

Physico-Chemical and Sensory Properties of Bread Prepared from Wheat and Unripe Plantain Composite Flours Fortified with Bambara Groundnut Protein Concentrate

Kiin-Kabari David Barine

Department of Food Science and Technology, Rivers State University of Science and Technology, Port Harcourt, Rivers State, Nigeria

Email address:

kabaridavid@yahoo.com

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Abstract: Matured, unripe plantain (*Musa paradisiaca*) fruits from a local cultivar, “Agbagba” were processed into flour. Protein concentrates were prepared from the flour of Bambara groundnut (*Vigna subterranean L. Verde*) using the alkaline extraction process. Bread was produced from the substitution levels of wheat/plantain/Bambara groundnut protein concentrate (BGPC) flour blends (100 – 30%, 0 – 40% and 0 – 30%), respectively and the physical, chemical and sensory properties of the product evaluated. The result showed that the loaf height, volume and specific volume decreased with an increase in the levels of plantain/BGPC flour blends. Loaf height decreased from 11.2cm (sample A) to 6.2cm (sample G) and loaf volume reduced from 2291.4cm³ to 1238.6cm³ for samples A and G, respectively. There was no significant difference in loaf height up to sample C (20% PF and 10% BGPC) when compared to the control (sample A). Specific volume also reduced with increasing levels of the blends from 6.3cm³/100g to 2.2cm³/100g for samples A and G, respectively. There was a corresponding increase in loaf weight in all samples as the plantain flour and BGPC increased. There was no significant difference in loaf weight up to sample C which also represents 20% PF 10% BGPC when compared to the control (sample A). The protein content in the fortified bread increased progressively from 10.4% (sample A) to 17.3% (sample G). From the result, it was observed that the addition of 10% BGPC in the formulation improved the protein content of the bread to 13.6%. Fat content increased significantly from 0.76% to 2.51% (samples A and F), respectively with increase in the protein concentrate added. Ash, crude fibre and energy values were also observed to increase with increasing addition of BGPC (0.76% - 2.21%, 9.1% - 11.29% and 276.88kcal/100g – 282.43kcal/100g), respectively. The sensory result showed that the bread produced from 15% BGPC and 25% plantain flour was acceptable with respect to flavour, crumb texture and general acceptability.

Keywords: Plantain Flour, Wheat Flour, Bambara Groundnut Protein Concentrate, Bread

1. Introduction

Protein deficiency is a major global problem particularly in developing countries like Nigeria. There are legumes and oilseeds which contain high level of protein that can be exploited in the formulation of plantain products. One of such legumes includes Bambara groundnut. This crop is an indigenous African grain legume and it is widely grown in Nigeria but it is less utilized because of the presence of anti-nutritional factors which interfere with protein digestibility and bioavailability of minerals [1, 2]. Detailed compositional studies showed that the beans contain between 17 – 24%

crude protein with a good balance of the essential amino acids and 6.8% of lysine and 1.3% of methionine [1] compared to soybeans or cowpea. Plant proteins are gradually gaining acceptance as food ingredients. These are often used to enhance nutritional value of foods [3] formulated from carbohydrate based ingredients such as plantain.

Plantain is one of the cheapest carbohydrate foods in terms of cost per hectare, per ton and per calorie. Adeniji *et al.*, [4] observed that plantain hybrid (PITA 14) had the highest total energy of 373.2kj/100g; which suggest that the new cultivars may constitute good raw materials for high energy food

formulations. Many scientists have tried to determine the food value of plantain by carrying out proximate and detailed chemical analyses of unripe and ripe plantain including the peels. Adeniji *et al.*, [5] reported that the protein content of both the hybrids and the local cultivar (Agbagba) were generally low – with a mean value of 2.94% and 3.06% for hybrids and local cultivar, respectively. However, it is important to fortify plantain food products with Bambara groundnut protein concentrate in order to increase the protein content and enhance acceptability.

Bread is considered a popular staple food consumed as part of the daily diet worldwide with over 9million kg of bread produced annually [6]. It has become a staple food for many families in developing countries and a convenient item for use in protein fortification of diets of children suffering from protein – energy malnutrition. Srikantha & Erdman [7] reported that fortifying wheat bread with oilseed and legume flours could minimize the necessities of large-scale importation of wheat and also enhance the nutrient composition of bread. Studies on the use of various oilseeds and legume flours, protein concentrates and isolates in bread making have been reported [8 – 10]. These studies showed that 2 – 15% of non-wheat flour, up to 18% protein concentrate and isolates can be used in bread making without undesirable changes in rheological properties. One of the nutritional limitations of using wheat flour in bread making is that it is low in lysine. Fortification of bread with soy flour and other composite flour dramatically improves protein quality [11] and also improves the well-being of consumers. Twenty (20%) replacement of wheat flour with defatted soy flour leads to significantly higher beany flavour in bread when compared to the control (white bread). In contrast, Shogren *et al.*, [12] found that bread made with 30% soy-wheat composite flours was not significantly different in beany flavour from whole wheat bread. According to Olaoye *et al.*, [13] bread produced with soy flour substitution up to 15% was nutritionally superior to that of whole wheat bread.

Composite flour from plantain/wheat flour blends have been used in bakery products, snacks and complementary food formulations [14]. These efforts were aimed at improving the protein content in particular and the overall nutritional value of the products. However, legumes and oil seeds contain very high protein but are less utilized because they are not easily digested and absorbed by man and animals. Therefore, the aim of this research is to produce bread from wheat and unripe plantain composite flours fortified with Bambara groundnut protein concentrate and to evaluate the physical, chemical and sensory properties of the resultant bread in order to ascertain the level of acceptability that will help to reduce the level of wheat flour.

2. Materials and Methods

2.1. Materials

A local cultivar (Agbagba) of plantain (*Musa paradisiaca*) was collected from the International Institute for Tropical

Agriculture, (IITA) High Rainfall Station; Onne, agro-ecology, located at lat, 04° 43¹ N, long. 07° 01; E and 10m, near Port Harcourt, Rivers State and used for the study. Bambara groundnut (*Vignasubterrenea L.*) seeds were purchased from markets in Enugu, Enugu State, all in Nigeria.

2.2. Methods

2.2.1. Preparation of Plantain Flour

Plantain fruits (Agbagba cultivar), obtained from hand number 2 from the proximal end of the bunch, as recommended by Baiyeri & Ortiz [15], were peeled manually with the aid of stainless steel kitchen knives and the pulp was cut into uniform slices with thickness of about 1.5mm, soaked in 1.25% sodium metabisulphite for 5min to prevent discolouration and dried in air circulating oven (Gallenkamp S/No 90/02/190, UK) at 65°C for 20h according to the method of Adeniji *et al.*, [4]. The dried samples were milled to pass a 0.25mm sieve as earlier reported by Kiin-Kabari & Giami [16] for non-wheat cookies.

2.2.2. Preparation of Bambara Groundnut Flour

Bambara groundnut flour was prepared using the method described by Barimalaa *et al.*, [17]. The beans were soaked for 24h in tap water and dehulled manually. The seeds were further boiled for 10 min, (1:4 bean to water ratio) in a stainless steel pot, drained and dried at 50°C in an air circulating oven for 19h. The dried samples were milled (FOSS, Cyclotec 1093, Sweden) and sieved into flour using 0.25mm sieves.

2.2.3. Preparation of Protein Concentrates

The protein concentrates from Bambara groundnut flour (BGF) were prepared using the alkaline wet extraction process described by Deshpande & Cheryan [18] with little modification as reported by Giami & Isichei [19], for fluted pumpkin seeds. Fifty grams of sample was suspended in 300ml of 0.04M NaOH and the mixture was stirred at room temperature (28±1°C) for 1h, using a mechanical shaker. The pH of the slurry was adjusted to 10.8 using 1.0M NaOH and centrifuged at 3500 rev. min⁻¹ for 25 min to obtain a residue and a supernatant. The residue was re-suspended in 0.04M NaOH (200ml) and the extraction procedure repeated to increase the yield of protein. The pH of the combined extract was adjusted to 4.5 using 1M HCl to precipitate more proteins. The mixture was centrifuged at 3500 rev min⁻¹ for 15 min to yield a precipitate (protein concentrate) which was washed twice with distilled water, adjusted to pH 7 using 1M NaOH, then air – dried for 48h at room temperature (28±1°C) and stored at 4°C as earlier reported by Kiin-Kabari & Giami [16].

2.2.4. Preparation of Flour Blends

Breads were prepared with graded levels of wheat/plantain flour fortified with Bambara groundnut protein concentrates. The graded levels ranged from 0 – 30% protein concentrates and 0 – 40% plantain flour with 100% wheat flour as the control.

Table 1. Recipe for production of bread from flour blends samples.

Ingredients	A	B	C	D	E	F	G
WF (g)	100	80	70	60	50	40	30
PF (g)	0	15	20	25	30	35	40
BGPC(g)	0	5	10	15	20	25	30
Yeast (g)	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Salt (g)	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Sugar (g)	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Fat (g)	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Water (ml)	56.0	56.0	56.0	56.0	56.0	56.0	56.0

Key: WF = Wheat flour, PF = Plantain flour, BGPC = Bambara groundnut protein concentrate.

2.2.5. Production of Plantain/Wheat Flour Bread Fortified with Bambara Groundnut Protein Concentrate

The batter method described by Ogazi [20] was used with modifications. This procedure was adopted using various levels of protein concentrate substitution ranging from 0 – 30%, as shown in Table 1. The flour and ingredients were weighed out as indicated in the recipe. The yeast and a portion of the sugar were dissolved in warm water at 35°C. The remaining sugar was dissolved separately. The flour, fat and salt were mixed together for 5 min. The dissolved yeast/sugar solutions were added and the mixing continued for 30 min. The resultant batter was scaled (500g), proofed for 15 – 20 min and baked at 100°C for 1h.

2.2.6. Physical Properties of the Bread

Physical parameters measured include loaf height, loaf volume, loaf weight and specific volume. Loaf weights were measured by means of an electronic weighing balance (Model HL250 AZ and Coy Ltd, Korea). Loaf volume and specific loaf volume were measured 30 min after removal from the oven using the method of Giami *et al.*, [9] and slightly modified by using pure rice grains instead of pearled barley. A box of fixed dimension (24.00 x 15.70 x 18.95cm) of initial volume 7140cm³ was put into a tray, half filled with rice grains, shaken vigorously four (4) times, then filled till slightly overfilled, so that the overspill fall into the tray. The box was shaken again twice then a rule was used to press across the top of the box once to give a level surface. The seeds were decanted from the box into a receptacle and weighed. These procedures were repeated three times and mean value for grain weight was noted (Bg). A weighed loaf was placed in the box and levelled off as before. The overspill was weighed and the weight obtained. The weight of seeds around the loaf and volume of seeds displaced by the loaf were calculated using the following equations.

Grains/seed displaced by Loaf (L) = Bg + Overspill weight – 4500g.

$$\text{Volume of loaf (V)} = \frac{L \times 7140\text{cm}^3}{Bg}$$

$$\text{Specific volume of loaf} = V/\text{loaf wt (cm}^3/\text{g)}$$

2.2.7. Sensory Evaluation of the Fortified Bread

Sensory evaluation of the bread was carried out after

baking using the method described by Giami & Barber [21] for fluted pumpkin cookies. A panel of twenty (20) consumers comprising staff and student from Rivers State University of Science and Technology, Port Harcourt, Rivers State, Nigeria was used. Criteria for selection were that panelist were 18 years of age, regular consumers of bread and were neither sick nor allergic to any food. Panelists were trained in the use of sensory evaluation procedures. At each session, samples were served on white saucers, properly coded with 3-digit random numbers to prevent bias. The sensory attributes of the bread including crust/crumb colour, texture, flavour and overall acceptability was evaluated using a 9 – point hedonic scale with 1 representing the least score (dislike extremely) and 9 the highest score (like extremely) as described by Iwe [22]. Necessary precautions were taken to prevent carryover flavour during the tasting by ensuring that panelists rinse their mouth with water after each stage of sensory evaluation.

2.2.8. Chemical Analysis

Crude protein, moisture content, fat, ash and crude fibre content of the bread was determined according to the AOAC [23] method. Total available carbohydrate was determined using the Clegg Anthrone method as described by Osborne & Voogt [24]. Energy was calculated using the Atwater factor as reported by Okoye [25].

2.2.9. Statistical Analysis

Results were expressed as mean values and standard deviation of three (3) determinations. Data were analysed using a one-way analysis of variance (ANOVA) using Statistical Packaging for Social Science (SPSS) version 20.0 software 2011 to test the level of significance (P < 0.05). Duncan New Multiple Range Test was used to separate the means where significant differences existed.

3. Results and Discussions

3.1. Physical Properties of the Bread

Loaf volume, loaf height and specific loaf volume were observed to reduce with increase in the level of plantain/BGPC flour blends as shown in Table 2. Loaf height reduced from 11.2cm (sample A) to 6.2cm (sample G), loaf volume reduced from 2291.4cm³ (sample A) to 1238.6cm³ (sample G) and specific loaf volume also reduced from 6.3cm³/g to 2.2cm³/g. This is probably due to the reduction in wheat protein of the various samples which translated to lower gluten content. The higher the gluten content of flour, the higher the ability of the flour to extend (elasticity) and retain the carbon dioxide produced during fermentation thereby yielding a higher loaf volume. Similar observations had been reported by Ocheme *et al.*, [10]. In this study, there was no significant difference in loaf height at 20% PF and 10% BGPC (sample C) and sample B (15% PF and 5% BGPC) when compared to the control (sample A).

Reduction in bread volume and quality as a result of

blending wheat flour with more than 5% oil seeds or legume flour and protein concentrates have been reported by various workers [26, 27]. An increase in loaf weight from 364.3g (sample A) to 558.4g (sample G) was observed. As loaf height and volume reduced, there was a corresponding increase in loaf weight in all samples as the plantain flour and BGPC increased. However, there was no significant difference in loaf weight up to sample C which represents 20% PF and 10% BGPC when compared to the control (sample A).

Table 2. Physical characteristics of bread prepared from different levels of substitution of wheat/plantain/BGPC blends.

Samples	Loaf height (cm)	Loaf volume (cm ³)	Loaf weight (g)	Specific volume cm ³ /g
A	11.2±0.6 ^a	2291.4±0.5 ^a	364.3±1.2 ^c	6.3±0.6 ^a
B	10.7±0.6 ^a	2184.6±0.5 ^a	369.4±0.9 ^c	5.9±0.3 ^a
C	10.1±0.8 ^{ba}	2076.8±0.2 ^b	374.6±1.3 ^c	5.5±0.1 ^a
D	9.4±0.2 ^b	1948.3±0.7 ^b	426.6±1.1 ^b	4.6±0.7 ^b
E	7.2±0.2 ^c	1790.4±0.6 ^c	513.3±0.8 ^b	3.5±0.4 ^c
F	6.6±0.1 ^c	1246.2±0.2 ^d	542.7±1.4 ^a	2.3±0.4 ^c
G	6.2±0.3 ^c	1238.6±0.4 ^d	558.4±0.9 ^a	2.2±0.5 ^d

^{a,b,c,d} Means bearing the same superscript within the same column do not differ significantly ($p > 0.05$).

± = means ± standard deviation of triplicate determination.

Key: Samples: A = 100% WF (control); B = 80% WF, 15% PF, 5% BGPC; C = 70% WF, 20% PF, 10% BGPC; D = 60% WF, 25% PF, 15% BGPC; E = 50% WF, 30% PF, 20% BGPC; F = 40% WF, 35% PF, 25% BGPC; G = 30% WF, 40% PF, 30% BGPC.

Where WF = Wheat flour, PF = Plantain flour, BGPC = Bambara groundnut protein concentrate.

3.2. Sensory Characteristics of the Bread

Acceptable bread was prepared from wheat/plantain/BGPC flour blends containing up to 15% protein concentrate and 25% PF (sample D) with regards to general acceptability as shown in Table 3. Crust colour showed no significant difference ($p > 0.05$) up to 20% protein concentrate and 30% PF (sample E) when compared to sample A (100% WF). The crust colour developments occurring on the dough surface are mainly by thermal non enzymatic caramelization reaction and Millard reactions between reducing sugars and amino acids [28]. Excessive dark crust colour may result in unacceptable taste and flavour. However, only 5% protein concentrate and 25% PF compared significantly with the control with regards to flavour. The crumb texture compared favourably with the control also up to 15% protein concentrate and 25% plantain flour (PF). This crumb texture which is represented by crumb firmness and denseness decreased with increase in PF and BGPC. Similar observations were reported by Shogren *et al.*, [12]. Vittadini & Vodovotz [29] concluded that 20% soy flour

substitution can be used to produce bread without significantly affecting textural attributes of the crumb.

Table 3. Sensory scores for bread prepared from wheat/plantain/BGPC flour blends.

Samples	Crust colour	Crumb colour	Texture	Flavour	Overall acceptability
A	8.4 ^a	8.2 ^a	7.8 ^a	8.0 ^a	7.9 ^a
B	8.2 ^a	8.0 ^a	7.6 ^a	7.9 ^a	7.7 ^a
C	7.8 ^{ba}	7.5 ^b	7.2 ^a	7.5 ^b	7.4 ^b
D	7.9 ^a	6.4 ^b	7.0 ^{ba}	8.2 ^a	8.1 ^a
E	7.8 ^{ba}	6.1 ^b	6.2 ^b	7.5 ^b	7.0 ^b
F	7.6 ^b	5.4 ^c	5.7 ^b	7.1 ^b	6.2 ^c
G	7.0 ^c	5.2 ^c	5.5 ^b	7.2 ^b	6.0 ^c

Means bearing the same superscripts within the same column are not significantly different.

Key:

Samples: A = 100% WF (control); B = 80% WF, 15% PF, 5% BGPC; C = 70% WF, 20% PF, 10% BGPC; D = 60% WF, 25% PF, 15% BGPC; E = 50% WF, 30% PF, 20% BGPC; F = 40% WF, 35% PF, 25% BGPC; G = 30% WF, 40% PF, 30% BGPC.

Where WF = Wheat flour, PF = Plantain flour, BGPC = Bambara groundnut protein concentrate.

3.3. Chemical Analysis

Crude protein in the fortified bread increased progressively from 10.4% (sample A) to 17.5% (sample G) as presented in Table 4. However, there was no significant difference ($p > 0.05$) between samples A, B and C. This result showed that 10% protein concentrate in the composite flour blends can provide bread with 13.6% crude protein. This level of protein content was higher when compared to 8.39% obtained by supplementing WF with 15% soy flour composite bread as reported by Olaoye *et al.*, [13]. As well as the 9.60% obtained by replacing milk and egg with fresh *Moringa* leave paste in cookie production as reported by Emelike *et al.*, [30]. However, successful use of soy ingredients as low cost protein supplements in bread is challenging due to the unpleasant off-flavour compounds found in soy beans [31, 32].

The fat content of the enriched bread increased significantly from 0.76% (sample A) to 2.51% (sample F), with increase in the level of protein concentrate added. This trend was also observed in ash 0.76% (sample A) to 2.21% (sample F) and crude fibre to be 9.1% (sample A) to 11.29% (sample D). Similar observations had been reported by Olaoye *et al.*, [13] and Abioye *et al.*, [33]. Higher fat value may be detrimental to long storage life of the product. The energy values also increased from 276.88kcal/100g to 282.43kcal/100g. These values are low when compared to the energy requirement for a 55kg woman in bed which is 420 kcal [34].

Table 4. Chemical composition of bread prepared from wheat/plantain/BGPC flour blends.

Samples	Crude protein (%)	Moisture content (%)	Fat (%)	Carbohydrate (%)	Ash (%)	Crude fibre (%)	Energy (kcal/100g)
A	10.4 ^c	18.4 ^a	0.8 ^d	60.6 ^a	0.8 ^d	9.1 ^b	276.9 ^c
B	11.2 ^c	18.7 ^a	1.3 ^c	58.4 ^a	0.9 ^d	9.5 ^b	276.9 ^c
C	13.6 ^b	18.2 ^a	2.3 ^b	56.1 ^{ba}	1.2 ^c	8.6 ^c	287.8 ^a
D	13.8 ^b	17.1 ^b	2.5 ^a	54.2 ^b	1.3 ^b	11.3 ^a	282.6 ^b
E	14.3 ^b	17.5 ^b	2.5 ^a	53.2 ^b	1.6 ^b	10.9 ^a	281.4 ^b
F	15.4 ^b	17.2 ^b	2.5 ^a	52.3 ^c	2.2 ^b	10.4 ^a	282.4 ^b
G	15.0 ^b	17.1 ^b	2.6 ^a	55.1 ^b	2.3 ^a	10.5 ^a	287.6 ^a

Means bearing the same superscript within the same column are not significantly different.

Key:

Samples: A = 100% WF (control); B = 80% WF, 15% PF, 5% BGPC; C = 70% WF, 20% PF, 10% BGPC; D = 60% WF, 25% PF 15% BGPC; E = 50% WF, 30% PF, 20% BGPC; F = 40% WF, 35% PF, 25% BGPC; G = 30% WF, 40% PF, 30% BGPC.

Where WF = Wheat flour, PF = Plantain flour, BGPC = Bambara groundnut protein concentrate.

4. Conclusion

Acceptable bread was produced from wheat/plantain/BGPC flour blends containing up to 15% protein concentrate and 25% plantain flour (sample D) with regards to general acceptability, flavour and crumb texture. Addition of 15% BGPC to bread generally improved the protein content compared with the control. This confirms that the bread so developed had a better nutritional value than the control and could be used to combat protein energy malnutrition and also reduce the level of wheat flour in bread production by 30%. However, further research on the glycemic index of baked products from wheat/plantain flour blend enriched with Bambara groundnut protein concentrate is on-going.

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