LWT - Food Science and Technology 70 (2016) 223–228

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Effect of acha and bambara nut sourdough flour addition on the quality of bread

Chiemela Enyinnaya Chinma*, Julian Chukwuemeka Anuonye, Ocheme Boniface Ocheme, Salisu Abdullahi, Shola Oni, Caleb Maina Yakubu, Shakirah Omotoke Azeez

Department of Food Science and Technology, Federal University of Technology Minna, Nigeria

ARTICLE INFO

Article history:
Received 1 December 2015
Received in revised form
11 February 2016
Accepted 23 February 2016
Available online 26 February 2016

Keywords:
Sourdough flour
Bread
Nutritional
Antioxidant
Bread properties

ABSTRACT

The effect of substituting wheat flour with acha and bambara nut sourdough flours on bread properties was investigated. Bread was prepared by replacing wheat flour with acha and bambara nut sourdough flour at different proportions (0, 5:5, 10:10 and 15:15). Nutritional, antinutritional, antioxidant and bread properties of bread were determined. Estimated intakes of nutrients were compared with dietary reference intakes (DRIs). Addition of sourdough flour influenced pasting properties of wheat flour. Total dietary fiber, protein digestibility (77.92–84.63%), mineral, amino acid and antioxidant contents of composite breads were significantly improved compared to wheat bread. Composite breads contained lower phytate (1.20–1.36 mg/100 g) compared to control bread (1.63 mg/100 g) while tannin was not detected in composite breads except at 15% sourdough flour inclusion (with a low value of 0.11 mg/100 g). Composite breads would contribute to DRIs of protein (50.29–71.65% in male and female), dietary fiber (47.33–50.44% in adult), iron (47.03–104.74% in male and female). Specific volume, color and texture of composite breads were not significantly different from control. Substitution of up to 10% sourdough flours in bread significantly improved taste, flavor and acceptability scores compared to wheat bread.

1. Introduction

Bakery products are the most consumed foods worldwide (Rosell, 2015). The incorporation of sourdough flour in wheat-based bread could be one of the approaches to prepare nutritious bread with potential health benefits, because sourdough has the potential to enhance the nutritional benefits of bread by improving mineral bioavailability, lowering the glycemic response and regulating the accessibility of bioactive compounds in the flour (Poutanen, Flander, & Katina, 2009). Therefore, utilization of composite whole grain-legume sourdough flour in wheat-based bread could be promising as a health-promoting food considering the health benefits of whole grain flour (as sources of dietary fiber and phytochemicals) and legumes (protein rich relative to cereals and better sources of essential amino acids).

Acha (*Digitaria exilis*) is an important source of antioxidant phenolics, dietary fiber and cholesterol-lowering waxes and capable of helping diabetic patients in West Africa (Jideani & Jideani, 2011). Acha protein contains higher amount of sulphur amino acids (methifne and cystine) and is less susceptible to denaturation while its starch is composed of total starch (43.6%), resistant (2.1%) and digestible starch (41.4%) with low glycemic index (Jideani & Jideani, 2011). On the other hand, bambara nut contains sufficient quantities of protein (20.5%), with relatively high proportions of micronutrient, essential amino acid (6.6% lysine and 1.3%, methionine) (Brough, Azam-Al, & Taylor, 1993) and antioxidative properties (Onyilagha, Islam, & Ntamatungiro, 2009). Additionally, bambara nut like other legume sources contains slow digestible starch that promotes slow and moderate postprandial glucose and insulin responses, and has low glycemic values.

The addition of composite sourdough flours in bread making have been reported (Hugo, Rooney, & Taylor, 2003; Coda, Rizzello, & Gobbetti, 2010; Coda et al., 2011; Alaunyte, Stojceska, Plunkett, Ainsworth, & Derbyshire, 2012; Rizzello, Calasso, Campanella, De Angelis, & Gobbetti, 2014). There is paucity of information in literature on the utilization of acha-bambara nut sourdough flour in bread making. Utilization of non-conventional grain-legume sourdough flour in bread requires research attention because of

* Corresponding author.
E-mail address: chinmachiemela@futminna.edu.ng (C.E. Chinma).

http://dx.doi.org/10.1016/j.lwt.2016.02.050
0023-6438/

growing demand for healthier baked products. The study aimed at evaluating the effect of substituting acha-bambara nut sourdough flour on the pasting properties of resultant flour blends, and the nutritional properties of wheat bread, and to compare the estimated intakes of nutrients to the dietary reference intakes (DRIs). Also, the antioxidant, anti-nutritional, physical and sensory properties of breads was evaluated.

2. Materials and methods

2.1. Materials

Bambara nut and acha seeds, wheat flour (Golden penny) and baking ingredients were purchased from Minna, Central market, Minna, Nigeria.

2.2. Preparation of flour

2.2.1. Acha flour

Acha flour was prepared as described by Ayo, Ayo, Nkama, and Adewori (2007). Acha seeds were sorted and dried at 60 °C in an air-draft oven and milled using attrition mill (Globe P 44, Diamond Tools Co. Ltd., Henan, China) to obtain acha flour. Acha flour was sieved through 100 μm sieve and stored in plastic containers with lids in a refrigerator.

2.2.2. Bambara nut flour

Bambara nut flour was prepared according to the method reported by Alozie, Udofia, Lawal, and Ani (2009). The seeds were sorted, cleaned, dehulled and toasted at 85 °C for 3 h in an air-draft oven (Gallenkamp 300 plus series, Widnes, Cheshire, U.K.). The toasted seeds were allowed to cool at room temperature and manually dehulled. The dehulled seeds were milled into flour using attrition mill to obtain bambara nut flour. Bambara nut flour was sieved through a 100 μm sieve and stored in plastic containers with lids in a refrigerator.

2.3. Preparation of sourdough and flour

The method of Edema, Emmambux, and Taylor (2013) was used in the preparation of sourdough. Acha and bambara nut flours were separately mixed with tap water (1:1 w/v) and incubated at 30 °C for 48 h. The sourdoughs were separately dried in an oven at 50 °C until 10% moisture content (dry basis) was achieved. The dried sourdough was sieved through 100 μm sieve and stored in plastic containers with lids.

2.4. Formulation of blends

Wheat flour and acha-bambara nut sourdough flours were blended at different proportions (100: 0:0; 90: 5: 5; 80:10:10 and 70:15:15) where 100% wheat flour served as control. A Kenwood mixer was used for blending flour and sourdough flours at speed 6 for 5 min to achieve uniform blending.

2.5. Determination of pH and titratable acidity

The pH value of sourdough and bread dough was measured using a pH meter (PHS-25, TECHMEL, USA). Total titratable acidity was determined according to the method of Coda et al. (2010). A 10 g of dough was homogenized with 90 ml of distilled water and expressed as the amount (ml) of 0.1 M NaOH to obtain pH 8.3.

2.6. Determination of pasting properties

Pasting properties of wheat flour-acha-bambara nut sourdough flour blend was determined using rapid visco analyzer (RVA) (Newport Scientific Pty Ltd., New South Wales 2102, Australia) according to AACC method (2000). A 2.5 g of flour was weighed into a dried empty canister; then 25 ml of distilled water was dispensed into the canister containing the sample. The suspension was thoroughly mixed, and the canister was fitted into the RVA. Each suspension was kept at 50 °C for 1 min, heated to 95 °C at 12.2 °C/min and then held at 95 °C for 2.5 min, cooled to 50 °C at 11.8 °C/min and held for 2 min to determine the RVA profile. The RVA parameters determined include: peak viscosity (maximum paste viscosity achieved in stage 2, the heating stage of the profile), final viscosity (viscosity at the end of run), break down viscosity (difference between peak viscosity and trough), set back viscosity (difference between final viscosity and trough), pasting temperature (temperature at which starch granules begin to swell and gelatinize due to water uptake) and peak time (time at which peak viscosity was recorded) (Marston, Khouryieh, & Aramouni, 2016).

2.7. Preparation of bread

The straight dough method of bread making as reported by Mohammed, Ahmed, and Senge (2012) was used in bread making. The recipe was based on flour weight, as follows: 100 g flour, 10 g sugar, 0.75 g salt, 1.0 g baker's yeast, 1 g fat (margarine) and 50 ml water. The dough was rested for 30 min, hand-kneaded and left for 15 min. Dough pieces were divided (100 g), manually rounded, rolled and put into baking pans greased with margarine and placed in a proofer at 40 °C for 60 min. The bread was baked in an oven at 200 °C for 15 min. The baked bread loaves were allowed to cool for 2 h for subsequent analysis.

2.8. Chemical analysis

Protein, fat, ash, total dietary fiber and mineral (calcium, iron, magnesium and zinc) contents of samples were determined according to AOAC method (2005). The in-vitro protein digestibility of bread samples were determined using the procedure described by Aboubacar, Axiell, Huagng, and Hamaker (2001). Amino acid composition of breads were determined as described by Bidlingmeyer, Cohen, and Tarvin (1984) and results reported as g/100 g protein.

2.9. Phytic acid and tannin analysis

Phytic acid content of samples was determined spectrophotometrically according to the AOAC method (2005). Tannin was determined using the method described by Price, Van and Butler (1987).

2.10. Determination of antioxidant properties

The method of Beta, Nam, Dexter, and Sapirstein (2005) was used for the ferric reducing antioxidant power (FRAP) assay. The free radical scavenging activity of breads was measured by 1,1-diphenyl-2-picryl-hydrazil (DPPH) according to the method described by Silva, Ferreres, Malva, and Dias (2005).

2.11. Determination of physical properties of bread

Weight of bread loaves was determined by weighing in an electronic weighing balance. Loaf volume was determined using the rape seed displacement method as described by AACC (2000).

Specific loaf volume was obtained by dividing the loaf volume by the corresponding loaf weight (AACC, 2000).

2.12. Sensory evaluation

Sensory analysis of bread samples was carried out by 20 panelists (11 female and 9 male, mean ages: 32, range: 23–48 years). The panelists were instructed to evaluate the coded samples for color (crust and crumb), texture, flavor, taste and overall acceptability. Each sensory attribute was rated on a 9-point Hedonic scale (1 = disliked extremely and 9 = liked extremely). The sensory attributes were discussed with the panellists during a sensory training session. Tap water was provided to rinse the mouth between evaluations.

2.13. Statistical analysis

Data obtained were subjected to analysis of variance (ANOVA) and differences among means were compared by Tukey tests at 5% probability level. All computations were made by statistical software SPSS (version 11).

3. Results and discussion

3.1. Composition of sourdough and flour

The composition of sourdough and flours was first evaluated. The pH of acha and bambara nut sourdough was 4.17 and 4.22, respectively. The moisture, ash, protein, fat, total dietary fiber, carbohydrate, phytic and tannin contents of acha sourdough flour were 7.29%, 1.26%, 12.51%, 0.47%, 4.63%, 78.47%, 1.58 mg/100 g and 0.16 mg/100 g, respectively. Bambara nut sourdough flour contained 8.11% moisture, 3.68% ash, 23.80% protein, 4.31% fat, 3.82% total dietary fiber, 56.28% carbohydrate, 2.03 mg/100 g phytic acid and 1.27 mg/100 g tannin. The pH and titratable acidity values of bread dough prepared from blends of wheat flour and acha-bambara nut sourdough flours at different proportions of 100: 0:0; 90: 5: 5; 80:10:10 and 70:15:15 were 4.63 and 9.62, 4.37 and 8.87, 4.30 and 8.39, 4.19 and 8.07, respectively.

3.2. Pasting properties

Substitution of acha and bambara nut sourdough flours to wheat flour significantly ($P \leq 0.05$) decreased peak viscosity (from 135.64 to 100.81 RVU), trough viscosity (from 81.10 to 60.11 RVU), breakdown viscosity (from 54.52 to 40.73 RVU), final viscosity (from 155.37 to 121.07 RVU) and setback viscosity (74.27–60.96 RVU) and pasting temperature (from 69.80 to 67.56 °C) of wheat flour (Table 1) while peak time showed no significant ($P \geq 0.05$) increase. The decrease in pasting parameters of wheat flour when substituted with acha and bambara nut sourdough flours could be attributed to alteration in the starch content, composition and properties, which in turn impacts the viscosity profile. Also, high protein and fat contents in food samples are known to influence pasting properties (Eliasson, Carlson, Larsson, & Miezis, 1981).

3.3. pH, nutritional properties, phytate and tannin contents of bread

The pH, nutritional properties, phytate and tannin contents of breads are shown in Table 2 pH of breads containing sourdough had increased acidity and this was evident from their lower pH range (5.20–5.31) compared to 100% wheat bread (5.80). The acidity of the composite breads increased with an increase in sourdough substitution level. Ash, fat, protein and total dietary fiber of composite bread ranged from 2.53 to 3.02%, 4.06–4.45%, 14.08–16.48% and 4.26–4.54%, respectively, while 100% wheat bread contained 2.19% ash, 3.81% fat, 12.14% protein and 3.91% crude fiber (Table 2). The calcium, iron, magnesium and zinc contents of composite bread ranged from 52.62 to 53.30 mg/100 g, 3.48–4.73 mg/100 g, 75.85–108.65 mg/100 g, 0.98–1.42 mg/100 g, respectively and were significantly higher compared to 100% wheat bread (51.08 mg/100 g calcium, 2.72 mg/100 g iron, 54.50 mg/100 g magnesium and 0.91 mg/100 g zinc). Generally, ash, fat, protein, total dietary fiber and mineral contents of composite bread were significantly higher than 100% wheat bread, and could be attributed to inclusion of acha and bambara nut sourdough flours. Sourdough fermentation modified the availability of fiber fraction, protein and increased mineral contents of flour (Katina et al., 2005).

Protein digestibility is one of the indices used for evaluation of protein quality as well as an indicator for protein bioavailability in foods (Chinma, James, Imam, Anuonye, & Yakubu, 2013). Composite bread samples had higher protein digestibility (77.92–84.63%) compared to 100% wheat bread (72.30%). The protein digestibility values of composite bread was higher than the values (68.98–77.85%) reported by Rizello et al. (2014) for sourdough bread prepared from wheat, chickpea, lentil and bean flour blends.

Phytic acid and tannins are anti-nutrients in foods. Phytic acid has ability to bind minerals, proteins, and starch which alters the solubility, functionality, digestion, and absorption of these food components (Oatway, Vasanthan, & Helm, 2001) while tannins lower the overall quality of foods by reducing the bioavailability of protein and iron (Mosha & Vicent, 2005). Opposed to the anti-nutritive effect of phytic acid, there are scientific evidence demonstrating a diverse range of benefits to health and wellbeing such as decrease in plasma cholesterol and triglycerides, decrease the availability of heavy toxic metals and possess antioxidant and anti-carcinogenic effects (Kumar, Sinha, Makkar, & Becker, 2010). Composite breads contained lower phytic acid content (1.20–1.36 mg/100 g) compared to wheat bread (1.66 mg/100 g),

Table 1
Effect of substitution of acha-bambara nut sourdough flour on the pasting properties of wheat flour.

Parameters	100WF	90WF: 5ASF:5BSF	80WF: 10ASF:10BSF	70WF: 15ASF:15BSF
Peak viscosity (RVU)	135.64 ± 0.56[a]	128.20 ± 0.59[b]	120.54 ± 0.38[c]	100.81 ± 0.73[d]
Trough (RVU)	81.10 ± 0.29[a]	77.84 ± 0.91[b]	72.28 ± 0.25[c]	60.11 ± 0.52[d]
Breakdown (RVU)	54.52 ± 0.45[a]	50.36 ± 0.81[b]	48.26 ± 0.77[c]	40.73 ± 0.60[d]
Final viscosity (RVU)	155.37 ± 0.80[a]	148.76 ± 0.63[b]	139.78 ± 0.30[c]	121.07 ± 0.78[d]
Setback (RVU)	74.27 ± 0.75[a]	70.92 ± 0.27[b]	67.30 ± 0.61[c]	60.96 ± 0.56[d]
Peak time (Min)	5.12 ± 0.10[a]	5.19 ± 0.39[a]	5.23 ± 0.85[a]	5.29 ± 0.40[a]
Pasting temperature (°C)	69.80 ± 0.42[a]	68.57 ± 0.44[b]	67.68 ± 0.40[c]	67.56 ± 0.92[c]

Mean and standard deviation of three determinations.
Values in the same row with different superscript are significantly ($P \leq 0.05$) different.
100WF = 100% wheat flour; 90WF:5ASF:5BSF = 90% wheat flour: 5% acha sourdough flour: 5% bambara nut sourdough flour; 80WF: 10ASF:10BSF = 80% wheat flour: 10% acha sourdough flour: 10% bambara nut sourdough flour; 70WF: 15ASF:15BSF = 70% wheat flour: 15% acha sourdough flour: 15% bambara nut sourdough flour.

Table 2
Effect of substitution of acha-bambara nut sourdough flour on the chemical composition and antioxidant properties of bread.

Parameter	100WF	90WF:5ASF: 5BSF	80WF:10ASF:10BSF	70WF:15ASF:15BSF
pH	5.82 ± 0.03[a]	5.31 ± 0.01[b]	5.24 ± 0.00[b]	5.20 ± 0.01[c]
Ash (%)	2.19 ± 0.10[d]	2.53 ± 0.05[c]	2.67 ± 0.10[b]	3.02 ± 0.19[a]
Fat (%)	3.81 ± 0.16[d]	4.06 ± 0.21[c]	4.28 ± 0.08[b]	4.45 ± 0.11[a]
Protein (%)	12.14 ± 0.10[d]	14.08 ± 0.18[c]	15.11 ± 0.14[b]	16.48 ± 0.09[a]
Total dietary fiber (%)	3.91 ± 0.06[d]	4.26 ± 0.17[c]	4.38 ± 0.10[b]	4.54 ± 0.22[a]
In vitro protein digestibility (%)	72.30 ± 0.84[d]	77.92 ± 1.01[c]	81.17 ± 0.96[b]	84.63 ± 0.75[a]
Calcium (mg/100 g)	51.08 ± 0.50[d]	52.62 ± 0.37[c]	54.62 ± 0.59[b]	55.30 ± 0.86[a]
Iron (mg/100 g)	2.72 ± 0.10[d]	3.48 ± 0.17[c]	3.96 ± 0.21[b]	4.73 ± 0.05[a]
Magnesium (mg/100 g)	54.40 ± 0.01[d]	75.85 ± 0.02[c]	94.20 ± 0.01[b]	108.65 ± 0.61[a]
Zinc (mg/100 g)	0.91 ± 0.04[b]	0.98 + 0.32[ab]	1.30 ± 0.16[a]	1.42 ± 0.21[a]
Phytic acid (mg/100 g)	1.63 ± 0.00[a]	1.20 + 0.01[a]	1.25 ± 0.01[a]	1.36 ± 0.00[a]
Tannin (mg/100 g)	ND	ND	ND	0.11 ± 0.21[a]
DPPH value (mmol TEAC/100 g)	102.47 ± 0.60[d]	128.20 + 0.71[c]	137.16 ± 0.44[b]	143.65 ± 0.59[a]
FRAP (mmol TE/100 g)	498.50 ± 1.05[d]	512.91 + 0.68[c]	529.43 ± 0.75[b]	565.10 ± 0.97[a]

Mean and standard deviation of three determinations.
Values in the same row with different superscript are significantly ($P \le 0.05$) different. ND = Not detected; 100WF = 100% wheat flour; 90WF:5ASF:5BSF = 90% wheat flour: 5% acha sourdough flour: 5% bambara nut sourdough flour; 80WF: 10ASF:10BSF = 80% wheat flour: 10% acha sourdough flour: 10% bambara nut sourdough flour; 70WF: 15ASF:15BSF = 70% wheat flour: 15% acha sourdough flour: 15% bambara nut sourdough flour.

and this suggests that the consumption of the composite breads could be beneficial to those who wish to enhance bioavailability of minerals. Tannin was not detected in 100% wheat bread and composite breads except for 15% substituted sourdough bread (0.11 mg/100 g). Phytic acid and tannin contents were below their toxic levels in substituted bread. The phytic acid content of breads obtained in this study were lower than the value (1.77–6. 54 mg/g) reported by Tuncel, Yılmaz, Kocabıyık, and Uygurfor (2014) for infrared stabilized rice bran substituted breads. Also, Ktenioudaki et al. (2015) reported a phytic acid valued of 0.14–0.28 g/100 g for breads supplemented with brewer's spent grain sourdough flour.

Antioxidant properties of bread samples were evaluated using two assays: 1, 1-diphenyl-2-picryl-hydrazil (DPPH) and ferric reducing antioxidant power (FRAP) as presented in Table 2. Composite breads contained higher values of DPPH (128.20 to 143.65 mmol TEAC/100 g) and FRAP (512.91–565.19 mmol TE/100 g) than 100% wheat bread (102.47 mmol TEAC/100 g DPPH and 498.50 mmol TE/100 g FRAP). The antioxidant properties of composite bread samples increased with an increasing level of sourdough flour substitution in the blends; this trend is in agreement with the result of Moroni, Zannini, Sensidoni, and Arendt (2012) who reported that addition of buckwheat sourdough enhanced the antioxidant properties of wheat bread. The higher antioxidant activity of the composite breads is most probably attributed to the synthesis of antioxidantive peptides from lactic acid bacteria during sourdough fermentation of cereal flour (Coda, Rizzello, Pinto, & Gobbetti, 2012).

The contributions of protein, dietary fiber, iron, calcium and zinc to the dietary reference intakes (DRIs) is presented in Table 3. The calculation was based on a daily intake of 250 g of bread per person as recommended by World Health Organization given by the Food and Nutrition Board of National Academy of Science (NAS, 2004; Sanz-Penella, Wronkowska, Soral-Smietana, & Haros, 2013). In terms of DRIs, the control bread contributes 44.36% and 56.78% of the protein recommended for males and females respectively, while composite breads will contribute increased intakes of protein (50.29–58.86% in male, and 61.22–71.65% in female). Also, consumption of the control bread satisfies 43.44% of the dietary fiber recommendation, whereas composite bread will contribute 47.33–50.44% in adult. For iron, 100% wheat bread will contribute 62.53 and 38.86% in male and female respectively, while composite bread will contribute 80.00–104.74% (in male) and 47.03–63.92% (in female). For calcium, control bread will contribute 10.22% while composite bread will contribute 10.52–11.06% in adult. In terms of zinc, control bread will contribute 16.55 and 22.75% in male and female respectively while composite bread will contribute 17.82–25.82% (in male) and 24.50–35.50% (in female). The RDIs result indicates that wheat bread supplemented with acha-bambara nut sourdough flour will provide an adequate intake of protein, dietary fiber, iron and zinc.

Amino acid composition of composite bread (most acceptable blend after sensory evaluation) (80% wheat flour: 10% acha: 10% bambara nut sourdough flours) and 100% wheat bread is presented

Table 3
Contribution of nutrients to the relevant dietary reference intakes (DRIs) consuming an average daily portions of 250 g of wheat bread and composite bread.

Nutrient	Gender	DRIs	Contributions to DRIs (%)			
			100WF	90WF:5ASF:5BSF	80WF:10ASF:10BSF	70WF:15ASF:15BSF
Protein	Male	56 g/day	44.36	50.29	53.96	58.86
	Female	46 g/day	56.78	61.22	65.70	71.65
Dietary fiber	Adults	18 g/day	43.44	47.33	48.67	50.44
Iron	Male	8.7 mg/day	62.53	80.00	91.03	108.74
	Female	14.8 mg/day	38.86	47.03	53.51	63.92
Calcium	Adult	1000[a]	10.22	10.52	10.92	11.06
Zinc	Male	11 mg/day	16.55	17.82	23.64	25.82
	Female	8 mg/day	22.75	24.50	32.50	35.50

100WF = 100% wheat flour; 90WF:5ASF:5BSF = 90% wheat flour: 5% acha sourdough flour: 5% bambara nut sourdough flour; 80WF: 10ASF:10BSF = 80% wheat flour: 10% acha sourdough flour: 10% bambara nut sourdough flour; 70WF: 15ASF:15BSF = 70% wheat flour: 15% acha sourdough flour: 15% bambara nut sourdough flour.
[a] Males between 19 and 70 years, females between 19 and 50 years. Food and Nutrition Board, Institute of Medicine, National Academy of Science (NAS, 2004). Data adapted from the National Academy of Science (NAS, 2004).

Table 4
Effect of substitution of acha and bambara nut sourdough flour on the amino acid compositions (g/100 g) of wheat bread.

Amino acid	Wheat bread	80WF:10ASF: 10BSF
Histidine	1.03 ± 0.00[b]	2.28 ± 0.04[a]
Arginine	2.16 ± 0.03[b]	2.81 ± 0.01[a]
Threonine	1.35 ± 0.02[b]	1.97 ± 0.03[a]
Valine	0.79 ± 0.01[b]	1.80 ± 0.00[a]
Methionine	0.98 ± 0.01[b]	2.65 ± 0.04[a]
Isoleucine	0.90 ± 0.04[b]	1.86 ± 0.03[a]
Leucine	3.27 ± 0.03[b]	3.98 ± 0.01[a]
Phenylalanine	2.31 ± 0.10[b]	3.01 ± 0.03[a]
Lysine	2.20 ± 0.17[b]	2.90 ± 0.00[a]
Cysteine	1.05 ± 0.13[a]	1.73 ± 0.01[a]
Aspartic	1.92 ± 0.20[b]	3.54 ± 0.02[a]
Glutamic	5.90 ± 0.10[b]	6.62 ± 0.17[a]
Serine	1.03 ± 0.05[b]	1.98 ± 0.20[a]
Glycine	0.98 ± 0.04[b]	1.85 ± 0.06[a]
Alanine	1.30 ± 0.01[b]	2.22 ± 0.03[a]
Proline	5.22 ± 0.03[b]	5.98 ± 0.10[a]
Tryosine	1.97 ± 0.01[b]	2.73 ± 0.02[a]
Total amino acid	34.36	49.91

Mean and standard deviation of three determinations.
Values in the same row with different superscript are significantly ($P \leq 0.05$) different.
100WF = 100% wheat flour.
80WF: 10ASF:10BSF = 80% wheat flour: 10% acha sourdough flour: 10% bambara nut.

in Table 4. When compared to 100% wheat bread, incorporation of sourdough flour increased the amounts of essential and non-essential amino acids. The limiting amino acids (lysine, methionine and threonine) were higher in composite bread (2.90, 2.65 and 1.97 g/100 g, respectively) compared to 100% wheat bread (2.20, 0.98 and 1.35 g/100 g, respectively). Also, the total amino acid value of composite bread (49.91 g/100 g) was significantly higher than 100% wheat bread (34.36 g/100 g), and could be attributed to higher amino acid content of acha and bambara nut sourdough flours than wheat flour. Bambara nut flour has a good balance of essential amino acids with a relatively high proportion of lysine (6.6%) than wheat flour (Elegbede, 1998). Also, acha sourdough flour contains higher level of free amino acid (Coda et al., 2011).

3.4. Physical and sensory properties of bread

Physical properties of the breads are shown in Table 5. Bread weights were significantly different, with composite breads having the highest weight. The loaf weight of 100% wheat bread was 163.60 g while composite breads ranged from 165.25 to 167.18 g. The higher loaf weight of composite breads could be attributed to their ability to retain maximum amount of water or less retention of gas in the composite dough, hence providing denser bread loaf. Bread volume of composite breads decreased (from 501.17 to 490.48 cm^3) significantly with an increase in the level of sourdough flour substitution compared to wheat bread (517.92 cm^3). Consequently, composite breads specific volume decreased (from 3.02 to 2.93 cm^3/g) upon addition of sourdough flour compared to 100% wheat bread (3.17 cm^3/g). This could be attributed to dilution effect on gluten which caused less retention of gas resulting to low loaf volume. Addition of legume sourdough flour to wheat flour is associated with weak dough structure (Rizzello et al., 2014). On the other hand, the presence of brans in acha (whole grain) sourdough flour may mechanically hamper gluten network development causing the rupture of gas cells (Mariotti et al., 2014). Alaunyte et al. (2012) reported a reduction in loaf volume of wheat bread supplemented with teff sourdough, and attributed it to the disruption of the gluten matrix in the dough by the presence of bran particles in teff flour. In addition, differences in gas cell stabilization caused by differences in lipid population, perhaps contributed to variations in bread volume. The reduction in volume of composite bread accounted for a gradual reduction (although not significant) in specific loaf volume.

The sensory properties of breads are presented in Table 5. Substitution of acha-bambara nut sourdough flour in wheat bread had no significant difference in color (crust and crumb) scores of bread (Table 5). Texture score of 100% wheat bread was 7.2 while composite breads had higher score (7.4). Texture of composite breads was softer than 100% wheat bread, probably due to low peak viscosity value of composite blends compared to 100% wheat flour (Table 1). High peak and end viscosities of starch paste contribute to good textural qualities of food products (Otegbayo, Aina, Asiedu, & Bokanga, 2006). Flavor scores of composite breads were improved due to addition of sourdough flours (up to 10%), but an intense sour flavor was perceived in bread containing 15% sourdough flour. On the other hand, the taste and overall acceptability scores of composite bread differed significantly from the control at 15% substitution level, where taste and overall acceptability scores reduced (from 7.8 to 6.5, and 8.0 to 7.4, respectively). This implies that acceptable composite bread could be prepared with not more than addition of 10% sourdough flour. The intensity of bitter flavor and aftertaste in composite bread containing 15% sourdough flour was pronounced, which probability led to a reduction in acceptability score. This may be due to the buffering effect caused by higher acidity of the bread which led to the perceived bitter flavor and after taste. Also, it may be attributed to higher mineral content and

Table 5
Effect of substitution of acha-bambara nut sourdough flour on the physical and sensory properties of bread.

Parameters	100WF	90WF:5ASF: 5BSF	80WF:10ASF:10BSF	70WF: 15ASF. 15BSF
Physical properties				
Loaf weight (g)	163.60 ± 0.86[d]	165.25 ± 0.72[c]	166.41 ± 0.55[b]	167.18 ± 0.33[a]
Loaf volume (cm^3)	517.92 ± 1.03[a]	501.17 ± 1.19[b]	495.60 ± 1.08[c]	490.48 ± 0.87[d]
Specific volume (cm^3/g)	3.17 ± 0.24[a]	3.02 ± 0.17[a]	2.98 ± 0.11[a]	2.93 ± 0.37[a]
Sensory properties				
Crust color	7.0 ± 0.06[a]	7.1 ± 0.10[a]	7.3 ± 0.04[a]	7.3 ± 0.13[a]
Crumb color	7.2 ± 0.00[a]	7.2 ± 0.03[a]	7.1 ± 0.05[a]	7.1 ± 0.02[a]
Texture	7.2 ± 0.16[a]	7.4 ± 0.11[a]	7.4 ± 0.09[a]	7.4 ± 0.16[a]
Flavor	6.9 ± 0.00[b]	7.6 ± 0.03[a]	7.8 ± 0.01[a]	7.6 ± 0.05[a]
Taste	7.0 ± 0.13[b]	7.8 ± 0.08[a]	7.7 ± 0.15[a]	6.5 ± 0.03[b]
Overall acceptability	8.2 ± 0.17[a]	8.0 ± 0.10[a]	8.1 ± 0.06[a]	7.4 ± 0.01[b]

Physical parameters are mean and standard deviation of three determinations.
Sensory parameters are mean value of twenty panelists.
Values in the same row with different superscript are significantly ($P \leq 0.05$) different.
100WF = 100% wheat flour; 90WF:5ASF:5BSF = 90% wheat flour: 5% acha sourdough flour: 5% bambara nut sourdough flour; 80WF: 10ASF:10BSF = 80% wheat flour: 10% acha sourdough flour: 10% bambara nut sourdough flour; 70WF: 15ASF:15BSF = 70% wheat flour: 15% acha sourdough flour: 15% bambara nut sourdough flour.

the presence of bran in acha sourdough flour (whole grain sourdough flour). Alaunyte et al. (2012) reported phenolic compounds in cereal bran, are considered as one of the main contributing factors to bitterness. The authors reported a reduction in taste and overall acceptability scores of wheat-teff sourdough bread due to higher mineral content and bran particle size.

4. Conclusions

Addition of acha and bambara nut sourdough flour to wheat flour influenced the pasting properties of wheat flour. Incorporation of acha and bambara nut sourdough flours in bread making significantly improved protein, total dietary fiber, mineral, protein digestibility antioxidant and amino acid composition of composite breads. Phytic acid and tannin contents of composite breads were below toxic level. The RDIs result indicates that inclusion of acha-bambara nut sourdough flours in bread making will provide an adequate intake of protein, dietary fiber, iron, calcium and zinc in male, female and adult. Composite bread showed no significant difference in color and texture compared to wheat bread. Substitution of up to 10% sourdough flours in bread significantly improved taste, flavor and acceptability scores compared to 100% wheat bread. Acceptable bread was prepared by incorporating 10% sourdough flours in bread formula. Acha-bambara nut sourdough flour enriched bread will contribute to the promotion of good health considering its high nutritional and antioxidant properties.

References

Aboubacar, A., Axiell, J. D., Huagng, C., & Hamaker, D. (2001). A rapid protein digestibility assay for identifying highly digestible sorghum lines. *Cereal Chemistry, 78*(2), 160–165.

Alaunyte, I., Stojceska, V., Plunkett, A., Ainsworth, P., & Derbyshire, E. (2012). Improving the quality of nutrient-rich teff breads by combination of enzymes in straight dough and sourdough breadmaking. *Journal of Cereal Science, 55*(1), 22–30.

Alozie, Y. A., Udofia, S., Lawal, O., & Ani, I. F. (2009). Nutrient composition and sensory properties of cakes made from wheat and African yam bean flour blends. *Journal of Food Technology, 7*, 115–118.

American Association of Cereal Chemists, AACC. (2000). *Approved methods of the AACC* (10th ed.). St Paul, MN: AACC.

AOAC. (2005). Association of official analytical chemists. In W. Horwitz, & G. W. Latimer, Jr. (Eds.), *Official methods of analysis* (18th ed., pp. 1–14). Gaithersburg, MD: AOAC International (Chapter 32).

Ayo, J. A., Ayo, V. A., Nkama, I., & Adewori, R. (2007). Physicochemical, in vitro digestibility and organoleptic evaluation of “acha”-wheat biscuit supplemented with soybean flour. *Nigerian Food Journal, 25*(2), 77–89.

Beta, T., Nam, S., Dexter, J. E., & Sapirstein, H. D. (2005). Phenolic content and antioxidant activity of pearled wheat and roller-milled fractions. *Cereal Chemistry, 82*, 390–393.

Bidlingmeyer, B. A., Cohen, S. A., & Tarvin, T. L. (1984). Rapid analysis of amino acids using pre-column derivatization. *Journal of Chromatography B: Biomedical Sciences and Applications, 336*, 93–104.

Brough, S. H., Azam-Al, S. N., & Taylor, A. J. (1993). The potential of bambara groundnut (*Vigna subterranean*) in vegetable milk production and basic protein functionality systems. *Food Chemistry, 47*, 277–283.

Chinma, C. E., James, S., Imam, H., Anuonye, J. C., & Yakubu, C. M. (2013). Physicochemical and sensory properties, in- vitro digestibility of biscuits made from blends of tigernut (*Cyperus esculentus*) and pigeon pea (*Cajanus cajan*). *Nigerian Journal of Nutritional Sciences, 32*(1), 55–62.

Coda, R., Di Cagno, R., Rizzello, C. G., Nionelli, L., Edema, M. O., & Gobbetti, M. (2011). Utilization of African grains for sourdough bread making. *Journal of Food Science, 76*(6), M329–M335.

Coda, R., Rizzello, C. G., & Gobbetti, M. (2010). Use of sourdough fermentation and pseudo- cereals and leguminous flours for the making of a functional bread enriched of γ- aminobutyric acid (GABA). *International Journal of Food Microbiology, 137*(2), 236–245.

Coda, R., Rizzello, C. G., Pinto, D., & Gobbetti, M. (2012). Selected lactic acid bacteria synthesize antioxidant peptides during sourdough fermentation of cereal flours. *Applied and Environmental Microbiology, 78*(4), 1087–1096.

Edema, M. O., Emmambux, M. N., & Taylor, J. (2013). Improvement of fonio dough properties through starch modification by sourdough fermentation. *Starch-Stärke, 65*(9–10), 730–737.

Elegbede, J. A. (1998). Legumes. In A. U. Osagie, & O. U. Eka (Eds.), *Nutritional quality of plant foods. Post Harvest Research Unit, Department of Biochemistry, University of Benin* (pp. 120–133). Nigeria: Benin City.

Eliasson, A. C., Carlson, T. L.-G., Larsson, K., & Miezis, Y. (1981). Some effects of starch lipids on the thermal and rheological properties of wheat starch. *Starch⁄Starke, 33*, 130–134.

Hugo, L. F., Rooney, L. W., & Taylor, J. R. (2003). Fermented sorghum as a functional ingredient in composite breads. *Cereal Chemistry, 80*(5), 495–499.

Jideani, I. A., & Jideani, V. A. (2011). Developments on the cereal grains digitaria exilis (acha) and digitaria iburua (iburu). *Journal of Food Science and Technology, 48*(3), 251–259.

Katina, K., Arendt, E., Liukkonen, K. H., Autio, K., Flander, L., & Poutanen, K. (2005). Potential of sourdough for healthier cereal products. *Trends in Food Science & Technology, 16*(1), 104–112.

Ktenioudaki, A., Alvarez-Jubete, L., Smyth, T. J., Kilcawley, K., Rai, D. K., & Gallagher, E. (2015). Application of bioprocessing techniques (sourdough fermentation and technological aids) for brewer's spent grain breads. *Food Research International, 73*, 107–116.

Kumar, V., Sinha, A. K., Makkar, H. P., & Becker, K. (2010). Dietary roles of phytate and phytase in human nutrition: a review. *Food Chemistry, 120*(4), 945–959.

Mariotti, M., Garofalo, C., Aquilanti, L., Osimani, A., Fongaro, L., Tavoletti, S., et al. (2014). Barley flour exploitation in sourdough bread-making: a technological, nutritional and sensory evaluation. *LWT-Food Science and Technology, 59*(2), 973–980.

Marston, K., Khouryieh, H., & Aramouni, F. (2016). Effect of heat treatment of sorghum flour on the functional properties of gluten-free bread and cake. *LWT-Food Science and Technology, 65*, 637–644.

Mohammed, I., Ahmed, A. R., & Senge, B. (2012). Dough rheology and bread quality of wheat–chickpea flour blends. *Industrial Crops and Products, 36*(1), 196–202.

Moroni, A. V., Zannini, E., Sensidoni, G., & Arendt, E. K. (2012). Exploitation of buckwheat sourdough for the production of wheat bread. *European Food Research andTechnology, 235*(4), 659–668.

Mosha, T. C., & Vicent, M. M. (2005). Nutritional quality, storage stability and acceptability of home-processed ready-to-eat composite foods for rehabilitating undernourished preschool children in low-income countries. *Journal of Food Processing and Preservation, 29*(5–6), 331–356.

National Academy of Sciences, Institute of Medicine. (2004). *Food and nutrition board. Dietary reference intakes: Recommended intakes for individuals, vitamins, minerals and macronutrients*.

Oatway, L., Vasanthan, T., & Helm, J. H. (2001). Phytic acid. *Food Reviews International, 17*(4), 419–431.

Onyilagha, J. C., Islam, S., & Ntamatungiro, S. (2009). Comparative phytochemistry of eleven species of Vigna (Fabaceae). *Biochemical Systematics and Ecology, 37*(1), 16–19.

Otegbayo, B., Aina, J., Asiedu, R., & Bokanga, M. (2006). Pasting characteristics of fresh yams (Dioscorea spp.) as indicators of textural quality in a major food product–‘pounded yam’. *Food Chemistry, 99*(4), 663–669.

Poutanen, K., Flander, L., & Katina, K. (2009). Sourdough and cereal fermentation in a nutritional perspective. *Food Microbiology, 26*(7), 693–699.

Rizzello, C. G., Calasso, M., Campanella, D., De Angelis, M., & Gobbetti, M. (2014). Use of sourdough fermentation and mixture of wheat, chickpea, lentil and bean flours for enhancing the nutritional, texture and sensory characteristics of white bread. *International Journal of Food Microbiology, 180*, 78–87.

Rosell, C. M. (2015). *Processing, quality and storage of part-baked products. In minimally processed foods* (pp. 173–192). Springer International Publishing.

Sanz-Penella, J. M., Wronkowska, M., Soral-Smietana, M., & Haros, M. (2013). Effect of whole amaranth flour on bread properties and nutritive value. *LWT-Food Science and Technology, 50*(2), 679–685.

Silva, B. A., Ferreres, F., Malva, J. O., & Dias, A. C. (2005). Phytochemical and antioxidant characterization of Hypericum perforatum alcoholic extracts. *Food Chemistry, 90*, 157–167.

Tuncel, N. B., Yılmaz, N., Kocabıyık, H., & Uygur, A. (2014). The effect of infrared stabilized rice bran substitution on B vitamins, minerals and phytic acid content of pan breads: Part II. *Journal of Cereal Science, 59*(2), 162–166.