Research Paper

Future of Food: Journal on Food, Agriculture and Society
10 (5) August 2022

Physico- chemical characterization of Indonesian mangroves fruits species

INDAH ROSULVA[1], PURWIYATNO HARIYADI[1,2*], SLAMET BUDIJANTO[1], AND AZIS BOING SITANGGANG[1]

[1]Department of Food Science and Technology, Faculty of Agricultural Engineering and Technology,
[2]Southeast Asian Food and Agricultural Science and Technology (SEAFAST) center, IPB University, Dramaga, Bogor, Indonesia.

* Corresponding author: phariyadi@apps.ipb.ac.id

Data of the article

First received : 31 January 2022 | Last revision received : 19 May 2022
Accepted : 19 August 2022| Published online :30 September 2022
DOI : 10.17170/kobra-202204136017

Keywords

Avicennia sp.; *Bruguiera* sp.; mangrove flour; *Rhizophora* sp.; *Sonneratia* sp.

Carbohydrates in flour are essential ingredients for the food industry, often used as thickening, gelling, bulking, and water retention agents. In Indonesia, mangrove fruits have traditionally been used as a carbohydrate source. However, studies related to the physicochemical properties of the fruit, flour, and starch of mangroves as a food source are still minimal. This work reported the physico-chemical characteristic of four species of Indonesian mangrove, namely *Avicennia* sp., *Bruguiera* sp., *Rhizophora* sp., and *Sonneratia* sp. All mangrove fruits are not safe to be consumed because they contain cyanide more than a safe level (> 50 ppm). However, proper food processing can reduce cyanide to safe levels, depending on the characteristics of those fruits. Our results suggest that mangrove fruit flour can be utilized as a food source. *Bruguiera*'s can provide thickness in a short cooking time based on the pasting properties. *Rhizophora*'s is not suitable for use as a thickening agent in cold and semi-solid food products. *Avicennia* sp. and *Sonneratia* sp. require a long cooking time to produce a good consistency, but this consistency can withstand well at cold temperatures.

1. Introduction

Indonesia has the largest mangrove forest area globally, followed by Australia and Brazil, which are amount ± 3 million Ha (KLHK, 2019; Rahadian et al., 2019). This amount is about 23% or almost a quarter of all the world's mangrove ecosystems, from a total area of ± 16 million Ha (ITTO, 2017; KLHK, 2019), divided into the proximal, intermediate, and distal areas. They are distributed throughout the Indonesian archipelago, especially along the east coast of Sumatra, the north coast of Java, the west and east coasts of Kalimantan, the protected landscape in Sulawesi, Maluku, and the southern coast of Papua (Rahadian et al., 2019).

The proximal site is the area closest to the sea which is dominated by *Rhizophora* apiculata, *Rhizophora mucronata*, and *Sonneratia alba*. The intermediate zone, which is the area between the sea and land, is dominated by *Rhizophora* sp., *Avicennia* sp., *Bruguiera* sp., *Sonneratia* sp., and *Ceriops sp*. (Rahim & Baderan, 2017). Mangrove species that are often found in Indonesia are api-api (*Avicennia* sp.), pedada (*Sonneratia* sp.), lindur (*Bruguiera* sp.), and bakau (*Rhizophora* sp.) (Bengen, 2001; Putri et al., 2015). *Avicennia marina* and *Rhizophora* are the dominant mangrove species in the area near the sea in the mangrove zon-

ing of Pantai Indah Kapuk, North Jakarta. The density of mangrove forests in Pantai Indah Kapuk is in the category of sparse (<10 ind/100 m^2) to dense (≥15 ind/100 m^2) (Putri et al., 2015). Several studies reported that fishery potential obtained from mangrove litter reached 3.45 g/m^2/days (Aida et al., 2014), 548780 kg/ha/year (Aida et al., 2014; Mahmudi et al., 2012), and 1405.25 kg/ha/years (Aida et al., 2014).

Although the availability of mangrove fruits is abundant in Indonesia, information about the nutritional properties of mangroves from Indonesia is still limited. It makes this mangrove resource unable to become a valuable commodity, both economically and functionally. Some basic research related to the physicochemical qualities of mangrove fruit is still rarely carried out, even though in some areas in Indonesia, mangrove fruits have been consumed as a food source, mainly for traditional food products.

Mangrove fruit flour is rich in dietary fiber and bioactive compounds suitable for developing functional food products (Handayani et al., 2015; Jariyah et al., 2015, 2018; Widjanarko et al., 2014). Various kinds of existing mangrove fruits can be used as flours to become the essential ingredients of multiple foods, including crispy sticks, crackers, cakes, and others (Subandriyo et al., 2015). Mangrove fruits such as *Bruguiera gymnorrhiza* and *Avicennia marina* have high carbohydrate contents (Amalia et al., 2016; Sumartini et al., 2021). Carbohydrates are the primary source of calories for humans. About 60-80% of calories are obtained from carbohydrates (Hwanhlem et al., 2014).

Mangrove fruit also can reduce blood glucose levels after being processed into flour containing 7.50% soluble dietary fiber and 38.60% insoluble dietary fiber. Thus, mangrove fruit flour is a potent candidate for functional food, especially antidiabetic (Hardoko et al., 2015). Besides the beneficial properties, mangrove fruits also contain several antinutritional factors such as tannins, saponins, and hydrogen cyanide (Dewi et al., 2017). Hence, this study is of importance to demonstrate the potential of mangrove fruits as food sources, concomitantly exploring their benefits and reducing the antinutritional compounds.

2. Materials and Methods

Mangrove fruits, species *Avicennia marina*, *Bruguiera gymnorrhiza*, *Sonneratia* caseolaris, and *Rhizophora mucronata*, were obtained from Pantai Indah Kapuk (PIK), North Jakarta, Indonesia. The PIK was in the northern part of the Jakarta city (S: 06°07′28″ and E: 106°45′15″), Jakarta, Indonesia (Figure 1).

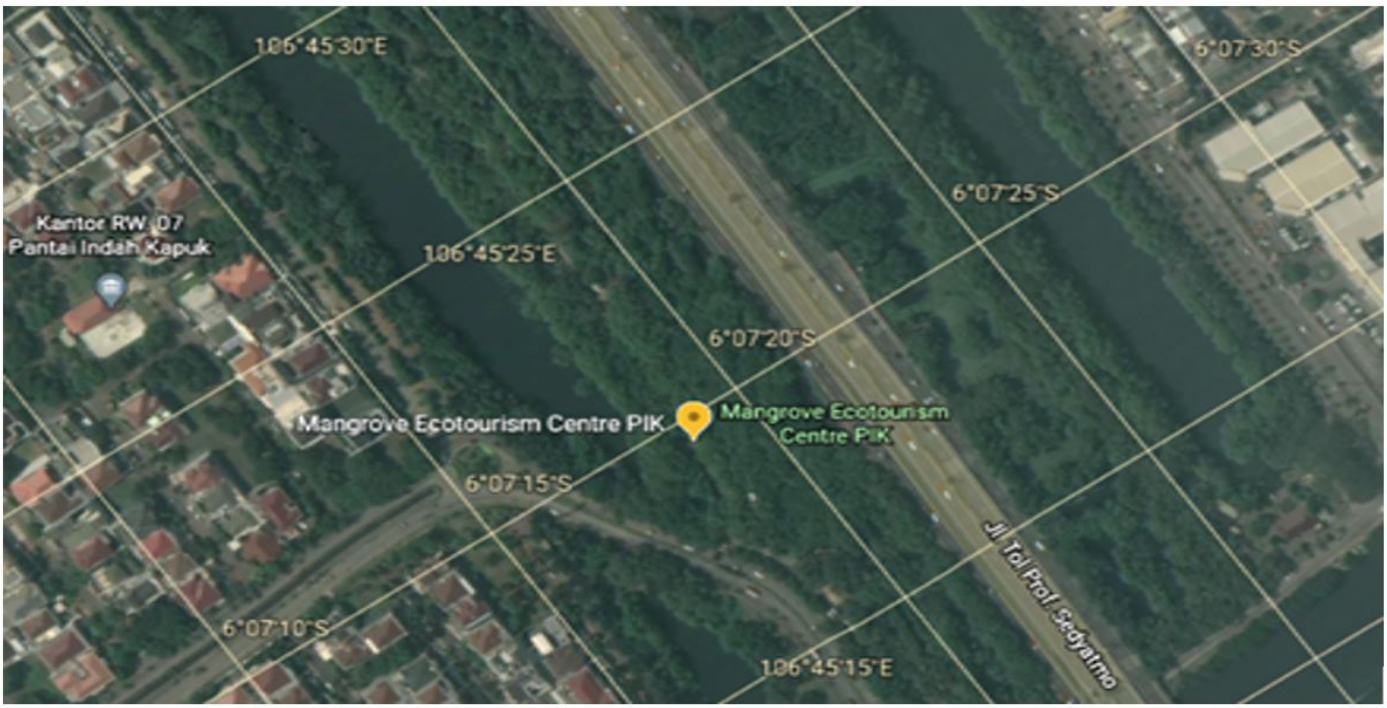

Figure 1. Location of sampling sites of mangrove fruits (Mangrove Ecotourism Centre, PIK, North Jakarta Sites, Indonesia).

ISSN-Internet 2197-411x OLCL 862804632

2.1. Sample preparations of mangrove fruits

Mangrove fruits that had excellent physical conditions and were not damaged were collected. The fruits were labelled for each species, kept in a box containing dry ice, and brought back to the Food Engineering Laboratory located at IPB University. Only clean fruits which were free from damage were selected and immediately packed in sealed plastic and then stored in the freezer at -20 ºC before further processing.

2.2. Flour preparation

Samples of mangrove fruits were prepared by peeling, soaking, blanching, slicing/reducing the size, drying, and shading. The drying process was carried out using a rack-type cabinet dryer (ND4-60 SP tray dryer, Teraba Seisakusho, Japan) at a temperature of 60-70 °C for 4-6 hours. Drying medicinal plants by oven at 70 °C for 5 hours warrants further research based on the level of phytochemicals that remain in the treated samples and the relatively low cost involved (Mahanom et al., 1999), and drying at 70 oC or below can provide reasonable drying time (Djaeni & Sari, 2015). Cabinet Dryer was suitable for food ingredients in the form of fruit pieces. The potential for food degradation due to high temperatures can be minimized (A'yuni et al., 2022). The dried fruits were comminuted using a Y2112M-2 laboratory grinding machine (Bartex Electric Motor, Japan). The flour was sieved using a 100 Tyler Mesh and stored prior to analyses.

2.2. Starch preparation

Starch was prepared by following Nurindra (2015) with modification. Mangrove flour was added with 0.25 % (w/v) sodium metabisulfite and water (1:4) (w/v). Mangrove flour is filtered using gauze until the dregs and the filtrate are separated. Milk starch obtained was deposited for 6 hours at room temperature. The water was discarded, and the starch was dried at 50 °C for 12 hours. The dried starch was mashed and sieved (150 mesh) to obtain a starch powder.

2.3. Proximate analysis of mangrove fruit and flour

Moisture content was determined using an ED series 53 hot air-drying oven (Binder, USA) at 100 °C for 18 hours (AACC, 2013 with modification). Determination of flour ash content by ignition of flour for 2 hours at a temperature of 600 °C (AACC, 2001 with modification). This was followed by the determination of crude fiber and fat (solvent extraction)(AOAC, 2012 with modification). The Kjeldahl method determined crude protein content with digestion and sample distillation. The distillate was titrated with 0.1 N hydrochloric acid solution until the solution changed from bluish-green to pink (AACC 46-13.01 with modifications) (AACC, 2010). The calculation of carbohydrates followed the "by-difference" method (FAO, 2003).

2.4. Physicochemical characterization of mangrove flour

2.4.1 Cyanide acid analysis

The study of cyanide acid from the flour followed the Lian and Hamir method (Marlina, 2000), which accelerated the release of cyanide glucoside compounds, using 3 N hydrochloric acids with incubation at room temperature for 3 hours. Measurement of the absorbance of each eluate was done at a wavelength of 490 nm using a UVmini-1240 Spectrophotometer (Shimadzu, Japan).

2.4.2. Starch analysis

A 2.5 g sample was transferred to a 10-mL graduated flask and added with 75 mL hydrochloric acid stepwise. The hydrolysis was performed in the autoclave with a heating pressure of 103.42 kN/m² for 10 min. The hydrolysed starch was cooled immediately down to a temperature of 20 oC. Carrez solution I (5 mL) and II (5 mL) were added, and subsequently, the mixture was diluted with 100 mL of distilled water. The solution was transferred to a 200 mm polarimeter tube and the optical rotation was measured by means of a polarimeter or saccharimeter (Sarmin NF et al., 2018).

2.4.3. Amylose and amylopectin analysis

A 40 mg mangrove flour was put in a tube, and then 1.0 mL 95 % ethanol and 9 mL 1 N NaOH were added. The next step was to heat the solution in a water bath at 100 oC for 10 min and cool it down for 1 h. The solution was diluted with distilled water to 100 mL. About 5 ml of the solution was placed into a 100 mL volumetric flask containing 60 mL of distilled water,

then added with 1.0 mL of 1 N acetic acid and 2.0 mL of 2 % iodine solution, respectively. The final volume was tared to 100 mL using distilled water. The solution was shaken and allowed to stand for 20 min, and the absorbance was monitored using a spectrophotometer at a wavelength of 625 nm (Apriyantono et al., 1989). Amylopectin content was obtained as follows: Amylopectin content = Starch content - Amylose content.

2.4.4. Colour measurement

The colour measurements were performed using CR 300 Chroma Meter (Konica Minolta, Japan) according to CIE 1976-Lab Color Space. A standard white plate was used to standardize the instrument. The colour of flour in the CIE-Lab parameters was L (white/black), a (red/green), and b (yellow/blue). Results were presented as the mean value of five measurements ± standard deviation (SD). The whiteness index (WI) was calculated based on the following equation $WI = 100 - [(100 - L)^2 + a^2 + b^2]^{½}$ (Lin et al., 2009).

2.4.5. Analysis of Birefringence, size, and shape of starch granule

The starch was suspended in distilled water at a concentration of 1 % (w/v). The suspension was dropped onto the slide using a pipette. The specimen was observed under a C-35AD-4 polarizing microscope (Olympus, Japan) with the help of a camera (ToupTek, China) connected to a computer (Chen et al., 2015). The observation of the birefringence structure, size, and shape of the starch granules was done at a magnification of 400X. Measurement diameters were analyzed using a histogram to determine granule size distribution (Sahin & Sumnu, 2006).

2.4.6. Pasting properties of mangrove flour

The pasting properties of the samples (flour and starch) were determined using a Tec-Master instrument, Rapid Visco Analyzer (RVA) (Newport Scientific, Australia) according to AACC 76.21.01 (1999).

2.4.7 Statistical analysis

One-way analysis of variance (ANOVA) and multiple comparisons (Duncan's post hoc test) were used to evaluate the significant difference in the data at $p < 0.05$. Pearson's correlation coefficient (r) was used to analyze the linear correlation between specific parameters. A two-way t-test (2-tailed) was used to test the statistical significance of the correlation coefficient ($p<0.05$). All the statistical analyses were done using SPSS, Version 22 (IBM, USA) (Allen et al., 2014).

3. Results

Mangrove fruits had different sizes and shapes (Figure 2). Table 1 shows that *Avicennia* sp. had the smallest size of the others, with a length of 1.50-3.80 cm, a diameter of 0.80-1.60 cm, and a weight of 0.30-2.37 gram. The *Sonneratia* sp. had a length of 1.00-5.40

Figure 2. Mangrove fruit of (a) *Avicennia* sp. (b) *Bruguiera* sp. (c) *Rhizophora* sp. (d) *Sonneratia* sp.

ISSN-Internet 2197-411x OLCL 862804632

Table 1. Size of mangrove fruits *)

Dimensional	*Avicennia* sp.	*Bruguiera* sp.	*Rhizophora* sp.	*Sonneratia* sp.
Length (cm)	1.50-3.80±0.53[a]	16.50-24.40±3.85[b]	36.70-58.80±6.14[c]	1.00-5.40±1.20[a]
Diameter (cm)	0.80-1.60±0.21[b]	1.00-2.00±0.20[a]	1.10-1.90±0.20[ab]	1.60-6.00±1.32[c]
Weight (gram)	0.30-2.37±0.48[a]	16.00-50.00±9.02[c]	22.00-70.00±12.56[b]	15.00-50.00±10.47[b]

*) Data were from 30 samples (n=30)

cm, a diameter of 1.60-6.00 cm, and a weight of 15.00-50.00 grams. The *Bruguiera* sp. had a length of 16.50-24.40 cm, a diameter of 1.00-2.00 cm, and a weight of 16.00-50.00 grams. The biggest size observed was *Rhizophora* sp. with a length of 36.70-58.80 cm, a diameter of 1.10-1.90 cm, and a weight of 22.00-70.00 grams.

The proximate compositions of wet basis (wb) of Indonesian mangroves fruits were presented in Table 2. The moisture contents of the fruits varied significantly from 50.77 to 77.73 g/100 g (wb). The level of moisture contents found in this research is in the range previously reported by other researchers, especially for *Avicennia* sp. was 52.94 % (67.50 % by (Chrissanty 2012)), *Bruguiera* sp. was 57.48 % (62.92 % by (Jacoeb et al. 2013)), *Rhizophora* sp. was 50.77 % (52.38 % by (Mile et al. 2021)), and *Sonneratia* sp. was 77.73 % (77.10 % by (Jariyah et al. 2014)). The ash contents were in the range of 1.05 to 2.05 g/100 g (wb). This value is slightly higher than previously reported, where *Avicennia* sp. was 2.05 % (1.22 % by (Chrissanty, 2012)), *Bruguiera* sp. was 1.18 % (1.15 % by (Sudirman et al., 2014)), *Rhizophora* sp. was 1.05 % (0.98 % by (Podungge et al., 2015)), and *Sonneratia* sp. was 1.63 %. The crude protein contents of mangrove fruits were in the range of 1.51 to 5.02 g/100 g (wb). This value is closer than previously reported, where *Avicennia* sp. was 5.02 % (4.83 % by (Chrissanty, 2012)), *Bruguiera* sp. was 2.09 % (2.11 % by (Sudirman et al., 2014)), *Rhizophora* sp. was 1.51 % (1.75 % by (Podungge et al., 2015)), and *Sonneratia* sp. was 2.12 % (2.24 % by (Jariyah et al., 2014)). The crude lipid contents were between 0.21 to 1.18 g/100 g (wb). This value is slightly higher than previously reported, where *Avicennia* sp. was 0.34 % (0.24 % by (Chrissanty, 2012)), *Bruguiera* sp. was 0.32 % (0.79 % by (Jacoeb et al., 2013), *Rhizophora* sp. was 0.21 % (1.69 % by (Podungge et al., 2015)), and *Sonneratia* sp. was 1.18 % (0.86 % by (Jariyah et al., 2014)). The crude fiber content was between 14.76 to 20.58 g/100 g (wb), which is *Bruguiera* sp. was 14.76 % and higher than ported by Sarungallo et al. (2010) of 11.48 %. The carbohydrate contents were in the range of 17.34 to 46.46 g/100 g (wb). Our results on carbohydrate content were not much different from those reported by others, they were *Avicennia* sp. was 39.65 % (25.25 % by (Chrissanty, 2012)), *Bruguiera* sp. was 38.93 % (32.91 % by (Priyono et al., 2010)), *Rhizophora* sp. by 46.46 % (34.68 % by (Podungge et al., 2015)), and *Sonneratia* sp. was 17.34 % (15.95 % by (Jariyah et al., 2014)). The proximate compositions amongst the species, on a wet basis, were significantly different ($p<0.01$).

The proximate compositions of dry basis (db) of Indonesian mangroves fruits were presented in Table 2. The moisture contents of the fruits varied significantly from 105.13 to 349.43 g/100 g (db). The ash contents were in the range of 2.13 to 7.32 g/100 g (db).

Our result on ash content of *Sonneratia* sp. was 7.32 %, not much different from reported by (Manalu et al., 2013) (8.40 %). The crude protein content was in the range of 3.37 to 10.67 g/100 g (db). Our result on the crude protein content of *Sonneratia* sp. was 9.56 %, not much different from reported by (Manalu et al., 2013) (9.21 %). The crude lipid content was in the range of 0.43 to 5.29 g/100 g (db). Our result on the crude lipid content of *Sonneratia* sp. was 9.56 %, not much different from reported by (Manalu et al., 2013) (9.21 %). The crude fiber content was in the range of 34.39 to 72.35 g/100 g (db). The value of fiber content of *Sonneratia* sp. was 72.35 g/100 g. The total dietary fiber in mangrove fruits found in this research is in the range previously reported by other researchers, especially for *Sonneratia* sp. was about 63.70 %,

Table 2. Proximate compositions of Indonesian mangroves fruits.

Proximat (g/100 g)	*Avicennia* sp.		*Bruguiera* sp.		*Rhizophora* sp.		*Sonneratia* sp.	
	wb	db	wb	db	wb	db	wb	db
Moisture	52.94±0.07^{ab}	112.54±0.33^{ab}	57.48±0.33^{b}	135.51±1.78^{b}	50.77±0.73^{a}	105.13±2.51^{a}	77.73 ±0.44^{c}	349.43±8.79^{c}
Ash	2.05 ±0.01^{c}	4.36±0.03^{b}	1.18±0.39^{a}	2.78±1.30^{a}	1.05±0.06^{a}	2.13±0.16^{a}	1.63±0.03^{b}	7.32±0.19^{c}
Protein	5.02±0.01^{c}	10.67±0.01^{c}	2.09±0.02^{b}	4.92±0.04^{b}	1.51±0.05^{b}	3.37±0.10^{a}	2.12±0.02^{a}	9.56±0.09^{C}
Lipid	0.34±0.22^{a}	0.72±0.00^{a}	0.32±0.08^{c}	0.76±0.19^{c}	0.21±0.04^{a}	0.43±0.09^{a}	1.18±0.05^{b}	5.29±0.18^{b}
Fiber	20.58±0.12^{b}	43.73±0.02^{b}	14.76±0.34^{a}	34.71 ±0.81^{a}	16.93±0.26^{a}	34.39±0.53^{a}	16.11±1.30^{c}	72.35±0.65^{c}
Carbohydrate	39.65±0.08^{bc}	84.25±0.08^{bc}	38.93±0.05^{bc}	91.54±0.05^{c}	46.46±0.80^{c}	94.07±0.80^{c}	17.34±0.11^{a}	77.83±0.11^{a}

Note: Different letters in the row indicate significant differences in the proximate composition amongst mangrove fruits

which is distributed amongst soluble (9.8%) and insoluble components (53.9%) (Jariyah et al., 2014). In comparison, seaweeds have comparable fiber content (74.11%) (Ahmad et al., 2012). It is well recognised that dietary fiber is important in human wellness because, for example, it binds and/or encapsulates bile salts to reduce cholesterol (Brown et al., 1999). The carbohydrate content was between 77.83 to 94.07 g/100 g (db). Our result on ash content of *Sonneratia* sp. was 77.83 %, not much different from reported by (Manalu et al., 2013) (77.57 %). The proximate compositions amongst the species, on a dry basis, were significantly different ($p<0.01$).

The proximate analyses of flours were presented in Table 3. For wet basis (wb), the moisture contents of the flours varied significantly from 4.94 to 9.86 g/100 g (wb). The level of moisture contents found in this research is in the range previously reported by other researchers, especially for *Avicennia* sp. was 8.08 % (9.36 % by (Chrissanty, 2012)), *Bruguiera* sp. was 4.94 % (6.68% by (Patil & Chavan, 2013)), *Rhizophora* sp. was 7.69 % (8.34 % by (Chrissanty, 2012)), and *Sonneratia* sp. was 9.86 % (9.63 % by (Ardiansyah et al., 2020)). The ash contents were to between 2.27 to 6.65 g/100 g (wb). This value is slightly higher than previously reported, where *Avicennia* sp. was 3.89 % (2.36 % by (Chrissanty, 2012)), *Bruguiera* sp. was 3.24% (2.70 % by (Priyono et al., 2010)), *Rhizophora* sp. was 2.27 % (1.27 % by (Hardoko et al., 2015)), and *Sonneratia* sp. was 6.65 % (wb) (5.39 % by (Ardiansyah et al., 2020)). The crude protein contents were between 3.43 to 9.83 g/100 g (wb). This value is closer than previously reported, where *Avicennia* sp. was 9.83 % (12.25 % by (Permadi et al., 2012)), *Bruguiera* sp. was 6.03 % (5.59 % by (Sulistyawati & Kumalaningsih, 2012)), *Rhizophora* sp. was 3.43 % (3.50 % by (Hardoko et al., 2015)), and *Sonneratia* sp. was 7.33 % (wb) (8.34 % by (Ardiansyah et al., 2020)). The crude lipid contents were approximately 1.14 to 3.14 g/100 g (wb). This value is closer than previously reported, where *Avicennia* sp. flour was 1.14 % (0.81 % by (Permadi et al., 2012)), *Bruguiera* sp. was 1.93 % (1.79 % by (Sulistyawati & Kumalaningsih, 2012)), *Rhizophora* sp. was 1.40 % (0.86 % by (Purwaningsih et al., 2013)), and *Sonneratia* sp. was 3.14 % (4.70 % by (Jariyah et al., 2014)). The crude fiber contents were between 5.65 to 14.28 g/100 g (wb). The level of crude fiber contents found in this research is in the range previously reported by other researchers, especially for *Avicennia* sp. was 5.65 % (4.85 % by (Chrissanty, 2012)), *Bruguiera* sp. was 10.21 % (10.09 % by (Patil & Chavan, 2013)), *Rhizophora* sp. was 8.25 % (9.01% by (Yamamoto et al., 1983)), and *Sonneratia* sp. was 14.28 % (9.80 % soluble fiber by (Jariyah et al., 2014)). The carbohydrate contents were in the range of 73.02 to 85.21 g/100 g (wb). This value is closer than previously reported, where *Avicennia* sp. flour was 77.06 % (78.13 % by (Permadi et al., 2012)), *Bruguiera* sp. was 83.36 % (82.09 % by (Sulistyawati & Kumalaningsih, 2012)), *Rhizophora* sp. was 85.21 % (87.68 % by (Chrissanty, 2012)), and *Sonneratia* sp. was 73.02 % (74.12 % by (Ardiansyah et al., 2020). The proximate compositions amongst the species, on a wet basis, were significantly different ($p<0.01$).

The proximate compositions of dry basis (db) of In-

ISSN-Internet 2197-411x OLCL 862804632

Table 3. Proximate compositions of Indonesian mangroves flours

Proximate (g/100 g)	*Avicennia* sp.		*Bruguiera* sp.		*Rhizophora* sp.		*Sonneratia* sp.	
	wb	db	wb	db	wb	db	wb	db
Moisture	8.08±0.07^{b}	8.75±0.40^{b}	4.94±0.07^{a}	5.21±0.18^{a}	7.69± 0.09^{b}	8.33±0.13^{b}	9.86± 0.06^{c}	10.94±0.07^{c}
Ash	3.89±0.06^{c}	4.23±0.41^{c}	3.24±0.06^{b}	3.42±0.22^{b}	2.27±0.06^{a}	2.46±0.30^{a}	6.65±0.05^{d}	7.38±0.13^{d}
Protein	9.83±0.01^{d}	10.69±0.02^{d}	6.03±0.01^{b}	6.43±0.04^{b}	3.43±0.05^{a}	3.72±0.10^{a}	7.33±0.03^{c}	8.13±0.15^{c}
Lipid	1.14±0.88^{a}	1.24±0.94^{a}	1.93±0.54^{c}	2.03±0.56^{c}	1.40±0.09^{a}	1.52±0.44^{a}	3.14±0.74^{b}	15.84±0.83^{b}
Fiber	5.65±0.12^{a}	6.15±0.20^{a}	10.21±0.17^{b}	10.72±0.40^{b}	8.25±0.26^{b}	8.94±1.64^{b}	14.28±0.15^{c}	15.84±0.52^{c}
Carbohydrate	77.06±0.08^{a}	83.83±0.08^{a}	83.86±0.05^{c}	88.88±0.05^{c}	85.21±0.80^{d}	92.31±0.80^{d}	73.02±0.11^{b}	81.01±0.11^{a}

Note: Different letters in the row indicate significant differences in the proximate composition amongst mangrove flours

donesian mangroves flours were presented in Table 3. The moisture contents of the flours varied significantly from 5.21 to 10.94 g/100 g (db). The ash contents were 2.46 to 7.38 g/100 g (db). The crude protein contents were in the range of 3.43 to 10.69 g/100 g (db). The crude lipid contents were in the range of 1.24 to 3.48 g/100 g (db). The crude fiber contents were in the range of 6.15 to 15.84 g/100 g (db). The carbohydrate contents were in the range of 81.01 to 92.31 g/100 g (db). The proximate compositions amongst the species, on a dry basis, were significantly different ($p < 0.01$).

Table 4 shows the cyanide acid contents of the mangrove fruits and their respective flours. The cyanide acid content of mangrove fruit of *Avicennia* sp. was 130 ppm, *Rhizophora* sp. was 120 ppm, *Bruguiera* sp. was 60 ppm, and the highest content is *Sonneratia* sp. was 140 ppm. The safe limit for cyanide acid in food is 50 ppm (Baskin & Brewer, 2006). Generally, mangrove fruits contain HCN of more than 50 ppm, so it is not safe for direct consumption. The cyanide acid content was reduced after flour preparation, ranging from less than 0.25 ppm to 79.65 ppm. The cyanide contents for *Avicennia* sp. and *Sonneratia* sp., flours were detected (limit of detection (LoD) was 0.25 ppm), while cyanide contents for *Bruguiera* sp. and *Rhizophora* sp. were 79.65 ppm and 21.19 ppm, respectively.

Figure 4 shows the results of the colour measurements of mangrove flour as recorded in terms of the L*, a*, b*, and whiteness index (WI). Positive values obtained for coordinates a* and b* were significantly different ($p < 0.05$) among samples. As seen in Table 5, a* values ranged from 2.59 ± 0.01 for *Avicennia* sp. to 14.81 ± 0.01 for *Sonneratia* sp. The b* values ranged from 12.07 ± 0.01 for *Avicennia* sp. to 26.30 ± 0.01 for *Bruguiera* sp. As seen in Table 5, L* values ranged from 43.27 to 64.79. The a* values ranged from 2.59 to 14.81, and b* values ranged from 12.07 to 26.30. L*, a*, and b* of *Avicennia* sp. are the lowest. The L* and b* values of *Bruguiera* sp are the highest of than others. The whiteness index (WI) values ranged from 40.13 ± 0.01 for *Rhizophora* sp. to 55.74 ± 0.00 for *Bruguiera* sp. The L*, a*, b*, and WI values were significantly different ($p<0.01$).

Table 6 shows the values of amylose, amylopectin, and starch compound from four mangrove starch. *Avicennia* sp. flour contains 19.84 % starch, with an amylose content of 2.46 % and amylopectin of 17.27 % of starch. *Bruguiera* sp. flour contains 27.59 % starch, 3.98 % amylose, and 25.19 % amylopectin from starch. *Rhizophora* sp. flour contains 25.48 % starch, 0.61 % amylose and 21.72 % amylopectin from starch. *Sonneratia* sp. flour contains 22.17 % starch, 0.61% amylose and 21.71% amylopectin from starch.

Among the mangrove fruit flours shown in Table 6, the highest starch, amylose, and amylopectin content were recorded from *Bruguiera* sp. (27.59 % for starch; 3.98 % amylose and 25.19 % amylopectin of the starch fraction). The lowest starch and amylopectin content came from *Sonneratia* sp. (0.61 % of the starch fraction). The highest starch content was found in *Bruguiera* sp. (27.59 %) and the least starch con-

Table 4. The values of cyanide acid in flour

Mangrove	Cyanide acid from mangrove fruits (db)(g/100 g)	Cyanide acid from mangrove flour (db) (g/100 g)
Avicennia **sp.**	130 ±0.10[a]	< 0.25 [a]
Bruguiera **sp.**	120 ±0.10[c]	79.65 ±0.14[c]
Rhizophora **sp.**	60 ±0.10[d]	21.19 ±0.02[b]
Sonneratia **sp.**	140 ±0.10[b]	< 0.25 [a]

Figure 3. Mangrove flour of (a) *Avicennia* sp. (b) *Bruguiera* sp. (c) *Rhizophora* sp. (d) *Sonneratia* sp.

Table 5. The whiteness index (WI) and parameters L*, a*, b* for the colour of mangrove fruit flour.

Flour mangrove	L*	a*	b*	WI
Avicennia **sp.**	43.27 ±0.06[a]	2.59± 0.01[a]	12.07 ±0.01[a]	41.94 ±0.06[b]
Bruguiera **sp.**	64.79 ±0.06[d]	5.25 ±0.01[b]	26.30 ±0.01[d]	55.74 ±0.00[d]
Rhizophora **sp.**	46.76 ±0.01[b]	6.62 ±0.01[d]	23.02 ±0.02[c]	40.13 ±0.01[a]
Sonneratia **sp.**	49.53 ±0.01[c]	14.81 ±0.01[c]	20.97 ±0.01[b]	44.94 ±0.01[c]

Note: Different letters in the column indicate significant differences in colour attribute composition amongst mangrove fruits

Table 6. The values of starch compound of flours from mangrove fruits

Mangrove Species	Amylose (g/100 g basis flour)	Amylopectin (g/100 g basis flour)	Starch (%)
Avicennia **sp.**	2.46 ±0.33[b]	17.27 ±0.08[a]	19.84±0.14[a]
Bruguiera **sp.**	3.98 ±0.11[c]	25.19 ±0.29[d]	27.59±2.24[c]
Rhizophora **sp.**	2.89 ±0.77[b]	22.57 ±0.19[c]	25.48±0.02[bc]
Sonneratia **sp.**	0.61 ±0.03[a]	21.72 ±0.01[b]	22.17±0.23[ab]

Note: Different letters in the column indicate significant differences in colour attribute composition amongst mangrove fruits

ISSN-Internet 2197-411x OLCL 862804632

tent was found in *Avicennia* sp. (19.84 %). The highest amylopectin content was recorded from *Bruguiera* sp. (of the starch fraction). Higher amylose content lowers the gelatinization profile of starch. The higher the amylose content, the more difficult it will be to form a gel. Because the amorphous structure formed will increase the gelatinization temperature so that gelatinization will run slowly.

Birefringence structure, size, and shape of granule analysis of starch of flour of *Avicennia* sp. could be seen in Figure 4, *Bruguiera* sp. could be seen in Figure 5, *Rhizophora* sp. could be seen in Figure 6, and *Sonneratia* sp. could be seen in Figure 7.

The values of pasting temperature analysis of flour from mangrove fruits could be seen in Table 7. The time for *Bruguiera* sp. flour to fully gelatinize was the fastest compared to others. It is indicated by the peak time; it was 7.5 minutes for flour, and 8.3 minutes for starch. Meanwhile, to complete gelatinization, *Rhizophora* sp. took 11.6 minutes. *Avicennia* sp. and *Sonneratia* sp. flour took the same time to gelatinize fully, which was 13 minutes for flour. For starch, *Sonneratia* sp. took 8.5 minutes, *Avicennia* sp. and *Rhizophora* sp. took the same time, which was 10 minutes. flour gelatinization of *Avicennia* sp., *Sonneratia* sp., *Rhizophora* sp., and *Bruguiera* sp. was 72 °C, 78 °C, 80 °C, and 82.5 °C. Meanwhile, the starch gelatinization of *Rhizophora* sp., *Avicennia* sp., *Bruguiera* sp., and *Sonneratia* sp. was 50 °C, 50.2 °C, 51.25 °C, and 56.25 °C, respectively.

4. Discussion

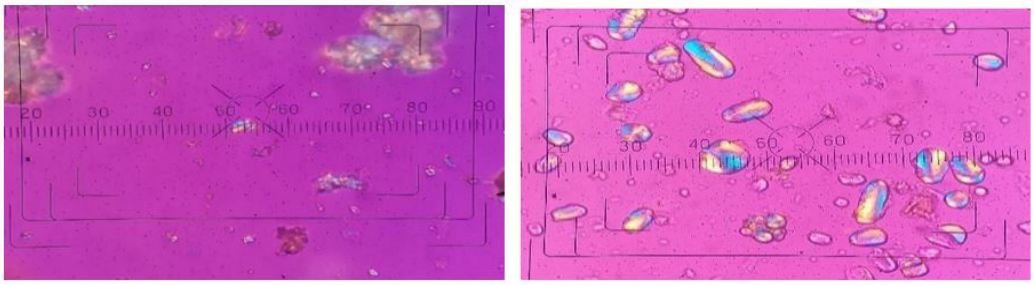

Figure 4. Birefringence structure, size, and shape of granule analysis of *Avicennia* sp's flour (a) and starch (b)

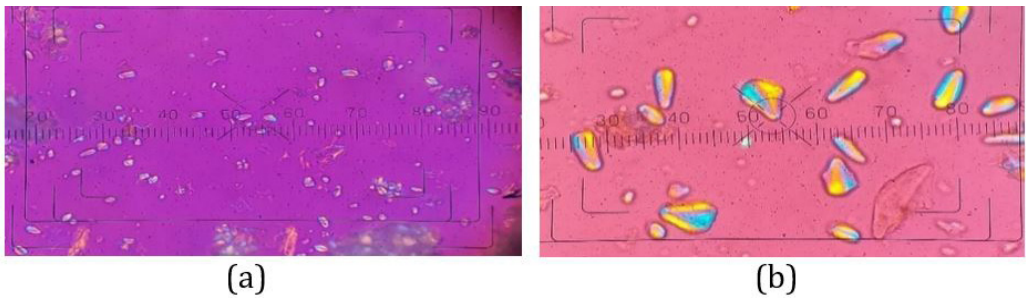

Figure 5. Birefringence structure, size, and shape of granule analysis of *Bruguiera* sp's flour (a) and starch (b)

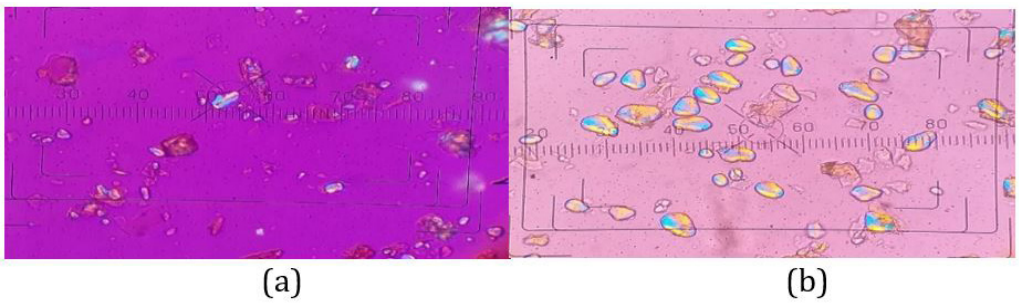

Figure 6. Birefringence structure, size, and shape of granule analysis of *Rhizophora* sp's flour (a) and starch (b)

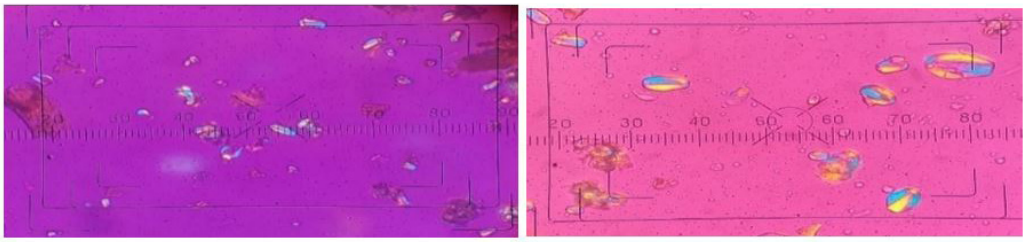

Figure 7. Birefringence structure, size, and shape of granule analysis of *Sonneratia* sp's flour (a) and starch (b)

Table 7. The values of pasting properties analysis of flour and starch

Mangrove Species	Flour						Starch					
	Pasting temperature (°C)	Viscosity (cP)					Pasting temperature (°C)	Viscosity (cP)				
		Peak	Trough	Break down	Final	Set back		Peak	Trough	Break down	Final	Set back
Avicennia **sp.**	72	101	102	0	188	86	50.2	289	98	191	208	110
Bruguiera **sp.**	82.5	820	471	349	702	231	51.25	502	142	360	275	133
Rhizophora **sp.**	80	49	46	3	67	21	50	50	43	7	59	16
Sonneratia **sp.**	78	161	161	0	406	245	56.25	156	74	82	98	24

Table 8 Initial temperature of gelatinization of several types of natural starch-containing low amylose (waxy)

Natural starch	Initial temperature of gelatinization (°C)	Reference
Rice	58,6	Waterschoot *et al.* (2014)
Rice	59,6	Vamadevan *et al.* (2013)
Barley	57,9	Schirmer *et al.* (2013)
Corn	66,6	Schirmer *et al.* (2013)
Potato	63,6	Schirmer *et al.* (2013)
Mangrove fruits of *Avicennia* sp.	50,2	Results of analysis
Mangrove fruits of *Bruguiera* sp.	51,25	Results of analysis
Mangrove fruits of *Rhizophora* sp.	50	Results of analysis
Mangrove fruits of *Sonneratia* sp.	56,25	Results of analysis

ISSN-Internet 2197-411x OLCL 862804632

4.1. Proximate composition of mangrove fruits

Table 2 and Table 3 show the proximate compositions of mangrove fruits and flours.

The highest water content for the fruit of mangroves is owned by the fruit of *Sonneratia* sp. The high moisture content accounts for its short shelf life as it deteriorates quickly after harvest if preservative measures are not employed. This high-water content promotes susceptibility to microbial growth and enzyme activities. This is what causes the fruits of *Sonneratia* sp. damage faster than other fruits. However, the moisture content of mangroves depends on their harvesting time, maturation period, and environmental conditions such as humidity and temperature in the growing period and storage conditions (Crisan & Sands, 1978). The production of mangrove flours aims to increase shelf life without reducing nutritional values. The drying process is one of the crucial stages because it determines the quality and durability of the further processed product from the flours (Erni et al., 2018).

The significant difference in proximate contents for fruits and mangroves flours was caused by the heat absorbed by the material during the drying process. It was affecting the dryness level of the flours. The proximate test of flours changed due to the temperature treatment and drying time. The drying process was carried out at a temperature of 60-70 °C for 4-6 h. The drying process at this temperature was chosen besides reducing the water content of a material, it can also significantly reduce cyanide levels (Jayanegara et al., 2019; Nelfiyanti, 2015; Sulistyawati & Kumalaningsih, 2012) and tannin levels (Nelfiyanti, 2015; Sulistyawati & Kumalaningsih, 2012) in mangroves flours. Moreover, low-temperature drying was chosen to minimize the degradation of phytochemicals (Mahanom et al., 1999, Djaeni & Sari, 2015, Mardiah et al. 2015, park et al. 2021, and A'yuni et al., 2022), amino acids (Park et al., 2021), and giving the best condition of physiological properties of the dry product (Pradana et al., 2019).

In the proximate composition, the mangrove flours produced in this study met the Indonesian commercial flours standard (SNI 7622 2011), with less than 13 % moisture content and at least 7 % for protein content. Overall, total values of both crude protein and crude lipid, when comparing fruits to flours, rose significantly. An increase in protein content after flouring was also reported by Riansyah et al. (2013). This is because the longer time and the higher the temperature used in the drying process causes an increase in lipid and protein content, which is inversely proportional to the value of the water content, which gradually decreases as the temperature and time used during the drying process increase. According to Yuniarti's research (2008), the length of time and high temperature employed in the drying process causes the lipid content in the material to increase and the moisture content to decrease.

4.2. Cyanide acid compound in flour

The safe limit for cyanide acid in food is 50 ppm (Baskin & Brewer, 2006). Based on these results, generally, mangroves fruits contain HCN of more than 50 ppm, so it is not safe for direct consumption. Processing steps that can reduce cyanide levels effectively in fruit are required, including drying, boiling, soaking, peeling, starch extraction, and fermentation (silage) (Jayanegara et al., 2019; Muryati & Nelfiyanti, 2015). Some of these food processing techniques can reduce anti-nutritional compounds, improve protein digestion, and increase plant biological value. Furthermore, the process of flours pre-treatment which includes washing, peeling, chopping, drying, and flouring can reduce the cyanide content. The exfoliation process can reduce cyanide by about 50 %. Based on the results, the decrease in HCN content due to the flour pre-treatment process can reduce 50 % to 100 % cyanide levels. This is in accordance with other researchers that a decrease in cyanide levels up to 80-85 % can be done by drying using the sun for 24 hours (Jayanegara et al., 2019; Rukmana, 1997), as well as drying using an oven at a temperature of 60 ^{0}C for 24 hours (Jayanegara et al., 2019; Sulistyawati & Kumalaningsih, 2012).

We can actually see that after flour preparation, the cyanide acid content decreases. Especially for the flours prepared from *Avicennia* sp., *Bruguiera* sp., and *Sonneratia* sp., they can be used as part of the ingredients since the cyanide levels are acceptable, below 50 ppm. According to Codex Alimentarius Commission (CAC), General Standard For Contaminants And Toxins In Food And Feed CXS 193-1995, Acute Reference

Dose (ARfD) of cyanide of 0.09 mg/kg body weight. This cyanide-equivalent ARfD applies to foods containing cyanogenic glycosides as the main source of cyanide. Additionally, the Provisional Maximum Tolerable Daily Intake (PMTDI) of cyanide is PMTDI of 0.02 mg/kg body weight. If we make a calculation of PMTDI with a person having 60 kg body weight, then per day, as much as 1.2 mg cyanide is acceptable to be consumed. If we considered the highest cyanide content of 79.65 ppm (Table 4, mangrove *Bruguiera* sp.), this number is not acceptable. Hereby, such processing is needed to reduce this value to an acceptable level. Further pretreatment is needed in addition to heating to reduce or eliminate the HCN content in fruit, including soaking (FAO 1990), withering (Hang & Preston 2005), boiling, steaming, roasting, frying, drying, fermenting, and steam distillation (Montagnac et al. 2009).

4.3. Colour Analysis

The positive values for a* and b* coordinates of four mangrove flours indicated that samples had varying red and yellow pigmentation concentrations in their flour. The figure showed that L*, a*, and b* values of *Avicennia* sp. were the lowest than others. It is indicated that *Avicennia* sp. flour is the darkest. *Bruguiera* sp. flour is significantly higher for L* value b* value, which indicated that *Bruguiera* sp. flour is lighter than others.

When compared to other flours, *Bruguiera* sp. flour had considerably higher L* values and Whiteness index. Chroma rose as pigment concentration increased and dropped as the sample became darker. Food samples with identical hue angles and chroma only are distinguished by their L* values (Wrolstad & Smith, 2017).

4.4. Starch content

Starch was the source of carbohydrates derived from plants, and had important value for the food industry. It was often used as a thickener, gelling agent, bulking agent, and water retention. The application of starch in food products is usually determined by its properties of gelatinization, pasting, solubility, swelling, and digestibility. Studies on the thermal properties of starch are needed to determine the structure of the starch and how to process and use the starch in its application to foodstuffs (Li et al., 2014). The physical properties of starch included starch paste characteristics, thermal properties, starch granule size, starch granule shape, birefringence structure, crystal type, and degree of starch crystallization. Starch could undergo gelatinization in the presence of water and heated at high temperatures, resulting in the breakdown of starch granules, loss of birefringence structure, and crystallinity. The values of the starch compound could be seen in Table 6.

Among the mangrove fruit flours that are shown in table 6, the highest amylose content was recorded derived from *Bruguiera* sp. (4.21 g/100 g basis flour) and the least from *Sonneratia* sp. (0.61 g/100 g basis flour).

The highest recorded total starch content was recorded with *Bruguiera* sp. (29.17 g/100 g) and the least with *Avicennia* sp. (19.73 g/100 g). The highest amylopectin content was recorded derived from *Bruguiera* sp. (24.96 g/100 g). Higher amylose content lowers the gelatinization profile of starch. Higher the amylose content so that the gel formation would be difficult. Because the amorphous structure formed would increase the gelatinization temperature so gelatinization would walk slowly.

4.5. Birefringence structure, size, and shape of starch granule

The birefringence structure was the property of starch granules that could reflect polarized light to form blue and yellow-coloured fields when viewed under a polarizing microscope (Richana & Sunarti, 2004). Starch had birefringence properties defined as the properties of intact starch granules that could form two colours (blue and yellow) crossing on the surface when passed on to polarized light due to differences in the refractive index in the starch granules (Xie et al., 2005). The refractive index is influenced by the molecular structure of amylose in starch (Richana & Sunarti, 2004). The helical form of amylose could absorb some of the light passing through the starch granules. The test was carried out on eight samples, four for flour and four for starch of *Avicennia* sp., *Bruguiera* sp., *Rhizophora* sp., and *Sonneratia* sp. According to (Cready RM, 1970), when water penetrates back and forth into the granules at a temperature of 60-85 oC, the granules will expand rapidly and lose their birefringence

ISSN-Internet 2197-411x OLCL 862804632

properties. When the starch is partially gelatinized, starch birefringence is still visible in small amounts. This is because it still contains intact starch granules. However, when the starch is completely gelatinized, the birefringence properties will be lost (Anwar et al., 2006). According to Jane & Chen (1992), differences in granule size, amylose content, and amylopectin branching chain length would result in differences in paste properties and gelatinization temperature. The granule analysis of starch of mangrove flours could be seen in figures 3, 4, 5, and 6.

4.6. Pasting properties

Based on Table 7 analysis of pasting properties of flour and starch from four mangrove species, it was found that the flour of *Bruguiera* sp. has the fastest time to fully gelatinize compared to others. This is indicated by the peak time, which is 7.5 minutes for flour and 8.3 minutes for starch. To achieve peak viscosity before the starch granules break, *Rhizophora* sp flour takes 11.6 minutes. *Avicennia* sp. flour and *Sonneratia* sp. take the same time to fully gelatinize, which is 13 minutes. For starch, *Sonneratia* sp. takes 8.5 minutes, and again *Avicennia* sp. and *Rhizophora* sp. take the same time, which is 10 minutes. The initial temperature of gelatinization is the temperature at which the starch granules begin to absorb water or can be seen as the viscosity increases. Based on these results, it can be said that the higher the temperature causes the starch granules to be more resistant to heat, thus requiring a higher temperature to start gelatinization. Starch gelatinization temperature indicates the temperature at which natural starch in semi-crystalline form changes to amorphous. The higher the gelatinization temperature, the higher the stability of the starch crystals. Microscopic changes in starch granules during cooking take place quickly and go through 3 stages. The first stage in cold water will occur in water absorption, which is reversible. The second stage occurs at a temperature of about 60 oC when the starch granules begin to expand and absorb large amounts of water to become irreversible. Gelatinization of *Avicennia* sp., *Sonneratia* sp., *Rhizophora* sp., and *Bruguiera* sp. flours are 72, 78, 80, and 82.5, respectively. While the starch gelatinization of *Rhizophora* sp., *Avicennia* sp., *Bruguiera* sp., and *Sonneratia* sp. are 50 oC, 50.2 oC, 51.25 oC, and 56.25 oC, respectively. According to Muhandri (2007), particle size affects the initial and maximum gelatinization temperatures, as well as lowers the maximum viscosity. Based on Table 7, it is found that the large flour particle size has a high gelatinization temperature and a low maximum viscosity.

For starch which has a smaller particle size than flour, it has a low gelatinization temperature with a high maximum viscosity value. This is because the larger particle size has not gelatinized the entire particle size so that the maximum viscosity has not been reached (Muhandri 2007). The composition of amylose and amylopectin can affect the gelatinization temperature of natural starch. According to Rasyda (2021), natural starch with low amylose content (waxy starch) has a lower initial gelatinization temperature than natural starch with medium amylose content. Research results from Hong et al. (2011) showed that waxy rice starch had a lower initial gelatinization temperature than waxy potato starch but higher than waxy corn starch. The amylopectin molecules in waxy starch remain in the granules during the swelling process of the starch granules, but if the heating process is extended, most of the granules will break and the starch suspension will turn into a solution of amylopectin macromolecules (Schirmer et al. 2013). Starch from mangrove flour has a low initial gelatinization temperature because it has low amylose and amylopectin composition. Table 8 shows the initial gelatinization temperature of several types of natural starch-containing low amylose (waxy).

Avicennia sp., *Bruguiera* sp., *Rhizophora* sp., and *Sonneratia* sp. have different gelatinization properties. The difference depends on the original structure and composition of amylose amylopectin. *Bruguiera* sp. had the highest peak viscosity and fastest gelatinization time. In food processing, *Bruguiera* sp.'s starch can be used to provide thickness in a short cooking time. *Rhizophora* sp. had the lowest peak viscosity, trough, final viscosity, and setback viscosity than others. In food processing, *Rhizophora* sp.'s starch was not suitable for use as a viscosity-forming material in cold products and semi-solid food products. It belonged to acid hydrolyzed starch with suitable gum-forming agents, candy, and liquid food formulations. *Avicennia* sp. and *Sonneratia* sp. had the longest time to reach peak viscosities, but these flours had the highest viscosity values in the setback phase. For application, they required a long cooking time to give the product

a good consistency, but this consistency could withstand well at cold temperatures.

Different types of flour have different particle distributions. Particle size plays an important role in flour wetting and water absorption in flour. If the particle size is wider, the surface area will be smaller. This indicates that the water takes longer to be absorbed into the starch particles. On the other hand, smaller particle size will increase the hydration level of flour (Immaningsih, 2012; Mailhot et al., 1988).

Flour derived from *Avicennia* sp., *Bruguiera* sp., *Rhizophora* sp., and *Sonneratia* sp. have different gelatinization properties. The difference depends on the structure and composition of amylose amylopectin. Flour from mangrove fruit has advantages based on indicators of the proportion of amylose content, viscosity, and degree of gelatinization. *Bruguiera* sp. flour has the highest peak viscosity and fastest gelatinization time. *Rhizophora* sp. flour has the lowest peak, trough, final viscosity, and setback viscosity. Flour of *Avicennia* sp. and *Sonneratia* sp. have the longest time to reach peak viscosity, but this flour has the highest viscosity value in the setback phase.

Mangroves are starchy plants that have the potential to be used as industrial raw materials in the form of flour and starch-based products. In the food processing industry, *Bruguiera* sp. has viscosity properties in a short time *Rhizophora* sp. flour is not suitable for use as a thickening agent in cold products and semi-solid food products, but suitable for liquid food formulations that are easily hydrolyzed by acid. *Avicennia* sp. flour and *Sonneratia* sp. require a longer processing time to produce a good consistency in the product, but this consistency only holds up well at cold temperatures. Based on the different characteristics of the four mangrove species, it will produce many uses, namely as raw materials and auxiliary materials in various industries. Therefore, mangrove fruit and its derivative products in the form of flour, starch, starch hydrolyzate, and starch products are superior raw materials for both food and non-food products.

5. Conclusions

The proximate compositions either in fruits or flour, for *Avicennia* sp., *Bruguiera* sp., *Rhizophora* sp., and *Sonneratia* sp., were considerably different. The colours and degrees of whiteness were also significantly different for the four mangrove species. From the perspective of cyanide content, all the mangrove fruits do not feel safe for consumption.

In food processing, *Bruguiera* sp.'s starch can be used to provide thickness in a short cooking time. *Rhizophora* sp.'s starch was not suitable for use as a viscosity-forming material in cold products and semi-solid food products. It belonged to acid hydrolyzed starch with suitable gum-forming agents, candy, and liquid food formulations. *Avicennia* sp. and *Sonneratia* sp. required a long cooking time to give the product a good consistency, but this consistency could withstand well at cold temperatures.

Conflict of interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

[AACC] Association of American Cereal Chemist Approved Methods of Analysis, 11th Edition. (2001). 08-01.01: Ash basic method. Retrieved from https://www.cerealsgrains.org/resources/Methods/Methods/08-01.pdf

[AACC] Association of American Cereal Chemist Approved Methods of Analysis, 11th Edition . (2013). 44-15.02: Moisture-Air-Oven Methods. Retrieved from https://www.cerealsgrains.org/resources/Methods/Methods/44-15.pdf

[AACC] Association of American Cereal Chemist, Approved Methods of Analysis, 11th Edition. (2010). 46-30.01: Crude Protein-Combustion Method. Retrieved from https://www.cerealsgrains.org/resources/Methods/Methods/46-30.pdf

[AACC] Association of American Cereal Chemist, Approved Methods of Analysis, 11th Edition. (2010). 26-50.01: Brabender Quadrumat Jr. (Quadruplex) Method. Retrieved from https://www.cerealsgrains.

ISSN-Internet 2197-411x OLCL 862804632

org/resources/Methods/Methods/26-50.pdf

[AACC] Association of American Cereal Chemist, Approved Methods of Analysis, 11th Edition. (2010). 54-40.02: Mixograph Method. Retrieved from https://www.cerealsgrains.org/resources/Methods/Methods/54-40.pdf

[AACC] Association of American Cereal Chemist, Approved Methods of Analysis, 11th Edition. (2010). 38-12.02: Wet Gluten, Dry Gluten, Water-binding Capacity, and Gluten Index. Retrieved from https://www.cerealsgrains.org/resources/Methods/Methods/38-12.pdf

[AACC] Association of American Cereal Chemist, Approved Methods of Analysis, 11th Edition. (2010). 66-50.01: Pasta and Noodle Cooking Quality-Firmness. Retrieved from https://www.cerealsgrains.org/resources/Methods/Methods/66-50.pdf

[AACC] Association of American Cereal Chemist Approved Methods of Analysis, 11th Edition. (1999). 76-21.02: General Pasting Method for Wheat or Rye Flour or Starch Using the Rapid Visco Analyser. Retrieved from https://www.cerealsgrains.org/resources/Methods/Methods/76-21.pdf

[AOAC] Association of Official Analytical Chemists. (2006). Method 2003.06.-2006, Crude Fat in Feeds,Cereal Grains,and Forages. Retrieved from http://www.aoacofficialmethod.org/index.php?main_page=product_info&products_id=1552

[FAO] Food Agricultural Organization. (2003). Food Energy: Methods of Analysis and Conversion Factors. Retrieved from https://www.fao.org/uploads/media/FAO_2003_Food_Energy_02.pdf

[ITTO] The International Tropical Timber Organization. (2017). ITTO Annual Report 2017. Retrieved from https://www.itto.int/direct/topics/topics_pdf_download/topics_id=5734&no=1

[KLHK] Ministry of Environment and Forestry of Indonesia. (2019). Mangrove Rehabilitation in order to Sustain Mangrove Ecosystem Management. Retrieved from https://seminar.bio.unsoed.ac.id/index.php/ICoMIRE/ICoMIRE-2019/paper/viewFile/607/22

A'yuni, D. Q., Djaeni, M., Asiah, N., & Subagio, A. (2022). Enhancement of onion bulb drying with air dehumidification assisted dryer. AIMS Agriculture and Food, 7(1), 168–183. doi: 10.3934/agrfood.2022011

Ahmad, F., Sulaiman, M. R., Saimon, W., Yee, C. F., & Matanjun, P. (2012). Proximate Compositions and Total Phenolic Contents of Selected Edible Seaweed From Semporna, Sabah, Malaysia. Borneo Science, 31, 85–96. Retrieved from https://jurcon.ums.edu.my/ojums/index.php/borneo-science/article/view/171/113

Aida, G. R., Wardiatno, Y., Fahrudin, A., & Kamal, M. M. (2014). Mangrove litter production on the Tangerang coast, Banten. Jurnal Ilmu Pertanian Indonesia, 19(2), 91–97. Retrieved from https://www.journal.ipb.ac.id/index.php/JIPI/article/view/8803/6877

Allen, P., Bennett, K., & Heritage, B. (2014). SPSS statistics version 22: A practical guide. Cengage Learning Australia Pty Limited. Retrieved from https://research-repository.uwa.edu.au/en/publications/spss-statistics-version-22-a-practical-guide

Amalia, U., Darmanto, Y. S., Sumardianto, & Rianingsih, L. (2016). Chemical Characteristics of Fish Nugget with Mangrove Fruit Flour Substitution. Aquatic Procedia, 7, 265–270. doi: 10.1016/j.aqpro.2016.07.037

Anwar, E., Khotimah, H., & Yanuar, A. (2006). An approach on pregelatinized cassava starch phosphate esters as hydrophilic polymer excipient for controlled release tablet. Journal of Medical Sciences, 6(6), 923–929. doi: 10.3923/jms.2006.923.929

Apriyantono, A., Fardiaz, D., NL, P., Sedarnawati, & Budiyanto, S. (1989). Food Analysis. Indonesia: IPB University.

Ardiansyah, P. R., Wonggo, D., Dotulong, V., Damongilala, L. J., Harikedua, S. D., Mentang, F., & Sanger, G. (2020). Proximate to *Sonneratia alba* mangrove fruit flour. Media Teknologi Hasil Perikanan, 8(3), 82-87. doi: 10.35800/mthp.8.3.2020.27526

Baskin, S. I., & Brewer, T. G. (2006). Cyanide Poisoning. In Textbook of Military Medicine (pp. 271–286). Maryland, USA: TMM Publications.

Bengen, D. G. (2001). Technical Guidelines for the Identification and Management of Mangrove Ecosystems. Bogor: PKSPL-IPB.

Beta, T., & Corke, H. (2001). Noodle quality as related to sorghum starch properties. Cereal Chemistry, 78(4), 417–420. doi: 10.1094/CCHEM.2001.78.4.417

Brown, L., Rosner, B., Willett, W. W., & Sacks, F. M. (1999). Cholesterol-lowering effects of dietary fiber: a meta-analysis. The American Journal of Clinical Nutrition, 69(1), 30–42. doi: 10.1093/ajcn/69.1.30

Chen, P., Liu, X., Zhang, X., Sangwan, P., & Yu, L. (2015). Phase transition of waxy and normal wheat starch granules during gelatinization. International Journal of Polymer Science, 2015. doi: 10.1155/2015/397128

Chrissanty, P. A. (2012). Decreasing Tannins Level in MangroveType *Avicennia marina*, Brugueira *gymnorrhiza* and Rhyzophora stylosa for Producing Mangrove Flour. Industria: Jurnal Teknologi Dan Manajemen Agroindustri, 1(1), 31–39. doi: 10.1873/industria.ub.ac.id.2012.8643

Cready RM. (1970). Determination of Starch and Dextrin. In Methods in Food Analysis 2nd Ed. series of monographs ed. By Joslyn A.M. (pp. 522-557). New York: Academic Press.

Crisan, E. V., & Sands, A. (1978). Nutritional value. In: The Biology and Cultivation of Edible Mushrooms. Eds. S. T. Chang and W.A. Hayes. (pp. 137-168). New York: Academic Press.

David, O., Arthur, E., Kwadwo, S. O., Badu, E., & Sakyi, P. (2015). Proximate composition and some functional properties of soft wheat flour. International Journal of Innovative Research in Science, Engineering and Technology, 4(2), 753–758. doi: 10.15680/IJIRSET.2015.0402097

Dewi, E. N., Kurniasih, R. A., & Purnamayati, L. (2017). Nutritional and Antinutritional Properties of lindur (*Bruguiera gymnorrhiza*) Fruits Flour from Different Pre-Treatments. Advanced Science Letters, 23(4), 3427–3430 (4). doi: 10.1166/asl.2017.9118

Djaeni, M., & Sari, D. A. (2015). Low temperature seaweed drying using dehumidified air. Procedia Environmental Sciences, 23, 2–10. doi: 10.1016/j.proenv.2015.01.002

Erni, N., Kadirman, K., & Fadilah, R. (2018). The Influence of Temperature and Length of Drying to the Chemical Characteristic and Organoleptic of Taro Flour (Colocasia esculenta). Jurnal Pendidikan Teknologi Pertanian, 4(1), 95–105. doi: 10.26858/jptp.v1i1.6223

Eshun, G. (2012). Nutrient composition and functional properties of bean flours of three soya bean varieties from Ghana. African Journal of Food Science and Technology, 3(8), 176–181. Retrieved from https://www.interesjournals.org/articles/nutrient-composition-and-functional-properties-of-bean-flours-of-three-soya-bean-varieties-fromghana.pdf

Freitas, R. A., Paula, R. C., Feitosa, J. P. A., Rocha, S., & Sierakowski, M.-R. (2004). Amylose contents, rheological properties and gelatinization kinetics of yam (Dioscorea alata) and cassava (Manihot utilissima) starches. Carbohydrate Polymers, 55(1), 3–8. doi: 10.1016/S0144-8617(03)00142-5

Guelpa, A., Bevilacqua, M., Marini, F., O'Kennedy, K., Geladi, P., & Manley, M. (2015). Application of Rapid Visco Analyser (RVA) viscograms and chemometrics for maize hardness characterisation. Food Chemistry, 173, 1220–1227. doi: 10.1016/j.foodchem.2014.10.149

Handayani, S., Yuwono, S. S., Aulanni'am, A., & Suprayitno, E. (2015). Isolation and identification structure antioxidant active compounds of ethyl acetate fraction hypocotyl *Bruguiera* gymnorhiza (L) Lamk. International Journal ChemTech Research, 8(4), 1858–1867. Retrieved from https://www.sphinxsai.com/2015/ch_vol8_no4/3/(1858-1867)V8N4.pdf

Hardoko, S. E., Puspitasari, Y. E., & Amalia, R. (2015). Study of ripe *Rhizophora mucronata* fruit flour as functional food for antidiabetic. International Food Research Journal, 22(3), 953-959. Retrieved from http://www.ifrj.upm.edu.my/22%20(03)%202015/(11).pdf

Hwanhlem, N., Chobert, J.-M., & H-Kittikun, A.

ISSN-Internet 2197-411x OLCL 862804632

(2014). Bacteriocin-producing lactic acid bacteria isolated from mangrove forests in southern Thailand as potential bio-control agents in food: Isolation, screening and optimization. Food Control, 41, 202–211. doi: 10.1016/j.foodcont.2014.01.021

Immaningsih, N. (2012). Gelatinisation profile of several flour formulations for estimating cooking behaviour. Penel Gizi Makan, 35(1), 13–22. Retrieved from: http://ejournal.litbang.kemkes.go.id/index.php/pgm/article/download/3079/3047

Jacoeb, A. M., Suptijah, P., & Zahidah. (2013). Chemical Composition, Bioactive Component and Antioxidant Activity of Large-Leafed Mangrove (*Bruguiera gymnorrhiza*) Fruit. Jurnal Pengolahan Hasil Perikanan Indonesia, 16(1), 86–94. doi: 10.17844/JPHPI.V16I1.7772

Jane, J.-L., & Chen, J.-F. (1992). Effect of amylose molecular size and amylopectin branch chain length on paste properties of starch. Cereal Chemistry, 69(1), 60–65. Retrieved from https://www.cerealsgrains.org/publications/cc/backissues/1992/Documents/69_60.pdf

Jariyah, J., Widjanarko, S. B., Yunianta, Y., & Estiasih, T. (2015). Phytochemical and acute toxicity studies of ethanol extract from Pedada (*Sonneratia* caseolaris) fruit flour (PFF). International Journal on Advanced Science, Engineering and Information Technology, 5(2), 95–98. doi: 10.18517/ijaseit.5.2.485

Jariyah, J., Yektiningsih, E., Sarofa, U., & Sopadeo, P. A. (2018). Effect of Partial Replacement of Wheat Flour with Various Mangrove Fruit Flours and Different Emulsifiers on Physicochemical Properties of Biscuits. Indonesian Journal of Agricultural Research, 1(2), 152–161. doi: 10.32734/injar.v1i2.318

Jariyah, J., Widjanarko, S. B., Yunianta, Y., Estiasih, T., & Sopade, P. A. (2014). Pasting properties mixtures of mangrove fruit flour (*Sonneratia* caseolaris) and starches. International Food Research Journal, 21(6), 2161-2167. Retrieved from http://www.ifrj.upm.edu.my/21%20(06)%202014/15%20IFRJ%2021%20(06)%202014%20Jariyah%20174.pdf

Jayanegara, A., Ridla, M., Laconi, E. B., & Nahrowi. (2019). Antinutrition component for feed. IPB Press.

Kadiri, M., & Fasidi, I. O. (1990). Studies on enzyme activities of Pleurotus tuber-regium (Fries) Singer and Tricholoma lobayensis Heim at various fruitbody stages. Food/Nahrung, 34(8), 695–699. doi: 10.1002/food.19900340808

Koehler, L. H. (1952). Differentiation of carbohydrates by anthrone reaction rate and color intensity. Analytical Chemistry, 24(10), 1576–1579. doi: 10.1021/ac60070a014

Li, S., Zhang, Y., Wei, Y., Zhang, W., & Zhang, B. (2014). Thermal, pasting and gel textural properties of commercial starches from different botanical sources. Journal of Bioprocessing & Biotechniques, 4(4), 1-6. doi: 10.4172/2155-9821.1000161

Lin, L.-Y., Liu, H.-M., Yu, Y.-W., Lin, S.-D., & Mau, J.-L. (2009). Quality and antioxidant property of buckwheat enhanced wheat bread. Food Chemistry, 112(4), 987–991. doi: 10.1016/j.foodchem.2008.07.022

Mahanom, H., Azizah, A. H., & Dzulkifly, M. H. (1999). Effect of different drying methods on concentrations of several phytochemicals in herbal preparation of 8 medicinal plants leaves. Malaysian Journal ofNutrition, 5(1), 47–54. Retrieved from https://pubmed.ncbi.nlm.nih.gov/22692357/

Mahmudi, M., Manajemen, J., Perairan, S., & Brawijaya, F. (2012). Estimated Fish Production Through Mangrove Leaf Litter Nutrients in Reforestation Areas *Rhizophora*, Nguling, Pasuruan, East Java. ILMU KELAUTAN: Indonesian Journal of Marine Sciences, 15(4), 231–235. doi: 10.14710/ik.ijms.15.4.231-235

Mailhot, W. C., Patton, J. C., & Pomeranz, Y. (1988). Wheat Chemistry and Technology. American Association of Cereal Chemists. Minnesota, USA: Buchbesprechung.

Manalu, R. D. E., Salamah, E., Retiaty, F., & Kurniawati, N. (2013). Macronutrient and vitamin contents of Pedada's fruit products. Journal of Nutrition, Food Research and Technology, 36(2), 135–140. doi: 1035/jnfrt.2013.764.135

Marlina, N. (2000). Analysis of cyanide in Cassava with Lian and Hamir methods. Lokakarya Fungsional Non Peneliti.

Megayana, Y. (2011). Study of Alginate and Chlorophyll Content of Sargassum sp. at different harvest ages. International Food Research Journal ,1(1). doi: 8337/ifrj.2011.38.23

Meyer, L. (1973). Food Chemistry. New York, Reinhold Publishing Corporation.

Moniharapon, E., Nendissa, S. J., & Laiyan, D. D. (2017). Characterization of chemical properties of "Lawa Merah" bean (Phaseolus vulgaris L.) flour with several preliminary treatments. AGRITEKNO, Jurnal Teknologi Pertanian, 6(1), 21-26. doi: 10.30598/jagritekno.2017.6.1.21

Nelfiyanti, M. D. (2015). Separation of tanin and HCN by cold process extraction in mangrove fruit powder processing for food industry substitution. Jurnal Riset Teknologi Pencegahan Pencemaran Industri, 6(1), 9–16. doi: 10.21771/jrtppi.2015.v6.no1.p9-16

Nurindra, A. P., Alamsjah, M. A., & Sudarno. (2015). Characterization of Edible Film From Propagules Mangrove Lindur (*Bruguiera Gymnorrhiza*) Starch with Addition of Carboxymethyl Cellulose (CMC) as Plasticizer. Jurnal Ilmiah Perikanan & Kelautan, 7(2), 125–132. doi: 10.20473/jipk.v7i2.11195

Okoro, I. O., & Achuba, F. I. (2012). Proximate and mineral analysis of some wild edible mushrooms. African Journal of Biotechnology, 11(30), 7720–7724. doi: 10.5897/AJB11.590

Ovando-Martínez, M., Bello-Pérez, L. A., Whitney, K., Osorio-Díaz, P., & Simsek, S. (2011). Starch characteristics of bean (Phaseolus vulgaris L.) grown in different localities. Carbohydrate Polymers, 85(1), 54–64. doi: 10.1016/j.carbpol.2011.01.043

Park, C. H., Yeo, H. J., Park, C., Chung, Y. S., & Park, S. U. (2021). The effect of different drying methods on primary and secondary metabolites in Korean mint flower. Agronomy, 11(4), 698. doi: 10.3390/agronomy11040698

Patil, P. D., & Chavan, N. S. (2013). A need of conservation of mangrove genus *Bruguiera* as a famine food. Annals Food Science and Technology, 14(2), 294–297. Retrieved from http://www.afst.valahia.ro/images/documente/2013/issue2/full/section2/s02_w06_full.pdf

Permadi, Y. B., Sedjati, S., & Supriyantini, E. (2012). Effect of rub ash concentration and Immersion time of water on nutritive content of mangrove fruit flour Avicenia *marina*. Journal of Marine Research, 1(1), 39–47. doi: 2984/jmr.3333421

Podunge, F., Purwaningsih, S., & Nurhayati, T. (2015). The Characteristic of Black Bakau Fruit as Extract of Antioxidant Source. Jurnal Pengolahan Hasil Perikanan Indonesia, 18(2), 140–149. doi: 10.17844/jphpi.v18i2.10609

Pradana, G. B., Prabowo, K. B., Hastuti, R. P., Djaeni, M., & Prasetyaningrum, A. (2019). Seaweed drying process using tray dryer with dehumidified air system to increase efficiency of energy and quality product. IOP Conference Series: Earth and Environmental Science, 292(1), 012070. doi: 10.1088/1755-1315/292/1/012070

Priyono, A., Ilminingtyas, D., Mohson, Yuliani, L. S., & Hakim, T. L. (2010). Various processed products made from mangrove (pp.4). Indonesia: KeSEMat.

Purwaningsih, S., Salamah, E., Sukarno, A. Y. P., & Deskawati, E. (2013). Antioxidant activity of mangrove fruit (*Rhizophora mucronata* Lamk.) in different temperature. Jurnal Pengolahan Hasil Perikanan Indonesia, 16(3), 199–206. Retrieved from https://journal.ipb.ac.id/index.php/jphpi/article/view/8057/6316

Putri, L., Yulianda, F., & Wardianto, Y. (2015). Mangrove zonation and its associated macrozoobenthos in Pantai Indah Kapuk, Jakarta. International Journal of Bonorowo Wetlands, 5(1), 29–43. doi: 10.13057/bonorowo/w050104

Rahadian, A., Prasetyo, L. B., Setiawan, Y., & Wikantika, K. (2019). A Historical Review of Data and Information of Indonesian Mangroves Area. Media Konservasi, 24(2), 163–178. https://doi.org/10.29244/medkon.24.2.163-178. doi: 10.29244/med-

ISSN-Internet 2197-411x OLCL 862804632

kon.24.2.163-178

Rahim, S., & Baderan, D. W. K. (2017). Mangrove forest and its use. Deepublish.

Riansyah, A., Supriadi, A., & Nopianti, R. (2013). The effect of differences in temperature and drying time on the characteristics of sepat siam salted fish (Trichogaster pectoralis) using an oven. Jurnal Fishtech, 2(1), 53–68. doi: 10.36706/fishtech.v2i1.1103

Richana, N., & Sunarti, T. C. (2004). Characterization of physicochemical properties of tuber flour and starch from umbi ganyong, suweg, ubikelapa and gembili. Jurnal Pascapanen, 1(1), 29-37. doi: 294.34/jp.2004.34.37

Rukmana, R. (1997). Cassava cultivation and postharvest. Yogyakarta: Kanisius.

Sahin, S., & Sumnu, S. G. (2006). Physical properties of foods. Springer Science & Business Media.

Sarmin NF, Puth, C., & Ng Yi Fu. (2018). Starch Determination (p. 208). Germany: Schmidt Haensch.

Sarungallo, Z. L., Santoso, B., & Tethool, E. F. (2010). Physicochemical and Functional Properties of Aibon Fruit (Brugueira gymnorhiza L.) starch. Jurnal Natur Indonesia, 12(2), 156–162. doi: 10.31258/jnat.12.2.156-162

Schirmer, M., Höchstötter, A., Jekle, M., Arendt, E., & Becker, T. (2013). Physicochemical and morphological characterization of different starches with variable amylose/amylopectin ratio. Food Hydrocolloids, 32(1), 52–63. doi: 10.1016/j.foodhyd.2012.11.032

Singh, A., Hung, Y.-C, Corredig, M., Phillips, R. D., Chinnan, M. S., & McWatters, K. H. (2005). Effect of milling method on selected physical and functional properties of cowpea (Vigna unguiculata) paste. International Journal of Food Science & Technology, 40(5), 525–536. doi: 10.1111/j.1365-2621.2005.00964.x

Smith, P. S. (1982). Starch derivatives and their use in foods. In Lineback D. R., and Inglett, G. E. Eds. (pp. 237). Food Carbohydrates. Westport, United States: AVI Publishing.

Sodamade, A., Bolaji, O. S., & Adeboye, O. O. (2013). Proximate analysis, mineral contents and functional properties of Moringa oleifera leaf protein concentrate. IOSR Journal of Applied Chemistry, 4(6), 47–51. doi: 10.6084/M9.FIGSHARE.1097420

Srichuwong, S., Sunarti, T. C., Mishima, T., Isono, N., & Hisamatsu, M. (2005). Starches from different botanical sources II: Contribution of starch structure to swelling and pasting properties. Carbohydrate Polymers, 62(1), 25–34. doi: 10.1016/j.carbpol.2005.07.003

Subandriyo, S., Setianingsih, N. I., & Muryati, M. (2015). Multilevel Extraction for Reducing Tannin of Mangrove Fruit (*Bruguiera* gumnorrhiza Lamk) as a Raw Material in Mangrove Flour. Journal of Applied Food Technology, 2(1). doi: 10.17728/jaft.63

Sudirman, S., Nurjanah, & Jacoeb, A. M. (2014). Proximate compositions, bioactive compounds and antioxidant activity from large-leafed mangrove (*Bruguiera gymnorrhiza*) fruit. International Food Research Journal, 21(6), 2387–2391. Retrieved from http://agris.upm.edu.my:8080/dspace/handle/0/11236

Sulistyawati, Wignyanto, & Kumalaningsih, S. (2012). Low tannins and HCN of Lindur fruit flour products as an alternative food. Jurnal Teknologi Pertanian, 13(3), 187–198. Retrieved from https://www.academia.edu/25317999/Low_Tannins_and_HCN_of_Lindur_Fruit

Sumartini, S., Harahap, K. S., & Mujiyanti, A. (2021). Brownies from mangrove fruit flour: the use of variation of flours as an alternative to high food nutrition. Indonesian Food and Nutrition Progress, 17(1), 16–22. doi: 10.22146/ifnp.55188

Tester, R. F., & Morrison, W. R. (1990). Swelling and gelatinization of cereal starches. I. Effects of amylopectin, amylose, and lipids. Cereal Chem, 67(6), 551–557. Retrieved from https://www.cerealsgrains.org/publications/cc/backissues/1990/documents/67_551.pdf

Vamadevan, V., Bertoft, E., Soldatov, D. V, & Seetharaman, K. (2013). Impact on molecular organization of amylopectin in starch granules upon annealing. Carbohydrate Polymers, 98(1), 1045–1055. doi: 10.1016/j.

carbpol.2013.07.006

Wang, S., Li, C., Copeland, L., Niu, Q., & Wang, S. (2015). Starch Retrogradation: A Comprehensive Review. Comprehensive Reviews in Food Science and Food Safety, 14(5), 568–585. doi: 10.1111/1541-4337.12143

Waterschoot, J., Gomand, S. V, Willebrords, J. K., Fierens, E., & Delcour, J. A. (2014). Pasting properties of blends of potato, rice and maize starches. Food Hydrocolloids, 41, 298–308. doi: 10.1016/j.foodhyd.2014.04.033

Wrolstad, R. E., & Smith, D. E. (2017). Color analysis. In Food analysis (pp. 545–555). Springer.

Xie, S. X., Liu, Q., & Cui, S. W. (2005). Starch modification and applications. In Cui, S. W., Ed. Food Carbohydrates. Boca Raton, Florida: CRC Press.

Yamamoto, T., Uenakai, K., & Sugi, J. (1983). Starch and alcohol fermentation of viviparous buds of mangroves. Journal of the Japanese Society of Starch Science, 30(4), 342–347. doi: 10.5458/jag1972.30.342

Yuniarti, N., Syamsuwida, D., & Aminah, A. (2008). Effect of Decreased Water Content on Changes in Physiological and Biochemical Content of Eboni Seeds (Diospyros Celebica Bakh.). Jurnal Penelitian Hutan Tanaman, 5(3), 191–198. doi: 10.7226/jpht.21.2.92

ISSN-Internet 2197-411x OLCL 862804632