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FULL PAPER

Evaluation of physicochemical and functional characteristics of flour from three cultivars of unripe banana (Musa sp.) cultivated in Sabah, Malaysia

[1,]*Hasmadi, M., [1]Addrian, I., [1]Umairah Balqis Adawiyah, Z., [1]Mansoor, A.H. and [2]Zainol, M.K.

[1]*Food Technology and Bioprocessing Program, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia*

[2]*Faculty of Fisheries and Food Sciences, Universiti Malaysia Terengganu, 21030, Kuala Nerus, Terengganu, Malaysia*

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Abstract

Banana is a climacteric fruit that is available throughout the region of Malaysia. In this study, banana flour was produced from different varieties of unripe banana, namely Saba, Mas and Berangan and characterised in its chemical composition and functional properties. The results obtained showed that the chemical composition of the flour varied according to the variety. The ranged obtained were 3.71 – 4.53% crude protein, 10.32 – 10.72% moisture, 0.12 - 0.16% crude fat, 1.20 – 2.38% ashes, 0.68 – 1.19% crude fibre, 81.95 – 83.15% carbohydrate and 8.00 – 8.54% dietary fibre. The colour analysis found that significant differences were observed for the L*, a* and b* values of all varieties of banana flours. Flour from Saba cultivar was significantly different from other banana flours in its highest pH value (5.79), oil absorption capacity (1.08 g/g) as well as emulsion activity (17.36%) and had the smallest particles size. Flour obtained from Mas variety had the highest foaming capacity (10.85%) and the swelling capacity while Berangan cultivar had the highest water absorption capacity (1.10%). Pasting profiles of banana flours differed significantly for peak, final, breakdown and setback viscosities. It was ranged from 1511.17 - 3145.33, 4197.00 - 5213.67, 1419.67 - 2871.00 and 4401.00 - 5121.67 cP, respectively. Gelatinisation properties of all banana flours showed significant differences in peak temperatures, whereas no significant differences were observed for enthalpy (ΔH).

1. Introduction

Banana is one of the most widely consumed fruit in tropical and subtropical regions (Alkarkhi *et al.,* 2011). Banana (Musa sp.) is the fourth most valuable commodity in the world after rice, wheat, and milk. Banana is also a healthy fruit, and global demand for bananas continues to increase every year. Approximately 90% of the bananas produced and used in a country are from fresh fruits, and 2.5% are bananas processed as banana-based food products while others used as additives in other foods (Rashmi and Jyothsna, 2011).

In general, bananas classified into two categories: dessert bananas and cooking bananas. The main difference between the two categories is that cooking bananas have higher starch content than dessert bananas and should be used before they reach maturity. Banana cultivars are derived from *M. acuminata* species or a combination of two species of wild diploid, i.e., *M. acuminata* Colla (AA) and *M. balbisiana* Colla (BB) (Mohapatra *et al.,* 2010).

Popular dessert banana species in Malaysia are Mas and Berangan while cooking bananas are Awak, Saba, and Tanduk. Bananas have beneficial properties to humans because bananas are rich in carbohydrates, vitamins A, B, and C and phosphorus, potassium, magnesium, selenium, and iron. Additionally, bananas have the benefit to human health, such as reducing the risk of high blood pressure and stroke, protecting gastric ulcers, catalysts, and reducing cholesterol (Kumar *et al.,* 2012). However, bananas will quickly ripen after harvest. Because of this, banana is suitable for processing to make flour to improve its durability to reduce its damaging effects and used in food products.

Banana flour is the result of banana processing. Banana flour mixed with wheat flour in a certain quantity used in the production of pastry and bakery products (Noorfarahzilah *et al.,* 2014). It can be produced using a banana that has not reached the

*Corresponding author.
Email: *idamsah@ums.edu.my*

maturity stage and is still green (plantain). Bananas that have reached maturity are no longer suitable as flour because they contain high sugar content and changes the colour of the flour to a darker hue due to sugar production (Falade and Oyeyinka, 2014). This study aimed to investigate the properties of unripe banana flour produced from three different cultivars, namely Saba, Mas and Berangan grown in Sabah, Malaysia. In this investigation, the proximate composition of banana flour is determined. Besides, the physical and functional properties of banana flour were also measured.

2. Materials and methods

2.1 Raw materials

Hard green (unripe) pre-climacteric banana (*Musa paradisiaca* L.) fruits were purchased from the Village Development Cooperation (KPD) located in Likas, Kota Kinabalu, Sabah. In this study, three banana cultivars, namely Saba (BBB), Mas (AA) and Berangan (AAA), were selected (Figure 1).

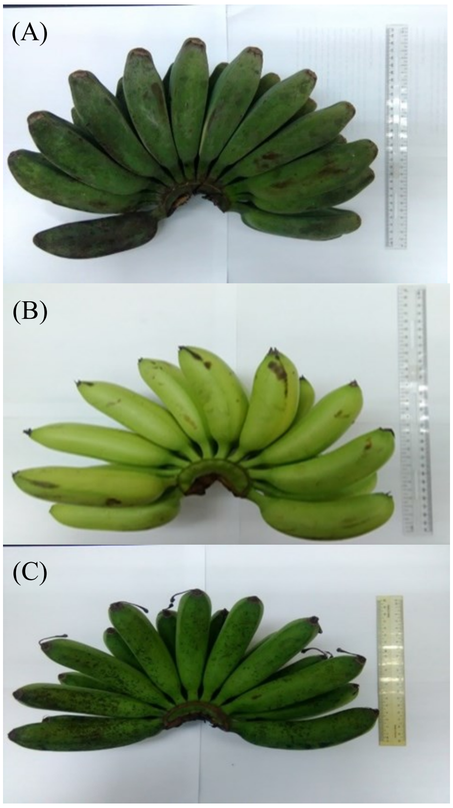

Figure 1. Banana varieties used in the study. (A) Saba, (B) Mas and (C) Berangan

2.2 Banana flour production

Fresh unripe bananas were thoroughly washed with tap water to clean dirt such as dust or soil attached to the banana. Then it was peeled and cut into 1 cm slices and immediately rinsed in sodium metabisulphite solution (0.2% w/v). The slices were dried using a cabinet dryer (Thermoline Scientific, Australia) at 50°C for 24 hrs. The dried banana was ground using an electric grinder (Waring 8011S, USA) and passed through a 250 µm sieve and stored at 25°C in sealed plastic containers for further analysis.

2.3 Proximate analysis and dietary fibre determination

Proximate analysis was conducted to determine the percentage of moisture, ash, crude protein, crude fat, crude fibre, and dietary fibre according to the AOAC procedure (2000), while carbohydrates were determined by difference (Hasmadi *et al.,* 2018).

2.4 Colour determination

Colour characteristics of the flour were analysed by measuring lightness (L*), redness (a*) and yellowness (b*) using a Hunter Colorimeter (Hunterlab ColorFlex®, USA), as described by Anyasi *et al.* (2015).

2.5 pH determination

The pH of the flour was determined using a digital pH meter following AOAC (2000) procedures, method 981.12.

2.6 Particle size determination

The particle size of the flour was determined using the method described by Vishwanathan *et al.* (2011) with slight modifications. A sample of 100.0±5.0 g of flour was placed in the sieve shaker equipped with 3 sieves with 125 µm, 250 µm, and 500 µm openings and vibrated for 10 mins. The remaining flour on each of the sieves and in the flour collector (pan) was weighed and respective per cent fractions were calculated.

2.7 Bulk density determination

The bulk density of the flour was measured according to the procedure described by Onabanjo dan Dickson (2014). The flour sample (50 g) was put into a 100 mL graduated cylinder and tapped until constant volume obtained. The bulk density was calculated as the weight (g) per unit volume (mL) of a sample.

2.8 Foaming capacity determination

Foaming capacity was determined following methods described by Ohizua *et al.* (2016). Two grams of flour sample was weighed and added to 50 mL distilled water in a 100 mL measuring cylinder. The suspension was mixed and shaken adequately for 5 mins to foam, and the total volume after 30 s was recorded. The percentage increase in volume after 30 s is expressed as foaming capacity.

2.9 Water absorption capacity determination

The water absorption capacity of the flour samples was determined according to the procedure described by Bashir *et al.* (2017). The flour sample (3 g) was dispersed in 25 mL of distilled water into pre-weighed centrifuge tubes. The dispersions were stirred for 30 mins at room temperature (27°C) and then centrifuged at 3000×*g* for 15 mins. The supernatant was decanted, excess moisture was removed by draining and the centrifuge tubes containing samples were re-weighed. The gain in weight was expressed as grams of water absorbed per gram of flour.

2.10 Oil absorption capacity determination

The oil absorption capacity of banana flour was determined generally as per the method of Bashir *et al.* (2017) with modifications. About 0.5 g of flour was mixed with 6 mL of vegetable oil in pre-weighed centrifuge tubes. The contents were vortexed for 1 min to disperse the sample in the oil. The samples were then kept for 30 mins in vertical positions and then subjected to centrifugation 3000×*g* for 15 mins. The layer of the oil was removed by pipette and the tubes were kept in an inverted position for 10 mins to drain the oil before re-weighing. The gain in weight was expressed as grams of oil absorbed per gram of flour.

2.11 Emulsion activity determination

The emulsion activity of the flours was determined by the method of Chandra *et al.* (2015). In this measurement, 1 g flour, 10 mL distilled water and 10 mL soybean oil was prepared in the calibrated centrifuge tube. The emulsion was centrifuged at 2000×*g* for 5 mins. The ratio of the height of the emulsion layer to the total height of the mixture was calculated as emulsion activity in percentage.

2.12 Swelling capacity determination

The method by Ikegwu *et al.* (2010) adapted to determine the swelling capacity of banana flour. Flour (1.0±0.1g) was transferred into a test tube and re-weighed. The flour was then dispersed in 50 mL of distilled water. The slurry was heated at different temperatures (65, 75, 85 dan 95°C) for 10 mins in a water bath. The mixture was cooled to 28±2°C and centrifuged at 2200 rpm for 15 mins to separate the gel and supernatant. After the supernatant removed, the weight of the swollen was determined.

2.13 Pasting properties determination

The pasting profiles of banana flour measured according to the procedures as described by Gunaratne *et al.* (2016) using a Newport Scientific Rapid Visco Analyser 4 (RVA-4) (Newport Scientific, Warriewood, Australia). The sample (3.0 g, 14% moisture) was weighed and dispersed in 25 mL distilled water. The resultant slurry was held in the RVA at 50°C for 1 min, heated from 50 to 95°C at a rate of 6°C/min, held at 95 °C for 5 mins, cooled from 95 to 50°C at a rate of 6°C/min, and held at 50°C for 2 mins. From the RVA plots, the pasting temperature, peak viscosity, trough, breakdown, final viscosity and setback were identified using the Thermocline Version 2.2 software (Newport Scientific).

2.14 Gelatinisation properties determination

Flour gelatinisation properties were analysed in triplicate using a differential scanning calorimeter (DSC) (Perkin Elmer, USA) following the method of Gunaratne *et al.* (2016) with modifications. Banana flour (2.0± 0.1 mg) was placed in an aluminium pan, and 9 µL water was added to give a sample-to-water weight ratio of 1:3. The sample heated from 30 to 120°C at a rate of 10°C/min. An empty aluminium pan was used as a reference. Onset temperature (To), peak temperature (Tp), conclusion temperature (Tc), and enthalpy of gelatinisation (ΔH) were determined from the endotherm.

2.15 Statistical analysis

All determinations were replicated three times; mean values and standard deviations were reported, generated from SPSS (Statistical Package of Social Sciences) version 23.0.

3. Results and discussion

3.1 Proximate composition

Proximate compositions of three banana varieties were summarised in Table 1. The moisture content of bananas flour ranged from 10.32% to 10.72%, and they were significantly different ($p<0.05$). Berangan variety had the highest moisture content, while Mas banana flour showed the least. According to Suas (2009), the moisture content of flour should not exceed 14%. Although all banana flour showed a significant difference, the moisture content of the three banana flour varieties was less than 14%. The moisture content of flour that exceeds 14% will affect the quality of storage and increase the growth of microorganisms that can shorten the shelf life of flour and will make it difficult to produce flour. Therefore, the low moisture content of flour will increase the shelf life of the flour. The growth of microorganisms will be retarded due to low water activity due to the low moisture content of flour.

The ash content of the Saba variety showed a significant difference ($p>0.05$) compared to Mas and Berangan variety. The ash content contained in the Saba

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variety was the lowest compared to the ash content of the Mas and Berangan banana flour, as shown in Table 1. The results showed that the ash content of the three banana varieties was only about 1.20 - 2.38%. The study conducted by Reddy *et al.* (2015) also showed that the ash content of different banana varieties was lower (0.78 -2.08%). The ash content attributed to the amount of mineral content in the flour where the high ash content of Mas and Berangan banana flour refers to the high mineral content of the two banana varieties.

Table 1. Proximate composition and the dietary fibre content of unripe banana flour

Parameter (%)	Variety		
	Saba	Mas	Berangan
Moisture	10.48±0.04^{b}	10.32±0.06^{a}	10.72±0.03^{c}
Ash	1.20±0.66^{a}	2.36±0.26^{b}	2.38±0.03^{b}
Crude protein	3.86±0.08^{b}	4.53±0.01^{c}	3.71±0.07^{a}
Crude fat	0.12±0.09^{a}	0.16±0.02^{a}	0.13±0.09^{a}
Crude fibre	1.19±0.06^{b}	0.68±0.12^{a}	0.86±0.08^{a}
Carbohydrate	83.15±0.52^{b}	81.95±0.36^{a}	82.20±0.21^{ab}
Dietary fibre	8.00±0.81^{a}	8.29±0.51^{a}	8.54±0.44^{a}

Values are expressed as mean±SD. Values with different superscript within the same row are significantly different (p<0.05).

The crude protein content of banana flour analysed in this work ranged from 3.71% to 4.53%. Results showed that the protein content of Saba, Mas, and Berangan banana flour was significantly different (p<0.05). Mas banana flour contained the highest protein content, while Berangan banana flour had the lowest (Table 1). The protein content found in these three varieties of banana flour is similar to that of banana flour protein, as reported in the previous study, which is within 3.3-5.3% (Rodriguez-Ambriz *et al.,* 2008). Studies conducted by Ramli *et al.* (2010) also found that the protein content of banana flour was in the range of 3.49 to 5.24%. Protein content affects the functional properties of flour, such as foaming capacity.

The crude fat content found on Saba, Mas, and Berangan banana flour did not show significant differences (p>0.05). The amount of crude fat ranged from 0.12% to 0.16%. Reddy *et al.* (2015) reported that the amount of fat in different banana varieties is low (0.22-0.28%). The crude fat concentrations were notably lower than were those observed by Da Mota *et al.* (2000). They found that the fat content of different banana varieties ranged from 0.3% to 0.8%. Low-fat content in the flour will prevent the development of rancidity throughout the storage period. Therefore, low fat on the flour can maintain the quality of the flour during storage.

Carbohydrate content ranged from 81.5% to 83.15%. Generally, carbohydrate content is high in unripe banana. The high carbohydrate content of banana flour is due to the high amount of starch and dietary fibre (Rodriguez-Ambriz *et al.,* 2008). According to Bello-Perez *et al.* (2011), starch is the main carbohydrate found in unripe banana (73-77%). Unripe banana is rich in carbohydrate content (60-80%) consisting of cellulose, hemicellulose, lignin, starch, dietary fibre, and starch (Menezes *et al.,* 2011).

3.2 Dietary fibre

The dietary fibre of banana flour ranged from 8.00% to 8.54%. There was no significant difference observed for all samples. The results obtained was lower than reported by Ramli *et al.* (2010) (14.25-15.5%). However, the values recorded in this study were higher than reported by Haslinda *et al.* (2009) for Awak ABB bananas (7.53%). Dietary fibre refers to plant parts or carbohydrate components that are resistant to digestion and absorption in the small intestine with complete fermentation in the large intestine (Hasmadi *et al.,* 2018). A sufficient dietary fibre diet is essential in maintaining human health.

3.3 Physical and functional properties

The physical and functional properties of unripe banana flour obtained from different varieties results are shown in Table 2. In the present research, the pH of all varieties of banana flour showed a significant difference (p<005). The mean of flour ranged from 5.38 to 5.79 and the Saba variety showed the highest pH while the Berangan variety showed the least. The results obtained were consistent with Rayo *et al.* (2015) and Alkarkhi *et al.* (2011), who reported a mean pH of 5.94 and 5.06, respectively. Abbas *et al.* (2009) and Ramli *et al.* (2010) were found that the pH value of banana flour from different varieties was lower than recorded in this study (4.51-5.72). According to Adeleke and Odedeji (2010), acidic food products are more stable. However, the high pH value increases starch solubility in flour by increasing hydrophilic properties and can further improve the use of the flour (Nabubuya *et al.,* 2012).

The bulk density of Berangan banana flour was significantly lower than Saba and Mas variety. This is due to the larger particle size that reducing the bulk density measured. Bulk density is influenced by particle size as the particle size is inversely proportional to the bulk density (Onimawo and Akubor, 2012). The larger the particles size of the flour, the lower the bulk density. The low bulk density of the flours implied that their packaging materials would be less dense, which is economical in terms of packaging cost. The bulk density of the flour in a package varies depending on the type of flour.

Particle size distributions of banana flour are shown in Table 2. The results showed that 125 µm were the major sizes of the flour particle, ranged from 76.31 to 85.43%. The banana varieties of Saba and Mas recorded the highest amount for 125 µm while the Berangan variety showed the lowest. The mean particle size value (250 µm) of the Berangan variety flour is higher than the other samples (22.73%) indicating the flour granules of Berangan to be coarser and larger. The fine particle size of flour is important for flour to absorb the required water and increase the absorption of flour water which will affect the quality and functional properties of the final product. Besides that, particle size is also important to assist in the design and storage of flour. Particle size also affects the bulk density of the flour, the finer the particle size, the higher the density of the flour (Hasmadi *et al.,* 2020).

Table 2. Physical and functional properties of unripe banana flour

Parameter	Variety		
	Saba	Mas	Berangan
pH	5.79±0.00[d]	5.57±0.01[c]	5.38±0.00[a]
Bulk density (g/mL)	0.85±0.00[b]	0.85±0.00[b]	0.78±0.01[a]
Water absorption capacity (g/g)	0.99±0.02[b]	1.01±0.02[b]	1.10±0.04[c]
Oil absorption capacity (g/g)	1.08±0.07[b]	0.86±0.08[a]	0.86±0.02[a]
Foaming capacity (%)	7.68±0.94[b]	10.85±0.88[c]	4.28±1.01[a]
Emulsification capacity (%)	17.36±1.20[c]	6.25±0.00[b]	2.08±0.00[a]
Particle size distribution (µm):			
> 500	0.15±0.02[a]	0.12±0.03[a]	0.37±0.46[a]
250 – 500	14.13±0.05[b]	15.39±0.15[c]	22.73±0.17[d]
< 125	85.43±0.08[b]	83.52±0.13[b]	76.31±2.11[a]
Colour:			
L*	87.79±0.00[c]	85.15±0.01[b]	78.60±0.00[a]
a*	1.14±0.01[b]	1.15±0.00[b]	2.25±0.02[c]
b*	13.59±0.01[c]	15.67±0.02[d]	11.94±0.03[b]

Values are expressed as mean±SD. Values with different superscript within the same row are significantly different ($p<0.05$).

Colour is an important parameter for consumer acceptance of a food product. The results of the colour properties of banana flour are presented in Table 2. All the flours tend to be whiter with the value L* more than 80 except for the Berangan variety (78.60). Nevertheless, the lightness value significantly differed among the varieties. According to Alkarkhi *et al.* (2011), the low L* value of banana flour can be attributed to the drying process in the oven. The a* value which represents the redness showed that the Berangan variety had the highest value (2.25) and differed significantly with other flours. The yellowness results (b* value) showed a significant difference for all samples, where Mas variety showed the highest, followed by Saba and Berangan, respectively. The previous study by Ohizua *et al.* (2016) found that unripe banana flour had high b* values (16.64) compared to the results reported in this study.

The water absorption capacity for unripe banana flours is given in Table 1. The water absorption capacity ranged from 0.99 g/g to 1.10 g/g for all flours. The water absorption was observed highest in Berangan banana flour and lowest in Saba banana flour. This may be attributed to the low protein and high dietary fibre of Berangan banana flour. This also is due to its large particle size compared to other flours. Large particle sizes can accommodate more water than wheat flour that has a finer particle size. Flour containing high water absorption capacity is important in food products such as bakery products which require hydration to improve the dough handling characteristics. Besides, confectionery products and foodstuffs such as thickener require high water absorption capacity (Alimi *et al.,* 2016). Therefore, Berangan banana flour with the highest water absorption capacity can accommodate more water quantity and improve the dough handling feature. Awolu *et al.* (2016) described water absorption as a characteristic that represents the ability of the product to associate with water under conditions when water is limiting, such as dough and pastes.

Oil absorption capacity attributed to the ability of food material to absorb oil. It is a manifestation of the rate at which the protein binds to fat in food constituents. Oil absorption capacity results showed that Saba banana flour had the highest (1.08 g/g) effect on the oil absorption capacity. It was significantly different from other flour samples. The oil absorption capacity of banana flours in this study (0.86 to 1.08 g/g) was similar to that reported by Falade and Oyeyinka (2014). Oil absorption capacity can be attributed to the presence of a large hydrophobic group while low oil absorption capacity is due to the presence of more polar amino acids present in flour (Ikegwu *et al.,* 2010). Oil absorption capacity is an indicator of protein bonding with fat in food formulations (Onimawo and Akubor, 2012). Absorbed oil gives a soft texture and flavour to the food, so the absorption of oil helps to improve oral taste and retention (Amandikwa *et al.,* 2015). Additionally, products such as dough for frying and mayonnaise will require starch with appropriate oil absorption capacity (Alimi *et al.,* 2016).

The foaming capacity of banana flours ranged from 4.28% to 10.85% in which Mas variety showed the highest foaming capacity while Berangan variety had the lowest (Table 3). This was expected since the protein content of Mas variety is significantly higher than Berangan and Saba banana flours. The foaming capacity of Mas variety is higher than the findings reported by Asif-Ul-Alam *et al.* (2014). The authors also depicted that foaming capacity is used to determine the ability of the flour to foam which is dependent on the presence of the flexible protein molecules which decrease the surface tension of water. This foaming capacity is influenced by the protein content in which high protein content forms an interaction between the protein molecules on the surface of the water and air and this will form multiple film coating on the foam that resistant to breakage (Acuna *et al.,* 2010). The foaming capacity depends on the configuration of protein molecules in which a flexible protein has a good foaming capacity (Babu *et al.,* 2014).

The emulsion activity of banana flours is shown in Table 3. Emulsion activity of different flours ranged between 2.08 and 17.36%. The highest emulsion activity was Mas variety, and the lowest was Berangan variety. According to Olatunde *et al.* (2017), flour with high emulsifiers can be used to increase the emulsion ability of food products that do not have sufficient presence or quantity of protein for emulsification purposes. Based on the previous study conducted by Asif-Ul-Alam *et al.* (2014), the emulsion activity for unripe banana flour is low (1.67%).

The swelling capacity of banana flour was determined at 65°C, 75°C, 85°C and 95°C, respectively and the results are shown in Figure 2. The swelling capacity of flour samples increased with temperature. From Figure 2, it is clear that the lowest value of swelling capacity was observed in the Berangan variety, whereas the maximum in the Mas variety. The swelling capacity of flours depends on the size of particles, types of variety and types of processing methods or unit operations (Chandra *et al.,* 2015). Swelling power is the measurement of water intake by flour granules at a rising temperature without the presence of shear force. When starch granules are heated in excess water, the hydrogen bonds that bind to the starch structure become weak and allow the granules to absorb water which causes swelling to occur and one of the factors for high swelling is the presence of a small crystal structure (Avula, 2005).

High swelling power is an important requirement for good quality flour. Swelling power is associated with amylose content. The abundant amylose content has a strong structural structure because its crystalline structure has a strong network and this will block the swelling (Babu *et al.,* 2014). An increase in disturbance to the crystalline structure during warm-up in water will lead to an increase in starch granules in flour (Aina *et al.,* 2012). Swelling capacity is important in manufacturing and maintaining structures for different food products such as bakery products, i.e., during and after the process (Awolu *et al.,* 2016).

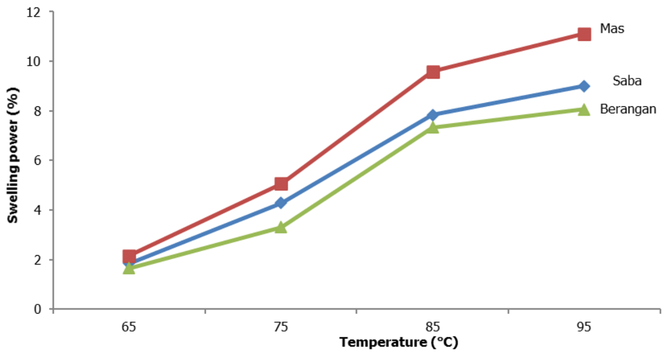

Table 2. Physical and functional properties of unripe banana flour

3.4 Pasting properties

The results from the Rapid Visco Analyzer (RVA) of different flours are summarised in Table 4. The pasting temperature of banana flour ranged from 77.17 to 80.33° C. There were no significant differences in pasting temperatures for a different type of flour investigated. Pasting temperatures recorded were in line with Ohizua *et al.* (2016), where the authors reported the pasting properties of mature unripe cooking banana.

The highest point during the heating cycle is the

Table 3. Pasting profile of unripe banana flour measured by Rapid Visco Analyser

Parameter	Variety		
	Saba	Mas	Berangan
Pasting temperature (°C)	77.17±5.17^{a}	78.45±0.26^{a}	80.33±0.38^{a}
Peak viscosity (cP)	1511.67±57.97^{b}	3145.33±31.97^{d}	2291.67±88.79^{c}
Trough viscosity (cP)	92.00±11.27^{a}	274.33±3.06^{b}	11.00±9.54^{a}
Breakdown (cP)	1419.67±66.73^{b}	2871.00±30.51^{d}	2280.67±79.29^{c}
Final viscosity (cP)	5213.67±54.50^{d}	4675.33±55.77^{c}	4197.00±17.35^{b}
Setback (cP)	5121.67±45.37^{d}	4401.00±53.36^{c}	4186.00±12.49^{b}
Peak time (min)	6.98±0.00^{a}	6.98±0.00^{a}	6.98±0.00^{a}

Values are expressed as mean±SD. Values with different superscript within the same row are significantly different ($p<0.05$).

peak viscosity. There were significant differences observed for the peak viscosity of all flours. The highest peak viscosity was banana flour of Berangan variety, followed by Mas and Saba, respectively. However, the results obtained in this study do no support findings reported by Kaushal *et al.* (2012), where they described that the swelling power of flours is related to their protein and starch contents. High protein content in the flours may cause the starch granules to be embedded within a stiff protein matrix which limits the access of the starch to water and restricts the swelling. The peak viscosity attained during the heating portion of tests indicates the water-binding capacity of the starch mixture. This often correlates with final product qualities. Swelling of granules, accompanied by leaching of starch biopolymers, increased the viscosity and during further heating, granules would rupture further which resulted in a decrease in the viscosity (Noorfarahzilah *et al.,* 2017).

Breakdown viscosity recorded for all banana flours ranged between 1419.66 cP and 2871.00 cP with the lowest being observed for Saba banana flour and the highest for Berangan banana flour. The breakdown is a parameter that measures the ease with which the swollen granules can be disintegrated (Kaur and Singh, 2005). Mas banana flour showed the lowest breakdown viscosity, indicates that it is more resistant to breakdown upon shearing during heating (Aina *et al.,* 2012). According to Babu *et al.* (2014), high breakdown viscosity on banana flour can be attributed to composition such as protein, lipid and amylose content.

The final viscosity indicated the re-association of the amylose molecules during the cooling period after gelatinisation and a formation of a gel network. The final viscosity of different flours showed significant differences, ranging from 4197.00 cP to 5213.67 cP. Saba banana flour had higher final viscosity compared to Mas and Berangan banana flour. Final viscosity indicates the ability of the material to form a viscous paste. Setback viscosity is the recovery of the viscosity during the cooling of the heated starch suspension. It is a measure of the syneresis of starch upon cooling of cooked starch pastes (Kaushal *et al.,* 2012). The setback value of Saba banana flour, Mas banana flour and Berangan banana flour were 5121.67cP, 4401.00 cP and 4186.00 cP, respectively.

3.5 Gelatinisation properties

When starch is heated in the presence of enough water, i.e., excess water, starch granules swell, and the crystalline organisation in starch decomposes to form amorphous regions. This molecular disordering is called gelatinisation (Mamat *et al.,* 2018). Gelatinisation profiles of banana flours are shown in Table 4. The onset, peak and conclusion temperatures were similar to the results reported by Nimsung *et al.* (2007). The authors investigated starch properties isolated from three Thai banana cultivars Musa (AA) sp. They found that the onset, peak and conclusion temperature ranged from 70.50 to 76.27°C, 73.91 to 80.35°C and 78.20 to 86.18°C, respectively. The gelatinisation temperature, referred to as the peak temperature (Tp), was higher for banana flours (77.49 to 79.99°C) than that reported by Bertolini *et al.* (2010) (66 to 69°C), Tribess *et al.* (2009) (67.95 to 68.63°C), Da Mota *et al.* (2000) (68 to 76°C), and Faisant *et al.* (1995) (69°C). Amongst factor that influenced the gelatinisation temperature are amylose content, size, form and distribution of starch granules, and the internal arrangement of starch fractions within the granules (Mamat *et al*., 2018).

4. Conclusion

This research on the unripe flour of green banana fruit shows that flour obtained from Saba cultivar had a higher amount of crude fibre and carbohydrate while Mas cultivar is high in crude protein and crude fat.

Table 4. Gelatinisation and retrogradation properties of unripe banana flour

Parameter	Variety		
	Saba	Mas	Berangan
Gelatinisation:			
Onset temperature, T_0 (°C)	75.56±0.27^{c}	73.61±0.25^{b}	75.31±0.07^{c}
Peak temperature, T_p (°C)	79.20±0.25^{c}	77.49±0.23^{b}	79.99±0.07^{d}
Conclusion temperature, T_c (°C)	83.90±0.08^{b}	83.58±0.31^{b}	85.13±0.30^{c}
Enthalpy, ΔH (J/g)	2.78±0.31^{b}	2.44±0.19^{b}	2.36±0.10^{b}
Retrogradation:			
Onset temperature, T_0 (°C)	57.74±11.91^{a}	65.47±1.15^{ab}	65.33±1.00^{ab}
Peak temperature, T_p (°C)	61.38±14.77^{a}	70.20±0.56^{a}	70.69±0.61^{a}
Conclusion temperature, T_c (°C)	65.02±17.25^{a}	74.91±0.76^{a}	75.76±0.17^{a}
Enthalpy, ΔH (J/g)	0.84±0.53^{b}	0.89±0.08^{b}	1.00±0.14^{b}

Values are expressed as mean±SD. Values with different superscript within the same row are significantly different ($p<0.05$).

Berangan cultivar showed a high percentage of ash and dietary fibre. Functional properties of banana flour revealed that the Berangan cultivar had better water absorption capacity as compared to other varieties. Mas cultivar had the highest foaming capacity due to the higher content of protein. Further, the Saba cultivar had the highest oil absorption capacity and emulsification ability. Meanwhile, pasting profiles depict that Berangan cultivar had a higher pasting temperature while Mas cultivar showed the highest results in peak, trough and breakdown viscosity. Saba cultivar recorded the highest final and setback viscosity.

Conflict of interest

The authors declare no conflicts of interest.

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