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Mineral composition and pasting properties of banana pseudo-stem flour from *Musa acuminata* X *balbisiana* cv. Awak grown locally in Perak, Malaysia

Ho, L. H., *Noor Aziah, A. A. and Rajeev Bhat
Department of Food Technology,
School of Industrial Technology,
Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia

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Abstract

The banana pseudo-stem is not currently utilised in the food industry. The aim of this research was to investigate the chemical and pasting profile of banana pseudo-stem flour (BPF). Wheat flour were substituted with BPF (0, 5, 15 and 30%) and the pasting profile were determined. Results from mineral analysis showed that the levels of sodium (Na), potassium (K), calcium (Ca), magnesium (Mg) and phosphorus (P) were higher than those of iron (Fe), zinc (Zn) and manganese (Mn). The BPF had a 0.04% total titratable acidity (TTA) and a total soluble solid (TSS) of 1.30 ^{o}Brix with pH 5.41. BPF contained 28.26% total starch, 12.81% resistant starch and a total digestible starch value of 15.45%. An increased substitution level of BPF into wheat flour significantly ($p<0.05$) decreased the pasting viscosity (PV), breakdown (BD), final viscosity (FV), setback (SB) and pasting temperature (PT) of the mixtures.

Introduction

Minerals play an important role in maintaining proper function and good health in the human body (Bhat *et al*., 2010). According to Hendricks (1998), approximately 98% of the calcium (Ca) and 80% of the phosphorus (P) in the human body are found in the skeleton. Inadequate intake of minerals in the diet is often associated with an increased susceptibility to infectious diseases due to the weakening of the immune system. Plants, animal foods and drinking water are an important source of essential elements (Chaturvedi *et al*., 2004). An average adult requires an intake of more than 100 mg per day of macro-minerals [Ca, P, sodium (Na), potassium (K), magnesium (Mg), chlorine (Cl), and sulphur (S)] and trace elements [selenium (Se), zinc (Zn), copper (Cu), cobalt (Co), manganese (Mn), molybdenum (Mo) and iron (Fe)], with a recommended daily intake within the microgram range to maintain specific functions in the body (Hendricks, 1998).

The banana is a tropical herbaceous plant; its stem is composed of concentric layers of leaf sheaths. The banana is one of the most heavily consumed fruits in the world, with a global annual production of 72.5 million tons (FAO, 2006). Banana production has become increasingly important in recent years, and hence, the land area of banana cultivation has increased from year to year. It is estimated that 26, 855 hectares of land area were planted with bananas in 2006, and this value increased to 29, 790 hectares in 2010, with a production of approximately 294, 530 tonnes of fruit, which is equivalent to a production value of RM 432, 375, 826 in 2010 (MOA, 2010).

Each plant produces a single bunch of fruits. After harvesting, the bare pseudo-stems are cut, and thus, several tons of banana pseudo-stems are produced daily on the plantations (Cordeiro *et al*., 2004). The production of bananas generates a large amount of pseudo-stem waste and therefore creates a major agro-waste problem and an environmental nuisance. Hence, a better way to solve the problem of banana pseudo-stems is worth pursuing.

The banana fruit, peel and trunk from various species and sampling areas have been reported to be rich in essential minerals, mainly containing high concentrations of K (Twyford and Walmsley, 1974; Selema and Farago, 1996; Cordeiro *et al*., 2004; Oliveira *et al*., 2007; Haslinda *et al*., 2009). Furthermore, in many parts of India, the pith or the tender core of the banana pseudo-stem has been used as food after boiling and the addition of spices (Mohapatra *et al*., 2010). According to Haslinda *et al*. (2009), both the banana pulp and the unpeeled banana have a high content of total starch and resistant starch. Moreover, the banana pseudo-stem has been

*Corresponding author.
Email: *naziah@usm.my*

reported to contain high-quality starch (Shantha and Siddappa, 1970).

Resistant starch is the indigestible starch that passes through the small intestine to the large intestine and is fermented in the colon, where it acts as dietary fibre to improve the health of the digestive system (Fu *et al*., 2008). Recently, wheat flour blends with high-dietary fibre flour have been commonly applied in the bakery industry to reduce the utilisation of large quantities of wheat flour as well as to increase the dietary fibre intake of the consumer. The substitution of dietary flour into food may also contribute to the reduction of malnutrition (Marin *et al*., 2009). However, the inclusion of the dietary fibre flour into wheat flour often changes the viscosity pattern of the flour. The pasting properties of the blends are commonly studied by using a rapid visco-analyzer (RVA) to observe changes in the viscosity of a starch system based on rheological principles (Zaidul *et al*., 2007a).

A previous study of bananas (*Musa acuminata* X *balbisiana* cv. Awak) focused on the banana pulp and unpeeled banana (Haslinda *et al*., 2009). However, no research has been conducted on the mineral contents of the banana pseudo-stem from *Musa acuminata* X *balbisiana* cv. Awak or its starch and pasting properties. In this work, the content of minerals, starch (total, resistant and digestible starch) and the pasting properties of the banana pseudo-stem flour (BPF) were investigated.

Materials and Methods

Materials

The banana pseudo-stems (*Musa acuminata* X *balbisiana* cv. Awak) were collected from local farms in Perak, Malaysia. The samples were transported from the farm to the laboratory for further processing and analysis. All the chemicals used in this study are of analytical grade. The commercial wheat flour (CWF) purchased from the local market in Penang, Malaysia was used for the pasting properties analysis.

Methods

Preparation of banana pseudo-stem flour

The BPF was processed by manual peeling of several layers of the skin (epidermis) of the banana pseudo-stem with a clean knife. The samples were then rinsed with running tap water and cut into small pieces. The pseudo-stem was then boiled for 15 min to soften the texture before being soaked in 0.1% w/w sodium metabisulfite solution for ½ h. The pseudo-stem was then sliced using the slicer (Robot coupe, France) before being dried in a ventilated dryer (Afos, Model Mini, No. CK 80520, England) at 60 °C for overnight (16 h). The dried slices of pseudo-stem were then blended in a blender (Panasonic Model: PB-325, Malaysia) and further sieved by passing through a mesh sieve of size 355 µm (No. 42). The BPF was then kept in an airtight plastic container and stored in chiller prior to use.

Mineral analysis

A 69% HNO_3 (6 ml) and 30% H_2O_2 (1 ml) were added into a 1.0 g sample. The samples were digested for 15 min in a microwave digester (Millestone Ethos 900, Italy). The digested samples were then transferred into 100 ml volumetric flask and top up with distilled deionised water until to the mark. The concentrations of Na, K, Ca, Mg, Fe, Zn and Mn were determined by using a flame atomic absorption spectrophotometer (Perkin Elmer 4100 Z, Massachusetts, USA), and P was measured according to the colorimetric methods with slight modification (Method 986.24) (AOAC, 2000). The concentration of P in the sample was measured using a Shimadzu UV-Vis Spectrophotometer (Shimadzu Model 1601, Kyoto, Japan) at 400 nm. The results were expressed in milligrams per 100 g dry sample.

Total titratable acidity (TTA), pH and total soluble solid (TSS)

Approximately 2 g of dried BPF was extracted with 30 ml distilled water and 20 ml methanol at 45 °C for 15 min in a water bath. The mixture was filtered, and 4 ml of filtrate was pipetted into a flask containing 5 ml distilled water followed with the addition of 3 drops of 1% phenolphthalein. The mixture was then titrated against 0.1 N NaOH until the faint pink end point persisted for 30 seconds (Adelekan and Oyewole, 2010).

Sample preparation for the analysis of pH and TSS were conducted according to the method of Adelekan and Oyewole (2010) with slight modification. Approximately 2 g of dried BPF was added to 50 ml of distilled water and stirred for 10 min. The mixture was filtered and the pH of the sample was determined by dipping the electrode of the pH meter (pH meter Model: ORION 410A, UK) in the filtrate. The HI 96801 Refractometer (0-85 °Brix) (Hanna Instruments Inc., Romania) was used for the determination of TSS of the sample, and the obtained results were expressed in °Brix (Uma *et al*., 2005).

Total starch, resistant starch and digestible starch determination

To determine the total starch content,

approximately 6 ml 2 M KOH was added into the 50 ml centrifuge tube containing 50 mg of sample. The centrifuge tube was shaken constantly in a shaking water bath at room temperature for 30 min. Then, 3 ml of 0.4 M sodium acetate buffer (pH 4.75) and 60 µL amyloglucosidase (Cat No A 9913; Sigma-Aldrich, St. Louis, Missouri, USA) was added and incubated at 60 °C for 45 min with a constant shaking water bath. Glucose was determined using the glucose oxidase/peroxidase reagent (Cat No GL 2623; Randox Laboratories Ltd, UK.). Total starch was calculated as glucose (mg) X 0.9 (Goni *et al*., 1996).

Resistant starch was analysed by the method of Goni *et al*. (1997). A 100 mg sample was treated with 0.2 ml of pepsin (Cat No P-7012; Sigma-Aldrich, St. Louis, Missouri, USA) (1 g pepsin per 10 ml KCl-HCl buffer, pH 1.5) to remove protein and then incubated for 16 h at 37 °C with 1 ml of pancreatic α-amylase (Cat No A-3176; Sigma-Aldrich, St. Louis, Missouri, USA) solution containing 40 mg α-amylase per ml Tris-maleate buffer, pH 6.9 to remove digestible starch. The residue was treated with 4 M KOH and hydrolysed with amyloglucosidase (Cat No A-9913; Sigma-Aldrich, St. Louis, Missouri, USA). The glucose content was determined using the glucose oxidase/peroxidase reagent. Resistant starch was calculated as glucose X 0.9. The digestible starch content was obtained from the difference between total starch and resistant starch.

Pasting properties analysis

The CWF was substituted with BPF (WF + BPF) at different percentage levels; 5, 15 and 30% (95:5, 85:15 and 70:30, respectively), and the CWF (100:0) was used for the pasting behaviour analysis. The pasting properties of wheat flour blend with BPF were assessed using the Rapid Visco-Analyzer (Model RVA series 4; Newport Scientific Pty Ltd, Warriewood, Australia). An amount of 3 g sample was dispersed in an aluminium canister containing 25 g distilled water. The flour-water suspension was held at 50 °C for 1 min and then heated up to 95 °C and held for 10 min. Block temperature was cooled to 50 °C and held for another 2 min. Results were expressed as viscosity in centipoise (cP) for pasting viscosity (PV), breakdown (BD), final viscosity (FV) and setback (SB), and °C for pasting temperature (PT).

Statistical analysis

Statistical analyses were carried out by using SPSS 14.0 software (SPSS Inc., Chicago, IL, USA). The results obtained in the present study are reported as mean values (obtained from the three replications) ± standard deviation (SD). The significant differences between mean values were analysed by the Duncan multiple range test at a significance level of $p<0.05$ for pasting profile analysis.

Results and Discussion

Mineral contents

Table 1 shows the concentration of minerals (mg/100 g of dry sample) in BPF. The predominant elements found in the BPF were Na, K, Ca, Mg and P which are classified as macro-elements. Calcium was found in the highest amount (1,335.33 mg/100 g of dry sample) in BPF, followed by K (944.12 mg/100 g of dry sample), Na (444.12 mg/100 g of dry sample), Mg (255.00 mg/100 g of dry sample) and P (137.82 mg/100 g of dry sample). However, the BPF results obtained from the present study differ from those reported by Selema and Farago (1996), who have reported that the banana pseudo-stem (*Musa Paradisiaca*) possesses a higher amount of K (3810 mg/100 g) than Ca (1500 mg/100 g). Montagut *et al*. (1965) stated that the Ca concentrations increased with age, especially at the end of the cycle. Calcium entering tissues with reduced activity replaced other cations, especially K.

Banana pseudo-stem flour was found to be lower in K compared with the banana pulp and unpeeled banana flour (Haslinda *et al*., 2009). Our study is in accordance with that published by Twyford and Walmsley (1974), who reported that the K concentration in the pseudo-stem decreased during the fruiting phase and that most of the K accumulated in the fruit stalk and inflorescence due to its substantial requisite amounts for fruit development. Potassium content in BPF is beneficial for those suffering from hypertension and those who suffer excessive excretion of K through body fluids (Siddhuraju *et al*., 2001).

It is noteworthy to mention that the concentration of Ca in the BPF observed in this study exceeded the amount obtained from the banana pulp, peels and unpeeled bananas (Selema and Farago, 1996; Happi Emaga *et al*., 2007; Haslinda *et al*., 2009). According to Twyford and Walmsley (1974), Ca was relatively high in the pseudo-stem due to the vital role of this element in the cell strength of the trunk that supports the plant. The macro-elements, such as Na, K, Ca, and Mg, are essential for our daily diet due to their involvement in neural conduction and muscle contraction (Hendricks, 1998). Furthermore, Ca is also essential for strengthening bones and teeth. Hence, the fortification of foods with BPF allows

Table 1. Mean value of mineral and ash contents of banana pseudo-stem flour

	mg/100g dry sample [a]
Sodium	444.12 ± 4.08
Potassium	9 44.12 ± 1.41
Calcium	1,335.33 ± 14.11
Magnesium	255.00 ± 2.83
Phosphorus	137.82 ± 1.89
Iron	3.31 ± 0.05
Zinc	8.05 ± 0.05
Manganese	1.27 ± 0.11
Ash (%)	6.75 ± 0.34

[a] Values are expressed as mean ± standard deviation, n = 3

Table 2. Mean value of total titratable acidity, total soluble solid and pH of banana pseudo-stem flour

Parameter	Mean ± SD [a]
TTA (%)	0.04 ± 0.00
TSS (°Brix)	1.30 ± 0.00
pH	5.41 ± 0.02

[a] Values are expressed as mean ± standard deviation, n = 3

Table 3. Mean value of the total starch, resistant starch and digestible starch content of banana pseudo-stem flour

Composition	% [a]
Total starch	28.26 ± 0.15
Resistant starch	12.81 ± 0.15
Digestible starch	15.45 ± 0.01

[a] Values are expressed as mean ± standard deviation, n = 3

the addition of minerals to some foods that have a low content of Ca and K. Banana pseudo-stem flour showed a higher concentration of Mg compared with the pulp (105.37 mg/100 g of dry matter), peel (69.5-189.5 mg/ 100 g of dry sample) and unpeeled banana (107.64 mg/100 g of dry matter) (Happi Emaga *et al*., 2007; Haslinda *et al*., 2009).

In the case of trace elements (micro-elements), the contents of Fe, Zn and Mn were found to be low. Iron, which is an essential element for both animals and plants, was found to be 3.31 mg/100 g of dry sample in BPF. This value was similar to that reported by Happi Emaga *et al*. (2007). However, the BPF contains a higher concentration of Fe compared with other findings for banana pulp and unpeeled bananas (Haslinda *et al*., 2009).

The Zn content (8.05 mg/100 g of dry sample) in BPF was found to be higher than the banana pulp (0.74 mg/100 g of dry matter), banana peel (1.54-3.88 mg/100 g of dry matter) and unpeeled bananas (0.83 mg/100 g of dry matter) (Happi Emaga *et al*., 2007; Haslinda *et al*., 2009). The results obtained in the present study are in agreement with those reported by Selema and Farago (1996), who stated that trace elements generally accumulated in large quantities in the trunks rather than in the fruit peels. In addition, their findings showed that the trunk of *Musa paradisiaca* contained 59.7 mg/100 g of dry amount of Zn, which was almost 8-fold higher than that found in the present study. However, both species of the BPF were still in the range of the normal levels of Zn content in plants (2.5-15.0 mg/100 g) (Valkovic, 1978).

According to Selema and Farago (1996), the normal level of Mn in plants ranged from 2.0-50.0 mg/100 g of dry matter. However, our findings indicated that the Mn content (1.27 mg/100 g of dry sample) in the BPF was lower than the normal range. Overall, the BPF banana pseudo-stem was high in both macro-elements and micro-elements due to the high ash content (6.75%).

Biochemical parameters of banana pseudo-stem flour

The TTA, TSS and pH of the BPF are shown in Table 2. The TTA (0.04%) of the BPF from the 'Awak' variety in this investigation was higher than in the findings of Uma *et al*. (2005), who found that the TTA of the banana pseudo-stem from different cultivars ('Poovan', 'Karpuravalli', 'Pachanadan', 'Saba', 'Peyan', and 'Robusta') ranged from 0.020-0.034%.

The TSS present in the pseudo-stem flour was 1.3 °Brix. The TSS in this variety was similar to the findings of Uma *et al*. (2005), who found that the TSS ranging from 1.47-1.93 °Brix. The TSS, which includes the soluble sugars sucrose, glucose and fructose, is correlated with the starch content. The lower TSS in the BPF pseudo-stem might be attributable to the lower starch content, because the starch content is calculated based on the total glucose released (Goni *et al*., 1996).

The result indicated that the pH (5.41) of the BPF of the 'Awak' variety was more acidic than the other varieties of banana ('Poovan', 'Karpuravalli', 'Pachanadan', 'Saba', 'Peyan', and 'Robusta'), which ranged from 6.390-6.663 (Uma *et al*., 2005). The result obtained from this study showed slightly lower pH (0.98-1.253) than the reported study by Uma *et al*. (2005). This might be attributed to the geographical factors; soil condition and weather, and different in genetic of banana varieties which are affecting the pH value of the plant.

Total starch, resistant starch and digestible starch

Table 3 shows the total starch, resistant starch and digestible starch in BPF. The total starch obtained from this study was similar to the findings of Shantha and Siddappa (1970), who reported a starch content of 25.50 %. However, the BPF was lower in total starch compared with the banana pulp (81.83 %) and unpeeled bananas (81.55%) (Haslinda *et al*., 2009). According to Shantha and Siddappa (1970), during the early period of growth, the starch reserve increased in the rhizome and remained practically

Table 4. Pasting properties of the control wheat flour and the wheat-banana pseudo-stem flour blends

Treatments	PV[a] (cP)	BD[b] (cP)	FV[c] (cP)	SB[d] (cP)	PT[e] (°C)
	Mean ± SD[f]				
100:0[g]	$3001.00^{A} \pm 18.38$	$1212.50^{A} \pm 33.23$	$3286.00^{A} \pm 5.66$	$1497.50^{A} \pm 20.51$	$68.55^{A} \pm 0.07$
95:5[h]	$2731.00^{B} \pm 8.49$	$1137.50^{B} \pm 7.78$	$2945.50^{B} \pm 2.12$	$1352.00^{B} \pm 2.83$	$67.30^{B} \pm 0.42$
85:15[i]	$2297.00^{C} \pm 2.83$	$969.50^{C} \pm 4.95$	$2447.50^{C} \pm 6.36$	$1120.00^{C} \pm 4.24$	$66.93^{B} \pm 0.04$
70:30[j]	$1921.00^{D} \pm 8.49$	$619.00^{D} \pm 1.41$	$2201.50^{D} \pm 0.71$	$899.50^{D} \pm 7.78$	$66.55^{B} \pm 0.57$

Values in the same column with the same superscript uppercase letters are not significantly different from each other ($p>0.05$)

[a] Peak viscosity; [b] Breakdown; [c] Final viscosity; [d] Setback; [e] Pasting temperature (all expressed in centipoises, [f] mean ± standard deviation, n = 3); [g] Control wheat flour; [h] Wheat flour substituted with 5% banana pseudo-stem flour; [i] Wheat flour substituted with 15% banana pseudo-stem flour; [j] Wheat flour substituted with 30% banana pseudo-stem flour.

constant in the pseudo-stem. After the initiation of inflorescence, there was no further increase in the starch content in the rhizome or in the pseudo-stem. However, starch increased in the fruit. The starch that accumulates in the rhizome until the onset of inflorescence can be degraded through the action of enzymatic hydrolysis to form glucose, which is transferred for de novo synthesis in the developing fruit. Hence, there is no further increase in the starch content in the rhizome. The starches, as well as the sugar contents, are at maximum at the time of inflorescence. The subsequent transfer of starch in the form of sugars for re-synthesis in the developing fruit, through the central core, followed the outer sheath of the pseudo-stem.

The resistant starch content in the BPF (12.81%) was classified as flour high in resistant starch content (Goni *et al*., 1996). Through the results observed from this work, BPF has the potential to be added into food systems to increase the resistant starch intake in the diet. The BPF is reported to be lower in digestible starch (15.45%) than the banana pulp and unpeeled bananas (Haslinda *et al*., 2009).

Pasting properties

The obtained results of the pasting properties of CWF and WF + BPF at various percentage levels are summarised in Table 4. Substitution of flour rich in dietary fibre for wheat flour, included in a starch-based food system for improving the nutritional value, might greatly influence the pasting conditions of the final product. Significant differences were observed in the pasting profiles of the samples. The pasting profile of CWF exhibited higher PV, BD, FV, SB and PT than those of the WF + BPF blends. The PV differed significantly with the substitution level of BPF. PV decreased with increasing levels of BPF substitution in the following order: 95:5 > 85:15 > 70:30. It was observed that the substitution of non-wheat flour (inulin, sugar beet fibre, pea cell wall fibre, pea hull fibre, resistant starch, and nopal powder) into wheat-based food systems showed PV trends similar to those obtained in our study (Collar *et al*., 2006; Fu *et a*l., 2008; Cornejo-villegas *et al*., 2010). The reduction in PV might be associated with a competition between the swelling of starch granules and fibre particles with water (Cornejo-Villegas *et al*., 2010). The water-binding capacity of the fibre is higher than the starch granules. Hence, there is less water available for the starch granules to swell, thereby leading to a lower PV with increasing levels of dietary fibre in the mixture.

During the hold period of the test, the sample was subjected to a period of constant, high temperature (95 °C) and mechanical shear stress, which further disrupted the starch granules in the grains, resulting in amylase leaching and realignment. This period is commonly associated with a BD in viscosity (Newport Scientific, 1998). BD was lowest for the 70:30 (619.00 cP) mixture compared with CWF (1212.50 cP), which suggests an increased ability of the flour to withstand heating and shear stress (Fu *et al*., 2008). According to Zaidul *et al*. (2007b), the starch granules of the CWF are easily broken down due to their weak intermolecular forces that cause the CWF to become more sensitive to the shear force with increasing temperature. The highest FV was observed in CWF (3286.00 cP). The result indicates that the WF + BPF was more resistant to BD than was the CWF upon shearing during heating.

The SB is correlated to the FV and related to the gelling ability or retrogradation (re-ordering) of the starch molecules. During cooling, re-association between starch molecules, especially amylase, will result in the formation of a gel structure, and therefore, viscosity will increase to the FV (Newport Scientific, 1998). Similarly, the SB was highest for CWF (1497.50 cP). The SB of the WF + BPF blends decreased rapidly with an increase in BPF from 5 to 30% (1352.00 to 899.50 cP, respectively). This result indicates that CWF had the highest amylase retrogradation (Fu *et a*l., 2008). FV is an important indicator of the strength of the gel formed upon cooling and represents an important quality parameter (Cornejo-Villegas *et al*., 2010). The gel formation of the WF + BPF blends (2945.50, 2447.50 and 2201.50 cP for 5, 15, and 30% substitution levels, respectively) was significantly lower than that of the CWF (3286.00 cP) with an increase in the substitution level.

For PT, the WF + BPF blends (5-30%) required a lower temperature to cook the blends (67.30-66.55 °C, respectively) than did the CWF (68.55 °C). A higher PT would result from delayed swelling and amylase leaching, as observed in this study.

Conclusions

Calcium was the most abundant mineral in the

BPF, followed by K. All the micro-elements were present in small quantities (Fe, Zn and Mn). In terms of TTA and pH, the BPF was found to be lower in pH and slightly acidic. The soluble sugars were present in small quantities in the BPF. A high amount of resistant starch was present in BPF which is beneficial to the human digestive tract. The viscosity of the WF + BPF blends decreased with increased substitution of BPF. The results obtained from the present study indicate that fortification of wheat flour with BPF can meet dietary requirements, especially because of the substantial content of minerals and resistant starch.

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