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Pasting and physical properties of green banana flours and pastas

[1,4]Cheok C. Y., [1,2*]Sulaiman, R., [1]Manan, N. A., [1]Zakora, A. J., [3]Chin, N. L. and [1,2]Hussain, N.

[1]Department of Food Technology, Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
[2]Halal Products Research Institute,Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
[3]Department of Process and Food Engineering, Faculty of Engineering,Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
[4]Department of Chemical and Petroleum Engineering, Faculty of Engineering and Built Environment, UCSI University, 56000 Kuala Lumpur

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Abstract

Viscosity and physical properties of flours and pastas prepared from four cultivars of green bananas (namely Pisang Berangan, Pisang Nangka, Pisang Tanduk, and Pisang Nipah) have been evaluated. The moisture content and water activity of banana flours were found in the range of 7.71%-8.50% wet basis and 0.33-0.37, respectively. The peak viscosity of banana flours were observed in the order of Pisang Tanduk > Pisang Nipah > Pisang Nangka > Pisang Berangan. The water activity and colour of pastas prepared from banana flours were lower and darker compared to wheat pasta. The firmness of banana flour dried pastas were observed significantly higher than wheat pasta, with Pisang Berangan pasta recorded the highest value of 446.53 ± 7.44 g. Among the green banana cultivars, pastas prepared from Pisang Nipah and Pisang Nangka flours are recommended for consumer who is preferred of bright colour and firm texture cooked pastas.

Introduction

Banana (*Musa* spp.) is a popular and leading fruit crop which grows in tropical countries (Aurore *et al*., 2009). It is a well-known as good source of its mineral contents, especially of its high content of potassium (Sulaiman *et al*., 2011). As such, the addition of banana flour of 10%, 15%, 20%, 25%, and 30% into wheat bread formulation, has been found produced bread contains of 42.87 – 128.60 mg potassium/30 g of bread and 0.33 – 1.00 g of fibre (Mohamed *et al*., 2010). In a recent study, 29 accessions of banana from different genomic groups have been discovered having bioactive compounds with high antioxidant potential and anti-tumour activity (Borger *et al*., 2014). Besides the pulp, banana flower and pseudo-stem have been discovered rich in dietary fibre which is associated with antioxidant capacity that could promote health beneficial effects (Bhaskar *et al*., 2012). Hence, banana pseudo-stem flour has been attempted to use as a partial substitute for producing wheat bread, and the bread produced has been proven containing greater total phenolics and antioxidant properties (Ho *et al*., 2013). In addition, Villaverde *et al.* (2013) have identified high valuable compounds of phytosterols, a sterol family widely used in nutraceutical application in reducing cholesterol absorption and its blood levels, from the unripe peel of several *Musa* species cultivated in Madeira Island, Portugal. The dietary use of the green dwarf banana flour constitutes an important dietary supplement and complementary medicine product for prevention and treatment of human inflammatory bowel disease, as indicated in an in vivo study (Scarminio *et al*., 2012).

Despite being rich in nutritional facts and pharmaceutical properties of antioxidant and anti-tumoral, banana fruit is susceptible to diseases, undergoes rapid enzymatic peel browning and oxidation decay after harvest during storage. Even though low oxygen condition to extend storage life (Imahori *et al*., 2013) and application of oxalic acid on anti-browning (Huang *et al*., 2013) of banana were tried, more solutions are still needed in order to sustain the stability of this agriculture economy. Therefore, not only the ripe banana has been processed into juice, fermented drinks, puree, marmalade, jam, flakes, and ice-cream (Aurore *et al*., 2009), but most recently, the unripe green banana also has been processed into flour for other food products such as snacks and cookies.

*Corresponding author.
Email: *rabiha@upm.edu.my*

Banana starch, contains high amount of starch of more than 70% (Bello-Perez *et al*., 2011; Bezerra *et al*., 2013), has been emerging as a new substitute for food products recently. The products produced with substitution of banana flours were pasta (Agama-Avecedo *et al*., 2009; Ovando-Martinez *et al*., 2009; Krishnan and Prabhashankar 2011; Zandonadi *et al*., 2012), macaroni (Alvarenga *et al*., 2011), cookies (Agama-Acevedo *et al.*, 2012), snack (Wang *et al.,* 2012), bread (Mohamed *et al*., 2010; Ho *et al*., 2013; Sarawong *et al.*, 2014a), and even in production of environmentally-friendly films (Pelissari *et al*., 2013). Amongst, pasta is the most commonly studied foods due to the demand of gluten free diet by people who is intolerant to gluten, which is known as celiac disease. Besides banana flour, flours of rice (Cabrera-Chávez *et al*., 2012), and cassava (Fiorda *et al*., 2013) were attempted in production of gluten-free pasta as well.

In response to the demand of various products with banana flour substitution, the physicochemical properties of banana flour that was produced using osmo-dehydration (Tortoe *et al.,* 2009), spouted bed drying (Bezerra *et al*., 2013) and extrusion cooking (Sarawong *et al.*, 2014b) have been characterized. The storage of banana is always a challenging task due to its rapid enzymatic peel browning and oxidation decay after harvest. By transforming it into flour from the unripe stage not only helps to sustain the economy stability of this agriculture product, but also serves as nutritious raw material to be used in other food product development. Nevertheless, the evaluation of physical and pasting properties of banana flours from different banana cultivars is still scarce.

Therefore, characterizing the flour and pasta in terms of physical, pasting properties and textural analysis of different green banana cultivars provide practical will provide useful information to food processing industry, especially in pasta industry. The specific objectives is to evaluate the physical and pasting properties of flours and texture analysis of pastas prepared from four cultivars of green bananas: Pisang Berangan *(Musa acuminate)* group AAA, Pisang Nangka *(Musa x paradisiacal)* group AAA, Pisang Tanduk *(Musa x paradisiacal*) group AAB, and Pisang Nipah *(Musa balbisiana)* group BBB.

Materials and Methods

Green banana flours preparation

Green (unripe) bananas from four types of cultivars, Pisang Berangan, Pisang Nangka, Pisang Tanduk, and Pisang Nipah, are used in this study. The bananas were harvested in July 2012 from MARDI's farmer in Rembau, Negeri Sembilan, Malaysia (2°43' North, 101°53' East). The skin of bananas were peeled-off and soaked in 4% salt solution to prevent browning. Then, the peeled green bananas were sliced into thickness of 2 mm using a slicer (M2000, Berkel, USA). The sliced bananas were placed on a tray and dried in a cabinet dryer (Model 250 RFS, Smoke-Master, Texas, USA) for three hours at 50°C. The dried green banana was pre-ground using food processor (MK-5087M, Panasonic, Malaysia) and further ground using a grinder (GW-FM2, Taiwan) and sieved to obtained green banana flour with particle size of ≤ 500 µm. The green banana flours were stored in a cold room in sealed plastic containers until analysis.

Pasta ingredients preparation

Pasta was prepared from the four types of green banana flours (Table 1) with formulation of 47.0% green banana flour, 31.5% egg whites, 16.5% water, 2.5% guar gum and 2.5% xanthan gum (Zandonadi *et al*., 2012). The ingredients were mixed for 30 minutes for complete homogenization to produce dough. The dough was strained in a cylindrical machine (Atlas 150, Marcato, Italy) and cut into fettuccine strips of pasta. Then, the pasta was dried in a cabinet dryer at 60°C for 2 hours. Pasta of each formulation was prepared in duplicate. After drying, pasta was cooked in boiling water until the disappearance of the white colour in the pasta central core (Ovanda-Martinez *et al*., 2009). The dried and cooked pastas were subjected to water activity, colour, and texture analysis. The results were compared to the whole-wheat pasta as control, which was prepared from 60.6% of whole-wheat flour and 39.4% of whole egg (Zandonadi *et al*., 2012).

Physical properties measurement of green banana flours and pastas

The moisture content of banana flours and pastas were determined using Association of Analytical Chemists (AOAC) method. All crucibles were dried in the oven at 105˚C for a minimum of 30 minutes.

Water activity (aw) and the colour of the green banana flours, dried and cooked pastas were measured using a water activity meter (Aqua Lab Series 3, Decagon Devices Inc, USA) and Chromameter (R-300, Minolta Camera Co. Ltd., Osaka, Japan) with CIE L^* a^* b^* scale (Huang *et al.* 2013) in triplicate, respectively. The lightness and darkness are denoted by L^* (value of zero is measured as black while value of 100 is measured as white), a^* indicates green to red colour (negative value indicates greenness and

Table 1. Moisture content, water activity, and colour of banana flours.

Types of banana	Moisture content (%)	Water activity (a_w)	Colour		
			L^*	a^*	b^*
Pisang Berangan	8.50 ± 0.26 ^{a}	0.36 ± 0.00 ^{a}	71.77± 0.72 ^{a}	0.74 ± 0.08 ^{a}	19.12 ± 0.30^a
Pisang Nangka	7.71 ± 0.09 ^{c}	0.33 ± 0.00 ^{b}	77.49 ± 0.80 ^{c}	0.79 ± 0.06 ^{ab}	15.31 ± 0.32^c
Pisang Tanduk	7.86 ± 0.04 ^{b}	0.37 ± 0.00 ^{a}	83.38 ± 1.26 ^{b}	0.69± 0.11^b	18.84 ± 0.31^b
Pisang Nipah	7.71 ± 0.08 ^{c}	0.36± 0.01 ^{a}	85.79 ± 0.52 ^{b}	-0.09 ± 0.04^c	13.04± 0.21^d

Values are mean ± standard deviation of triplicate analysis. ^{abcd} values followed by different superscript letters in column indicate significantly different ($p \leq 0.05$) as measured by Tukey's test.

positive value indicates redness) and b^* demonstrates colour of blue to yellow (negative values indicates blueness and positive values indicates yellowness).

Pasting properties

The pasting properties for the four types of green bananas flours were investigated using a stress rheometer (AR-G2, TA Instrument Ltd, Crawley, UK) attaching with a starch pasting cell (Aprianita *et al.*, 2009; Agudelo *et al.*, 2014). The prepared green banana flours were dispersed to 7% (w/v) with distilled water before subjected to measurement. Twenty five grams of the dispersed flour was placed in the cylindrical container and inserted into the base of the pasting cell. The sample was stirred vigorously at 100 s^{-1} for 10 s and the stirring speed was set to 30 s^{-1} until the end of the test. The sample flours were equilibrated for 1 mins at 50°C, and then the temperature was increased to 95°C at rate of 6°C/min. By holding the temperature at 95°C for 5 minutes, the banana flours were cooled back to 50°C at the same rate and finally held for 2 minutes at a constant temperature of 50°C. The measurement was conducted at a constant paddle rotating speed of 160 rpm throughout the entire analysis after the beginning of 10 s at 960 rpm to disperse the sample flour. The parameters recorded were peak viscosity (PV), hot paste viscosity (HPV), cold paste viscosity (CPV), breakdown, and total setback (Arocas *et al.*, 2009; Agudelo *et al.*, 2014; Martínez-Cervera *et al.*, 2014). The peak viscosity represents the highest viscosity of the flour gelatinization achieved during heating. Hot paste viscosity is the value at the end of the isothermal period at 95°C, while cold paste viscosity indicates viscosity value at the end of the isothermal period at 50°C. Breakdown is peak viscosity minus hot paste viscosity, and total setback is cold paste viscosity minus hot paste viscosity. The measurement of each type of banana flour was done in duplicate and results were recorded in mean values (n=2, ± standard deviation).

Texture analysis

The firmness and adhesiveness of the dried and cooked pastas were evaluated using a Texture Analyzer (TA-XT2i, Stable Micro Systems Ltd., Surrey, UK). The testing was performed using a 5-kg load cell and a cylinder probe of 5 mm diameter (Mohamed *et al.,* 2010; Alkarkhi *et al.,* 2011). The probe moved at 2 mm/s. The force-time curve was recorded and the result was interpreted using the software of Texture Exponent 32 (Surrey, UK). The maximum peak force gives the firmness and is expressed in grams, where the adhesiveness is defined as the negative force area and expressed in gram sec (Wang *et al*., 2012; Bagaud *et al.*, 2013; Yildiz *et al*., 2013).

Statistical analysis

Results are expressed as mean ± standard deviation. Analysis of variance (ANOVA) was performed using Minitab® version 16 software to compare the pasting properties of flours and texture of pastas from different green banana cultivars. Tukey's multiple comparison was used to analyze inter-group differences with a 95% confidence interval.

Results and Discussion

Physical properties characterization of green banana flours and pastas

The moisture content, water activity and colour of the green banana flours are presented in Table 1. The moisture content of the green banana flours was ranging from 7.7% to 8.5% w.b. The range of moisture content obtained in this study was different from previous work by Tortoe *et al.* (2009), where they reported slightly lower in the range of 5.1% to 7.3% w.b. This difference was probably due to the different banana cultivars used in their study, i.e., False Horn, French Horn, and True Horn, which obtained from the eastern region of Ghana. Among the banana cultivars used in this study, flour prepared from Pisang Berangan is recorded as the highest ($p < 0.05$) moisture content of 8.50% w.b., while both the Pisang Nangka and Pisang Nipah shown the lowest in moisture content of 7.71% w.b.

For safety measurement in prevention of food product spoilage because of microorganism growth,

Table 2. Water activity and colour analysis of dried and cooked pastas.

Pasta	Water activity (a_w) Dried	Water activity (a_w) Cooked	Colour analysis Dried L^*	Dried a^*	Dried b^*	Cooked L^*	Cooked a^*	Cooked b^*
Pisang Nangka	0.42 ± 0.01^d	0.88 ± 0.01^a	55.12 ± 0.55^c	5.43 ± 0.19^a	13.94± 0.55^c	52.04 ± 0.68^d	6.49 ± 0.37^a	15.93 ± 0.55^c
Pisang Tanduk	0.49 ± 0.00^c	0.88 ± 0.01^a	54.83 ± 0.79^c	5.30 ± 0.32^a	10.71 ± 0.04^d	53.50 ± 0.73^c	6.17 ± 0.12^a	14.57 ± 0.04^d
Pisang Berangan	0.56 ± 0.02^b	0.88 ± 0.01^a	50.74 ± 0.57^d	4.29 ± 0.11^c	16.30 ± 0.40^b	53.70 ± 0.13^c	6.13 ± 0.51^a	17.81 ± 0.40^b
Pisang Nipah	0.53 ± 0.02^b	0.82 ± 0.00^b	64.41 ± 0.60^b	4.81 ± 0.13^b	17.38 ± 0.18^b	57.45 ± 0.19^b	5.26 ± 0.14^b	17.68 ± 0.18^b
Wheat	0.63 ± 0.02^a	0.87 ± 0.01^a	68.10 ± 0.98^a	1.44± 0.13^d	31.19 ± 0.95^a	66.37 ± 0.29^a	1.56± 0.35^c	28.55 ± 0.95^a

Values are mean ± standard deviation of triplicate analysis. ^{abcd} values followed by different superscript letters indicate significantly different
($p \leq 0.05$) as measured by Tukey's test.

the drying procedure used in this study is aimed to produce green banana flours with low water activity irrespective of banana cultivar (Table 1). The range of water activity for the green banana flours is recorded in 0.33 to 0.37. The lowest water activity of banana flours is observed for flour prepared from Pisang Nangka with the value of 0.33. As recommendations in previous studies that focused on moisture adsorption and desorption isotherms, it is important to obtain water activity of banana flour of not higher than 0.60 to prevent microbial proliferation in determining the shelf life and type of packaging material to be used (Yan *et al*. 2008; Cardoso and Pena, 2013). This is in agreement with previous findings by Tortoe *et al.* (2009) where they also recorded in the range of 0.27 to 0.39 for plantain flours of three cultivars.

The lightness and brightness of the flour colour are denoted by L^* when the value closes to 100, and vice versa. Flours prepared from Pisang Tanduk (83.38) and Pisang Nipah (85.79) show significantly brighter ($p < 0.05$) colour compared to Pisang Berangan (71.77) and Pisang Nangka (77.49) (Table 2). The a^* value refers to green (-) or red (+), and b^* value refers to blue (-) or yellow (+) chromaticity. Analysis at the a^* coordinates showed that flour prepared from Pisang Nipah has the tendency towards green colour, while Pisang Nangka was towards red colour. As for the b^* coordinates, flour prepared from Pisang Berangan has the tendency towards lighter yellow colour while Pisang Nipah towards blue colour. A previous work done by Alkarkhi *et al.* (2011) observed that the colour of green Cavendish pulp flour were L^* 74.18, a^* 2.53, and b^* 17.36, which is in between of flours prepared from Pisang Berangan and Pisang Nangka in this study. However, Bezerra *et al.* (2013) observed that green banana flour prepared from the same cultivar of Cavendish processed at 80°C using a conical spouted bed dryer, has a brighter colour of L^* 104.30, a^* -0.48, and b^* 1.87. The difference in colour observations in these two studies were most probably due to vary in the method of flour preparation and geographical location of the banana obtained. On the other hand, Tortoe *et al*. (2009) reported contradictory results, where they revealed that there were no significant differences in colour among the flours produced from varieties of False Horn, True Horn local, and French Horn plantains.

Table 2 demonstrates the water activity and colour analysis of dried and cooked pasta prepared from flours of Pisang Berangan, Pisang Nangka, Pisang Tanduk, Pisang Nipah, and wheat. Colour is an important quality determinant of pasta as it influences consumer preference (Carini *et al*., 2013). Irrespective of dried and cooked pastas, pasta prepared from Pisang Nipah flour shows lighter colour and more yellowness among the banana pastas. However, in comparison with wheat pasta, all the pastas prepared from green banana flours showed darker colour. This observation is in agreement with Agama-Acevedo *et al*. (2009) where they observed that the increased percentage of banana flour addition to the formulation decreased the lightness of pastas produced. The lightness *(L^*)* of green banana pastas is ranging from 50.74% to 64.41% irrespective of dried and cooked conditions.

Among the dried pastas, wheat pasta showed the highest water activity of 0.634, followed by pastas prepared from flours of Pisang Berangan, Pisang Nipah, Pisang Tanduk and Pisang Nangka. The water activity of dried pasta prepared in this study was ranging from 0.42 to 0.63. This result is slightly differed from previous study by Sun-Waterhouse *et al*. (2013), where they used the elderberry juice concentrate to enhance pastas, obtained water activity range of 0.57 to 0.69. Among the cooked pastas, Pisang Berangan pasta has the highest water activity of 0.884, followed by Pisang Tanduk, Pisang Nangka, Pisang Nipah and wheat pasta (Table 2). Agama-Acevedo *et al.* (2009) concluded that pasta made with unripe banana flour increased the water

Table 3. Pasting properties of banana flours.

Types of banana	Peak viscosity (Pa.s)	Hot paste viscosity (Pa.s)	Cold paste viscosity (Pa.s)	Breakdown (Pa.s)	Total setback (Pa.s)
Pisang Berangan	0.59 ± 0.07^c	0.51 ± 0.06^a	0.69 ± 0.07^a	0.08 ± 0.01^a	0.18 ± 0.11^a
Pisang Nangka	1.49 ± 0.05^b	1.37 ± 0.03^c	1.71 ± 0.00^c	0.12 ± 0.02^a	0.34 ± 0.02^a
Pisang Tanduk	2.84 ± 0.60^a	2.50 ± 0.46^b	2.95 ± 0.56^b	0.34 ± 0.14^b	0.45 ± 0.11^b
Pisang Nipah	1.67 ± 0.02^b	1.55 ± 0.01^c	2.24 ± 0.05^c	0.12 ± 0.00^a	0.69 ± 0.06^c

Values are mean ± standard deviation of duplicate analysis. abc values followed by different superscript letters indicate significantly different ($p \leq 0.05$) as measured by Tukey's test.

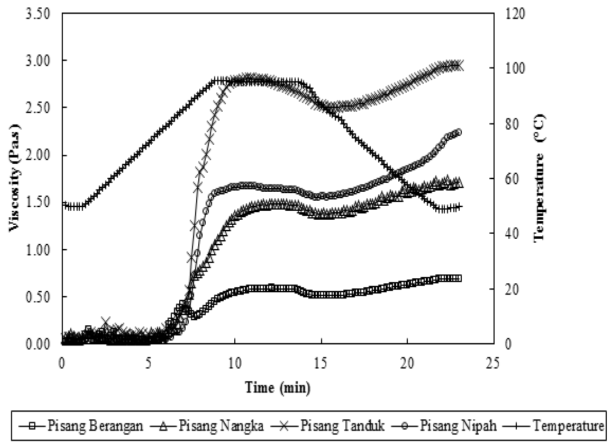

Figure 1. Viscosity-temperature profiles of flours from four banana cultivars

absorption of the product. Water activity that closes to aw 1.0 leads to microbial spoilage. In this study, the pastas prepared from all the green banana flours showed significantly lower water activity than wheat pasta, which indicate that the green banana pastas has higher resistance against microbial spoilage.

Pasting properties of green banana flours

Table 3 represents the pasting properties of four banana cultivars flours. The peak viscosity of banana flours in this study were found within the range of 0.589 to 2.837 Pa.s. Flour prepared from Pisang Tanduk was observed having the highest ($p < 0.05$) peak viscosity of 2.837 Pa.s, followed by Pisang Nipah, Pisang Nangka, and Pisang Berangan. These observation is different from previous study done by Bezerra *et al.* (2013), where they reported the maximum peak viscosity of 3.915 and 3.361 Pa.s for banana flours prepared from peeled and unpeeled Cavendish *(Musa acuminate)* using a conical spouted bed dryer.

Flour prepared from Pisang Tanduk showed the highest hot paste viscosity of 2.500 Pa.s, and this is followed by Pisang Nangka and Pisang Nipah, and Pisang Berangan. The highest cold paste viscosity was Pisang Tanduk which recorded at 2.946 Pa.s, and followed by Pisang Nipah, Pisang Nangka, and Pisang Berangan. In terms of breakdown and total setback, flours prepared from Pisang Tanduk and Pisang Nipah recorded the highest values of 0.338 and 0.687 Pa.s, respectively.

Sarawong *et al.* (2014b) investigated the effects of extrusion cooking conditions on pasting properties of green banana flour. They revealed that at the same screw speed, lower feed moisture resulted in lower peak viscosity, hot paste viscosity, cold paste viscosity, breakdown and setback. And they stated that this was because of higher degree of gelatinization and starch degradation occurred during extrusion cooking under lower feed moisture. Flour prepared from unripe green banana (*M. balbisiana* Colla) demonstrated lower consistency and setback values compared to corn starch which indicated it has high paste stability in mechanical processes (Torre-Gutiérrez *et al*. 2008).

Trends of the pasting property of different types of banana flours are presented in Fig. 1. Flour prepared from Pisang Tanduk has the highest viscosity profile with the highest peak viscosity and final viscosity followed by flours prepared from Pisang Nipah, Pisang Nangka, and Pisang Berangan. This result indicates that among the banana flours, flour prepared from Pisang Tanduk has higher stability in further mechanical processes due to its higher peak viscosity, final viscosity, breakdown, and setback. The results indicate that the peak viscosity of flours does not solely dependent on moisture content, but also on the banana cultivars.

Texture analysis

The values of firmness and adhesiveness of the dried and cooked pasta prepared from flour of four types of banana cultivars and wheat are tabulated in Table 4. The firmness of dried pastas prepared from the banana flours were observed significantly higher than the wheat pasta. Among the pastas prepared from banana flours, Pisang Berangan flour produced significantly ($p < 0.05$) greater firmness pasta. It is surprisingly found that the firmness of cooked pasta

Table 4. Texture analysis for the firmness and adhesiveness of dried and cooked pasta.

Pasta	Firmness (gram) dried	Firmness (gram) cooked	Adhesiveness (gram.sec) dried	Adhesiveness (gram.sec) cooked
Pisang Berangan	446.53 ±7.44^{a}	153.33 ±10.07^{c}	-3.89 ± 0.98^{ab}	-14.00 ± 0.81^{b}
Pisang Nangka	262.81 ±9.01^{c}	230.69 ±21.11^{b}	-7.75 ± 1.23^{c}	-10.57 ± 0.33^{a}
Pisang Tanduk	350.04 ±18.04^{b}	204.92 ±16.89^{b}	-5.35 ±1.03^{bc}	-18.07 ±1.22^{c}
Pisang Nipah	200.40 ±20.99^{d}	214.65 ±11.64^{b}	-4.97 ±1.08^{bc}	-12.34 ± 0.95^{ab}
Wheat	104.02 ±3.38^{e}	484.81 ±26.07^{a}	-1.15 ±1.30^{a}	-24.79 ± 0.69^{d}

Values are mean ± standard deviation of triplicate analysis. ^{abcde} values followed by different superscript letters indicate significantly different ($p \leq 0.05$) as measured by Tukey's test.

increases as the firmness of dried pasta decreases. The cooked pasta firmness is due to the hydration of starch granules and subsequent to protein matrix gelatinization during cooking (Sun-Waterhouse *et al*., 2013). The results in this study indicated that pastas prepared from banana flours has lesser degree in starch gelatinization consequence of cooking, hence, all the cooked banana pastas gave lower firmness compared to wheat pasta. As regard to the cooked pasta firmness due to starch gelatinization, Sun-Waterhouse *et al.* (2013) have the same observation in which they found that the cooked Hi-maize starch pasta enhanced with elderberry juice concentrate has lower firmness compared to the non-enhanced. Similarly, Krishnan and Prabhashankar (2011) observed that with the increase on percentage substitution of banana flours into pasta formulation, the firmness values decreased. Despite the firmness, Alvarenga *et al.* (2011) evaluated macaroni in terms of tensile strength and they reported that macaroni prepared from green banana flour has lower tensile strength compared to commercial macaroni. However, Agama-Acevedo *et al*. (2009) reported there were no differences in hardness of the cooked spaghetti prepared from 100% durum wheat semolina with those formulations of 15%, 30%, and 45% substituted with banana flours.

The adhesiveness of all the dried pastas prepared from the four cultivars of banana flours showed higher values compared to the wheat pasta (Table 4). However after cooking, the pastas prepared from banana flours showed lower adhesiveness values compared to the wheat pasta. This result is contradicted with the observation in a previous study done by Agama-Acevedo *et al.* (2009). They observed that the adhesiveness value of spaghetti was higher with addition of banana flour into the spaghetti formulation compared to the commercial spaghetti, and the values were increased when the percent of banana flour added increased. In addition, Zandonadi *et al.* (2012) discovered that green banana pasta has higher adhesiveness value compared to the standard pasta. Lower adhesiveness value of cooked green banana pasta in this study compared to previous researches might due to different green banana cultivar used.

Conclusion

The characterization of rheological and physical properties on flours and pastas prepared from different banana cultivars provides useful scientific information for food processing industry and related research in future. Many food products could be developed and optimized to suit consumer sensory acceptance and preference base on the pasting properties of banana flours, despite being rich in nutritional values. Pisang Tanduk flour, observed with the highest peak viscosity among the banana flours, is suitable and stable to be used for many food products such as snacks and cookies. Pasta prepared from Pisang Nipah flour is recommended for production of green banana pasta which has brighter colour while Pisang Nangka flour is suggested for production of green banana pasta with firmer texture after cooked. Additionally, the ease to transform green banana into flour with low water activity, which facilitates in handling and transportation, enhances its potential as a good choice of raw material in food processing industry.

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