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Pasting properties mixtures of mangrove fruit flour (*Sonneratia caseolaris*) and starches

[1,2*]Jariyah, [3]Widjanarko, S. B., [3]Yunianta, [3]Estiasih, T. and [4]Sopade, P. A.

[1]*Department of Food Technology,Faculty of Industrial Technology, University of Pembangunan Nasional "Veteran", Surabaya, East Java, Indonesia 60294*

[2]*Doctoral Program of Agriculture Technology, Faculty of Agriculture, Universityof Brawijaya, Malang, East Java, Indonesia 65145*

[3]*Departement ofFood Science and Technology, Faculty of AgriculturalTechnology, University of Brawijaya, Malang, East Java, Indonesia 65145*

[4]*Centre for Nutrition and Food Sciences,Queensland Alliance for Agriculture and Food Innovation, University of Queensland, St Lucia QLD 4072, Australia.*

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Abstract

Mangrove fruit from species *Sonneratia caseolaris* can be an important raw material in functional food with dietary fiber, vitamins, and flavonoid, as well as its anti-cholesterol and anti-diabetic properties. Understanding its pasting properties of the flour from it when mixed with starches will further enhance its utilization as a functional ingredient, so its can be added to food as a supplement to enhance the beneficial health properties.The aims of this research were to study pasting properties, including physicochemical. An experiment the mangrove fruit flour (Mang) mixed with waxy maize starch (WaMa), potato starch (PS) and wheat flour (WhF) at level ranges of 0-100% were studied in water using the Rapid Visco-Analyser (RVA). The results showed that the mangrove fruit flour did not change the pasting patterns of the mixtures, and the pasting temperatures of the samples ranged 65.1–77.3^{o}C. The mangrove fruit flour significantly decreased ($p < 0.05$) the pasting parameters of the WaMa and PS as it diluted the starch contents in the mixtures. The peak viscosity of the Mang:WaMa mixtures decreased from 4342 to 1617cP. Similarly, in the Mang:PS it decreased from 10883 to 3127cP and in the Mang:WhF from 4079 to 1651 cP. The mangrove fruit flour did not change the setback viscosity of the Mang:PS and Mang:WhF mixtures, and there were significant positive correlations ($r \geq 0.89$; $p \leq 0.01$) between the breakdown and peak viscosities of the mixtures. In mangrove fruit composite flours, therefore, more starch-containing base flours are required to achieve the same consistency as the undiluted flours.

Introduction

Mangrove fruit has been long consumed by society living in coastal area in Indonesia as a food material or ingredient in various processed food products. At present this fruit is consumed only for domestic needs, not for commercialization. Especially East Java Province of Indonesia, there are nine species of mangrove that produce edible fruits (Kesemat, 2007; Mangrove Information Center, 2009). These are *Sonneratia*, *Ceriops*, *Bruguiera*, *Avicennia*, *Xylocarpus*, *Aegiceras*, *Lumnitcera*, *Waru* and *Bariringtonia asiatica* (Noor *et al.*, 2006). *Sonneratia caseolaris* is a popular one, which is non-toxic (Chen *et al.*, 2009), soft in texture having specific flavours and nice taste, various food products have been produced from it, including syrup (Abeywickrama and Jayasooriya, 2010), cakes and steamed pudding (Brown *et al.*, 2006). During harvesting season, each mangrove tree can produce up to two kg per day. Despite its availability, information on the food properties of mangrove fruit from Indonesia is limited, and this has hindered these mangrove resources from becoming a valuable commodity, economically and functionally.

Previous research has shown that the mangrove fruits (*Sonneratia caseolaris*) contain about 15.95% carbohydrate (by difference), moisture 77.10%, fat 0.86%, ash 3.85% and protein 2.24%. While the mangrove species *Bruguiera ghymnorrhiza* having high calorific value (300.29 Kcal/100 g), crude fiber 10.09% and 68.88% of carbohydrate (Patil and Chavan, 2013). Moreover, amylose content of mangrove species *Rhizophpora stylosa* has been reported to be about 22.3–26.3% (Hanashiro *et al.*, 2004). Starch in *Canavalia cathartica* mangrove seeds about 44.7-52%, crude protein 25.9%, carbohydrate 58.5-73.3%, magnesium, zinc, manganese were 122.65; 18.38; 8.15 mg/100 g, respectively and calorific value of about 1516-1517 kJ/100 g (Bhagya *et al.*, 2007).

*Corresponding author.
Email: *jariyah_icha@yahoo.co.id/jariyahupn65@gmail*
Tel: +62 318782179; Fax: +62 318782257

In medicine, mangrove fruits are also used as analgesic and anti-inflammatory agent, anti-bacteria (Bandaranayake, 2002) and they possess hepatoprotective (Charoenteeraboon *et al*., 2007), antihyperglycemic (Sadhu *et al*., 2006; Ashok *et al*., 2010) and contain antioxidants (Banerjee, 2008; Minqing *et al*., 2009; Phaechamud *et al*., 2012).

Mangrove fruit and consequently, its flour, is usually used with starch-containing materials for various food preparations. Wheat flour is widely used for baked goods, while maize and potato starches, for example, have unique properties, and can form pastes with high viscosity and high clarity, and are widely used in the food industry as, for instance, thickeners (Park *et al*., 2009 and Cai *et al*., 2011). It is, therefore, possible, to mix these starch-containing materials with mangrove fruit flour for various products with the added benefits of the functional properties of mangrove fruits. Pasting properties are important in the food industry when materials are heated in (excess) water. Pasting properties of various materials, individually and in mixtures, have been studied (Collar *et al*., 2006; Sopade *et al*., 2006; Park *et al.*, 2009; Sharma *et al.*, 2009; Tsakama *et al.*, 2010; BeMiller, 2011; Cai *et al*., 2011; Waramboi *et al*., 2011), but despite being a food ingredient, pasting characteristics of mangrove fruit flours have not been studied alone or mixed with other materials. Hence, this research investigated pasting properties of mangrove fruit flour when mixed with starch-containing materials with a view to guiding food uses of mangrove resources.

Materials and Methods

Materials

Mangrove fruits from species *Sonneratia caseolaris* (growing period, July – September) were obtained from Surabaya, East Java, Indonesia. Waxy maize and potato starches were products of National Starch (Pty) Ltd., Epping Rd, Lane Cove, NSW 2066, while plain wheat flour was obtained from a local shop in Brisbane, Australia, where the studies were done. These starches and flour were chosen to represent cereals, root crops and tubers that can be combined with mangrove fruit flours to prepare various and diverse foods. The starches and flour were individually mixed with the mangrove fruit flour in ratios 0-100%, with the mixing done in a rotary mixer overnight (about 12 hr) for homogeneity before analysis.

Processing of mangrove fruit flour

The mature mangrove (*Sonneratia caseolaris*) fruits were collected and selected randomly from different parts of mangrove trees, and were immediately transferred to the laboratory, where they were peeled and blended (Speed 1; Philips HR-2810/A, Mexico) with distilled water (1:3). The resulting dispersion was sieved 50 mesh (Tristar-237, Surabaya, Indonesia) to remove seeds, was dried in a cabinet drier (Kersa Jaya, Surabaya, Indonesia) for 15-18 h at 50-60°C, and ground to pass through 80-mesh sieve.

Chemical properties

Mineral analysis was done using the procedures in Waramboi *et al.* (2011), and calcium, potassium, magnesium, phosphorus, and sulphur contents are reported. Moisture content of the mangrove flour was determined using the oven dry method (AOAC, 2007). The procedure (Dumas method) in Waramboi *et al*. (2011) was followed for the protein content, and crude protein was defined as N x 6.25.

Dietary fibre

The Megazyme™ dietary fibre procedure (K-TDFR) was used. The mangrove fruit flour (1 g) was dissolved in 40 mL MES-TRIS 0.05 M buffer solution (pH 8.2) at 24°C and stirred, before 50 µL thermostable α-amylase solution was added, shaken in a water bath at 95-100°C for 35 min, cooled to 60°C, and 100 µL protease solution was added. The mixture was incubated at 60°C for 35 min before 5 mL 0.56 N HCl was added and pH adjusted to 4.1–4.8, and 200 µL amyloglucosidase was added, prior to incubation at 60°C for 30 min., with stirring. The mixture was filtered with two portions of 10 mL water at 70°C.

Insoluble dietary fibre was determined by dividing the residue into two parts; one residue was analysed for protein (Kjeldahl procedure), and the second residue was analysed for ash. Soluble dietary fibre was determined using the filtrate by adding 95% ethanol at 60°C, precipitating for 60 min, filtering and drying the residue, with one residue analysed for protein and the second residue analysed for ash as before.

Pectin content

This was determined following the procedure in Ranggana (1979), and it involved weight about 50 g of the mangrove flour into a beaker, to which 300 mL of 0.01 N HCl was then added, boiled and filtered under suction. The residue was washed with hot water, and the filtrate was collected. To the residue was added 100 mL of 0.3 N HCl, boiled for 10 min, and filtered. All the filtrate was pooled, cooled and made to 500 mL, before 100–200 mL aliquot was pipetted into a beaker, into which 250 mL of distilled water was added prior neutralization with 1 M NaOH. About 10 mL of 1 M NaOH was added, stirred before standing overnight, after which 50 mL of 1 N acid was added, allowed to stand for 5 min, before 25 mL of 1 N calcium chloride was added, stirred, left to stand for 1 h before boiling for 1-2 min, and filtering using a washed, dried and pre-weighed Whatman No.1 filter paper to collect the formed calcium pectinate. The pectinate was washed with boiling water until free of chloride (silver nitrate, $AgNO_3$ test), and the paper with the pectinate was dried overnight at 100°C, cooled and weighed for the amount of the calcium pectinate produced.

Galacturonic acid

The galacturonic acid of the pectin was determined following the procedure of Ranggana (1979). About 50 mg was weighed into a conical flask, before 50 mL of 0.05 N NaOH was added, and allowed to stand for 30 min. About 1 mL of the solution was taken, and 50 mL of water was added before 1 mL was pippetted into a tube, to which 1 mL of carbazole and 12 mL of H_2SO_4 were added. This was allowed to stand for 10 min before the colour was read at 525 nm in a spectrophotometer (Pharmacia LKB-Ultrospec III UV-Vis Spectrophotometer) against a sample blank.

Pasting properties

The pasting properties of the mixtures of the potato starch, waxy maize strach and wheat flour individually with the mangrove fruit flour were determined using the Rapid Visco Analyser (RVA-4, Newport Scientific Pty Ltd., Warriewood, NSW2102, Australia). Distillled water was added to the sample mixtures to give a total weight of 25 g and 15% solids content (from preliminary studies). The RVA Standard Profile 1 (Mahasukhonthachat *et al.*, 2010) was used, and pasting parameters were obtained using Thermocline for Windows. In order to further characterise the pasting behaviours, the visosity breakdown ratios (BDR) was defined as the ratio of trough to peak viscosity (Waramboi *et al.*, 2011).

Statistical analysis

Samples were randomised and duplicated in all the analyses above. The Minitab_ver15 software (Minitab Inc., 1829 Pine Hall Road, State College, PA 16801-3008, USA) was used for analysis of variance (ANOVA). A 95% confidence level was used to judge significance. Instead of the standard deviations of the means, standard errors of the means (SE of mean), as obtained from the Minitab, are reported.

Results and Discussion

Chemical properties

Table 1 shows the mineral content of the mangrove fruit flour with potassium being about 23 g/kg. This value is higher than the value reported for sweet potato by Waramboi *et al.* (2011). The mangrove fruit flour would, therefore, be a better source of potassium than sweet potato. Minerals are very important for biochemical reactions in the body as a co-factor of enzyme. For examples, calcium, phosphorus and magnesium build and maintain bones and teeth, whereas sodium and potassium help maintain balance of water, acids and bases in body fluids, and are involved in acid-base balance and transfer of nutrients in and out of individual of cells (Ensminger *et al*., 1995).

The total dietary fiber in mangrove fruit flour was about 63.7%, which is distributed amongst soluble (9.8%) and insoluble components (53.9%). In comparation, bread fruit flour was measured to have a slightly higher (68%) total dietary fiber (Manullang and Vivin, 1995), while seaweeds have comparable fiber content (64%) (Benjama and Mansniyom, 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 (Lisa *et al*., 1999). The mangarove fruit flour pectin content measured (9%) is lower than 11% reported by Duke and Jackes (1987). The starch content of the mangrove fruit flour, which was determined following the modified Megazyme™ procedure in Mahasukhonthachat *et al*. (2010), was negligible.

General observation of the pasting properties of the samples

Figures 1-3 show the pasting properties of the mixtures of the mangrove fruit flour, waxy maize starch (MaWa), potato starch (Mang-PS), and wheat flour (Mang-WhF), while Table 2 shows the pasting parameters of these mixtures. Potato starch displayed higher peak and final viscosities than pure waxy maize starch and wheat flour. The higher RVA viscosity of potato starch than that of waxy maize starch has been discussed before (Sorba and Sopade, 2013). The mangrove fruit flour on its own pasted without the characteristic starch pasting pattern (not shown). As reported above, the starch content of the mangrove fruit flour was negligible, and the changes in the pasting viscosity of the mangrove fruit flour in the RVA could have resulted from the swelling of its pectin. As expected because of its no-starch diluting effects, the pasting parameters of the mixtures were significantly ($p < 0.05$) affected by the presence of

Table 1. Chemical properties of the mangrove fruit flour

Component	Content
Ca (g/kg)	0.9 ± 0.1
K (g/kg)	23.0 ± 1.2
Mg (g/kg)	0.8 ± 0.0
Na (g/kg)	8.0 ± 0.5
P (g/kg)	2.2 ± 0.0
S (g/kg)	1.5 ± 0.0
Crude protein (%)	6.2 ± 0.1
Crude fats (%)	4.7 ± 0.3
Moisture (%)	11.3±0.2
Pectin (%)	9.0± 0.1
In vitro protein digestibility (%)	69.1±0.2
Galatorunic acid (%)	2.2±0.0
IDF (%)	53.9 ±0.0
SDF (%)	9.8 ±0.0

Values are mean ± standard deviation.
In vitro protein digestibility was dteremined using the procedure Tinus *et al.* (2012).

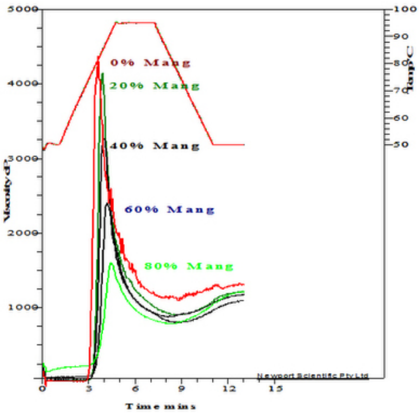

Figure 1. Typical pasting curves the mangrove fruit flour with wazy maize starch mixtures

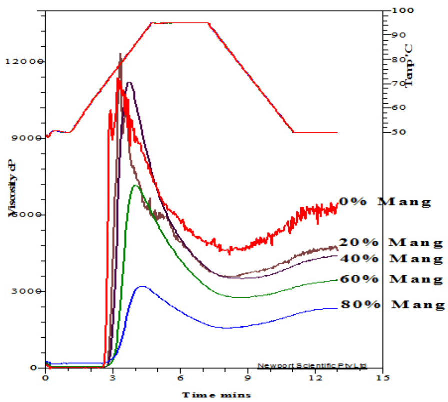

Figure 2. Typical pasting curves the mangrove fruit flour with potato starch mixtures

Typical pasting curves for the mangrove fruit flour with potato starch mixtures

the mangrove fruit flour, and all the mixtures pasted at a higher viscosity than the mangrove fruit flour.

The presence of the mangrove fruit flour did not significantly ($p > 0.05$) change the pasting temperatures of the mixtures (Table 2). This suggests that the pectin and dietary fiber in the mangrove fruit flour did not preferentially bind and/or withdraw water from the starches. For the waxy maize starch, the peak, trough, breakdown, and final viscosities reduced with the mangrove fruit flour at all the concentrations. The setback viscosity, which is a measure of starch retrogradation, increased as the mangrove fruit flour content increased in the Mang:WaMa mixtures.

Pasting properties of mangrove fruit flour and waxy maize starch mixtures

The peak viscosity of the Mang:WaMa mixtures

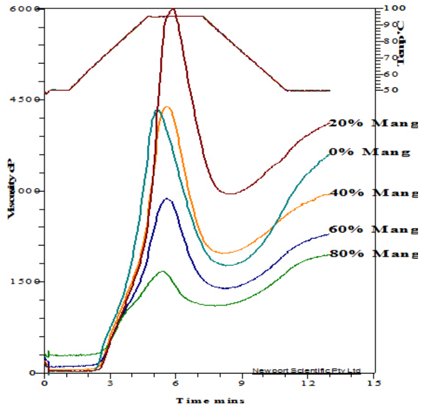

Figure 3. Typical pasting curves the mangrove fruit flour with wheat flour mixtures

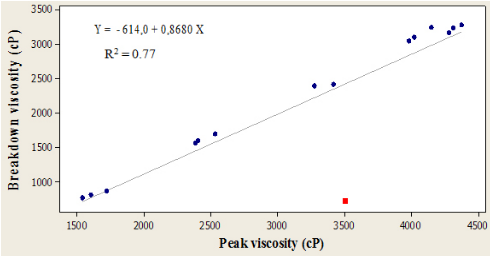

Figure 4. Relationship between the peak and breakdown viscocities of the mangrove fruit flour with waxy maize starch mixtures

decreased from 4323-1617 cP and there were insignificant ($p > 0.05$) differences at substitutions 40-80% (Table 2). The mangrove fruit flour substantially reduced the viscosity, and being a non-starch material, this is akin to the dilution effects of dietary fiber on sweet potato pasting properties as reported by Mais (2008). Moreover, the soluble dietary fibre in magrove fruit flour are pectins, whereas insoluble dietary fiber are cellulose, hemicellulose, lignins, and these are generally known to reduce viscosity of starch (Gomez *et al.*, 2003; Collar *et al.*, 2006). However, guar gum has been reported to increase the pasting properties of starch-water systems (Sharma *et al.*, 2009).

Reduction in peak viscosity indicates a decreased ability to swell and/or gelatinise. Beta and Corke (2001) reported peak viscosity indicates the water-binding capacity and has a positive correlation with the quality of the final product, for example, the volume of dough development. Peak viscosity is considered to represent the equilibrium point between swelling and the rupture of starch granules (Sharma *et al.*, 2009). Peak viscosity can also reduce relative to one another if the amount of ungelatinised starch decreases prior to pasting. Trough viscosity of the mixtures ranged from 794 cP (80:20) to 912 cP (20:80), and were significantly ($p < 0.05$) affected by the mangrove fruit flour. Trough viscosity is the viscosity at the end of holding time at 95°C. The final viscosity ranged from 1122 cP to 1315 cP. The final

Table 2. Pasting properties of the mangrove fruit flour with waxy maize starch, potato starch and wheat flour

Fraction	PV (cP)	TV (cP)	BV (cP)	FV (cP)	SV (cP)	PT (^{0}C)
			Mang:WaMa			
0:100	4323.3 ± 38.7^a	1091.3 ± 15.2^a	3232.0 ± 47.2^a	1315.3 ± 7.5^a	224.0 ± 8.8^c	72.6 ± 0.2^c
20:80	4052.0 ± 71.2^a	911.7 ± 10.3^b	3140.3 ± 80.7^a	1224.0 ± 13.4^{ab}	312.3 ± 15.2^b	75.7 ± 0.2^b
40:60	2731.3 ± 870.5^b	881.0 ± 92.7^b	1850.3 ± 790.1^b	1223.6 ± 59.1^{ab}	342.7 ± 53.4^{ab}	76.8 ± 0.5^{ab}
60:40	2438.0 ± 66.1^b	815.0 ± 10.7^b	1673.0 ± 58.8^b	1121.7 ± 17.8^b	306.7 ± 7.1b^c	77.4 ± 0.1^a
80:20	1617.3 ± 65.7^b	794.0 ± 30.6^b	823.3 ± 35.1^b	1223.7 ± 47.0^{ab}	429.7 ± 16.6^a	77.3 ± 0.5^a
			Mang:PS			
0:100	10883.3 ± 457.1^b	3777.3 ± 1104.1^a	7106.0 ± 726.3^b	6817.3 ± 286.4^a	3040.0 ± 1353.2^a	63.5 ± 0.4^b
20:80	12513.3 ± 119.7^a	3032.0 ± 808.5^{ab}	9481.3 ± 910.1^a	4825.7 ± 293.7^b	1793.7 ± 1100.5^a	65.1 ± 0.0^a
40:60	11128.3 ± 102.9^b	3427.0 ± 99.8^{ab}	7701.3 ± 165.5^b	4314.0 ± 146.4^b	887.0 ± 47.7^a	65.5 ± 0.0^a
60:40	7069.0 ± 117.3^c	2715.0 ± 50.0^{ab}	4354.0 ± 67.5^c	3359.7 ± 67.8^c	644.7 ± 40.0^a	65.8 ± 0.4^a
80:20	3127.0 ± 206.9^d	1549.0 ± 60.7^b	1578.0 ± 146.3^d	2288.0 ± 96.1^d	739.0 ± 38.1^a	65.2 ± 0.4^a
			Mang:WhF			
0:100	4079.3 ± 305.5^b	1767.0 ± 31.6^c	2977.3 ± 284.4^a	2321.3 ± 1053.0^b	1219.3 ± 516.3^a	66.2 ± 0.5^a
20:80	5679.0 ± 218.1^a	2777.0 ± 52.9^a	2902.0 ± 171.9^a	3938.0 ± 91.1^a	1161.0 ± 49.7^a	68.0 ± 0.5^a
40:60	4230.7 ± 64.8^b	1929.3 ± 53.9^b	2301.3 ± 12.3^b	2868.0 ± 68.2^{ab}	938.7 ± 16.9^a	68.7 ± 0.3^a
60:40	2907.0 ± 58.7^c	1418.0 ± 40.6^{bc}	1489.0 ± 22.8^c	2321.3 ± 40.5^b	903.3 ± 7.1^a	68.0 ± 0.6^a
80:20	1650.7 ± 74.8^d	1063.0 ± 46.1^c	587.7 ± 49.7^d	1902.7 ± 49.7^b	839.7 ± 3.7^a	68.8 ± 0.5^b

In a column for each mixture, values with different letters are significantly ($p < 0.05$) different. PV: peak viscosity, TV: trough viscosity, BD: breakdown visosity, FV: final viscosity, SV: setback viscosity, PT: pasting temperature, Mang:mangrove fruit flour; WaMa: waxy maize starch, PS: potato starch, and WhF: wheat flour

viscosity of the mixtures are significantly different ($p < 0.05$), and the results (Table 2) indicated that the Mang:WaMa mixtures had a very rigid viscous formation than the non-substituted waxy maize starch (Mang:WaMa, 0:100). The final viscosity is the most commonly used parameter to define sample quality, as it indicates the ability of the material to form a viscous paste or gel after cooking and cooling (Sopade *et al*., 2006). The setback viscosity ranged between 224 and 430 cP with Mang:WaMa (80:20) having the highest and Mang:WaMa (0:100) was the lowest (Table 2). A low setback viscosity indicates a higher resistance to retrogradation (Ikegwu *et al*., 2009), and the results in Table 2 implies that the mangrove fruit flour enhanced retrogradation of the waxy maize starch. For food systems, for example, soups, puddings and thickeners, where retrogradation is desirable for high final viscosity, the mangrove fruit flour would be an ingredient of choice. However, for baked goods, where retrogradation is not desirable because of attendant quality and sensory issues (e.g. staling), the mangrove fruit flour would not be preferred.

Figure 4 shows a significant positive relationship ($r = 0.89$, $p \leq 0.01$) between the breakdown and peak viscosities. The breakdown viscosity is a derived pasting parameter, and it is the difference between the peak and trough viscosities. The observed positive relationship indicates that the Mang:WaMa mixtures, which exhibited high peak viscosity, are likely to have high breakdown values. A high breakdown viscosity indicates a lower ability to withstand heating and shear stress during cooking (Tsakama *et al.*, 2010). This is important for heat processing that involves shearing such as extrusion. From the trends between the primary RVA parameters (peak, trough and final viscosities) and the mangrove fruit flour substitution, an exponential relationship could be used to describe the trends (not shown). It appeared that the peak viscosity was the most sensitive to the mangrove fruit flour substitution, and the final viscosity was the least sensitive, while the substitution did not materially change the final viscosity of the Mang:WaMa mixtures when the non-substituted sample (Mang:WaMa, 0:100) was excluded.

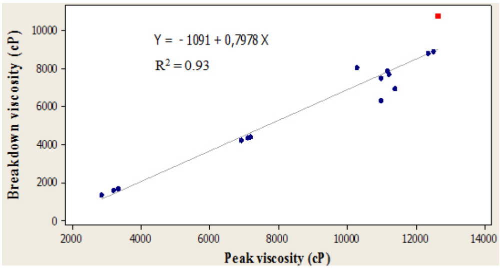

Figure 5. Relationship between the peak and breakdown viscocities of the mangrove fruit flour with potato starch mixtures

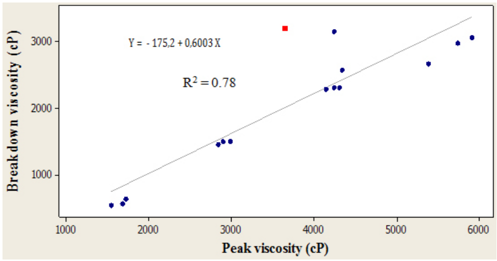

Figure 6. Relationship between the peak and breakdown viscocities of the mangrove fruit flour with wheat flour mixtures

Pasting properties of mangrove fruit flour and potato starch mixtures

The pasting temperature of the Mang:PS mixtures was also not significantly affected by the mangrove flour substitution (Table 2). Figure 5 also shows the significant positive relationship ($r = 0.97$, $p \leq 0.01$) between the peak and breakdown viscosities. Like the Mang:WaMa mixtures, the peak viscosity appeared to be the most sensitive to the mangrove fruit flour substitution, while the trough viscosity of the Mang:PS seemed to be the least sensitive.

Pasting properties of mangrove fruit flour and wheat flour mixtures

The mangrove fruit flour did not significantly ($p > 0.05$) affect the setback viscosityof the Mang:WhF mixtures (Table 2). This shows that possibly because of differences in the constituents of waxy maize starch, potato starch and wheat flour, the mangrove fruit flour affected the pasting parameters differently. Of particular mention is the increase in the pasting parameters at the 20% substitution (Mang:WhF, 20:80). Perhaps, the mangrove fruit flour interacted with the starch and non-starch (e.g. protein and fiber) components of the wheat flour to increase swelling. Sasaki *et al.* (2000) reported that addition of non-starch polysaccharide to wheat flour can increase peak and breakdown viscosity and cause rigid gel as water binding capacity is modified.

Like for the other mixtures, the peak and breakdown viscosities of the Mang:WhF mixtures were significantly positively related ($r = 0.89$, $p \leq 0.01$) as shown in Fig. 6. With or without the non-substituted mixture, the peak viscosity of the Mang:WhF mixtures appeared to be the most sensitive, while the final viscosity seemed to show the least sensitivity to the substitution like the Mang:WaMa mixtures. Comparing the three groups of mixtures, however, the Mang:PS mixtures appeared to be the most sensitive to the substitution, while both the Mang:WaMa and Mang:WhF seemed to be equally sensitive.

Conclusions

The mangrove fruit flour is a rich mineral source, and can also be a valuable source of dietary fiber with functional properties. While harvesting time and post harvest handling can affect the nutrients, the mangrove fruit flour can be incorporated in cereals, root crops and tubers to make foods. Mixing the mangrove fruit flour with the waxy maize starch, potato starch and wheat flour did not change the pasting patterns or viscograms of the non-substituted samples, but the pasting parameters were mostly reduced with the increase of mangrove fruit flour. Without starch, the mangrove fruit flour diluted the starch matrix in the samples, the effects of the mangrove fruit flour additional differed with the base material, and the influence on starch retrogradation depended on the concentration of the mangrove fruit flour. The peak viscosity was the most sensitive to the mangrove fruit flour substitution, irrespective of the base material, and this shows that the mangrove fruit flour affected water binding and swelling. With a low viscosity, more solids are required to main the consistency of mangrove fruit composite flours, and consequently, this will increase nutrient (e.g. minerals and dietary fiber) intakes without bulk. However, the mangrove fruit flour did not affect the pasting temperature of the mixtures, and this suggests that the pectin and other fiber components did not preferentially bind or withdraw water from the starches. Practically, with a constant pasting temperature despite the level of substitution by the mangrove fruit flour, it implies that heating or processing will not require a change in energy before viscosity development. The information in this study will help utilization of mangrove resources for human foods, and it suggests that mangrove fruit flour can be used in food products which do not require expansion such as food bars and biscuit. For fiber and protein enrichments, mangrove fruit flour can be extruded in a cereal mixture.

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