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QUALITY EVALUATION OF FLOUR BLENDS AND BISCUITS PRODUCED FROM BREADFRUIT AND LIMA BEAN FLOURS

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Abstract

This study investigated the nutritional composition and physicochemical properties of breadfruit based flour blends as a way of showcasing its potential as an alternative intermediate food material in the production of some foods on the diet list of developing countries. Breadfruit was processed into flour and its flour was substituted with lima bean flour (0 – 40%). Proximate and amino acid composition, functional and pasting properties of the flour blends were determined using standard methods. Antioxidant activity, physical properties and sensory acceptability of biscuits produced from the flour blends were also evaluated using standard methods. Wheat biscuit served as control. The results revealed that protein ranged from 6.67 to 9.14%, fat 0.54 – 1.51%, ash 1.85 – 3.07%, crude fibre 4.62 – 4.98% and carbohydrate 68.23 – 80.58%. All essential amino acids were present in the flour blends constituting 34.86 -40.03% of the total amino acid present. There were significant variations in the functional and pasting properties. Biscuits produced from the flour blends exhibited appreciable radical scavenging ability and reducing power; DPPH values were 9.67 – 78.01%, ABTS 0.016 – 0.0216 mM/g and FRAP 1.03 – 14.56 mg/g. Biscuit produced from breadfruit flour with inclusion of 20% lima bean flour showed comparable overall acceptability with the control.

Keywords: breadfruit, lima bean, biscuit, amino acid, pasting properties, antioxidant activity

Introduction

The present food security situation in Nigeria and some other developing nations of the world is gradually nose-diving. The prices of foods in the open market have reached an alarming level. This situation is caused by myriad of challenges facing developing economy. Some of these challenges include poor leadership, economic instability, unfavorable climate condition/irregular rainfall, activities of terrorists

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and bandits, and dependence on common crops such as cassava, yam, sorghum, rice and maize which have heavy competing demand. The last factor listed appears to be the least challenge that can be overcome by shifting attention from common agricultural crops to underutilized and indigenous agricultural produce. Breadfruit and lima beans are regarded as underutilized crops (Peters *et al.,* 2016; Farinde *et al.*, 2018) and there is a need to explore these crops in the production of intermediate food materials which could be used as part of staple food items on the diet list of people in developing countries.

Breadfruit (*Artocarpus altilis*) is a good source of food because of its high calorific value, moderate glycemic index and appreciable quantity of micronutrients such as vitamins and minerals. Breadfruit tree is highly productive and it produces fruits twice in a year (Deivanai and Subhash, 2010). However the utilization of the fruit is hampered by its short shelf life and inadequate preservation techniques especially in areas where it is grown. Processing the fruit into flour has remained a major way to preserve the fruit and enhance its utilization. Breadfruit flour has been used in combination with cereal and leguminous crops; however there are few reports on the quality of breadfruit-lima bean flour blends. Lima bean (*Phaseolus lunatus*) is a leguminous crop which possess appreciable nutritional and/or health benefits (De Oliveira, 2006). Due to its protein content, amino acid composition and appreciable functional properties lima bean flour could be used to fortify flours of other unexploited crops (Yellavila *et al.,* 2015). The exploitation and utilization of underutilized crops depend on the available information on their nutritional and physicochemical properties as well as possible intermediate products that could be derived from them. There is scanty information on the quality and use of breadfruit-lima bean flour blends in food application. Therefore this study was designed to evaluate some nutritional and physicochemical properties of flour blends as well as the antioxidant activity and sensory acceptability of biscuits produced from breadfruit and lima bean.

Materials and Methods

Materials

Lima beans were procured from King's market, Ado-Ekiti, Ekiti State, while matured unripe breadfruits were obtained from a farm in Ile-Ife, Osun State, Nigeria.

Production of breadfruit flour

Breadfruits were washed with clean water, peeled, cored, sliced into tiny slices and dried at 70°C for 10hours in Hinotek hot air oven (DHG 9030A; Hinotek Group Ltd., China). The dried breadfruit pieces were milled using hammer mill (FT2 hammer mill, Armfield, England) and sieved using a fine screen (500µm) to get breadfruit flour. Breadfruit flour produced was packaged in high density polythene film, sealed and then stored under ambient conditions.

Production of lima bean flour

Lima beans were sorted to remove stones and dirt, boiled at 100^{o}C in clean water for 45 minutes and thereafter dehulled manually. The seeds were oven dried at 70°C for

8 hours in Hinotek hot air oven (DHG 9030A; Hinotek Group Ltd., China). The dried lima beans were milled using hammer mill (FT2 hammer mill, Armfield, England) and sieved using a fine screen (500µm) to get lima bean flour. Lima bean flour was packaged in high density polythene film, sealed and stored under ambient conditions.

Substitution of breadfruit flour with lima bean flour

Lima bean flour was used to substitute breadfruit flour at 0%, 10%, 20%, 30% and 40% to obtain five flour blends. The flours were thoroughly mixed to obtain homogenous blends and stored at ambient temperature in air tight plastic containers.

Proximate composition analysis of the flour blends

AOAC (2005) Official Methods 2001.11(protein: Kjeldahl Method), 963.15 (fat: Soxhlet Extraction Method), 923.03 (ash) and 978.10 (fibre) and 925.10 (moisture) were used to analyse the protein, fat, ash, fibre and moisture contents of the flour blends while carbohydrate was obtained by difference.

Amino acid analysis of the flour blends

Sample (0.5g) was defatted by extracting the fat content with 50 mL petroleum spirit (three times) using the Soxhlet extractor equipped with thimble. The defatted sample was soaked in 30 mL of 1M potassium hydroxide solution and was incubated at 110°C in hermetically closed borosilicate glass container for 48 hours. After the alkaline hydrolysis, the hydrolysate was neutralized to get pH in the range of 2.5 – 5.0. The solution was purified by cation-exchange solid-phase extraction. To enhance the volatility of the amino acids in gas chromatography, the amino acids in the purified solution were derivatized with ethylchloroformate. The derivatization reagent was removed by scavenging it with nitrogen gas. The derivatised sample solution which was free of derivatization reagents was made up to 1ml volume in a vial and then injected into Gas Chromatography (HP 6890 Powered with HP ChemStation Rev. A09.01 [1206] software) for amino acids analysis. Hydrogen was used as carrier gas with a flow rate of 1.0 ml/ minute, column dimension was 1.0 m × 0.2 mm × 0.25 µm, initial oven temperature was 110°C, ramped at 27°C/minutes to 320°C and maintained at 320°C for 5 minutes. The amount of each amino acid present in the sample was calculated from the net weight and approximate area of each peak (representing each amino acid) and expressed as g/100g protein (AOAC, 2005; Danka *et al*., 2012). The essential amino acids, non essential amino acids, sulphur containing amino acids, acidic, basic and neutral amino acids were estimated from the result of amino acid composition. Predicted Protein Efficiency Ratio (P-PER) was calculated from the amino acid composition using the equation developed by Alsmeyer *et al.* (1974) (Equation 1).

$$\text{P-PER} = -0.468 + 0.454\,(\text{Leu}) - 0.105\,(\text{Tyr}) \qquad (1)$$

Functional properties analysis of the flour blends

Swelling power of the samples was determined at 60°C according to the method described by Kaur *et al.* (2011). Water absorption capacity and oil absorption capacity were determined by the method of Sathe *et al.* (1982). Least gelation concentration, foaming capacity and wetability were determined by the methods of Onwuka (2005). Dispersibility was determined by the procedures described by Adegunwa *et al.* (2017). Loose and Packed bulk densities were determined using the method of Mpotokwane *et al.* (2008).

Pasting properties analysis of the flour blends

Pasting properties (peak viscosity, hot paste viscosity, breakdown viscosity, final viscosity, setback viscosity, pasting temperature and peak time) were determined using Rapid Visco Analyser (RVA 4500; Perten Instruments, Sweden). Suspension of sample (12%) was prepared in the RVA canister; the canister paddle was put in place and its blade was trotted through the suspension for about 6 times to ensure proper mixing of the suspension. The canister, which was fitted with the paddle, was placed in the machine as recommended. The 12 minutes profile was used; idle time and temperature were 1minutes and 50 ^oC respectively, sample was heated from 50 ^oC to 95 ^oC in 3 minutes 45 seconds, held at 95 ^oC for 2 minutes 30 seconds and then cooled back to 50 ^oC over 3 minutes 45 seconds period, this was followed by 2 minutes period when the temperature was maintained at 50 ^oC.

Production of biscuits

Biscuits were produced from the five flour blends; biscuit produced from wheat flour was used as control. The flour (500 g), sugar (150 g), vegetable fat (Topper, Heerenveen, Holland) (190 g), powder milk (25 g) and salt (5 g) were mixed together manually for 5 minutes, this is followed by the addition of baking powder (2.5 g). Measured amount of water (125 mL) was gradually added with continuous mixing until good texture, slightly firm dough was obtained. The dough was kneaded on a clean flat surface for 4 minutes. It was manually rolled into sheets and cut into shapes using the stamp cutting method. The cut dough pieces were transferred into baking trays greased with fat and baked at 180°C for 20 min; the resulting biscuits were allowed to cool and packaged in high density polyethylene for analysis

Antioxidant activity of biscuits

Aqueous extract was prepared by grinding and sieving the various biscuit samples. The powder biscuit samples (10g each) were extracted (by soaking) with 100mL of distilled water for 24 hours at 37 ^oC. The extracts were separated by filtration and centrifugation, and stored at 4 ^oC for antioxidant analysis (Oboh *et al.*, 2010). DPPH (1,1-diphenyl-2-picryl-hydrazyl) radical scavenging ability was carried out using the method described by Moodley *et al.* (2015). Briefly, 200 µL of sample extract was mixed with 1 mL 0.4mM methanolic solution containing DPPH radicals, the mixture was left in the dark for 30 min. The absorbance was measured spectrophotometrically at 517 nm and ability to scavenge DPPH radical was calculated using equation 2.

$$DPPH\text{-}RSA\ (\%) = [(Abs_{control} - Abs_{sample})/(Abs_{control})] \times 100 \qquad (2)$$

ABTS (2, 2-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid)) radical scavenging ability was carried out using the methods described by Shah and Modi (2015). The ABTS was generated by reacting 7 mM ABTS aqueous solution with $K_2S_2O_8$ (2.45 mM final concentration) in the dark for 16 h and adjusting the absorbance at 734 nm to 0.700 with ethanol. Thereafter, 200 µL of sample extracts were added to 2.0 mL ABTS solution and the absorbance was measured at 734 nm after 15 min. The Trolox equivalent antioxidant capacity was subsequently calculated using Trolox as the standard and the result was expressed as millimoles of Trolox equivalent antioxidant capacity (TEAC) per gram of sample (mM/g).

FRAP (ferric reducing antioxidant power) was evaluated by using the procedure described by Nyau *et al.* (2015). The method involved measurement of the ability of the aqueous extract of the sample to reduce ferric (Fe^{3+}) 2, 4, 6-tripyridyl-s-triazine (TPTZ) complex to ferrous (Fe^{2+}) form. The amount of Fe^{2+} produced from the reduction of Fe^{3+} was calculated from the standard curve prepared from ferrous sulphate solution and ferric reducing antioxidant power was reported in mg/g.

TPC (Total phenolic content) was determined using the method described by Mahloko *et al.* (2019). A 500 µL of sample extract was mixed with 2.5 mL of 10% Folin–Ciocalteau's reagent and 2 mL of 7.5% sodium carbonate. The mixture was thoroughly mixed and incubated for 40 min at 45 ^{o}C and the absorbance was measured at 765 nm. Total phenolic content was calculated from a calibration curve prepared by using gallic acid as standard and the result was expressed as mg gallic acid equivalent (GAE) per gram of the sample.

Physical properties of biscuits

Weight (g) and diameter (cm) of the biscuits were determined by using weighing balance and a calibrated ruler respectively. The height of five stacked biscuit was measured and divided by 5 to get thickness (cm) of each biscuit; the spread ratio was obtained by dividing the diameter of each biscuit with thickness.

Sensory evaluation of biscuits

A Panel of twenty two members who are regular consumers of biscuit and were not allergic to any food were chosen for the sensory analysis. Panellists were presented with coded biscuit samples in random sequence and were instructed to evaluate taste, aroma, colour, crispiness, texture, and overall acceptability of the biscuits. A 9 - point hedonic scale with 1 representing dislike extremely and 9 representing like extremely was used.

Statistical analysis

Data obtained from the analysis were subjected to analysis of variance using SPSS 21 computer program.

Results and discussion

Proximate composition of breadfruit-lima bean flour blends

The proximate compositions of the samples are presented in Table 1. Moisture contents of flour blends ranged from 6.67 – 9.14%. The moisture content increased with increase in the level of lima beans in the flour blends, moisture content of the flour blends were relatively low and this may enhance shelf stability of the blends. Protein content of breadfruit flour was 5.38%, this is similar to 4.91 – 5.54% reported in the literature (Huang *et al.,* 2020). Substitution of breadfruit flour with lima beans flour increased the protein content to 13.43%. This trend of result indicates that lima beans contributed significantly to the protein content of the flour blends. This was expected because as leguminous crop lima beans have good quantity of protein, 22.24% (Farinde *et al.*, 2018). The range of protein content reported in this study was higher than 8.24 – 9.49% reported for wheat-plantain- tigernut composite flour (Bamigbola *et al.*, 2016). There was marginal increase in the fat content of the flour blends; the increase became significant at 30% level of lima bean inclusion. The low quantity of fat in the flour blends suggests that it may be stable against oxidative deterioration during storage. Ash content, which provides information on the quantum of the total mineral constituent of a sample, increased from 1.85% for breadfruit flour to 3.07% for blends with highest level of lima bean inclusion. The flour blends have appreciable quantity of crude fibre content (4.62 – 4.98%) and there was no significant difference in the crude fibre content of the flour blends. Significant reduction in carbohydrate content of the flour blends was observed with increasing lima bean level. Lowest carbohydrate content of 68.23% was recorded in flour blends with highest level of lima bean.

Table 1. Proximate composition (%) of breadfruit-lima bean flour blends.

Samples	Moisture	Protein	Fat	Ash	Crude Fibre	Carbohydrate
BFLB0	$6.67{\pm}0.13^{c}$	$5.38{\pm}0.11^{e}$	$0.54{\pm}0.01^{c}$	$1.85{\pm}0.06^{c}$	$4.98{\pm}0.01^{a}$	$80.58{\pm}0.14^{a}$
BFLB1	$7.09{\pm}0.10^{c}$	$7.03{\pm}0.10^{d}$	$0.57{\pm}0.00^{c}$	$1.88{\pm}0.04^{c}$	$4.80{\pm}0.02^{a}$	$78.63{\pm}0.18^{b}$
BFLB2	$7.78{\pm}0.05^{b}$	$8.69{\pm}0.09^{c}$	$0.69{\pm}0.02^{c}$	$2.47{\pm}0.05^{b}$	$4.92{\pm}0.02^{a}$	$75.45{\pm}0.13^{c}$
BFLB3	$8.95{\pm}0.11^{a}$	$11.31{\pm}0.10^{b}$	$0.98{\pm}0.01^{b}$	$2.82{\pm}0.02^{a}$	$4.69{\pm}0.01^{a}$	$71.25{\pm}0.26^{d}$
BFLB4	$9.14{\pm}0.12^{a}$	$13.43{\pm}0.16^{a}$	$1.51{\pm}0.04^{a}$	$3.07{\pm}0.03^{a}$	$4.62{\pm}0.02^{a}$	$68.23{\pm}0.34^{e}$

Values in the same column with different superscript are significantly different ($p \leq 0.05$)
BFLB0 = Breadfruit flour 100% + Lima bean flour 0%; BFLB1 = Breadfruit flour 90% + Lima bean flour 10%; BFLB2 = Breadfruit flour 80% + Lima bean flour 20%; BFLB3 = Breadfruit flour 70% + Lima bean flour 30%; BFLB4= Breadfruit flour 60% + Lima bean flour 40%.

Amino acid composition of breadfruit-lima bean flour blends

The result of amino acid composition (Table 2) showed the total amino acid content of the flour blends to be in the range of 83.95 – 91.53 g/100g protein, this range was higher than the range 70.55 – 87.97 g/100g protein reported for nixtamalized maize - sprouted soy flour blends (Inyang *et al.*, 2019). All the essential amino acids were present in the flour blends constituting 34.86 – 40.03% of the total amino acid. There was fluctuation in the percentage essential amino acid of the samples; sample with 20% lima bean had the highest percentage essential amino acid which may indicate its high nutritional value. Leucine was the most abundant among the essential amino acids (6.50 – 7.02 g/100g protein), the amino acid has been reported to stimulate protein synthesis and enhance the ability to build and spare muscle in the body when dieting (Amaechi *et al.*, 2017). The considerable level of lysine in the flour blends (2.67 – 3.57 g/100g) is of interest.

Table 2. Amino acid composition of breadfruit-lima bean flour blends.

Amino Acid (g/100g protein)	**BFLB0**	**BFLB1**	**BFLB2**	**BFLB3**	**BFLB4**
Glycine	3.77	3.93	4.71	3.41	4.88
Alanine	3.43	2.78	3.04	3.26	3.12
Serine	4.54	4.82	4.27	3.97	3.90
Proline	6.69	5.27	5.07	6.41	5.18
Valine*	4.61	5.03	6.18	4.09	6.33
Threonine*	4.01	3.32	3.22	3.91	3.41
Isoleucine*	3.32	3.78	2.61	3.11	4.03
Leucine*	7.02	6.57	6.50	6.78	6.96
Aspartate	7.33	6.68	6.55	7.05	6.65
Lysine*	3.57	2.89	2.67	3.38	3.45
Methionine*	1.41	1.21	4.29	1.31	1.17
Glutamate	24.82	20.47	19.01	27.00	21.57
Phenylalanine*	5.24	3.84	5.76	4.95	6.15
Histidine*	2.58	2.21	2.25	2.42	2.30
Arginine	3.23	4.29	4.82	3.14	5.29
Tyrosine	2.59	3.70	3.30	2.42	3.35
Tryptophan*	1.47	1.31	1.39	1.29	1.39
Cystine	1.90	1.85	1.47	1.71	1.39
Total Amino Acid (TAA)**	91.53	83.95	87.11	89.61	90.52
TEAA	33.23	30.16	34.87	31.24	35.19
% TEAA	36.31	35.93	40.03	34.86	38.88
TNEAA	58.30	53.79	52.24	58.37	55.33
% TNEAA	63.69	64.07	59.97	65.14	61.12
TSAA Met + Cys	3.31	3.06	5.76	3.02	2.56
% TSAA	3.62	3.65	6.61	3.37	2.83
TAAA Asp+Glu	32.15	27.15	25.56	34.05	28.22
% TAAA	35.13	32.34	29.34	38.00	31.18
TBAA Lys+His+Arg	9.38	9.39	9.74	8.94	11.04
% TBAA	10.25	11.19	11.18	9.98	12.20
TNAA	50.00	47.41	51.81	46.62	51.26
% TNAA	54.63	56.47	59.48	52.03	56.63
P-PER	2.45	2.13	2.14	2.36	2.34

*Essential amino acid.

** Total Amino Acid = (Glycine + Alanine + Serine + Proline + Valine + Threonine + Isoleucine + Leucine + Aspartate + Lysine + Methionine + Glutamate + Phenylalanine + Histidine +Arginine + Tyrosine + Trptophane + Cystine). TEAA - Total Essential Amino Acids; TNEAA - Total Non Essential Amino Acids; TSAA Met + Cys - Total Sulphur Amino Acids; TAAA Asp+Glu - Total Acidic Amino Acids; TBAA Lys+His+Arg - Total Basic Amino Acids; TNAA - Total Neutral Amino Acids; P-PER - Predicted Protein Efficiency Ratio.

BFLB0 = Breadfruit flour 100% + Lima bean flour 0%; BFLB1 = Breadfruit flour 90% + Lima bean flour 10%; BFLB2 = Breadfruit flour 80% + Lima bean flour 20%; BFLB3 = Breadfruit flour 70% + Lima bean flour 30%; BFLB4= Breadfruit flour 60% + Lima bean flour 40%.

Lysine is the limiting amino acid of most cereals which form the diet of people in developing nations, inclusion of this flour blends in the diet may therefore help to bridge the gap of inadequate lysine. With respect to essential amino acids, the samples met the FAO/WHO (2007) requirement for adults and children (2-5 years) to a very large extent except lysine, methionine and phenylalanine for adult, and methionine for children. This suggests that utilization of the flour blends in formulation of complementary foods for children may be more beneficial than when use for adult foods. The proportion of the two sulphur containing amino acids (methionine and cystine) ranged from 2.83 – 6.61% of the total amino acid. The acidic, basic and neutral amino acids constituted 29.34 - 38.00%, 9.98 - 12.20% and 52.03 - 59.48% of the total amino acid respectively. Glutamate has the highest concentration among all the amino acids, similar observation was reported for African locust bean pulp (Arinola *et al.,* 2019), brown bambara groundnut (Oyeyinka, 2017) and protein isolates of *Cucumeropsis mannii* seeds (Ogunbusola *et al*., 2008).

The quality of protein depends on the amino acid content of food materials and on the physiological utilization of specific amino acid after digestion and absorption. One of the parameters usually used in determining protein quality is protein efficiency ratio. In this study the protein efficiency ratio was not determined through in-vivo experiment; it was rather evaluated using one of the equations reported by Alsmeyer *et al.* (1974). There was fluctuation in the value of predicted protein efficiency ratio which ranged from 2.13 to 2.45. Breadfruit flour had the highest predicted protein efficiency ratio followed by sample substituted with 30% and 40% lima bean respectively. The predicted protein efficiency ratio reported in this study were comparable to 2.4 reported for some protein fraction of *Lagenaria siceraria* (Ogunbusola *et al.*, 2010). The predicted protein efficiency ratios of all the samples were higher than 1.5, which is considered to be the minimum for protein of good quality (Friedman, 1996).

Functional properties of breadfruit-lima bean flour blends.

The swelling power and water absorption capacity of 100% breadfruit flour was 5.95 g/g and 6.20 mL/g respectively (Table 3), these values progressively reduced with increase in the level of lima beans flour in the flour blends. This pattern of result may be attributed to dilution effect, breadfruit flour is known to be majorly a starchy sample with higher capacity to absorb water and swell while lima beans is rich in protein and fat with lesser water absorption and swelling capacity. Water absorption capacity and swelling power of all the flour blends were higher than 5.07 mL/g and 2.03 respectively reported for wheat flour (Offia-Olua, 2014), this suggest that the flour blends may contribute to improved yield and consistency when used in food system. High water absorption and swelling capacity is considered critical in food formulations because it improves reconstitution ability, yield and texture of food (Bamigbola *et al.*, 2016). The oil absorption capacity of the flour blends ranged from 2.00 - 2.80 mL/g, inclusion of lima beans in the flour blends appeared to improve the oil absorption capacity of the flour blends probably due to higher protein content which enhance hydrophobic interaction with oil. Ability of flour sample to absorb oil reflects its usefulness in fat based foods and its ability to improve mouth feel and retain flavors.

Table 3. Functional properties of breadfruit-lima bean flour blends.

	BFLB0	BFLB1	BFLB2	BFLB3	BFLB4
Swelling Power (g/g)	5.95±0.04[a]	5.60±0.02[b]	5.50±0.03[b]	4.80±0.02[c]	4.70±0.01[c]
Water Absorption Capacity (mL/g)	6.20±0.02[a]	6.10±0.03[a]	5.70±0.01[b]	5.60±0.03[bc]	5.40±0.00[c]
Oil Absorption Capacity (mL/g)	2.00±0.02[c]	2.00±0.01[c]	2.40±0.03[b]	2.50±0.02[b]	2.80±0.02[a]
Least Gelation Concentration (%)	8.00 ±0.00[a]	8 .00±0.00 [a]	8 .00 ±0.00[a]	6.00 ±0.00[b]	6.00±0.00 [b]
Dispersibility (%)	65.00±0.50[a]	62.00±0.50[b]	56.00±0.00[c]	54.00±0.50[d]	50.00±0.50[e]
Foaming Capacity (%)	5.00±0.20[d]	7.00±0.40[c]	10.00±0.20[b]	16.00±0.60[a]	15.00±0.40[a]
Wetability (Seconds)	66.00±0.30[a]	62.00±0.10[b]	56.00±0.50[c]	49.00±0.30[d]	50.00±0.20[d]
Packed Bulk Density (g/mL)	0.64±0.02[c]	0.65±0.00[c]	0.69±0.01[b]	0.69±0.01[b]	0.72±0.00[a]
Loose Bulk Density (g/mL)	0.34±0.01[d]	0.37±0.01[c]	0.39±0.00[b]	0.37±0.00[c]	0.43±0.01[a]

Values in the same row with different superscript are significantly different ($p \leq 0.05$).

BFLB0 = Breadfruit flour 100% + Lima bean flour 0%; BFLB1 = Breadfruit flour 90% + Lima bean flour 10%; BFLB2 = Breadfruit flour 80% + Lima bean flour 20%; BFLB3 = Breadfruit flour 70% + Lima bean flour 30%; BFLB4= Breadfruit flour 60% + Lima bean flour 40%.

Least gelation concentration is a measure of the minimum amount of sample needed to form a stable gel in a defined quantity of water. Least gelation concentration is majorly influenced by carbohydrate, protein and their interactions (Akubor and Fayashe, 2018). The least gelation concentration of 100% breadfruit flour was 8%, at higher level of lima beans inclusion the least gelation concentration was reduced from 8% to 6%. This reduction may be due to relative increase in the protein content of the flour blends which might have enhanced interaction of the binding forces resulting in improved gelling ability. The low least gelation concentration of the flour blends indicates that low quantity of the flour blends is needed to form gel which may be desirable in some food product formulations. The dispersibility of 100% breadfruit flour was the highest, increase in the level of lima beans in the flour blends reduced dispersibility value. Dispersibility of the flour blends were lower than 52 - 79% reported for flour blends produced from unripe cooking banana, pigeon pea and sweet potato (Ohizua *et al.,* 2017). Dispersibility indicate ease of reconstitution, the higher the value the greater the reconstitution ability. Lima beans generally improve the foaming capacity of the flour blends; this may be due to its protein contents.

Foaming capacity, which is important in some food preparations, is usually influenced by quantity of protein, solubility of protein and pH. The foaming capacity of the flour blends ranged from 5.00 - 16.00%. There was significant difference in the wetability of the samples, which ranged from 49 to 66 seconds. Packed and loose bulk densities varied from 0.64 – 0.79 g/mL and 0.34 – 0.43 g/mL respectively, increase in inclusion of lima bean in the flour blends increased the values. The values reported in this study were lower than 0.81 – 0.92 g/mL reported for plantain-tiger nut flour blends (Adegunwa *et al.,* 2017). Bulk density generally measures the heaviness of flour and gives an indication of the handling, packaging and transportation requirements of food materials (Oppong *et al.*, 2015). High bulk density offers packaging advantage because greater quantity of the materials can be packaged within a constant volume. However, in food application, low bulk density may be desirable in some products such as complementary foods because it enhances consumption of more quantity of the food product which translates to more nutrients for the consumer (Ocheme *et al.*, 2018).

Pasting properties of breadfruit-lima bean flour blends

The pasting properties of the flour blends are shown in Table 4. Pasting properties give an indication of the texture, digestibility and possible end use of food materials. There were significant differences in pasting values of the samples; the peak viscosity of breadfruit flour was 88.17 RVU while substitution with lima bean reduced it to the lowest value of 62.25 RVU at 20% level of substitution. Generally substitution with lima bean affected the pasting indexes of the flour blends; samples with 10% and 40% level of lima bean substitution have exceptionally higher peak viscosity. The fluctuation in the peak viscosity with respect to level of substitution with lima bean may be due to decrease in starch content and interaction between starchy and non-starchy components like protein and fat.

The hot paste viscosity of all the samples were higher than the peak viscosity, this is contrary to observation reported for other flour blends like wheat-groundnut protein concentrate (Ocheme *et al.*, 2018) and plantain-tiger nut (Adegunwa *et al.,* 2017). This observation may be ascribed to pasting characteristic of breadfruit flour which constituted a major proportion of the flour blends. Breadfruit flour has been reported to show little or no breakdown during isothermal stage of the pasting test resulting in higher hot paste viscosity. This observation has been attributed to the structural integrity of breadfruit starch granules which do not readily disintegrate and are able to withstand heating and shear (Rincon and Padilla 2004; Akanbi *et al.*, 2009; Arinola and Omowaye-Taiwo, 2020). Ajatta *et al.* (2016) reported that the breakdown viscosity of composite flour produced from wheat-breadfruit-cassava starch reduced with increase in the proportion of breadfruit in the composite flour, this gives credence to the fact that breadfruit flour do not exhibit much reduction in viscosity during continuous heating and stirring. Breakdown viscosity measures the extent to which swollen starch granules can disintegrate at high temperature and with continuous shearing, it has an inverse relationship with paste thermal stability and it is an important factor in many processes especially those requiring stable paste and low retrogradation.

Table 4. Pasting properties of breadfruit-lima bean flour blends.

	BFLB0	BFLB1	BFLB2	BFLB3	BFLB4
Peak Viscosity (RVU)	88.17±1.05^{c}	107.17±1.80^{a}	62.25±1.21^{d}	63.17±1.45^{d}	101.75±1.00^{b}
Hot Paste Viscosity (RVU)	93.50±1.76^{c}	110.08±1.40^{a}	68.67±1.43^{d}	70.42±0.92^{d}	105.17±1.11^{b}
Breakdown Viscosity (RVU)	-5.33±0.10^{a}	-2.92±0.12^{b}	-6.42±0.14^{a}	-7.25±0.10^{a}	-3.42 ±0.09^{b}
Final Viscosity (RVU)	157.67±1.60^{c}	194.42±2.04^{a}	113.42±1.22^{d}	113.33±1.83^{d}	173.92±2.37^{b}
Setback Viscosity (RVU)	64.17±0.92^{c}	84.33±1.34^{a}	44.75±0.94^{d}	42.92 ±1.12^{d}	68.75±1.07^{b}
Peak Time (Mins)	7.00±0.02^{a}	6.93±0.01^{a}	7.00±0.02^{a}	7.00±0.01^{a}	7.00±0.02^{a}
Pasting Temperature (^{o}C)	78.20±0.20^{c}	79.10±0.30^{c}	87.20±0.10^{a}	87.20±0.20^{a}	85.55±0.00^{b}

Values in the same row with different superscript are significantly different ($p \leq 0.05$)

BFLB0 = Breadfruit flour 100% + Lima bean flour 0%; BFLB1 = Breadfruit flour 90% + Lima bean flour 10%; BFLB2 = Breadfruit flour 80% + Lima bean flour 20%; BFLB3 = Breadfruit flour 70% + Lima bean flour 30%; BFLB4= Breadfruit flour 60% + Lima bean flour 40%.

As a result of the fact that hot paste viscosity was higher than peak viscosity, the breakdown viscosity for all the samples was negative; this suggests that the sample would have high paste thermal stability and may be suitable for products involving extrusion at high temperature. The final viscosity ranged from 113.33 to 194.42 RVU, this viscosity defines the textural quality of the final products. The range of final viscosity reported in this study was higher than 110 – 130 RVU reported for sorghum-wheat composite flour (Adebowale *et al.,* 2012). Setback is the phase of the pasting curve after cooling of the sample to 50ºC and it indicates the tendency for retrogradation to occur; low setback value had been associated with greater resistance to retrogradation or syneresis (Sandhu *et al.,* 2007; Fasasi, 2009; Bamigbola *et al.,* 2016). Setback also has implication on resistance to enzyme hydrolysis and digestibility. The result showed that samples with 30% lima bean had the lowest setback viscosity of 42.92 RVU, the sample may be less susceptible to retrogradation when used in food systems and it may exhibit improved dough digestibility (Alamu *et al.*, 2017). There was no significant difference in the peak time of the samples although sample with 10% lima bean had a lower peak time of 6.93 minutes. Pasting temperature ranged from 78.20 to 87.20ºC, the value increased with increase in lima bean level in the flour blends. The pasting temperature provides an indication of minimum temperature required to cook a given sample and it also has implication on energy cost.

Physical properties* and *antioxidant activity of biscuits produced from breadfruit-lima bean flour blends

The physical properties and antioxidant activity of biscuits produced from breadfruit-lima beans flour blends are presented in Table 5. Biscuit produced from the flour blends exhibited lower spread ratio and diameter but higher weight and thickness when compared with the control biscuit. Increase in lima beans flour in the blends increased the spread ratio and diameter of the biscuit but reduced the weight and thickness of the biscuits. The increase in spread ratio as the level of lima bean in the blends increased may be attributed to hydrophilic starch. It can be deduced from the result of functional properties (Table 3) that lima bean had lower hydrophilic starch than breadfruit flour as reflected in the values of water absorption capacity and swelling power. The reduction in the level of hydrophilic starch in the flour blends as the level of lima beans increased might have reduced the limiting impact of hydrophilic starch on spread ratio. During mixing and baking, hydrophilic starch absorbs moisture and gelatinized, the gelatinization increases dough viscosity which in turn limit spread ratio (Temesgen *et al.*, 2015).

DPPH and ABTS are two major antioxidant indices commonly used to assess the ability of food materials to scavenge free radicals. Free radicals are atoms or molecules containing one or more unpaired electrons in valency shell and are capable of independent existence; they are products of normal cellular metabolism and are involved in many pathological conditions in human body (Phaniendra *et al.*, 2015). The results showed that biscuit produced from 100% breadfruit flour had lower DPPH radical scavenging ability than biscuit produced from wheat flour (Table 5). However, the addition of lima beans to breadfruit flour significantly increased the

DPPH scavenging ability of the biscuits and this might be attributed to the array of phytochemicals inherent in lima beans which are majorly responsible for antioxidant activity.

Table 5. Physical properties and antioxidant activity of biscuits produced from breadfruit-lima bean flour blends.

	BFLB0	BFLB1	BFLB2	BFLB3	BFLB4	Wheat Biscuit
Weight (g)	10.80±0.02[a]	10.68±0.01[a]	10.22±0.00[b]	9.89±0.01[c]	9.55±0.01[d]	7.08±0.03[e]
Diameter (cm)	4.53±0.00[d]	4.56±0.01[d]	4.73±0.02[c]	4.87±0.01[b]	4.93±0.01[b]	5.13±0.00[a]
Thickness (cm)	0.78±0.00[a]	0.77±0.01[a]	0.75±0.00[a]	0.73±0.01[a]	0.73±0.02[a]	0.68±0.01[b]
(Spread Ratio)	5.81±0.02[d]	5.95±0.01[d]	6.31±0.00[c]	6.67±0.02[b]	6.75±0.01[b]	7.54±0.02[a]
DPPH-RSA (%)	9.67±1.12[f]	21.47±0.74[d]	35.78±1.02[c]	50.09±1.47[b]	78.01±1.32[a]	19.06±0.48[e]
FRAP (mg/g)	1.03±0.08[e]	2.78±0.10[d]	6.45±0.21[c]	10.78±0.37[b]	14.56±0.59[a]	0.42±0.06[f]
ABTS-RSA (mM/g)	0.0160±0.0002[c]	0.0213±0.0000[b]	0.0213±0.0001[b]	0.0214±0.0000[b]	0.0216±0.0001[a]	0.0116±0.0001[d]
TPC (mg/g)	9.28±0.05[d]	11.95±0.09[c]	12.06±0.10[c]	14.25±0.12[b]	16.61±0.25[a]	1.81±0.04[e]

Values in the same row with different superscript are significantly different ($p \leq 0.05$)
BFLB0 = Breadfruit flour 100% + Lima bean flour 0%; BFLB1 = Breadfruit flour 90% + Lima bean flour 10%;
BFLB2 = Breadfruit flour 80% + Lima bean flour 20%; BFLB3 = Breadfruit flour 70% + Lima bean flour 30%;
BFLB4= Breadfruit flour 60% + Lima bean flour 40%.

The contribution of lima beans flour to antioxidant activity of biscuit produced from breadfruit was also observed in the values of ABTS. These results may suggest that consumption of biscuit produced from breadfruit flour with inclusion of lima bean can help to reduce the incidence and severity of degenerative diseases caused by free radical in human body. FRAP (ferric reducing antioxidant power) measured the reducing power (reduction of iron III complex to iron II complex), which is related to antioxidant activity because antioxidants are known to be reductants and inactivators of oxidants. The results revealed that biscuits produced from breadfruit and lima beans flours have appreciable FRAP value (1.03 – 14.56 mg/g) when compared with wheat biscuit (0.42 mg/g). TPC (Total phenolic contents) of the biscuits ranged from 9.28 mg/g for 100% breadfruit biscuits to 16.61 mg/g for biscuits with 40% lima bean inclusion. Phenolic compounds are of great importance as a result of their free radical scavenging ability and various biological activities with potential beneficial implication on human health (Sowndhararajan and Kang, 2013). The total phenolic content of breadfruit-lima bean cookies (9.28 to 16.61 mg/g) were higher than that of wheat biscuits corroborating the fact that the biscuits produced from breadfruit and lima beans may have better health benefit than wheat biscuits.

***Sensory properties of biscuits produced from breadfruit-lima bean flour blends*.**

The mean sensory scores of biscuits produced from breadfruit-lima bean flour blends are presented in Table 6.

There was significant difference in the taste of the biscuit produced from 100% breadfruit flour and those produced with inclusion of lima bean flour, samples with 20% and 30 % lima bean inclusion were not significantly different from the control (wheat biscuit) in term of taste. However, the aroma and texture of all the biscuits were significantly different from biscuit produced from wheat flour. This may be as a result of different inherent chemical components of the flours which to great extent dictate the development of aroma volatiles and texture of the biscuits. Another quality attribute affected by the chemical components of the flours is color, the test biscuit received lower significant score however the color of the sample with 20% lima bean compared favorably with wheat biscuits. This same pattern of result was observed for crispiness, there was no significant difference between the crispiness of biscuit produced from breadfruit flour with inclusion of 20% of lima bean and that produced from wheat flour. The crispiness of the test biscuit were generally rated lower, the relatively higher fibre content of breadfruit and lima bean flours might be the reason for this. In terms of overall acceptability, only biscuit produced from 80% breadfruit flour and 20% lima beans flour was not significantly different from biscuit produced from wheat flour. This indicates that this biscuit sample may compare favorably with wheat biscuit.

Table 6. Mean sensory scores of biscuits produced from breadfruit-lima bean flour blends.

Samples	Taste	Aroma	Color	Crispiness	Texture	Overall Acceptability
BFLB0	5.31 ± 0.35^{c}	5.46 ± 0.20^{b}	6.23 ± 0.47^{bc}	6.77 ± 0.45^{bc}	6.69 ± 0.47^{b}	6.15 ± 0.39^{c}
BFLB1	5.88 ± 0.50^{c}	6.23 ± 0.52^{b}	5.15 ± 0.21^{c}	7.08 ± 0.34^{b}	6.54 ± 0.55^{b}	6.71 ± 0.42^{bc}
BFLB2	7.43 ± 0.42^{ab}	6.08 ± 0.43^{b}	6.84 ± 0.56^{ab}	7.48 ± 0.52^{ab}	6.63 ± 0.48^{b}	7.42 ± 0.55^{ab}
BFLB3	7.25 ± 0.35^{ab}	6.23 ± 0.21^{b}	6.15 ± 0.33^{bc}	6.07 ± 0.39^{c}	6.30 ± 0.31^{b}	6.86 ± 0.38^{bc}
BFLB4	6.79 ± 0.30^{b}	6.23 ± 0.36^{b}	5.77 ± 0.39^{bc}	6.00 ± 0.40^{c}	6.85 ± 0.45^{b}	6.21 ± 0.45^{c}
Wheat Biscuits	8.38 ± 0.62^{a}	8.07 ± 0.59^{a}	7.90 ± 0.31^{a}	8.31 ± 0.73^{a}	8.31 ± 0.87^{a}	8.36 ± 0.65^{a}

Values in the same column with different superscript are significantly different ($p\leq0.05$)
BFLB0 = Breadfruit flour 100% + Lima bean flour 0%; BFLB1 = Breadfruit flour 90% + Lima bean flour 10%;
BFLB2 = Breadfruit flour 80% + Lima bean flour 20%; BFLB3 = Breadfruit flour 70% + Lima bean flour 30%;
BFLB4 = Breadfruit flour 60% + Lima bean flour 40%.

Conclusions

This study has shown that breadfruit-lima bean flour blends have appreciable nutritional and physicochemical properties with good predicted protein efficiency ratio which may qualify it for use in food formulations as a replacement to commonly used flours. Biscuits produced from the flour blends exhibited good antioxidant activity with potential of offering health benefits. Biscuit produced from breadfruit flour with inclusion of 20% lima bean flour was well accepted and compared favourably with wheat biscuit. Further study could be conducted on the nutritional quality of the flour blends through in-vivo experiments.

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