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Evaluation of Pasting Properties of Plantain, Cooking Banana, Selected Cereals and their Composites as Indicators for their Food Values

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Abstract

The pasting properties of unripe plantain, unripe cooking banana, some selected cereals and their composite flours were investigated in relation to their food values. Each of the samples was cleaned, air–dried and pulverized to form the native flours which were mixed in different proportions to form the composite flours. Soft doughs were prepared from the flours and subjected to textural evaluation. The adjudged best from each set was analysed using Rapid Visco–Analyser followed by determination of their proximate composition and functional properties. The results showed that the breakdown viscosity (cP) of each of the composite flours was less than 920.50 in plantain and 915.50 in cooking banana, indicating improved ability to withstand shear stress. The values of the final viscosity of the composite flours were generally lower than the native flours of plantain and cooking banana which indicated better flow property. The setback viscosities of the composite flours were lower than the native cereal flours except sorghum which indicated lower tendency to undergo retro–degradation. Furthermore, the composite flours gelled at lower temperature (72.1–84.9 °C) when compared with the native flours (82.7–89.2 °C) reflecting less energy requirement for cooking. Combination of cereals with plantain or cooking banana had led to production of composite flours which gave better and improved pasting properties without depreciation in functional properties and nutritional composition.

Keywords: Composite flour; Cereal–plantain; Cereal–cooking banana; Proximate composition; Functional and pasting properties.

Introduction

Pasting is a process that follows gelatinisation and involves granular swelling and leaching of amylose molecules. Different instrumental methods have been employed to study starch pasting properties, however, the Rapid Visco Analyser (RVA), being more sensitive, repeatable and versatile, became the instrument of choice in recent years (Zhang and Hamaker 2005). Usually, food is of plant or animal origin, and their values may be directly related to their nutritional composition and functionalities. Nutritional value, or as part of food quality, is the measure of well–balanced ratio of the essential nutrients, carbohydrates, fat, protein, minerals and vitamins in items of food or diet concerning the nutrient requirements of their consumer. Plantain, cooking banana and cereals are good examples of staple foods. Plantain can be processed into various products such as '*elubo ogede*' (dried half–ripe plantain flour), 'plantain chips' (fried half–ripe plantain pulp) and '*dodo'* (fried sliced ripe plantain pulp) (Akinwumi 1999). Nutrient composition and nutrient retention of processed plantain products have been reported (Adepoju et al. 2012).

It has been reported that plantains (*Musa* AAB) and cooking bananas (*Musa* AAB) are mostly derived from the AA.BB hybridization of *Musa acuminata* (AA) and *Musa balbisiana* (BB) (Robinson 1996). Plantain produces bigger but fewer fruits when compared with banana. In terms of production, cooking banana is less seasonal than plantain (Adeniji et al. 2010). Cooking banana has been used in the production of complementary food and pasta (Almanza–Bentiez et al. 2015). Nutrient composition, functional, and pasting properties of unripe cooking banana, pigeon pea, and sweet potato flour blends have been reported by Ohizua et al. (2017).

Cereal grain is a staple food that provides more food energy worldwide than any other type of crop. It is ideal for diabetics, children and pregnant women, and can also be a good supplement for marasmus patients. Whole–grain cereals have also been reported to be rich in micronutrients which may also have potential antioxidant effects. Maize, sorghum and wheat have been put among the world cultivated cereals (Marquart et al. 2007). Maize, also referred to as corn, is the most staple food for vast majority of Africans and it provides a great source of carbohydrates, protein, vitamins and minerals. The nutritional and mineral compositions of maize and maize products from markets in Kaduna have been reported (Enyisi et al. 2014). Characterization of sorghum grain and evaluation of sorghum flour in a Chinese egg noodle system have been reported (Liu et al. 2012). There has been a report on chemical, functional, pasting and sensory properties of sorghum–maize–mungbean malt complementary food (Onwurafor et al. 2017). Wheat is world's most widely cultivated food crop (Dewettinck et al. 2008). It is an economical means of calories and proteins; it provides almost 341 kcal/100g of wheat (Shewry 2009)

Nigeria has once been reported as the largest plantain–producing country with an average level of consumption of 190 kg/person/year (FAO 2011). Solution has been proffered to perishable nature and deterioration rate of plantain and cooking banana, which will guarantee their durability and reduction in postharvest losses (Falade and Oyeyinka 2014). It is therefore plausible to increase the spectrum of their usage to the benefits of the people. This could be done by preparing their composites with selected cereals (maize, sorghum and wheat) and investigate their nutritional composition, functional as well as pasting properties in relation to their food values. It is expected that, the results from the analysis will possibly reveal enhanced properties from the composite flour which may facilitate the discovery of new and improved nutritional staple food.

Materials and Methods

Sample collection and preparation

Fresh unripe fruits of plantain (*Musa* spp. AAB) and cooking banana (*Musa* spp. AAB or 'Pambo') were obtained from a local market in Osogbo, Osun State, South–western Nigeria. Grains of wheat, maize and sorghum were also bought at the same market. Before peeling, the plantain and cooking banana fruits were washed with distilled water and air–dried. The pulps were sliced, through cross section, into thin chips of about 3 cm, air–dried for seven days, pulverized with a blender and forced through a sieve (625 µm mesh). The cereal grains were washed with distilled water, air–dried, pulverized, and screened through a sieve (625 µm mesh) and kept in clean air–tight containers for analysis. The flours of the plantain, cooking banana and the cereals were collectively referred to as native flours.

Different composite flours were prepared by combining the cereal flours and each of the plantain and cooking banana flours in the ratios of 9:1, 4:1, 7:3, 3:2 and 1:1 with percentages of 90 to 10%, 80 to 20%, 70 to 30%, 60 to 40% and 50 to 50%, respectively. Lower percentages were chosen for the plantain and cooking banana because of the preliminary observation about their high viscosity. Each of the composite flours was prepared into soft dough with distilled water at 100 °C. To 100 mL of boiling distilled water (inside a 500 mL beaker) on a hot plate was added in portion the composite flour. The mixture was agitated continuously for 3 min using clean spatula. The set up was covered and boiled for 2 min, and was immediately removed from the heat source while the agitation continued for another 1 minute. The texture of the soft dough was evaluated by a set of 10 members trained panel in the Department of Food Science and Technology, Osun State University, Osogbo, Nigeria. The soft dough samples were coded with 3–figure random numbers and presented in random order to each panellist at 30 ± 1 °C. The judges were told to score for texture and acceptability using a five point hedonic scale, where 1 and 5 represented dislike extremely and like extremely, respectively. The adjudged best from each set of the cereal–plantain and cereal–cooking banana composite flour dough was selected and subjected to pasting analysis.

Pasting viscosity

The native and the composite flours were analysed for their pasting properties using Rapid Visco–Analyser (RVA, Newport Scientific, Warriewood, Australia) at the central laboratory, University of Ibadan, Nigeria. Pulverized samples of 3.5 g each were weighed and 25 mL of distilled water was dispensed into a canister. Paddle was placed inside the canister and then inserted into the RVA. The measurement cycle was initiated by pressing the motor tower of the instrument. The profile was monitored on a computer connected to the instrument. Thirteen (13) min. profile was used. The time–temperature regime used was: idle temperature for 50 °C for 1 min, heated from 50 °C to 95 °C in 3 min 45 sec, then held at 95 °C for 2 min 30 sec; the sample was subsequently cooled to 50 °C over a period of 3 min 45 sec followed by a period of 2 min while the temperature was controlled at 50 °C.

Proximate composition of the flours was determined using methods detailed in Adebowale et al. (2013), while the functional properties were determined using methods described by Falade and Okafor (2015).

Statistical analysis

The data were subjected to descriptive statistics and one way analysis of variance (ANOVA). Duncan’s multiple range test (IBM SPSS Statistics 20) was used to determine the level of significance ($P < 0.05$). Results were expressed as mean ± standard deviation.

Results and Discussion

The sensory evaluation panel

The scores obtained for the sensory evaluation study are as shown in Table 1. For the maize–plantain (M–P) composite, the score for the composite at a ratio of 3:2 was significantly higher than other ratios with a value of 4.8. Wheat–plantain (W–P) and wheat–cooking banana (W–CB) shared the same results with maize–plantain composite. However, the score for each of the maize–cooking banana (M–CB), sorghum–plantain (S–P) and sorghum–cooking banana (S–CB) composites were significantly higher at ratio 1:1 ($P < 0.05$) and better than the other four ratios (9:1, 4:1, 7:3 and 3:2).

Table 1: *Sensory scores for the cereal plantain/cooking banana composite flours

Samples	Ratio of cereal to plantain/cooking banana				
	9:1	4:1	7:3	3:2	1:1
Maize–Plantain	1.2^{a}	1.1^{a}	1.4^{a}	4.8^{b}	1.2^{a}
Maize–Cooking banana	2.1^{a}	2.2^{a}	2.2^{a}	2.2^{a}	4.8^{b}
Sorghum–Plantain	2.3^{a}	1.1^{a}	2.3^{a}	2.3^{a}	4.8^{b}
Sorghum–Cooking banana	2.2^{a}	2.2^{a}	2.2^{a}	2.2^{a}	4.8^{b}
Wheat–Plantain	1.2^{a}	1.1^{a}	1.1^{a}	4.7^{b}	1.2^{a}
Wheat–Cooking banana	2.3^{a}	2.3^{a}	2.3^{a}	4.8^{b}	2.3^{a}

Values are presented as mean ± SD (n = 10 adult staff of FST Department); $^{a-b}$Means followed by the same letters on the same row are not significantly different (P < 0.05); *Interpretation of scores: 1 = dislike extremely; 2 = dislike moderately; 3 = indifferent; 4 = like moderately; 5 = like extremely; **SD**: Standard Deviation; **FST**: Food Science and Technology.

Pasting properties of the flours

The results of the pasting properties of the native and composite flours are as shown in Tables 2 and 3, respectively. The values of the parameters determined for the native and composite flours were significantly different except the peak time for the composite flours. The peak viscosity, the trough viscosity and the pasting temperature (°C) of 886.16–2013.00, 846.13–1484.50 and 72.05–84.91 in the composite flours were within the range obtained for the values obtained in the native flour; all the values were significantly different at P < 0.05 indicating difference in the properties of the composite and native flours. Conversely, the breakdown viscosity, the set back viscosity and the peak time obtained for the native flours were within the range obtained in the composite flours and were significantly different at P < 0.05. Thus, the pasting properties of the composite and native flours were different.

Proximate composition of the flours

The results of the proximate composition of the native and composite flours were as shown in Tables 4 and 5, respectively. The parameters determined for the proximate composition of both the native and composite flours were significantly different at P < 0.05 indicating the values were not the same for each parameter. The proximate compositions of the native flours are comparable with available reports in the literature (Falade and Oyeyinka 2014, Jocelyne et al. 2020). The ash and protein contents of the composite flours were within the range of 1.26% to 2.98% and 4.06% to 10.03%, respectively in the native flours. The moisture content of the composite flours were within the range of 7.42–10.03% in the native flour except wheat–cooking banana which could be attributed to higher moisture contents recorded in the cooking banana flour. The upper limit of the level of lipid in the composite flour was higher than the value obtained in the native flour. The upper limit of the fibre in the composite flour was higher than that of the native flour. The lower limit of the protein content in the composite flour was higher than the lower limit of the native flours. However, the upper limit of the protein is approximately 10% in each of the composite and native flours. More importantly, the lower and the upper limits of the carbohydrate in the composite flours were less than 74.61% and 79.86%, respectively in the native flour. Thus, high levels of fibres, lipid and protein, and low level of carbohydrates in the composite flours underscore their food values.

Table 2: Pasting properties of the native flours

Parameters	Native flours				
	Plantain	Cooking banana	Maize	Sorghum	Wheat
Peak (cP)	3253.50 ± 47.92^{d}	3243.50 ± 28.29^{d}	1177.50 ± 14.43^{b}	741.00 ± 23.09^{a}	1471.00 ± 20.78^{c}
Trough (cP)	2333.00 ± 35.80^{d}	2328.50 ± 96.42^{d}	1016.50 ± 61.78^{c}	656.50 ± 20.21^{a}	889.50 ± 13.28^{b}
Breakdown (cP)	920.50 ± 83.72^{d}	915.00 ± 68.13^{d}	161.00 ± 47.34^{b}	84.50 ± 37.53^{a}	581.50 ± 7.51^{c}
Final Ƞ (cP)	3503.50 ± 16.74^{d}	3654.00 ± 48.50^{e}	3363.50 ± 31.75^{c}	2618.50 ± 37.53^{b}	2086.00 ± 16.17^{a}
Setback (cP)	1170.50 ± 19.05^{a}	1325.00 ± 47.92^{b}	2347.00 ± 30.02^{d}	1962.00 ± 17.32^{c}	1196.50 ± 2.89^{a}
Peak time (min)	5.13 ± 0.08^{a}	5.13 ± 0.00^{a}	5.50 ± 0.04^{b}	5.53 ± 0.08^{b}	5.83 ± 0.04^{c}
P T (°C)	82.68 ± 0.49^{a}	82.68 ± 0.43^{a}	83.95 ± 0.92^{b}	88.85 ± 0.00^{c}	89.23 ± 0.49^{c}

Values are means ± SD of triplicate determinations; $^{a-e}$Means followed by the same letters on the same row are not significantly different ($P < 0.05$); **SD**: Standard Deviation; **PT**: Pasting temperature.

Table 3: Pasting properties of the composite flours

Parameters	Composite flours with their ratios					
	M–P (Ratio 3:2)	M–CB (Ratio1:1)	S–P (Ratio 1:1)	S–CB (Ratio 1:1)	W–P (Ratio 3:2)	W–CB Ratio 3:2)
Peak (cP)	2013.00 ± 3.46^{f}	1652.50 ± 32.91^{c}	886.16 ± 18.91^{a}	1119.39 ± 167.27^{b}	1851.00 ± 258.65^{d}	1929.50 ± 76.79^{e}
Trough (cP)	1484.50 ± 43.30^{e}	1270.00 ± 16.17^{d}	846.13 ± 29.47^{a}	917.23 ± 139.27^{b}	1181.50 ± 230.36^{c}	1186.50 ± 49.07^{c}
Breakdown (cP)	528.50 ± 46.76^{d}	382.50 ± 16.74^{c}	311.12 ± 31.57^{b}	192.68 ± 28.00^{a}	669.50 ± 28.29^{e}	743.00 ± 27.71^{f}
Final viscosity (cP)	3268.50 ± 8.66^{e}	2907.00 ± 54.27^{d}	2470.93 ± 29.79^{b}	2615.49 ± 28.20^{c}	2134.00 ± 140.87^{a}	2140.00 ± 41.57^{a}
Setback (cP)	1784.00 ± 51.96^{d}	1637.00 ± 38.10^{c}	1465.95 ± 45.30^{b}	1998.1 ± 48.05^{e}	952.50 ± 89.49^{a}	953.50 ± 7.51^{a}
Peak time (min)	5.07 ± 0.00^{a}	5.33 ± 0.23^{a}	5.21 ± 0.32^{a}	5.00 ± 0.18^{a}	5.33 ± 0.23^{a}	5.17 ± 0.12^{a}
PT (°C)	81.90 ± 0.46^{c}	82.3 ± 0.95^{c}	84.91 ± 0.71^{d}	79.22 ± 6.45^{b}	83.08 ± 0.03^{c}	72.05 ± 12.87^{a}

Values are means ± SD of triplicate determinations; $^{a-f}$Means followed by the same letters on the same row are not significantly different ($P < 0.05$); **SD**: Standard Deviation; **M–P**: Maize–Plantain, **M–CB**: Maize–Cooking banana, **S–P**: Sorghum–Plantain, **S–CB**: Sorghum–Cooking banana, **W–P**: Wheat–Plantain, **W–CB**: Wheat–Cooking banana, **PT**: Pasting temperature.

Table 4: Proximate composition of the native flours

Sample	Parameters					
	Moisture Content (%)	Ash Content (%)	Total lipid (%)	Fibre (%)	Protein (%)	Carbohydrate (%)
Plantain	9.91 ± 0.02^{c}	2.98 ± 0.01^{d}	2.59 ± 0.01^{ab}	2.88 ± 0.01^{d}	4.06 ± 0.01^{a}	77.58 ± 0.01^{c}
Cooking banana	10.03 ± 0.01^{c}	2.79 ± 0.01^{d}	2.54 ± 0.01^{ab}	2.76 ± 0.01^{d}	4.15 ± 0.01^{a}	77.73 ± 0.02^{c}
Maize	9.31 ± 0.01^{bc}	1.80 ± 0.02^{c}	2.27 ± 0.01^{a}	1.71 ± 0.61^{c}	9.84 ± 0.02^{c}	75.07 ± 0.02^{b}
Sorghum (red)	7.42 ± 0.01^{a}	1.62 ± 0.01^{b}	1.22 ± 0.01^{a}	1.11 ± 0.01^{a}	8.77 ± 0.01^{b}	79.86 ± 0.01^{d}
Wheat	8.24 ± 0.01^{b}	1.26 ± 0.01^{a}	2.95 ± 0.03^{c}	1.36 ± 0.01^{b}	10.03 ± 0.01^{d}	74.61 ± 0.02^{a}

Values are means ± SD of triplicate determinations, $^{a-d}$Means followed by the same letters on the same column are not significantly different ($P < 0.05$), **SD**: Standard Deviation.

Table 5: Proximate composition of the composite flours

Composites	Moisture content (%)	Ash content (%)	Total lipid (%)	Fibre (%)	Protein (%)	Carbohydrate (%)
M–P	8.32 ± 0.02[a]	2.14 ± 0.01[a]	4.40 ± 0.01[c]	2.70 ± 0.01[ab]	6.13 ± 0.01[a]	76.33 ± 0.01[d]
M–CB	8.43 ± 0.02[a]	1.97 ± 0.009[a]	3.22 ± 0.01[b]	2.80 ± 0.01[ab]	7.22 ± 0.01[b]	76.38 ± 0.01[d]
S–P	8.44 ± 0.01[a]	2.98 ± 0.01[ab]	3.05 ± 0.01[b]	3.21 ± 0.01[c]	7.13 ± 0.01[b]	75.21 ± 0.01[c]
S–CB	9.62 ± 0.02[b]	1.77 ± 0.01[a]	6.36 ± 0.02[d]	3.11 ± 0.01[c]	8.23 ± 0.02[c]	70.98 ± 0.01[a]
W–P	9.72 ± 0.01[b]	2.64 ± 0.01[ab]	1.75 ± 0.01[ab]	2.00 ± 0.01[a]	9.63 ± 0.01[d]	74.29 ± 0.01[b]
W–CB	10.42 ± 0.02[c]	1.86 ± 0.01[a]	1.22 ± 0.01[a]	2.21 ± 0.01[a]	9.96 ± 0.01[d]	74.36 ± 0.01[b]

Values are means ± SD of triplicate determinations**;** [a-d]Means followed by the same letters on the same column are not significantly different (P < 0.05)**, SD**: Standard Deviation**, M–P**: Maize–Plantain, **M–CB**: Maize–Cooking banana, **S–P**: Sorghum–Plantain, **S–CB**: Sorghum–Cooking banana**, W–P**: Wheat – Plantain, **W–CB**: Wheat–Cooking banana

Functional properties of the flours

The results of the functional properties of the flours are as shown in Table 6 and Table 7, respectively. The functional properties of both the native and composite flours were all significantly different at P < 0.05 except oil absorption capacity. This indicated that the values were not the same. The water absorption capacities of the composite flours were within the values obtained in the native flours except wheat–cooking banana. The oil absorption capacities of both the native and composite flours were not significantly different at P < 0.05 justifying that the values were all the same. The lower and the upper limits of the range of dispersibility and emulsion capacity in the composite flours were higher than those of the native flours. This reflects an improvement in the dispersibility and emulsion capacities of the composite flours. The pH and foaming capacities of the composite flours were within the range obtained in the native flours. The swelling capacities of the composite flours were within the range of the values recorded in the native flours except sorghum–cooking banana and wheat–plantain representing the lower and upper limits, respectively in the composite flours. The bulk density of each of the composite flour was in the range obtained in the native flour except sorghum–plantain composite flour with a higher value.

Table 6: Functional properties of the native flours

Samples	WAC (g/mL)	OAC (g/mL)	Dispersibility (%)	pH	Foaming Capacity (%)	Emulsion capacity (%)	Swelling capacity (%)	Bulk density (g/mL)
Plantain	1.28 ± 0.03[b]	0.91 ± 0.04[a]	68.00 ± 1.73[a]	6.20 ± 0.03[b]	4.10 ± 0.00[a]	38.94 ± 0.66[ab]	4.50 ± 0.21[c]	0.72 ± 0.13[c]
CB	1.25 ± 0.02[b]	1.10 ± 0.01[a]	66.67 ± 3.21[a]	4.50 ± 0.03[a]	3.92 ± 0.02[a]	36.64 ± 0.02[b]	3.16 ± 0.04[a]	0.61 ± 0.02[b]
Maize	1.58 ± 0.08[c]	1.10 ± 0.04[a]	73.00 ± 2.65[b]	6.90 ± 0.01[b]	10.12 ± 0.41[d]	38.61 ± 0.22[ab]	4.10 ± 0.20[c]	0.44 ± 0.12[a]
Sorghum	1.61 ± 0.05[c]	0.97 ± 0.01[a]	72.33 ± 2.52[b]	6.60 ± 0.02[b]	5.92 ± 0.08[b]	43.15 ± 0.08[c]	3.67 ± 0.11[b]	0.46 ± 0.02[a]
Wheat	0.67 ± 0.29[a]	0.79 ± 0.01[a]	68.34 ± 2.84[a]	6.50 ± 0.02[b]	8.10 ± 0.21[c]	26.13 ± 0.12[a]	3.11 ± 0.71[a]	0.56 ± 0.01[b]

Values are means ± SD of triplicate determinations, [a-d]Means followed by the same letters on the same row are not significantly different (P < 0.05), **SD**: Standard Deviation; **WAC**: Water Absorption Capacity; **OAC**: Oil Absorption Capacity; **CB**: Cooking banana.

Table 7: Functional properties of the composite flours

Composite	WAC (g/mL)	OAC (g/mL)	Dispersibility (%)	pH	Foaming capacity (%)	Emulsion capacity (%)	Swelling capacity (%)	Bulk density (g/mL)
M– P	1.35 ± 0.02[a]	1.11 ± 0.03[a]	73.00 ± 2.16[b]	6.72 ± 0.02[b]	5.59 ± 0.02[a]	44.33 ± 0.03[a]	3.68 ± 0.02[ab]	0.74 ± 0.00[ab]
M – CB	1.50 ± 0.05[b]	0.96 ± 0.02[a]	74.67 ± 2.49[c]	6.44 ± 0.03[ab]	5.80 ± 0.01[a]	43.32 ± 0.02[a]	3.15 ± 0.03[a]	0.71 ± 0.00[ab]
S – P	1.16 ± 0.02[a]	1.16 ± 0.03[a]	73.67 ± 2.05[c]	6.70 ± 0.01[b]	7.34 ± 0.01[ab]	45.33 ± 0.03[b]	5.24 ± 0.03[c]	0.77 ± 0.00[c]
S – CB	1.36 ± 0.02[a]	1.06 ± 0.02[a]	72.67±1.70[b]	6.17 ± 0.02[a]	6.60 ± 0.02[a]	44.04 ± 0.06[a]	2.75 ± 0.02[a]	0.69 ± 0.01[ab]
W –P	1.45 ± 0.05[ab]	1.06 ± 0.02[a]	73.33 ± 1.25[b]	6.36 ± 0.03[ab]	7.69 ± 0.01[b]	44.23 ± 0.32[a]	5.47 ± 0.02[c]	0.74 ± 0.00[ab]
W–CB	1.76 ± 0.03[b]	0.96 ± 0.03[a]	69.67 ± 1.70[a]	6.07 ± 0.10[a]	6.56 ± 0.03[ab]	44.67 ± 0.02[b]	3.41 ± 0.03[a]	0.64 ± 0.02[a]

Values are means ± SD of triplicate determinations, [a-c]Means followed by the same letters on the same row are not significantly different (P < 0.05), **SD**: Standard Deviation, **WAC**: Water Absorption Capacity; **OAC**: Oil Absorption Capacity, **M–P**: Maize–Plantain, **M–CB**: Maize–Cooking banana, **S–P**: Sorghum–Plantain, **S–CB**: Sorghum–Cooking banana, **W–P**: Wheat – Plantain, **W–CB**: Wheat–Cooking banana

Correlation of the pasting properties of the composite flours with their proximate composition and functional properties

The results of the pasting properties of the native and composite flours are as shown in Tables 2 and 3, respectively; the correlation matrix between the pasting properties and functional properties of the composite flours are as shown in Table 8, while the correlation matrix between the pasting properties and proximate composition of the composite flours are as shown in Table 9. Each composite flour is a potential staple food based on the outcome of the decision of the panels that adjudged ratios 3:2 (maize–plantain), 1:1 (maize–cooking banana), 1:1 (sorghum– plantain), 1:1 (sorghum–cooking banana), 3:2 (wheat–plantain) and 3:2 (wheat–cooking banana) the best for each set of composite from different preparations.

The peak viscosities of the composite flours ranged from 886.16 cP (sorghum–plantain) to 2013.00 cP (maize–plantain) and were significantly different at P < 0.05, indicating that the values were not the same. The peak viscosity of the composite flours showed strong significant correlations with trough viscosity (r = 0.90), breakdown viscosity (r = 0.82) and water absorption capacity (r = 0.67). However, negative correlation was observed between the peak viscosity and fibre content (r = –0.80). Lower peak viscosity of sorghum–plantain could be traced to the viscosity of the sorghum flour that had the least viscosity among the five native flours, while higher viscosity of the composite flour of maize–plantain could be traced to higher viscosity of the native plantain flour. Thus, maize–plantain had the strongest ability to form gel, while sorghum–plantain had the weakest. Peak viscosity has also been reported to be useful in determining the viscous load to be encountered during processing (Maziya–Dixon et al. 2004). Comparison of the peak viscosity of the native (Table 2) and the composite (Table 3) flours showed that the peak viscosity of each of the plantain and cooking banana reduced after combining with the cereals to produce the composite flours. So, the viscosity load encountered during processing of the composite flour was lower than the value encountered when processing the native flour.

The trough viscosity of the composite flour ranged from 846.13 cP in sorghum–plantain to 1484.50 cP in maize–plantain. The values were significantly different at $P < 0.05$. The trough viscosity showed a slight correlation ($r = 0.61$) with the carbohydrate content of the composite flour. Indeed, after combining the cereals with the plantain and the cooking banana, the trough viscosity of the composite was observed to be lower than the trough viscosity of the native plantain and cooking banana flours. This indicated that combination of the cereal with the plantain or the cooking banana has brought about stability in the starch gels of the plantain and the cooking banana.

The breakdown viscosities of the composite flours ranged from 192.68 cP in sorghum–cooking banana) to 743 cP in wheat–cooking banana, and were significantly different at $P < 0.05$. The breakdown viscosity exhibited some correlation ($r = 0.68$) with water holding capacity. Nevertheless, negative correlation was observed between the breakdown viscosity ($r = –0.93$) and fibre content. The values of the breakdown viscosity of the composite flours were generally lower than the breakdown viscosity of the native plantain and the cooking banana flours; thus, the starch granules in the composite flours have stronger ability to withstand heating/shear stress during processing (Adebowale et al. 2005).

The final viscosity of the composite flours ranged from 2134.00 cP (wheat–plantain flour) to 3268.50 cP (maize–plantain). The values were significantly different at $P < 0.05$ indicating variations among the composite flours. The final viscosity showed a high significant correlation ($r = 0.78$) with setback viscosity and negative correlations with moisture ($r = –0.78$) and protein ($r = –0.90$) contents. The final viscosities of the composite flours were generally lower than the native flours of plantain and the cooking banana which indicated a concordance with the objective of the study

The setback viscosity of the composite flours ranged from 952.50 cP (wheat–plantain) to 1998.10 cP (sorghum–cooking banana) and the values were significantly different at $P < 0.05$. The setback viscosity showed a strong significant correlation with a total lipid ($r = 0.95$) and fibre ($r = 0.81$). It however exhibited negative correlation with the protein content ($r = –0.75$). The composite flours had setback viscosities which were generally lower than the native flours of plantain and the cooking banana which indicated easy digestibility and low rates of starch retrogradation (Leon et al. 2010).

The peak time (min) for the pasting of the composite flours ranged from 5.00 in sorghum–cooking banana to 5.33 in each of maize–cooking banana and wheat–plantain composite flours. The values of the peak time for the composite flours were not significantly different at $P < 0.05$. The peak time showed negative correlation with pH ($r = –0.69$) and total lipid ($r = –0.70$). The peak times of the composite flours were not significantly different from values of the peak time for the native plantain and the cooking banana flours, indicating that the same time would be needed to cook the native plantain and cooking banana flours as well as their composites with cereals.

The pasting temperature of the composite flour ranged from 72.05 °C in wheat–cooking banana to 84.91 °C in sorghum–plantain. There was strong significant correlation between pasting temperature and dispersibility ($r = 0.92$) and bulk density ($r = 0.95$). Negative correlation was however observed between pasting temperature and water absorption capacity ($r = –0.84$) and moisture content ($r = –0.77$). The pasting temperatures for the native plantain and the cooking banana as well as their composites were significantly different ($P < 0.05$). Therefore, the wheat–cooking banana, sorghum–cooking banana and the maize–cooking banana will be cooked at slightly lower temperature which is more economical in terms of energy consumption. Maize–plantain composite flour will be cooked at the same temperature as the native plantain flour, while sorghum–plantain and wheat–plantain will be cooked at slightly higher temperatures.

Table 8: The correlation matrix between pasting properties and functional properties of the composite flours

	Peak η	Trough η	Breakdown η	Final η	Setback η	Peak Time	PT	WAC	OAC	Dispersib.	pH	FC	EC	SC	BD
Peak η	1														
Trough η	*0.90	1													
Breakdown η	*0.82	0.55	1												
Final η	0.11	0.51	-0.40	1											
Setback η	-0.41	-0.06	-0.80	*0.78	1										
Peak time	0.20	0.12	0.37	-0.33	-0.61	1									
Pasting temperature	-0.38	-0.11	-0.50	0.35	0.31	0.31	1								
WAC	*0.67	0.40	*0.68	-0.36	-0.53	0.17	-0.84	1							
OAC	-0.49	-0.32	-0.4	0.20	0.29	-0.31	0.64	-0.89	1						
Dispersibility	-0.32	-0.02	-0.60	0.47	0.45	0.37	*0.92	-0.67	0.32	1					
pH	-0.54	-0.59	-0.40	-0.18	0.24	-0.69	0.04	-0.51	*0.70	-0.22	1				
Foaming capacity	0.30	0.46	-0.20	0.51	0.45	0.06	0.33	-0.04	-0.21	0.56	-0.34	1			
Emulsion capacity	-0.35	-0.45	0.11	-0.37	-0.31	-0.20	-0.01	-0.32	0.63	-0.37	0.62	-0.87	1		
Swelling capacity	-0.11	-0.20	0.28	-0.43	-0.56	0.52	0.54	-0.40	0.54	0.23	0.18	-0.32	0.56	1	
Bulk density	-0.33	-0.09	-0.30	0.30	0.19	0.23	*0.95	-0.87	*0.80	0.76	0.18	0.12	0.26	*0.68	1

η: Viscosity; PT: Pasting temperature; **WAC**: Water absorption capacity; **OAC**: Oil absorption capacity; **Dispersib.**: Dispersibility, **FC**: Foaming capacity; **EC**: Emulsion capacity, **SC**: Swelling capacity; **BD**: Bulk density.

Table 9: The correlation matrix between pasting properties and proximate composition of the composite flours

	Peak Visc.	Trough Visc.	Breakdown Visc.	Final Visc.	Setback Visc.	Peak time	Pasting Temp	Moist.	Ash	Total lipid	Fibre	Protein	Carbohyd.
Peak Visc.	1												
Trough Visc.	*0.90	1											
Breakdown Visc.	*0.82	0.55	1										
Final Visc.	0.10	0.51	-0.4	1									
Setback Visc.	-0.41	-0.06	-0.84	*0.78	1								
Peak time	0.2	0.12	0.37	-0.33	-0.61	1							
Pasting Temp	-0.38	-0.11	-0.45	0.35	0.31	0.31	1						
Moisture	0.23	-0.19	0.49	-0.78	-0.57	-0.10	-0.77	1					
Ash	-0.34	-0.32	0.01	-0.25	-0.33	0.44	*0.68	-0.34	1				
Total lipid	-0.44	-0.18	-0.81	0.60	*0.95	-0.70	0.23	-0.34	-0.34	1			
Fibre	-0.80	-0.49	-0.93	0.49	*0.81	-0.40	0.39	-0.59	0.05	*0.72	1		
Protein	0.22	-0.22	0.55	-0.90	-0.75	0.24	-0.60	*0.94	-0.12	-0.60	-0.70	1	
Carbohydrate	0.42	0.61	0.34	0.41	-0.18	0.53	0.31	-0.61	0.31	-0.50	-0.10	-0.46	1

Visc.: Viscosity; Carbohyd.: Carbohydrate; Moist.: Moisture; Temp.: Temperature.

Conclusion

It was established in this study that, the composite flours exhibited lower peak, trough, breakdown, final and setback viscosities in comparison with the native plantain and cooking banana flours which indicated lower viscosity load, improved starch stability, better flow properties, better ability to withstand heat/stress and lower tendency to undergo retro–degradation, respectively. The pasting temperature of the composite flour was also observed to be lower than the native flours which reflected lower energy requirement for cooking. Thus, the combination of the cereals with plantain or cooking banana had led to the production of composite flours which gave better and improved pasting properties.

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