Nutritional composition of gluten-free flour from blend of fonio (*Digitaria iburua*) and pigeon pea (*Cajanus cajan*) and its suitability for breakfast food

G. O. Babarinde¹ · J. A. Adeyanju¹ · K. Y. Ogunleye² · G. M. Adegbola¹ · A. A. Ebun¹ · D. Wadele¹

Revised: 16 January 2020 / Accepted: 1 April 2020 / Published online: 26 May 2020
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Abstract The promotion and enrichment of underutilized cereal based foods with legumes and oilseeds are receiving considerable attention in order to reduce the menace of protein and micronutrients malnutrition. This research therefore investigated the quality of flour produced from fonio (*Digitaria iburua*) and pigeon pea (*Cajanus cajan*) blend. Fonio and pigeon pea flour blends (100:0, 95:5, 90:10, 85:15 and 80:20 of fonio to pigeon pea) were analyzed for proximate, vitamin, mineral elements and amino acids. The flour blend with highest level of fiber, protein, ash and some essential amino acids (80:20 fonio to pigeon pea) and 100% fonio were developed into breakfast food and sensory attributes such as colour, taste, flavour and overall acceptability were evaluated. The results obtained were moisture (6.74–7.78%), protein (12.19–24.85%), fat (0.98–1.25%), crude fibre (1.03–1.20%), ash (0.58–1.03%), carbohydrates (63.69–77.77%) and energy (363.09–371.53 kcal/100 g). Eighteen amino acids comprising essential and non essential amino acids were identified in the flour samples. The essential amino acids were phenylalanine, histidine, isoleucine, leucine, lysine, methionine, threonine, tryptophan and valine. Vitamins identified in the samples were A, B₁, B₂, B₅, B₆, B₉, C, D, E and K. Significant amount of mineral elements were also recorded. The result of this study revealed that substitution of fonio grain with pigeon pea increased the protein, ash, some

amino acids and vitamins of the flour blends. Sensory evaluation of all the attributes of the breakfast food ranked above like-moderately on the 9-point hedonic scale. The flour mixes can be used in the production of breakfast food.

Keywords Fonio · Pigeon pea · Amino acid · Vitamins · Proximate composition

Introduction

There is high demand for gluten-free products due to several health benefits associated with them not it. Several tropical cereals and legumes fall into these categories and majority of such crops are grossly underutilized. Breakfast foods are first important meal of the day that help in maintaining mental performance compared to no breakfast or glucose drink among children (Adolphus et al. 2013). However, these meals in most developing countries are eroding away due to overdependence on certain expensive fortified breakfast cereals produced from corn, barley and wheat that are not affordable by people of low economic status which has led to malnutrition.

Effort to improve the health and nutritional status of growing children has focused on the production of nutritious, low cost complementary and breakfast foods from combination of cereals and legume. Cereals are generally low in protein and are limited in some essential amino acids such as lysine and tryptophan (Adekunle and Abiodun 2018); legume, on the other hand, is a major source of nutrients such as protein and minerals. The grains most commonly used in processing of breakfast foods are corn, wheat, oats, rice and barley and the least commonly consumed are acha (fonio), finger millet etc. Fonio (*Digitaria exilis*), an underutilized cereal, is one of the most nutritious

✉ G. O. Babarinde
gobabarinde@lautech.edu.ng

¹ Department of Food Science and Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

² Department of Agricultural Extension and Rural Development, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

cereals. It is one of the oldest cereals characterized with a pleasant small seeds (Jideani 2012). It covers about 300,000 hectares and serves as staple food for about 4 million people in some parts of Africa particularly northern part of Nigeria (Kwon-Ndung and Ochigbo 2001). It is traditionally used in production of unfermented porridge, gvette, pudding, etc. and consumed as first meal of the day. Abioye and Babarinde (2009) reported the potentials of fonio for production of breakfast cereal. The protein content of fonio grains is rich in methionine and cysteine (Jideani 2012). The major constituents of cereals are carbohydrates and proteins. However, other grain components such as lipids, minerals and vitamins may be of great significance in human nutrition because of the large contribution of cereals to the diet. Traditionally, fonio is a useful diet for those suffering from diabetes or for women after delivery. Its grain has been prepared in form of porridges and consumes as breakfast food. The grains have also been used in production of porridges, fonio *jollof*, flour creams, salads, couscous, stews, candy and alcoholic/non-alcoholic beverages (Abdul and Jideani 2019). Fonio has great potential as breakfast food due to its short cooking time when compared with other cereals. Fonio and iburu cook softly in boiling water within 3–8 min while other cereals such as rice cook for at least 20–30 min. Adekunle and Abiodun (2018) also reported that fonio has high water absorption capacity due to its appreciable amount of pentosan content. This quality will increase potential of fonio in producing a breakfast food with minimum cooking time.

Victor and James (1991) have advocated for fonio's complementation with protein rich foods to make an adequate nutritional food. Ayo et al. (2007) fortified fonio and wheat flour with soybean to increase its protein content. Pigeon pea (*Cajanus cajan*) is a locally available legume with protein contents ranging from 23 to 26% protein which compared favourably with other legumes such as cowpea and groundnut (El-Tabey and Ahmed 1992). However, pigeon pea like other legumes is deficient in methionine but high in lysine. In spite of its relatively high nutritional and sensory qualities, the crop has no industrial use in most developing countries especially Nigeria (Akubor 2017). It is mostly consumed whole after cooking; however, the hard-to-cook phenomenon has limited its utilization. While ample scientists have documented the potentials of blending fonio with some easy to cook crop (Victor and James 1991; Ayo et al. 2007), studies on nutritional potentials of the blend of fonio and pigeon pea have not received concerted attention by scientists. Consequently, it is important to explore possible means of reducing the cooking time of pigeon pea by converting it into another form which include blending it with fonio in breakfast food. Interaction with some local farmers in

Nigeria showed that pigeon pea could be eaten at any point of the day (Akinwande et al. 2014). However, due to its hard to cook phenomenon, it was usually parboiled overnight by rural resource poor farming families and the parboiled pulse would be soaked in the hot water and cooked the following morning and served as breakfast. This study therefore elucidated potential of pigeon pea, an underutilized legume, in improving the protein and vitamin contents of fonio. Converting pigeon pea seeds into flour in breakfast food production will not only increase its utilization but also increase the nutrients of the formulated products. One way to increase food and nutrition security is to diversify the use of underutilized crops: cereal and legumes contribute significantly to the global food pool in achieving food and nutrition security (Abdul and Jideani 2019). Production of flour from fonio and pigeon pea will play a vital role in reducing food and nutrition security in Africa.

This research work was designed to evaluate the proximate composition, amino acids and vitamin profiles of blend of fonio and pigeon pea flours.

Materials procurement and sample preparation

Sample preparation

Black fonio (*Digitaria iburua*; variety: *iburu*) grains were purchased from Terminus Market, Jos, Nigeria while pigeon pea seeds were purchased from Sabo Market, Ogbomoso, Nigeria. Fonio grains were sorted, washed and drained. The grains were then dried in a cabinet dryer at 55 °C for 12 h and milled using a hammer mill (Thomas Wiley Mill Model ED-5) and sieved with the aid of a 425-micron sieve. The flour was packaged in polythene bag and stored at 4 °C as fonio flour.

Pigeon pea (*Cajanus cajan*) flour was produced from variety *Otili pupa*. Pigeon pea was cleaned (to remove stones, dirt, chaff, perforated seeds and weevils), sorted, graded into sizes and then soaked for 24 h for easy dehulling. The dehulled sample was oven dried at 50 °C for 24 h, ground into flour with hammer mill (Thomas Wiley Mill Model ED-5) sieved and stored in air-tight polythene bag.

Product formulation

Fonio and pigeon pea flour were blended at different proportions of 100:0, 95:5, 90:10, 85:15 and 80:20 fonio to pigeon pea. The formulation ratios were selected based on findings of previous studies (Akinwande et al. 2014).

Production of breakfast food

Blends of fonio (var: iburu) and pigeon pea (var: otili pupa) flour were thoroughly homogenized in Kenwood mixer. Based on the preliminary results obtained for protein, fibre, ash, some essential amino acids and non-essential amino acids of flour blends of fonio and pigeon pea, the sample with highest contents of these attributes (80:20 fonio to pigeon pea) and 100% fonio (control) were used in producing breakfast food. The selection of 100% fonio as control was for comparison. About 500 ml of water was then added to form a thick paste. The paste obtained was fed into a cold extruder and the desired die was used to obtain a flake-like shape that resembles that of commercial corn flakes. The extruded sample was then baked in an oven at 280 °C for 5 min and a golden brown flake-like texture meal was obtained.

Analyses

Proximate composition of fonio-pigeon pea flour

Blend of fonio-pigeon pea flour was analyzed for ash, protein, fat, crude fiber, moisture, energy and carbohydrate using AOAC (2005) methods. Total carbohydrate was calculated by difference.

Amino acid determination

Amino acid composition of samples was measured using amino acid analyzer (Sykam-S7130) based on high performance liquid chromatography technique. Sample hydrolysates were prepared following the method of Moore and Stein (1963). Flour sample (200 mg) was hydrolysed using 5 ml of 6 N HCl in a hydrolysis tube after which it was incubated at 110 °C for 24 h. Filtrate was obtained after incubation and 200 ml of the filtrate was evaporated to dryness at 140 °C for 1 h. The evaporated hydrolysate was standardized using 2.2 N citrate buffer. Aliquot of 150 µl of sample hydrolysate was injected in a separation column at 130 °C. Ninhydrine solution and an eluent buffer (The buffer system contained solvent A: pH 3.45 and solvent B: pH 10.85) were simultaneously passed into a high temperature reactor coil (16 m length) at a flow rate of 0.7 ml/min. The buffer/ninhydrine mixture was heated in the reactor at 130 °C for 2 min to accelerate chemical reaction of amino acids with ninhydrine. The products of the reaction mixture were detected at wavelengths of 570 nm and 440 nm on a dual channel photometer. The amino acid composition was calculated from the areas of standards obtained from the integrator and expressed as percentages of the total protein.

Vitamin profile

Determination of water soluble vitamins B₁, B₂, B₃, B₅, B₆, B₉ and C

The stock standard solution was prepared by weighing 20 ml of the stock in a 100 ml volumetric flask; the standard sample was taken and dissolved in ultra-pure water. A buffer of 1 M phosphate was added and components were thoroughly mixed before finally topping up to 100 ml mark. The standard solution was kept in the dark at 4 °C. For the extraction of vitamin B, powdered samples (2 g) were mixed with 25 ml of H₂SO₄ (0.1 N) solution and incubated for 30 min at 121 °C. The content were cooled and adjusted to pH 4.5 with 2.5 M sodium acetate, and 50 mg diastase enzyme was added. The prepared sample was stored at 35 °C overnight. The mixture was filtered with Whatman no 4, diluted with 50 ml of pure water and filtered again through a micropore filter (0.45 µm). Vitamin C was extracted in metaphosphoric acid (0.3 m) and acetic acid (1.4 m). The mixture was placed in a conical flask and agitated at 10,000 rpm for 15 min. The mixture was then filtered over Whatman No 4 filter paper. The ascorbic standard was prepared by dissolving 100 mg of ascorbic acid in a metaphosphoric acid (0.3 m)/acetic acid (1.4 m) solution to a final concentration of 0.1 mg/ml. The filtrate of 20 ml of sample was injected into HPLC system. Quantification of vitamin B and C content was accomplished by comparison to standards. Chromatographic separation was achieved on a reversed phase HPLC column (Agilent 1100 series HPLC system) through isocratic delivery mobile phase at a flow rate of 0.5 ml/min and 1 ml/min for Vitamin B and C, respectively. Ultraviolet absorbance (UV) was recorded for Vitamin B and C at 270 nm and 254 nm at room temperature, respectively (Ciulu et al. 2011).

Determination of Fat soluble vitamins A, D, E and K

Samples of fonio and pigeon pea flour blend (10 g) were added to the mixture of 1 g of pyrogalllic acid, 70 ml ethanol, and 30 ml (80%) KOH, stirred, and refluxed for 40 min using a water bath at 50 ± 2 °C. Different ether concentrations (50 ml, 30 ml and 20 ml) were used to obtain extracts three times. Double-distilled water was used to neutralize the extract which was dehydrated using anhydrous sodium sulphate, the extract was concentrated to approximately 5 ml by using a water bath (50 ± 2 °C) diluted to 10 ml methanol, filtered using a 0.45 µm membrane and finally subjected to HPLC analysis. For fat soluble vitamins, Eclipse XDB-C18 column was used (5 µm, 4.6 × 150 mm). The solvent was methanol, and UV

detection was recorded at 325, 265, 290, and 240 nm for vitamins A, D, E and K, respectively (Lebiedzinska et al. 2007).

Mineral determination

The mineral profile of the formulated samples was evaluated using the method described by AOAC (2005). One gram of the blended flour was digested with 2.5 ml of 0.03 M hydrochloric acid (HCl). The digest was boiled for 5 min, allowed to cool to room temperature and poured into 50 ml volumetric flask which was later made up to mark with distilled water. The resulting digest was filtered with ashless Whatman No. 1 filter paper. Filtrate from each sample was analyzed for mineral (calcium, potassium, magnesium, iron, sodium, manganese, copper, lead and zinc) contents using an Atomic Absorption Spectrophotometer (Buck Scientific Atomic Absorption Emission Spectrophotometer model 205, manufactured by Nowalk, Connecticut, USA) using standard wavelengths. Values for each mineral were extrapolated from the respective standard curves.

Sensory evaluation of the breakfast food

Sensory attributes of the breakfast food from blend of fonio and pigeon pea were evaluated by conducting preference test using 50 panelists that are regular consumers of breakfast cereals. Reconstitution of the flake-like product was done by mixing 25 g of each sample with hot milk and was sweetened. Commercial corn flakes brand and 100% fonio were used as control for comparison. Samples were served at room temperature (28 ± 2 °C) to the judges to rate them on the basis of colour, aroma, taste, aftertaste, crispiness and general acceptability. The rating was done using 9-point hedonic scale (where 1 = dislike extremely; 5 = like slightly; 9 = like extremely).

Statistical analysis

Data obtained are means of triplicate determinations and data were subjected to ANOVA and means separated using Duncan multiple range test at 5% probability level using version 15, SPSS.

Results and discussion

Proximate composition of the flour from blends of fonio and pigeon pea

The results obtained from proximate composition of blend of fonio to pigeon pea are presented in Table 1. The

moisture contents differed significantly ($p < 0.05$) in the five samples and sample with 95:5 fonio to pigeon pea had the highest moisture content of 7.78%. The value for moisture content of white fonio flour as reported by Egbebi and Muhammad (2016) was 10.40% which is higher than the value (6.74%) obtained in this study. Coda et al. (2010) also reported moisture contents of 16.8% and 9.5% for *acha* and *iburu* fonio varieties, respectively. These values are higher than all the values (6.74–7.78%) obtained in this study. The low moisture content (6.74–7.78%) observed for all the samples in this study with control sample having the least moisture content (6.74%) is a good indication that the products would have a longer shelf life in water- and air-proof package as reported by Ogunbusola (2017). Sample with 80:20 fonio to pigeon pea had the highest value (1.03%) of ash while sample from 100% fonio had the least value (0.58%). The values obtained were however lower than ash contents of fonio starch defatted-moringa seed flour blends which ranged from 1.23 to 1.58% (Raji et al. 2018) and within the range of values (0.32–1.87%) reported by Raji et al. (2017) for *acha* as affected by different cooking time. High ash content indicates high mineral content and samples with inclusion of pigeon pea had higher ash contents. The variation in ash contents could be due to varietal differences and geographical locations. Annongu et al. (2019) reported that geographical location and varieties affected the nutritional contents of fonio. Values obtained are greater than the daily recommended dietary allowance for ash in foods $\leq 0.05\%$ (FAO/WHO 1998). Samples with different levels of pigeon pea flour had significantly ($p < 0.05$) higher fat contents than 100% fonio. Samples 90:10 and 85:15 fonio and pigeon pea had the highest fat content (1.25%) while 100% fonio had the least fat content (0.98%). Values of fat obtained for all samples with inclusion of pigeon pea flour were within the range (1.00–2.00%) reported for pigeon pea by Onweluzo and Nwabugwu (2009) but lower than fat contents reported by Annongu et al. (2019) for fonio. Fat is important in diet as it promotes absorption of fat soluble vitamin.

The protein contents differed significantly ($p < 0.05$) and ranged between 12.19 and 24.85%. Sample containing fonio and pigeon pea in the ratio 80:20 had the highest crude protein content (24.85%) which could be due to the higher quantity of pigeon pea in the blend, since pigeon pea is a rich source of protein (Oshodi et al. 1993). The high protein content of the sample will be of great nutritional importance, especially in developing countries such as Nigeria in order to curb the menace of protein-energy malnutrition. Protein contents obtained from the formulated flour blends are greater than 11–14% reported for wheat, 8–11% reported for maize and barley, 9–11% for sorghum and 12–14% for oats (Vasal 2004). The increase is due to the inclusion of pigeon pea which is a good source

Table 1 Proximate composition (%) of flour blends from fonio and pigeon pea

Sample	Attributes						
	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Fiber (%)	CHO (%)	Energy (%)
100:0	6.74 ± 0.06 ^a	0.58 ± 0.01 ^a	0.98 ± 0.01 ^a	12.19 ± 0.06 ^a	1.03 ± 0.01 ^a	74.10 ± 0.06 ^b	371.53 ± 0.24 ^b
95:5	7.78 ± 0.05 ^b	0.73 ± 0.02 ^b	1.19 ± 0.01 ^b	17.33 ± 0.10 ^c	1.09 ± 0.01 ^{ab}	72.38 ± 0.29 ^b	369.51 ± 1.09 ^b
90:10	7.50 ± 0.15 ^b	0.72 ± 0.01 ^b	1.25 ± 0.02 ^b	20.59 ± 0.25 ^c	1.20 ± 0.02 ^c	63.69 ± 1.29 ^a	371.05 ± 1.17 ^b
85:15	6.78 ± 0.17 ^a	0.87 ± 0.03 ^c	1.25 ± 0.02 ^b	16.57 ± 0.15 ^b	1.14 ± 0.01 ^b	77.77 ± 0.17 ^c	371.09 ± 0.79 ^b
80:20	7.49 ± 0.06 ^b	1.03 ± 0.01 ^d	1.20 ± 0.26 ^b	24.85 ± 0.31 ^d	1.18 ± 0.05 ^c	65.31 ± 0.08 ^a	363.09 ± 0.19 ^a

± standard deviation; values with different superscripts along the same column are significantly different ($p < 0.05$)

CHO Carbohydrate

100:0—100% fonio flour

95:5—95% fonio 5% pigeon pea flour

90:10—90% fonio 10% pigeon pea flour

85:15—85% fonio 15% pigeon pea flour

80:20—80% fonio 20% pigeon pea flour

of protein. The fiber contents were significantly higher ($p < 0.05$) in samples containing pigeon pea (1.09–1.20%) than what was observed in 100% fonio (1.03%). Higher fiber content recorded in samples with inclusion of pigeon pea indicates pigeon pea as a good source of fiber. According to Srivastava et al. (2012), when fiber absorbs large amount of water, it gives a sensation of fullness (having an appetite completely satisfied). Therefore, products made from this flour will have the potential for alleviating some dietary related disease such as obesity, coronary heart disease and arteriosclerosis as reported by Adekunle and Abiodun (2018). Since both fonio and pigeon pea are good sources of carbohydrates, the samples obtained were carbohydrate-dense and observed to supply nearly 363.09–371.53 kcal of energy per 100 g of flour (Table 1). Human needs energy for basal metabolic rate, metabolic response to food, physical activities, creation of new tissue during growth and pregnancy as well as the production of milk during lactation.

Amino acid profile of flour blends from fonio and pigeon pea

The amino acid profile of the formulation of blends of fonio and pigeon pea flour is shown in Table 2. Eighteen essential and non-essential amino acids were identified in the fonio and pigeon pea flour blend. Essential amino acids in the flour samples were phenylalanine, histidine, isoleucine, leucine, lysine, methionine, threonine, tryptophan and valine. The number of amino acid identified is higher than the one (seventeen) reported by Oshodi et al. (1993) for pigeon pea. Lysine has been reported to be a deficient essential amino acid in most cereals (Flidel et al. 2004), however some amounts were recorded in fonio and fonio-

pigeon pea mixes (3.33–3.63 mg/100 g N). The value obtained for lysine in this work is higher than 0.57 g/100 g protein reported by Oshodi et al. (1993) in pigeon pea flour. The main role of lysine is to participate in protein synthesis, thus it is important for growth and maintenance of the body. Samples prepared from 80:20 fonio to pigeon pea flour had highest values of proline (5.38 g/100 gN), threonine (3.38 g/100 gN), leucine (7.75 g/100 gN), asparagine (10.46 g/100 gN), lysine (3.63 g/100 gN), glutamic acid (17.67 g/100 gN), phenylalanine (4.60 g/100 gN), arginine (8.50). The amino acids obtained from 100% fonio and fonio-pigeon pea blend contained significant amount of methionine and cysteine, the two human vital amino acids that are almost deficient in the major cereals like sorghum, rice, wheat or barley (Flidel et al. 2004). Values (2.30–2.53 g/100 gN) obtained for methionine are higher than 0.032 mg/100 g reported by Oshodi et al. 1993 for pigeon pea. The authors further reported that cysteine was not detected in pigeon pea. Complementing fonio with pigeon pea improves the levels of limiting amino acids in most cereals; this agrees with the report of Okoye et al. (2016) who reported that mixing cereal with legume improves both protein quality and limiting amino acids as obtained in wheat flour biscuit fortified with soybean and bambara groundnuts. Glutamic acid was the most abundant amino acid in all the flour samples. Adeoti et al. (2013) also reported glutamic acid as the predominant amino acid in maize tuwo cirina forda flour blends. Glutamic acid values (16.27–17.67 mg/100 g) obtained in this study are higher than the ones (1.67–2.17 mg/100 g) reported by Adeoti et al. (2013). Tryptophan was the amino acid with the least values in all the samples. Amino acids are important attributes that promote healing and protein synthesis; deficiencies of the essential amino acids will hinder

Table 2 Amino acid profile of flour blends from fonio and pigeon pea

Samples	Non essential amino acids (g/100 gN)								
	Gly	Ala	Ser	Pro	Asp	Glu	Arg	Tyr	Cys
100:0	3.27 ± 0.03 ^e	4.27 ± 0.02 ^d	4.95 ± 0.03 ^b	5.05 ± 0.03 ^b	10.39 ± 0.03 ^b	17.57 ± 0.03 ^b	8.42 ± 0.03 ^b	4.18 ± 0.03 ^c	2.13 ± 0.03 ^c
95:5	4.37 ± 0.01 ^a	5.17 ± 0.03 ^a	4.95 ± 0.03 ^b	4.50 ± 0.03 ^c	9.18 ± 0.03 ^d	16.49 ± 0.03 ^c	8.15 ± 0.03 ^d	4.31 ± 0.03 ^a	2.20 ± 0.03 ^b
90:10	3.87 ± 0.01 ^c	4.61 ± 0.03 ^c	5.56 ± 0.03 ^a	5.10 ± 0.03 ^b	10.27 ± 0.03 ^c	16.27 ± 0.03 ^c	8.35 ± 0.03 ^e	4.12 ± 0.03 ^d	2.22 ± 0.03 ^b
85:15	4.18 ± 0.03 ^b	5.14 ± 0.03 ^a	5.10 ± 0.03 ^b	4.43 ± 0.03 ^c	8.69 ± 0.03 ^e	16.34 ± 0.03 ^d	8.13 ± 0.03 ^d	4.03 ± 0.03 ^e	2.27 ± 0.03 ^a
80:20	3.74 ± 0.03 ^c	4.72 ± 0.03 ^b	5.51 ± 0.03 ^a	5.38 ± 0.03 ^a	10.46 ± 0.03 ^a	17.67 ± 0.03 ^a	8.50 ± 0.03 ^a	4.23 ± 0.03 ^b	2.17 ± 0.03 ^b
Samples	Essential amino acids (g/100 gN)								
	Phe	His	Ile	Leu	Lys	Met	Thr	Try	Val
100:0	4.55 ± 0.03 ^a	2.07 ± 0.03 ^b	2.95 ± 0.03 ^b	7.65 ± 0.03 ^b	3.59 ± 0.03 ^{ab}	2.50 ± 0.03 ^c	3.29 ± 0.03 ^c	1.86 ± 0.03 ^b	4.87 ± 0.03 ^c
95:5	4.06 ± 0.03 ^c	2.15 ± 0.03 ^a	3.84 ± 0.03 ^a	7.27 ± 0.03 ^d	3.45 ± 0.03 ^c	2.61 ± 0.03 ^a	3.37 ± 0.03 ^a	1.79 ± 0.03 ^c	5.55 ± 0.03 ^a
90:10	4.54 ± 0.03 ^b	2.17 ± 0.03 ^a	2.97 ± 0.03 ^b	7.48 ± 0.03 ^c	3.55 ± 0.03 ^b	2.54 ± 0.03 ^b	3.32 ± 0.03 ^b	1.98 ± 0.03 ^a	4.93 ± 0.03 ^c
85:15	4.33 ± 0.03 ^b	2.07 ± 0.03 ^b	3.80 ± 0.03 ^a	7.17 ± 0.03 ^e	3.33 ± 0.03 ^d	2.30 ± 0.03 ^d	3.35 ± 0.03 ^b	1.77 ± 0.03 ^c	5.54 ± 0.03 ^a
80:20	4.60 ± 0.03 ^a	2.10 ± 0.03 ^a	3.00 ± 0.03 ^b	7.75 ± 0.03 ^a	3.63 ± 0.03 ^a	2.53 ± 0.03 ^{bc}	3.38 ± 0.03 ^a	1.89 ± 0.03 ^b	5.01 ± 0.03 ^b

± standard deviation; values with different superscripts along the same column are significantly different ($p < 0.05$)

100:0—100% fonio flour

95:5—95% fonio, 5% pigeon pea flour

90:10—90% fonio, 10% pigeon pea flour

85:15—85% fonio, 15% pigeon pea flour

80:20—80% fonio, 20% pigeon pea flour

recovery process (Zuraini et al. 2006). Glycine, alanine, arginine, and phenylalanine are parts of amino acids that promote growth and tissue healing. The amino acid values obtained for phenylalanine, isoleucine and tryptophan were higher than the recommended limits of 0.63 mg/100 g, 0.35 mg/100 g and 0.085 mg/100 g, respectively (FAO/WHO 1998).

Vitamin compositions of flour from blends of fonio and pigeon pea

The vitamin compositions of fonio and pigeon pea in different ratio are presented in Table 3. Vitamin B₃ was the most abundant vitamin followed by vitamin C. There was no wide variation in the content of each vitamin across the sample ratio. Moreover, vitamin A content was observed to be higher in sample with blend of fonio and pigeon pea in ratio 80:20, this could be because of the incorporation of pigeon pea; whereas, sample with fonio and pigeon pea in ratio 100:0 had the least vitamin A content. Vitamin A plays vital roles in growth and development of good eye health and vision, maintenance of healthy skin, etc. Vitamin B₁ contents ranged from 0.23 to 0.26 mg/100 g. Both 85:15 and 80:20 fonio-pigeon pea flours had the highest vitamin B₁ content 0.26 mg/100 g. Vitamin B₁ (thiamin) is an important coenzyme thiamin pyrophosphate (TPP) that has a critical role in carbohydrate metabolism (Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes (1998). It was clearly seen in the result that vitamin B₂ content is higher in sample 85:15 fonio to pigeon pea than other samples. Vitamin B₂ (riboflavin) is part of the coenzyme, Flavin mononucleotide (FMN), and Flavin adenine dinucleotide (FAD), needed for oxidation/reduction reactions and energy production (Onimawo and Asugo 2008).

Vitamin B₃ contents ranged between 1.58 and 2.21 mg/100 g and sample with fonio and pigeon pea in the ratio

95:5 had the highest vitamin B₃ 2.21 mg/100 g. The vitamin B₆ content was higher in sample with fonio and pigeon pea in ratio 85:15 while sample with fonio and pigeon pea in ratio 90:10 fonio to pigeon pea had the least vitamin B₆ content of 0.27 mg/100 g. Vitamin B₉ content were slightly different among the flour samples considered in the study. Sample with fonio and pigeon pea in ratio (90:10) was higher in vitamin B₉ content compared to others. The vitamin C contents ranged between 1.01 and 1.36 mg/100 g. Ascorbic acid content of breakfast cereals is the most prominent quality index due to its health significance as a vitamin and cellular antioxidant (Quanhong et al. 2003).

Vitamin D contents were very minute and this implies that the blend of fonio and pigeon pea flours are not good sources of Vitamin D. Vitamin E content ranged between 0.63 and 0.78 mg/100 g. The sample with fonio and pigeon pea in ratio 90:10 had the highest vitamin E content of 0.78 mg/100 g. It was also clear in the result that vitamin K content is higher in 85:15 fonio to pigeon pea (85:15) (0.0022 mg/100 g) than other samples. All samples with inclusion of pigeon pea had higher vitamins than sample with 100% fonio. This shows that pigeon pea has significant amount of vitamins than fonio alone. Although the vitamins obtained are below the recommended values for vitamin B₁ (1.2 mg/100 g), B₂ (1.3 mg/100 g) and B₃ (16 mg/100 g), it can however form parts of daily requirements (Richardson 1997).

Mineral contents of flour from blends of fonio and pigeon pea

The mean values for Zn, Fe, Mg Ca and K are 1.0–3.02, 1.35–2.73, 4.27–6.29, 3.56–5.08 and 3.01–5.60 ppm, respectively (Table 4). The samples were significantly different from one another. Least values were obtained from Mn and Cu and the values ranged from 0.10 to 0.20

Table 3 Vitamin profile (mg/100 g) of blend of fonio and pigeon pea flour

Sample	Vitamins (mg/100 g)										
	A	B ₁	B ₂	B ₃	B ₅	B ₆	B ₉	C	D	E	K
100:0	0.0068	0.24	0.14	2.03	0.46	0.46	0.018	1.36	0.00001	0.76	0.0038
95:5	0.0074	0.23	0.12	2.21	0.4	0.41	0.015	1.3	9.6E–05	0.63	0.0036
90:10	0.0073	0.23	0.16	1.86	0.45	0.27	0.021	1.06	8E–06	0.78	0.0035
85:15	0.0079	0.26	0.17	1.58	0.44	0.47	0.018	1.01	7.8E–05	0.72	0.0022
80:20	0.008	0.26	0.12	2.07	0.4	0.39	0.016	1.27	1.1E–05	0.76	0.0035
100:0—100% fonio flour											
95:5—95% fonio, 5% pigeon pea flour											
90:10—90% fonio, 10% pigeon pea flour											
85:15 — 85% fonio, 15% pigeon pea flour											
80:20—80% fonio, 20% pigeon pea flour											

Table 4 Mineral composition of flour blends of fonio and pigeon pea

Samples	Mineral							
	Zn (ppm)	Fe (ppm)	Mg (ppm)	Ca (ppm)	K (ppm)	Na (ppm)	Mn (ppm)	Cu (ppm)
100:0	2.00 ± 0.00 ^b	1.35 ± 0.10 ^d	4.27 ± 0.17 ^d	4.74 ± 0.11 ^b	4.76 ± 0.22 ^b	55.18 ± 0.06 ^a	0.20 ± 0.00 ^a	0.13 ± 0.04 ^b
95:5	2.02 ± 0.00 ^b	1.78 ± 0.05 ^b	6.70 ± 0.22 ^a	3.56 ± 0.28 ^c	3.01 ± 0.01 ^c	36.27 ± 0.29 ^c	0.12 ± 0.02 ^b	0.22 ± 0.03 ^a
90:10	1.00 ± 0.07 ^c	1.72 ± 0.01 ^b	4.47 ± 0.03 ^c	5.08 ± 0.01 ^a	5.60 ± 0.32 ^a	51.56 ± 0.36 ^b	0.10 ± 0.02 ^c	0.24 ± 0.01 ^a
85:15	3.02 ± 0.14 ^a	1.66 ± 0.13 ^c	6.29 ± 0.12 ^a	5.02 ± 0.02 ^a	3.99 ± 0.03 ^{bc}	33.59 ± 0.19 ^c	0.16 ± 0.02 ^b	0.17 ± 0.01 ^b
80:20	2.05 ± 0.01 ^b	2.73 ± 0.01 ^a	5.32 ± 0.02 ^b	4.65 ± 0.15 ^b	3.66 ± 0.09 ^c	52.58 ± 0.38 ^b	0.11 ± 0.00 ^c	0.20 ± 0.00 ^a

± standard deviation; values with different superscripts along the same column are significantly different ($p < 0.05$)

100:0—100% fonio flour

95:5—95% fonio, 5% pigeon pea flour

90:10—90% fonio, 10% pigeon pea flour

85:15—85% fonio, 15% pigeon pea flour

80:20 - 80% fonio, 20% pigeon pea flour

and 0.13 to 0.24 ppm, respectively. Samples with inclusion of pigeon pea had higher values of Fe, Zn, Mg and Ca. This confirmed the findings of Oshodi et al. (1993) who reported that pigeon pea is a good source of mineral and the highest minerals reported by the authors were K, Mg, Ca and Fe. However in this study, highest values were obtained from Na, Mg, K and Ca. The calcium content observed in this study is lower than that observed for maize, soybean and tiger-nut blend (Awolu et al. 2017). Calcium is an important element required for bone and teeth formation. It is also essential in intracellular and extracellular fluid with important functions such as nerve conduction, muscle contraction, blood clotting, and membrane permeability (Al-Fartusie and Mohssan 2017). Inadequate intake of calcium has been related with osteoporosis and hypocalcaemia. The sample containing 80:20 fonio to pigeon pea (2.73 ppm) had highest value of Fe. It has been reported that pigeon pea is a good source of iron and deficiencies of zinc and iron can lead to severe malnutrition, cognitive impairment, anaemia and immunological abnormalities (Oshodi et al. 1993). The most predominant element of all the samples was sodium. Sodium contents in the blends of fonio and pigeon pea ranged from 33.27 to 55.18 ppm. Sodium was highest in the sample containing 100% fonio. The formulated samples could provide RDA of 5 and 10% potassium and sodium, respectively. Potassium together with sodium are required in the maintenance of osmotic balance consequently protect against arterial hypertension. In addition, potassium regulates the body pH, irritability of the nerve and muscle, glucose absorption and protein retention during growth (Omoba et al. 2013). Minerals are important in the normal functioning of the body.

Sensory attributes of breakfast cereal produced from blend of fonio and pigeon pea

Based on the high contents of protein, ash and fiber recorded in 80:20 fonio to pigeon pea; the blend of this flour was used for sensory attributes evaluation. Breakfast meal was produced from 100% fonio, 80:20 fonio to pigeon pea and a commercial brand as control. The results of sensory attributes (Table 5) showed significant difference between the colour, mouth feel, texture, aftertaste and general acceptability of the commercial brand corn flakes fonio-pigeon pea samples. However, there was no significant difference between 100% fonio and 80:20 fonio and pigeon pea for all tested attributes. All samples were well accepted by the panelists although the commercial sample was rated best. There is possibility that the new product will be accepted with proper awareness of the cereal-legume blend.

Conclusion

This study has proven the potential of flour obtained from blend of fonio and pigeon pea in food product development. Some of the proximate compositions met the recommended dietary allowance for moisture, fat, protein and ash. The flour also contained eighteen amino acids that are either limiting or absent in other cereal and fortified flours. Eight essential amino acids were identified and majority of the identified amino acids are within the recommended dietary allowance. The flour samples also contained good amount of vitamins and minerals that form part of daily recommended allowance. The blend of fonio-pigeon pea flour may be used in breakfast cereal with 80:20 fonio to

Table 5 Sensory attributes of breakfast cereal produced from blend of fonio and pigeon pea

Samples	Colour	Aroma	Mouth feel	Texture	Taste	After taste	Crispiness	Overall acceptability
100:0	6.90 ± 0.16 ^{ab}	6.70 ± 0.23 ^a	6.36 ± 0.23 ^a	6.38 ± 0.21 ^a	6.26 ± 0.23 ^a	6.22 ± 0.22 ^a	6.32 ± 0.24 ^a	6.80 ± 0.25 ^a
80:20	6.52 ± 0.18 ^a	6.56 ± 0.21 ^a	6.14 ± 0.25 ^a	6.28 ± 0.23 ^a	6.14 ± 0.25 ^a	6.16 ± 0.24 ^a	6.46 ± 0.20 ^a	6.68 ± 0.20 ^a
Corn flakes	7.26 ± 0.20 ^b	6.94 ± 0.18 ^a	7.14 ± 0.22 ^b	7.24 ± 0.18 ^b	7.16 ± 0.22 ^b	7.18 ± 0.18 ^b	6.78 ± 0.22 ^a	7.60 ± 0.16 ^b

Means with the same alphabet along the column are not significantly ($p > 0.05$) different

100:0—100% fonio flour

pigeon pea blend showing outstanding potentials. Further studies on the potentials of the flour blends for bakery products are therefore recommended.

Acknowledgements This work was supported by the Federal Government of Nigeria under the scheme of Tertiary Educational Trust Fund (TETFund) Institution-based Research Grant, Ladoke Akintola University of Technology, Ogbomoso, Nigeria (LAUTECH2017).

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