GREEN PLANTAIN AND WHOLE WHEAT FLOUR BLENDS: PHYSICOCHEMICAL PROPERTIES OF FLOUR AND SENSORY QUALITY OF COOKED PORRIDGE

Adebowale O.J. [1*], Oladele A.K. [2]. And Fadairo O. S. [3]
[1]Department of Food Technology, The Federal Polytechnic, P.M.B. 50, Ilaro, Nigeria
[2]Department of Food Technology, Federal College of Freshwater Fisheries Technology, P.M.B. 1500, New Bussa, Nigeria
[3]Department of Food Safety and Quality Engineering, Institute of Food Science and Technology, University of Debrecen, Hungary
*Corresponding Author E-mail: jimiolalekan@gmail.com,; +234 803 538 3189)

ABSTRACT

Green plantain flour was substituted with whole wheat flour at 20, 40, 50, 60, 80, 100%. Physicochemical properties of flour blends and sensory quality of cooked porridge of the flours was investigated. Bulk density (0.64-0.83 g/L), water absorption (1.43-1.68 g/g), water solubility (6.71-12.4%), swelling (38.4-43.1) and browning indexes (47.7-64.8) increased significantly ($p<0.05$) with an increase in whole-wheat flour inclusion (0, 20, 40, 50, 60, 80, 100%). The control (100 % green-plantain flour) was lighter in colour ($L^* = 65.3$) than composited flours (35.1-52.3) while chroma (12.5-12.8) and hue angle (85.6-89.4) values were significantly higher in composited flours than the control. The fibre content increased from 6.22 to 8.21% as the levels of whole-wheat flour increased with a concomitant decrease in the carbohydrate and energy value contents. No significant differences were observed with brownness, taste and aroma but the texture and overall acceptability scores of porridges showed a mixed pattern. Consequently, compositing flours from green plantain with whole-wheat at 60:40 blend seems to be a sustainable way to improving the nutritional quality of the porridge.

Keywords: Composite flour, proximate composition, sensory properties,

INTRODUCTION

Over-nutrition diets have been linked to an increase in severe diseases such as obesity, type-2-diabetes and constipation (Adeniji, 2015). Further, child overweight and adult obesity are on the rise, especially in low and middle-income countries (FAO, 2017). In line with this, the FAO 2nd Sustainable Development Goal (SDG2) implores on countries of the world to "*end hunger, achieve food security and improve nutrition and promote sustainable agriculture*" by 2030. Speciality diets can be formulated from readily available raw materials within the locality for individuals having challenges with health-related diseases such as diabetes and obesity.

Most diabetics are placed on flour from whole-wheat grain (in case they must eat solid or calorie foods) with vegetables and are to desist from taking energy-dense food products. However, whole-wheat grain attracts huge foreign exchange in sub - Saharan Africa due to high importation cost (Adebowale, Ajayi, &Ibikunle, 2013). Meanwhile, some other crops including green plantain also possess some of the qualities of whole grains.

Plantain (*Musa paradisiaca*) remains the World's largest fruit crop is ranked as one of the most important sources of nutrition for people living in the humid tropic areas (Aurore, Parfait &Fahrasmane, 2009). Green-plantain flour is a good source of dietary fibre (Choo & Aziz, 2010) and contains a high amount of slowly digestible starch with a low glycemic index. It also has a high content of resistant starch in addition to dietary fibre (Ayodele & Godwin, 2010). The low glycemic index of green plantain implies that its carbohydrate could make an ideal food for diabetics by regulating blood sugar (David-Barine&Yorte, 2016). In addition, plantain is cheap and readily available particularly in the Southern region of Nigeria (Akubor&Ishiwu, 2013).

Many functional and health-promoting foods with high fibre content have been formulated using green plantain flour. These include biscuit (Adebowale et al., 2013), noodles (Choo & Aziz, 2010), pasta (Ovando-Martinez, Sáyago-Ayerdi, Agama-Acevedo, Goñi, & Bello-Pérez, 2009), cake (Akubor&Ishiwu, 2013) and bread (Juarez-Garcia, Agama-Acevedo, Sàyago-Ayerdi, Rodreguez-Ambriz, & Bello-Perez, 2006). A composited flour utilizing green plantain and whole-wheat flours would likely provide a sustainable nutritional, acceptable and affordable quality product.

Attempts to improve the nutritional profile have been directed to reducing fats, increase crude fibre and protein content of the resultant porridges prepared from green-plantain and whole-wheat flour blends. Adequate information on the partial replacement of green plantain with whole-wheat flour for the development of porridge is most likely missing.

To the best of our knowledge, there have been relatively few studies on the effects of compositing green plantain flour with whole-wheat flour on functionality and nutritional quality of the flours, and cooked-porridge sensory quality. The study evaluated the effects of compositing flours of green-plantain and whole-wheat on functional, nutritional properties and sensory quality of cooked-porridge

MATERIALS AND METHODS

Sample collection

Matured, hard green plantain (*MusaAAB*) fruits and whole-wheat grains were purchased from a retail main market in Abeokuta, Nigeria. All the reagents used in this study were of analytical grade from Merck (Pty) Limited, Kenilworth, New Jersey, USA).

Preparation of plantain flour

Plantain flour was produced using the method described by (Adebowale et al., 2013) with modifications using citric acid solution. Green-plantain fruits were washed with tap water to remove dirt, peeled and cut manually into 1 cm slices; and instantly rinsed in a citric acid solution (0.3 % w/v) to prevent browning. Slices were dried at 50 °C overnight in a cabinet dryer; ground using a hammer mill (Falling Number 1900, Perten Instrument AB, KungensKurva, Sweden) fitted with a 500 µm opening screen, vacuum-packed and stored at -20 °C prior to analyses.

Preparation of whole-wheat flour

Whole-wheat grains were sorted to remove extraneous materials; ground using a laboratory hammer mill (Falling Number 1900, Perten Instrument AB, KungensKurva, Sweden) fitted with a 500 µm opening screen, vacuum-packed and stored at -20 °C prior to analyses.

Formulation of green plantain and whole wheat flour blends

Blends of green plantain and whole wheat flour composite were prepared by substituting the green plantain with whole wheat flours at 0, 20, 40, 50, 60 and 100 % (w/w). After weighing, the blends were mixed manually with a turning stick before they were used for the preparation of porridges and analyses.

Preparation of porridge

One part by weight of flour was mixed with six parts by volume of water (Nantanga, Seetharaman, de Kock &Taylor, 2008). Flour-water suspension was instantly heated with gradual stirring until it began to boil and was kept boiling for 3 min till the porridge is ready.
Analyses

Proximate analysis

Moisture, crude protein, ash, crude fat and crude fibre contents of flour samples were determined according to a method of the AACC (2000). Moisture was determined using the hot-air oven. Ground samples (2-3 g) were dried at 103 °C for 3 h, and the percentage weight loss was calculated. Protein (N x 6.25), ash, crude fibre and fat contents were calculated on. Carbohydrate was calculated by difference [100 – (sum of moisture, ash, fat, protein and fibre contents)]. The energy value was calculated using the Atwater calorie conversion factor: 4 kcal/100 g of carbohydrate, 9 kcal/100 g of fat and 4 kcal/100 g of protein.

Color of flour

This was measured with the tristimulus colorimeter (CR-400C model, MINOLTA, Osaka, Japan) standardized with a white tile, based on the manufacturer's instruction. Parameters measured were expressed in terms of lightness (L*) from black (0) to white (100); redness (a*); yellowness or blueness (b*) and browning indexes (100 – *L**). Indications of the surface colour (Hue value, *h*) and colour intensity (Chroma, C) were calculated as described by (Avanza, Chaves, Acevedo, &Añón, 2012).

Bulk density of flour

This was determined by a volumetric displacement procedure described by (Meng, Threinen, Hansen, &Driedger, 2010). Flour samples were weighed (g) and put in a 1 litre beaker and then samples were added to fill up the beaker. Samples were taken out, and then the volume of the sample was measured.

Water absorption, water solubility and swelling indexes

Into a 50 ml centrifuge tube, 2.5 g sample was dispersed in 30 ml of distilled water at 30 °C, incubated in a shaking water bath for 30 min at 30 °C and vortexed at 5 min interval. The content was centrifuged (4500 rpm) for 15 min and the supernatant was decanted into moisture tin of known weight and dried (100 °C) overnight. The water absorption index was recorded as the weight of gel (g) obtained per gram of dry ground sample. The amount of dry solid recovered after evaporating the supernatant in an oven was expressed as dry solid in 2.5 g sample and defined as water solubility index (Gujral& Singh, 2002).

The swelling index was determined according to Abu, Muller, Duodu and Minnaar (2005). The sample was dispersed in de-ionized water (1:20 w/v), vortexed for 1 min and heated in a water bath at 90 °C for 30 min followed by intermittent mixing. The heated samples were cooled for 30 sec under running water and for 10 min in an ice bath to accelerate gel formation. The tube containing the gel was centrifuged (4500 x g, 20 °C) for 10 min. The sample was left to stand for 5 min at 25 °C. The supernatant was decanted, and the residue weighed. The swelling index was calculated as the ratio of the weight of the final residue to the initial sample weight.

Sensory evaluation of cooked porridge

A sensory panel of 65 untrained panellists (34 females and 31 males) between the ages of 18 to 32 years, who were eager to the consumer the porridge and did not have any food allergies was arranged for the evaluation sessions. The panellists had prior experience of food sensory evaluation. The panellists were screened for sensory acuity using basic sensory tests. The emphasis was on sensory differences, especially about attributes including colour, taste, aroma, texture and overall acceptability. The scoring of the perceived intensity was made on a 9-point category scale from 1 (extremely dislike) to 9 (extremely like), to evaluate the acceptance of porridges. Evaluation of the porridges was repeated three times at room temperature 25 ± 2 °C under fluorescent light equivalent to daylight. Purified water was provided for the panellists to clean their palates between samples.

2.5.6 Statistical analysis

Data were expressed as means ± standard deviation of three replications, with one-way analysis of variance. Means were compared by Fisher's least significant difference (LSD) test ($p < 0.05$). Pearson's correlation matrix and principal component analysis were carried out using XLSTAT® (Addinsoft^{TM}, New York, US).

RESULTS AND DISCUSSION

Table 1. Proximate Composition (% Dry Weight Basis) Of Green Plantain, Whole Wheat And Composite Flour Blends

Parameters	Flour blending ratios					
	100P:0W	80P:20W	60P:40W	40P:60W	50P:50W	0P:100W
Moisture	$9.71^{ef}\pm0.21$	$9.97^{e}\pm0.11$	$10.3^{d}\pm0.21$	$10.73^{bc}\pm0.28$	$11.1^{ab}\pm0.21$	$11.29^{a}\pm0.23$
Ash	$6.64^{f}\pm0.25$	$7.01^{e}\pm0.22$	$7.50^{d}\pm0.21$	$7.79^{c}\pm0.11$	$8.11^{b}\pm0.31$	$8.29^{a}\pm0.13$
Protein	$3.37^{f}\pm0.24$	$5.59^{e}\pm0.24$	$7.33^{d}\pm0.23$	$7.99^{c}\pm0.21$	$8.66^{b}\pm0.33$	$9.23^{a}\pm0.32$
Crude fat	$0.26^{f}\pm0.12$	$0.57^{e}\pm0.14$	$0.83^{d}\pm0.11$	$1.07^{c}\pm0.12$	$1.29^{b}\pm0.11$	$1.54^{a}\pm0.27$
Crude fiber	$6.22^{f}\pm0.11$	$6.79^{e}\pm0.26$	$7.29^{d}\pm0.21$	$7.79^{c}\pm0.31$	$8.21^{b}\pm0.21$	$8.79^{a}\pm0.28$
Carbohydrate	$80.1^{a}\pm0.21$	$76.19^{ab}\pm0.11$	$72.01^{bc}\pm0.22$	$68.03^{d}\pm0.31$	$62.02^{e}\pm0.22$	$58.05^{f}\pm0.25$
*Energy value	336.1	332.5	324.8	313.7	294.3	282.9

Values are means of two replicates. Means in the same row with different superscripts are significantly different ($p < 0.05$). *Calculated in kcal/100g

100P: 0W = Composite flour with 100-part green plantain: 0-part whole wheat flour
80P: 20W = Composite flour with 80-part green plantain: 20-part whole wheat flour
60P: 40W = Composite flour with 60-part green plantain: 40-part whole wheat flour
40P: 60W = Composite flour with 40-part green plantain: 60-part whole wheat flour
50P: 50W = Composite flour with 50-part green plantain: 50-part whole wheat flour
0P: 100W = Composite flour with 0-part green plantain: 100-part whole wheat flour

Chemical composition of green plantain, green plantain-whole wheat and whole wheat flours

Table 1 shows the proximate composition and energy values of green-plantain flour, whole-wheat flour and green plantain - whole wheat grain flour blends. The moisture, ash, protein, crude fat and the crude fibre content of green-plantain flour is significantly ($p < 0.05$) lower while the carbohydrate content is significantly ($p < 0.05$) higher compared to whole wheat flour. The ash, protein, crude fat and crude fibre contents of the composite flour increased significantly ($p < 0.05$) with additional increase of whole wheat flour from 0 to 50 % while both carbohydrate and energy values decreased significantly ($p < 0.05$).

The proximate composition of green-plantain and whole wheat flours have been previously reported. Yadav, Yadav and Dhull (2012) reported 3, 1.4, 2.4 and 3.6% while (Abioye, Babarinde, &Adesigbin (2011) reported 4.54, 0.75, 1.96 and 1.83% for protein, fat, ash and crude fibre of green-plantain flour respectively. The protein content of green plantain (3.37%) obtained in the present work is in agreement with the values (3.0 and 4.54 %) reported for green-plantain by Yadav et al. (2012) and Abioye et al. (2011) respectively. The moisture content (9.7%) is also within the range (8.8 and 9.65%) reported for plantain flour (Abioye et al., 2011;Yadav et al., 2012) and other shelf-stable products (≤ 10 %) (Singh, Sandhu & Kaur, 2005). The plantain flour can be said to be shelf stable. The protein content (9.23%) of the whole-wheat is lower while the crude fibre content (8.79%) is higher compared to 11.88 and 2.65% (Akhtar, Anjum, Rehman, Sheikh, & Farzana, 2008) and 13.9 and 4.5% (Ndife, Abdulraheem, &Zakari, 2011) reported for whole-wheat protein and crude fiber respectively. The variation in the proximate composition values of the green-plantain and whole wheat flours compared to values in the literature values may be due to the difference in the source of material and the variety used.

The increase in ash, protein, fat and crude fibre content of plantain flour substituted with whole wheat flour may be due to the whole wheat grain that is higher in the components compared to green plantain. The ash is an indication of the mineral content in food. The increase in ash content indicates that additional minerals were supplied by the whole wheat flour. This is an added advantage for the composite flours as minerals are needed for some physiological requirement in the body. The significant ($p < 0.05$) increase in crude fibre content of the flour blends can be attributed to the added whole wheat flour, although green plantain flour is also rich in fibre. Crude fibre is an ideal vehicle for healthy gastrointestinal and metabolic systems in humans because it may increase the intestinal mobility and transit time (Adebowale et al., 2013). However, the increase in crude fat content with whole wheat flour inclusion is not at a level that can cause either health challenges or storage instability.

Table 2. Colour Evaluation of Green Plantain, Composited and Whole-Wheat Flours

Colour parameters	Flour blending ratios					
	100P:0W	80P:20W	60P:40W	40P:60W	50P:50W	0P:100W
Redness (a*)	1.23 ± 0.01	0.95 ± 0.02	0.77 ± 0.02	0.28 ± 0.03	0.19 ± 0.01	0.08 ± 0.03
Yellowness (b*)	11.3 ± 0.2	12.5 ± 0.1	12.6 ± 0.3	12.8 ± 0.5	12.8 ± 0.6	13.0 ± 0.4
Lightness ($L*$)	65.3 ± 1.2	52.3 ± 0.5	50.7 ± 0.7	48.5 ± 0.4	35.1 ± 0.3	30.1 ± 0.2
Browning index	34.8 ± 0.6	47.7 ± 0.5	49.3 ± 0.6	51.5 ± 1.1	64.8 ± 1.2	69.8 ± 1.3
Chroma	11.4 ± 0.2	12.5 ± 0.3	12.6 ± 0.2	12.8 ± 0.1	12.8 ± 0.3	13.2 ± 0.5
Hue angle (h^{-})	83.8 ± 1.2	85.6 ± 1.1	86.5 ± 1.2	88.7 ± 1.2	89.4 ± 1.4	89.7 ± 1.3

Values are means of two replicates. Means in the same row with different superscripts are significantly different ($p < 0.05$). P = green-plantain flour; W = whole-wheat flour.
100P: 0W = Composite flour with 100-part green plantain: 0-part whole wheat
80P: 20W = Composite flour with 80-part green plantain: 20-part whole wheat
60P: 40W = Composite flour with 60-part green plantain: 40-part whole wheat
40P: 60W = Composite flour with 40-part green plantain: 60-part whole wheat
50P: 50W = Composite flour with 50-part green plantain: 50-part whole wheat
0P: 100W = Composite flour with 0-part green plantain: 100-part whole wheat

Color Evaluation of Green Plantain Flour, Composited Flour and Wheat Whole Flour

Colour values for the flours are shown in Table 2. Green plantain flour had higher a* and $L*$ values compared to whole-wheat flour with higher $b*$ value. Whole wheat flour presented a higher browning index, chroma and hue angle compared to green plantain flour. The $a*$ and $L*$ values of green-plantain flour substituted with whole-wheat flour decreased as the substitution level increased from 0 to 50% while the $b*$ value, browning index, chroma and hue angle increased with increase in substitution level. The $a*$, $b*$ and $L*$ values represent redness, yellowness and lightness of materials. The higher L* value of green plantain flour suggests that it is lighter in colour compared to whole wheat flour. The decrease in the $L*$ value with concurrent increase in $b*$ value in the flour blends indicates a change in the colour of the flour blend towards whole-wheat flour. The increase in the browning index of the flour blends with an increase in substitution level may be attributed to the brown colour of the whole-wheat flour. This is also manifested in the $C*$ values (which is an indication of colour intensity) generated. The hue angle is an indication of how an average person will perceive that colour of a sample (Avanza et al., 2012). Colour intensity values ranging between 11.4 and 13.0 obtained were similar to values reported for defatted maize germ-wheat flour blend (Siddiq et al., 2009). These results clearly indicated that the addition of whole-wheat flour decreased the $L*$ and increased the brownness of flour blends.

Table 3. Functional Properties of Green Plantain Composited and Whole Wheat Flours

Parameters	Flour blending ratios					
	100P:0W	80P:20W	60P:40W	40P:60W	50P:50W	0P:100W
Bulk density (g/L)	$0.46^{a} \pm 0.01$	$0.64^{b} \pm 0.02$	$0.69^{b} \pm 0.04$	$0.71^{ab} \pm 0.02$	$0.83^{a} \pm 0.01$	$0.84^{a} \pm 0.71$
Water absorption index (g/g)	0.64 ± 0.04	1.43 ± 0.01	1.53 ± 0.01	1.57 ± 0.01	1.68 ± 0.05	$1.73^{a} \pm 0.01$
Water solubility index (%)	4.12±0.01	6.71±0.04	8.62 ± 0.14	10.5 ± 0.12	12.4 ± 0.11	25.3± 0.23
Swelling index	32.6 ± 0.21	38.4 ± 0.31	41.5 ± 0.54	41.9 ± 1.32	43.1 ± 0.13	44.9 ± 0.51
Gluten index	1.0 ± 0.00	5.5 ± 0.11	9.1 ±0.15	18.2 ± 0.14	22.6 ± 0.14	60.2 ± 2.00

Values are means of two replicates. Means in the same row with different superscripts are significantly different ($p < 0.05$). P = green-plantain flour; W = whole-wheat flour
100P: 0W = Composite flour with 100-part green plantain: 0-part whole wheat
80P: 20W = Composite flour with 80-part green plantain: 20-part whole wheat
60P: 40W = Composite flour with 60-part green plantain: 40-part whole wheat
40P: 60W = Composite flour with 40-part green plantain: 60-part whole wheat
50P: 50W = Composite flour with 50-part green plantain: 50-part whole wheat
0P: 100W = Composite flour with 0-part green plantain: 100-part whole wheat

Functional Properties of Green Plantain Composited and Whole-Wheat Flours

Green plantain flour is lower in bulk density, water absorption index, water solubility index and swelling index compared to whole-wheat flour. Increase in substitution level of green-plantain flour with whole wheat flour increased the bulk density, water absorption index, water solubility index as well as swelling index. The substitution also increased the gluten index of green plantain flour from zero to 22.6 after substitution with 50% whole wheat flour (Table 3).

The bulk density of flour is the density measured without the influence of compressional forces (Chandra, Singh, & Kumari, 2015). The bulk density recorded in this study suggested that whole-wheat flour is denser than green-plantain flour. The difference in bulk density may be due to the difference in flour particle sizes (Singh et al., 2005). These values are lower than the values reported for wheat-rice flours (Chandra et al., 2015). Denser flour may facilitate transportation of more quantities of flours to sale outlets at a reduced cost compared to flour with low density (Ajanaku, Ajanaku, Edobor-Osoh, &Nwinyi, 2012).

The highest water absorption index was observed in 50:50 (1.68 g/g) and lowest in 80P:20W (1.43 g/g) flour blends. Water absorption index has been adjudged to be an important function of the protein in viscous food materials such as dough, soups and baked food products. The result suggests that the addition of whole-wheat flour influenced the amount of water absorbed. The increase in water absorption index of the flour blends may be due to change in total protein structure most likely due to whole-wheat flour addition. It may also be due to an increase in the concentration of total protein (Chandra et al., 2015) because protein has both hydrophilic and hydrophobic nature and may interact with water (Aremu et al., 2009). This may be responsible for the increase in water absorption and solubility indexes of the flour blends. Higher water absorption index in these flours suggests that they can be used in formulations of sausages, dough and bakery products.
Plantain flour contains no gluten. The inclusion of whole wheat flour gradually increased the gluten content of the flour blends. Therefore, gluten contributed by whole-wheat flour, may be responsible for the observed increase in water absorption and swelling indexes of the flour blends (Chandra et al., 2015).

Table 4.Sensory Evaluation of Porridges Made from Green-Plantain Flour Composited and Whole-Wheat Flours

Sensory attributes	Flour blending ratios					
	100P:0W	80P:20W	60P:40W	40P:60W	50P:50W	0P:100W
Color	5.9^{ab}±1.1	5.8^{ab}±0.8	5.8^{ab}±0.6	6.0^{a}±0.7	6.1^{a}±1.1	6.1^{a}±1.5
Taste	7.5^{a}±1.2	7.4^{a}±1.5	7.3^{a}±1.1	7.3^{a}±1.4	7.1^{ab}±1.1	7.1^{ab}±1.3
Aroma	7.5^{ab}±1.2	7.6^{ab}±1.2	7.7^{a}±1.3	7.1^{cd}±0.9	7.2^{cd}±0.9	7.2^{c}±0.9

Texture	$6.9^{d}\pm1.1$	$6.9^{d}\pm0.7$	$7.3^{b}\pm1.0$	$7.8^{a}\pm1.0$	$6.8^{e}\pm1.3$	$7.1^{c}\pm1.2$
Overall acceptability	$7.3^{cd}\pm1.2$	$7.2^{cd}\pm0.9$	$8.0^{a}\pm1.2$	$7.7^{ab}\pm0.8$	$7.0^{de}\pm1.1$	$7.5^{bc}\pm1.4$

Values are means of two replicates. Means in the same row with different superscripts are significantly different ($p < 0.05$).
100P: 0W = Composite flour with 100-part green plantain: 0-part whole wheat
80P: 20W = Composite flour with 80-part green plantain: 20-part whole wheat
60P: 40W = Composite flour with 60-part green plantain: 40-part whole wheat
40P: 60W = Composite flour with 40-part green plantain: 60-part whole wheat
50P: 50W = Composite flour with 50-part green plantain: 50-part whole wheat
0P: 100W = Composite flour with 0-part green plantain: 100-part whole wheat

Sensory Assessment of Porridges Made from Green Plantain, Whole-Wheat and Their Composite Flours
The colour of the cooked-porridges were not significantly ($p < 0.05$) different, though the instrumental values (Table 2) indicated that control (100% green-plantain flour) has the highest L^* (or lowest browning index) among the samples. However, this does not reflect in the colour of cooked porridges (Table 4) after hot water reconstitution. Highest rating for the colour of the porridges by panellists was 6.1 for 50:50 flour blends representing about 68%, thus indicating that the liking is more above average. Similarly, taste scores were not significantly ($p < 0.05$) different among the individual and composite flours. The texture of the porridges was significantly ($p < 0.05$) different, presumably because of gliadin and glutenin in whole-wheat flour that is absent in green-plantain flour. Gliadin and glutenin form a visco-elastic mass during hydration. As the level of inclusion of whole-wheat flour increased, the porridges become more viscous and hence, different textural characteristics.

From the principal component analysis (Figure 1): F1 explains the most information (52 %) about the samples. It shows clustering of the samples into either colour-dominant (0P:100W and 50P:50W) or aroma-dominant (60P:40W; 80P20W; 100P:0W) domains. F2 is a texture dimension, with high-textured (40P:60W and 60P:40W) against a low-textured group (50P:50W and 80P:20W…, 100P:0W). The products preference is being defined by F2. Texture (more/high) is the dimension mainly driving overall acceptance of products, with a flavour slightly influencing acceptance too (seeing taste and aroma vector lengths and closeness to the origin in F2). Products 60P:40W is most liked by the panellists.

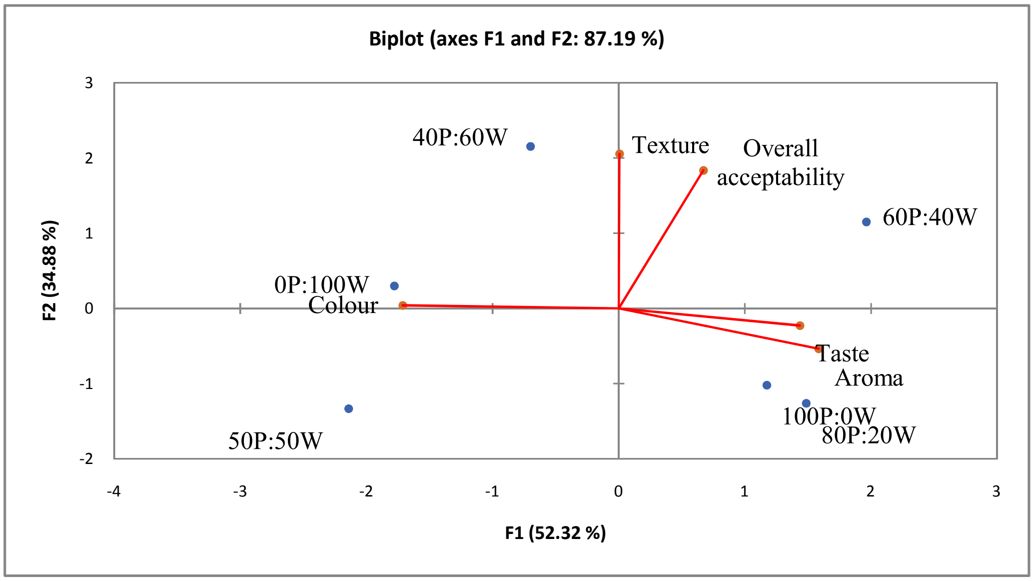

Figure 1 Factor coordinate biplot of the principal components using the correlation matrix for the sensory evaluation of porridges made from green plantain flour, composited and whole wheat flour blends
100P: 0W = Composite flour with 100-part green plantain: 0-part whole wheat
80P: 20W = Composite flour with 80-part green plantain: 20-part whole wheat
60P: 40W = Composite flour with 60-part green plantain: 40-part whole wheat
40P: 60W = Composite flour with 40-part green plantain: 60-part whole wheat
50P: 50W = Composite flour with 50-part green plantain: 50-part whole wheat

Table 5. Pearson Correlation Coefficient Between Selected Properties of Green Plantain Flour Composited and Whole Wheat Flours and Overall Sensory Acceptability of Porridge

Number	Variables	1	2	3	4	5	6	7
1	Bulk density	1.000						
2	Water absorption index	0.942^a	1.000					
3	Water solubility index	0.791^a	0.653^a	1.000				
4	Swelling index	0.973^a	0.968^a	0.779^a	1.000			
5	Lightness	-0.974^b	-0.859^b	-0.881^b	-0.917^b	1.000		
6	Browning index	0.973^a	0.859^a	0.880^a	0.978^a	-0.910^b	1.000	
7	Overall acceptability	-0.014^b	0.1527^a	0.056^a	0.210^a	0.124^a	0.224^a	1.000

^{a} Correlation is significant at 0.01 level, ^{b} correlation is significant at 0.05 level.

Correlation Matrix

The Pearson correlation results (Table 5) showed that certain quality attributes of composited flour blends are dependent on some properties of green-plantain flour used for its production. The swelling index of composited flour blends was found to be negatively correlated with L^* value ($r = 0.917$, $p < 0.05$) while it was positively correlated with overall acceptability ($r = 0.210$, $p < 0.05$). The selected functional properties (bulk density, swelling, water absorption and solubility indexes) were observed to be negatively correlated also with L^*value and but positively correlated with overall acceptability. This observation could probably be an indication that some quality attributes of the porridge are dependent on certain functional properties of the composited flour blends. The browning index of the porridge was however observed to exhibit a very strong correlation with the selected properties of the composited flours.

CONCLUSIONS

This study revealed that the addition of green plantain to whole wheat flour is a way of improving the nutritional and health benefits of porridge, in terms of increased dietary fibre and reduced fat. Therefore, 60% green plantain flour addition to 40% whole wheat flour may be used as raw materials in the confectionaries to produce speciality products like cakes, bread, snack and noodles for diabetics and obese. Also, by harnessing the potentials of green plantain into our diet plan will add value to fresh plantain, reduce post-harvest loss, and enhance food product diversification. In addition, it could be a means of developing more local agro-business that could encourage farmers to grow more of plantain resulting in higher income, reduced wheat importation and foreign reserves conservation.

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Conflict of interest

The authors declare no conflict of interest

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