncan's test at a significance level of 5%

Panelist Preference Level through Hedonic Test

The hedonic test aimed to assess the acceptability of herbal tea products made from three types of *Rhizophora* mangrove leaves (*Rhizophora* apiculata, *Rhizophora* mucronata, and *Rhizophora* stylosa) by panelists compared to commercial herbal green teas already on the market. The results of the hedonic test, which included panelists' assessments of the color, aroma, and flavor of the commercial herbal tea (comparison product) and functional herbal green tea made from *Rhizophora* sp. mangrove leaves, are presented in Table 1.

Table 1. Hedonic Test Results for Commercial Herbal Tea and Mangrove Leaf Herbal Tea

Parameter	Sample			
	Commercial herbal tea (A)	*Rhizophora* apiculata (B)	*Rhizophora* mucronata (C)	*Rhizophora* stylosa (D)
Color	5,80 ± 1,53^{a}	7,00 ± 1,53^{ab}	7,16 ± 1,72^{b}	7,64 ± 1,60^{b}
Aroma	5,88 ± 1,64^{a}	6,60 ± 1,53^{a}	6,44 ± 1,23^{a}	6,60 ± 1,53^{a}
Flavor	5,48 ± 1,33^{a}	7,00 ± 1,53^{b}	7,08 ± 1,47^{b}	7,16 ± 1,40^{b}

Description: Score 1 = really dislike; 3 = dislike; 5 = normal/neutral; 7 = like; 9 = really like
The average sample figures followed by the same letter show no significant difference based on a multiple comparison test at a significance level of 5%

Decision-making regarding the relative weighting and criteria for color, aroma, and flavor in *Rhizophora* sp. mangrove leaf herbal green tea was conducted using the pairwise comparison method. This method converts the pairwise comparisons into a set of numbers representing the relative priority of each criterion and alternative/treatment. The results of these pairwise comparisons were resolved through matrix manipulation to determine the weighting of each criterion. The results of the calculation of the weighting criteria for color, aroma, and flavor are shown in Table 2.

Table 2. Criteria Weighting Values for *Rhizophora* sp. Mangrove Leaf Herbal Green Tea.

Criteria	Criteria Weight
Color	0,13
Aroma	0,22
Flavor	0,65

The Bayesian method is a useful method for determining analysis results that indicate the product with the highest priority value as the most preferred product based on the hedonic assessment conducted by panelists. The calculation results, taking into account the criteria of

color, aroma, and taste, with the best assessments for commercial herbal tea and *Rhizophora* sp. mangrove leaf herbal tea, are presented in Table 3.

Table 3. Decision Matrix for Mangrove Leaf Herbal Tea Assessment Using the Bayesian Method

Sample	Kriteria			Alternative Values
	Color	Aroma	Flavor	
Commercial herbal tea (A)	5,00	5,00	5,00	5,00
Rhizophora apiculata (B)	7,00	7,00	7,00	7,00
Rhizophora mucronata (C)	7,00	7,00	7,00	7,00
Rhizophora stylosa (D)	9,00	7,00	7,00	7,27

DISCUSSION

Total Phenolic Content (TPC)

The results of the Total Phenolic Content (TPC) analysis on the three types of *Rhizophora* mangrove leaves (Figure 1) showed that the highest content was in *Rhizophora* stylosa at 84.645 mg GAE/g and the lowest was in *Rhizophora* apiculata at 39.716 mg GAE/g. This value is comparable to previous studies, namely the phenolic content in Sonneratia alba leaf extract of 33.600 mg GAE/g (Dotulang *et al.,*, 2018), *Rhizophora* mucronata leaf extract of 21.060-54.480 mg GAE/g (Ridlo *et al.,*, 2019), and green tea leaf extract (Camellia sinensis) of 30.890 mg GAE/g (Lelita *et al.,*, 2018). The phenolic content of three *Rhizophora* mangrove leaf species, ranging from 39.716 to 84.645 mg GAE/g, is comparable to previous research. Although *Rhizophora* apiculata had the lowest value, its levels are still within the ideal range for herbal plants.

Phenolic compounds, or phenolics, are bioactive compounds or secondary metabolites found abundantly in plants. They are characterized by an aromatic ring containing a hydroxyl group (-OH) and are known for their antioxidant activity. Phenolic compounds in plants have various health benefits, including anti-inflammatory, antimicrobial, antioxidant, anti-diabetic, and anti-carcinogenic properties (Winarti *et al.*, 2019). This is supported by research by Ridlo *et al.,* (2017), which empirically demonstrates that mangrove plants are effective as an aphrodisiac (libido stimulant), and can be used to treat asthma, diabetes, diuretics, hepatitis, leprosy, neuralgia, roundworms, rheumatism, skin diseases, tumors, ulcers (resin), and antifertility. The bioactive compounds contained in *Rhizophora* sp. leaves can be used as traditional medicinal ingredients, including to stop bleeding and act as an antiseptic for wounds. This indicates that all three types of *Rhizophora* mangrove leaves have the potential to be good sources of phenolic compounds, which act as natural antioxidants and have potential for development in the pharmaceutical and food industries.

Total Flavonoid Content (TFC)

The results of the Total Flavonoid Content (TPC) analysis in the three types of *Rhizophora* mangrove leaves (Figure 2.) showed that the highest content was in *Rhizophora* stylosa at 89.508 mg CAE/g and the lowest in *Rhizophora* apiculata at 61.075 mg CAE/g. This value is comparable to previous studies, namely the flavonoid content in *Rhizophora* mucronata leaf extract of 54.41 mg CAE/g (Diana *et al.*, 2021), Jeruju tea leaf extract (Acanthus ebracteatus) at 35.07 mg CAE/g (Issusilaningtyas *et al.*, 2023), and green tea leaf extract (Camellia sinensis) at 33.23 mg CAE/g) (Kurniawati *et al.*, 2024). The results of measurements of the phenolic content of the three types of *Rhizophora* mangrove leaves, which ranged from 61.075–89.508 mg CAE/g, showed an average flavonoid content comparable to previous

studies. Although *Rhizophora* apiculata had the lowest value, its levels were still within the ideal range for herbal plants.

Flavonoids are a type of phenolic compound found in plants characterized by a hydroxyl group structure generally found at positions 5 and 7 of ring A and consisting of 15 carbon atoms forming a C6-C3-C6 arrangement. They function as colorants in leaves, seeds, flowers, and fruit (Gazali *et al.*, 2020). The high flavonoid content in plants indicates their potential as a source of natural active ingredients with pharmacological benefits, such as antioxidant, anti-inflammatory, antimicrobial, anti-diabetic, and anti-cholesterol properties (Akhavan *et al.,* 2015). This finding is supported by the research of Manik *et al.,* (2014) that the flavonoid content of 5.624% in cherry leaves (Muntingia calabura L.) showed antibacterial activity against Staphylococcus aureus, 93% of which was influenced by the presence of flavonoid compounds. According to the research results of Usman *et al.,* (2022), *Rhizophora* mucronata mangrove leaves positively contained flavonoid compounds with anti-diabetic properties that were able to reduce blood glucose levels in mice by 68.78% (from 160.96 mg/dl to 44 mg/dl). These results indicate that all three types of *Rhizophora* mangrove leaves have strong potential to be used as natural raw materials in the development of health products, including functional herbal drinks. Flavonoid-based herbal drinks from mangrove leaves can not only offer benefits as natural antioxidants, but also have the potential to help control blood glucose levels, support the immune system, and prevent microbial infections naturally.

DPPH Antioxidant

The results of the analysis of DPPH antioxidant activity in three types of *Rhizophora* sp. mangrove leaves (Figure 3), the lowest IC50 value was in *Rhizophora* stylosa mangrove leaves at 72.339 ppm and the highest IC50 value was obtained in *Rhizophora* apiculata mangrove leaves at 76.626 ppm. The IC50 value in the DPPH method antioxidant activity test in the mangrove leaves of the three types of *Rhizophora* mangrove leaves is classified as strong because it is in the range of 50-100 ppm according to Ridlo *et al.,* (2017), which indicates that the three types of *Rhizophora* sp. leaves have strong antioxidant potential. The strength or weakness of the sample's antioxidant activity is seen from the Inhibition Concentration (IC50) value, which is the concentration/level of the sample extract material needed to ward off DPPH free radicals by 50%. The smaller the IC50 value, the stronger the antioxidant activity of the sample to capture free radicals (Ridlo *et al.*, 2017). The results of the study by Diana *et al.,* (2021), *Rhizophora* mucronata leaf extract has a DPPH antioxidant IC50 value of 71.06–82.5 ppm, indicating strong antioxidant activity. Research by Raharjo *et al.,* (2024) reported that *Rhizophora* stylosa Griff. leaf extract has a DPPH antioxidant IC50 value of 61.734 ppm, indicating strong antioxidant properties. Mutik *et al.,* (2022) found that *Rhizophora* apiculata leaf extract has a DPPH antioxidant IC50 value of 85.999 ppm, which is also categorized as a strong antioxidant and effective in counteracting free radicals. The antioxidant activity values of the three types of *Rhizophora* mangrove leaves, which range from 72.339–76.626 ppm, on average, have strong antioxidant activity and are comparable to the results of previous studies, which are still within the ideal range for herbal plants.

One factor influencing strong antioxidant activity is the high phytochemical content in plants, such as phenolic compounds, flavonoids, alkaloids, saponins, and terpenoids. These compounds are known to have the ability to donate electrons or hydrogen atoms to neutralize free radicals, thereby preventing oxidative damage to cells (Gazali *et al.,* 2020). Extracts from three types of *Rhizophora* mangrove leaves have been shown to contain relatively high levels of phytochemicals, including phenolics and flavonoids. These phenolic and flavonoid contents have great potential to be developed as natural antioxidant agents in various therapeutic and food industry applications. Phytochemicals such as phenols, flavonoids, tannins, saponins, and alkaloids are commonly found in plants and play an important role in antioxidant mechanisms.

Flavonoids are able to form complexes with metal ions that cause free radicals and also act as direct free radical scavengers. The high total phenolic compound content also contributes significantly to the reducing power of free radical stabilization. The higher the concentration of bioactive compounds in the extract, the stronger its ability to neutralize free radicals (Issusilaningtyas *et al.,* 2023). This indicates that the antioxidant activity of the three types of *Rhizophora* mangrove leaves has excellent prospects for development as a natural herbal drink that can provide benefits for supporting the immune system and general health, making it a potential alternative for consumers seeking plant-based health drinks.

Panelist Preference Level through Hedonic Test

The level of preference can determine the level of acceptance of a product by consumers. This preference level can be determined using a hedonic test of a product's color, aroma, and taste characteristics (Oktafa *et al.,* 2017).

Color

The results of the statistical test of panelists' preference for the color of the herbal green tea brewed with *Rhizophora* sp. mangrove leaf tea, shown in Table 1, revealed a significant difference between commercial herbal tea and *Rhizophora* sp. mangrove leaf tea, based on panelists' assessment of the color of the herbal tea at a 95% confidence level. The *Rhizophora* stylosa mangrove leaf tea obtained the highest average score of 7.64 (like), indicating that the panelists strongly preferred the color of the brewed water. The commercial herbal tea obtained the lowest average score of 5.80 (normal/neutral), indicating that, organoleptically, the panelists tended to prefer the color of the *Rhizophora* sp. mangrove leaf tea over the commercial product.

The color of the herbal green tea brewed with *Rhizophora* stylosa mangrove leaf tea (D) was a very bright yellowish green that was evenly distributed across the entire surface of the water, categorized as very good according to SNI 4324:2014 concerning the quality requirements for green tea bags. The color of the herbal green tea brewed with *Rhizophora* apiculata (B) and *Rhizophora* mucronata (C) mangrove leaves was a bright greenish-yellow color, evenly distributed throughout the water surface, categorized as good according to SNI 4324:2014 concerning the quality requirements for green tea bags.

The high average color value of *Rhizophora* stylosa herbal tea may be related to its higher total phenolic and flavonoid content compared to other samples. This aligns with the results of research conducted by Fajar *et al.,* (2018) on panelists' preference for the color of green tea. The higher the phenolic and flavonoid content, the stronger the color intensity produced in solution, thus influencing visual perception and panelists' preference. Flavonoids act as compounds that impart color to the brewed water or plant soak. The presence of flavonoids causes the color of the tea brew to tend toward green to yellowish-green, which then affects the final color appearance of the product (Irbah *et al.,* 2023).

Aroma

The results of the statistical test of panelists' preference for the aroma of the *Rhizophora* sp. mangrove leaf herbal green tea brew, shown in Table 1, showed no significant difference between commercial herbal tea and *Rhizophora* sp. mangrove leaf herbal tea, based on panelists' assessment of the herbal tea aroma at a 95% confidence level. The *Rhizophora* apiculata and *Rhizophora* stylosa mangrove leaf herbal tea samples obtained the highest average score of 6.60 (like), indicating that panelists really liked the aroma of the brewed tea. The commercial herbal tea received the lowest average score of 5.88 (average/neutral), indicating that panelists tended to prefer the aroma of the *Rhizophora* sp. mangrove leaf herbal tea over the commercial product.

Based on the SNI 4324:2014 standard, the recommended aroma is the distinctive aroma of green tea or the ingredients used. The aroma produced by the *Rhizophora* sp. mangrove leaf herbal tea is derived from the aroma of the mangrove leaf herbal tea. Herbal leaf tea is a distinctive leaf tea derived from the mangrove leaves of *Rhizophora* apiculata, *Rhizophora* mucronata, and *Rhizophora* stylosa. The aroma of herbal leaf tea generally originates from volatile components, including benzaldehyde, aldehydes, ketones, methyl esters, borneol, hexanol, or menthol, which give the tea leaves their characteristic aroma (Rahmah *et al.*, 2023). The aromas of the four samples were not significantly different, but on average, panelists preferred the aroma of the three types of *Rhizophora* mangrove leaf herbal tea compared to commercial herbal leaf teas.

Differences in panelists' preference for the aroma of brewed teas may be influenced by phytochemical content, including phenolic compounds, which play a key role in forming the distinctive aroma of herbal ingredients, ranging from fresh and earthy to slightly sharp, depending on the type and concentration. The phenolic compounds in mangrove leaf herbal tea can release their distinctive aroma when brewed with hot water because some of the components are volatile and evaporate easily at high temperatures. The aroma formed from the interaction of these phenolic compounds can increase or decrease the level of panelist preference depending on the intensity and suitability of the aroma to the olfactory sense preferences (Kurniawati *et al.*, 2024). The high average aroma value in *Rhizophora* stylosa and *Rhizophora* apiculata herbal teas may be related to the higher total phenolic content compared to commercial herbal tea samples. This is in line with the results of research conducted by Dewata *et al.,* (2017), which stated that the content of phenolic compounds not only affects taste but also produces a distinctive and complex aroma, which can increase the level of panelist preference for herbal tea. All three types of *Rhizophora* mangrove leaf tea contain bioactive components, one of which is a phenolic compound that contributes to the formation of the aroma of the brew when exposed to hot water, thus producing a natural aroma typical of herbal ingredients, which is an important attraction in organoleptic perception (Lelita *et al.*, 2018).

Flavor

The results of the statistical test of panelists' preference for the flavor of the *Rhizophora* sp. mangrove leaf herbal green tea brew, shown in Table 1, show a very significant difference between the commercial herbal tea and the *Rhizophora* sp. mangrove leaf herbal tea, based on the panelists' assessment of the herbal tea flavor at a 95% confidence level. The *Rhizophora* stylosa mangrove leaf herbal tea sample received the highest average score of 7.16 (like), indicating that the panelists really liked the flavor of the brewed tea. Meanwhile, the commercial herbal tea received the lowest average score of 5.48 (average/neutral), indicating that organoleptically, the panelists tended to prefer the flavor of the *Rhizophora* sp. mangrove leaf herbal tea over the commercial product.

Based on the SNI 4324:2014 standard, the recommended flavor is a typical green tea flavor or one that matches the ingredients used, with a slightly bitter and slightly sour aftertaste. The resulting flavor reflects the distinctive characteristics of tea leaves derived from the mangroves *Rhizophora* apiculata, *Rhizophora* mucronata, and *Rhizophora* stylosa. The flavor of herbal leaf teas generally originates from bioactive compounds such as phenolics and tannins, which can impart bitter, sour, and slightly sweet flavors depending on their concentration (Dewata *et al.,*, 2017). The flavors of the three types of *Rhizophora* mangrove leaf teas showed significant differences compared to commercial herbal tea samples, indicating that panelists preferred the flavor characteristics of these mangrove teas.

Differences in panelist preference for the flavor of the tea brews may be influenced by phytochemical content, including phenolic compounds, which play a key role in shaping the distinctive flavor of herbal ingredients. Phenolic compounds are bioactive components that not

only contribute to antioxidant activity but also have complex flavor characteristics, ranging from mild bitterness to very bitter, sour, and sweetness depending on the type and concentration (Kumalasari and Larasati, 2023). The phenolic compounds in mangrove leaf herbal tea can contribute to the flavor that emerges when brewed with hot water, as their interaction with water influences the resulting flavor profile. The flavors produced by these phenolic compounds can increase or decrease panelists' preference (Lelita *et al.*, 2018).

Decision Making Based on Bayes Method

Based on the calculation of the weighting criteria for color, aroma, and taste of *Rhizophora* sp. mangrove leaf herbal tea shown in Table 2, the results showed that taste assessment was the most important criterion that determined the panelists' final decision in choosing *Rhizophora* sp. mangrove leaf herbal tea with a criteria weight of 0.65 followed by aroma and color. Taste is the most important criterion in assessing *Rhizophora* sp. mangrove leaf herbal tea because psychologically and sensorially, taste is the primary experience felt directly by consumers when consuming a food or beverage product. *Rhizophora* sp. mangrove leaf herbal tea tends to have a distinctive taste that is able to present a balanced taste, both in terms of bitterness and acidity in herbal ingredients which are the main determining factors for the level of panelists' preference. According to Dewata *et al.,* (2017), although aroma and color provide an initial impression and influence expectations, a person's final decision to like or accept a product is largely determined by the taste sensation felt on the tongue. This aligns with the findings of Sari and Farida (2024), who stated that a pleasant and refreshing taste can compensate for deficiencies in visual aspects (color) or aroma. Conversely, tea with an attractive color and aroma but an unpleasant or unrefreshing taste tends to be rejected.

Based on calculations using the Bayesian method shown in Table 3, the results showed that *Rhizophora* stylosa mangrove leaf herbal tea obtained the highest relative value of 7.27. *Rhizophora* mucronata and *Rhizophora* apiculata mangrove leaf herbal tea obtained the highest relative value of 7.00. Commercial herbal tea, as a comparison product, obtained the lowest relative value of 5.00. *Rhizophora* stylosa mangrove leaf herbal tea was the most preferred, presumably because panelists preferred the balanced flavor profile of the herbal tea brew, with a slight bitterness, a faint sourness, a slightly astringent sensation, and a smooth and refreshing sensation on the tongue. *Rhizophora* stylosa mangrove leaf herbal green tea has a clearer green color, giving it a fresh, cloudy taste when brewed. The aroma of *Rhizophora* stylosa mangrove leaf herbal tea is also considered lighter and more refreshing, not overpowering, and provides a calming, natural feel, enhancing the enjoyment of drinking.

CONCLUSION

Based on the research results, it can be concluded that *Rhizophora* apiculata, *Rhizophora* mucronata, and *Rhizophora* stylosa mangrove leaves have the potential to be used as raw materials for functional herbal tea drinks. The three types of leaves were proven to contain bioactive compounds such as phenolics ranging from 39.716−84.645 mg GAE/g and flavonoids ranging from 61.075−89.508 mg CAE/g, strong antioxidant activity with IC50 values ranging from 72.339–76.626 ppm. The *Rhizophora* stylosa mangrove leaf type showed the highest results in phytochemical content and antioxidant activity among *Rhizophora* apiculata and *Rhizophora* mucronata mangrove leaves. The phytochemical content of the three types of *Rhizophora* mangrove leaves correlated with the panelists' level of preference for the color, aroma, and taste produced in the herbal tea of the three types of *Rhizophora* mangrove leaves, where the average value of the level of preference for the color attribute was 7.00-7.64, aroma was 6.44-6.60, and taste was 7.00-7.16. The results of the alternative decision-making score based on the Bayes method were obtained for *Rhizophora* stylosa mangrove leaf herbal tea with the highest alternative value of 7.27. The herbal tea of the three types of *Rhizophora*

leaves was organoleptically preferred when compared to commercial herbal teas already on the market. This product has the potential to be developed as an alternative functional beverage based on natural and local ingredients that can attract consumer interest and compete competitively in the market, as well as support the utilization of mangrove plants in a more productive, value-added, and sustainable manner.

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