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# Nutritional, functional and sensory properties of gluten-free composite flour produced from plantain (Musa AAB), tigernut tubers (*Cyperus esculentus*) and defatted soybean cake (*Glycine max*)

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ABSTRACT

Plantain, tigernut and soycake were processed into flour and blended to obtain PSB (plantain, 64.46; soycake, 35.54%); TNS (tigernut, 59.83; soycake, 40.17%); PTS (plantain, 51.07; tigernut, 11.50; soycake, 37.43%); TNT (100% tigernuts); PLT (100% plantain), and CNT (a commercial flour) samples. The blended samples were evaluated for nutritional, antinutritive, functional and sensory attributes. Data were analysed using statistical package and means were subjected to ANOVA and separated using Duncan New Multiple Range (DNMR) test at $p<0.05$. Protein content (g/100 g) of experimental dough meals ranged from 16.22 to 29.72, and were significantly ($p<0.05$) higher than PLT (9.45) and CNT (14.29), while energy values (Kcal/100 g) ranged from 399.63 to 488.86. Phosphorus, iron, zinc and manganese concentration in experimental samples were significantly higher ($p<0.05$) than in PLT, but comparable to CNT. Total amino acids (mg/100 g protein) of experimental food samples ranged from 63.48 to 74.25, and were significantly ($p<0.05$) higher than CNT (60.91) and PLT (67.3). For saturated, monounsaturated and polyunsaturated fatty acid, the range values were 14.86-21.29, 55.14-56.56 and 23.14-27.84%, respectively. As far as polyunsaturated/saturatedn ratios are concerned, the values ranged from 1.09 to 1.92, and were higher than CNT (1.40).In conclusion, the study established that composite flour produced from plantain, tigernut and soycake were rich in essential amino acids and fatty acids, low in antinutritional factors and they exhibited good functional properties. Hence, the composite flour samples may be suitable for production of functional bakeries and dough products, particularly for diabetes and coeliac disease.

## Introduction

Awareness of gluten-related diseases such as coeliac disease and gluten ataxia increases among the people of various communities (Gujral et al., 2012). Coeliac disease is an inheritable, chronic, systemic, autoimmune disorder that occurs in the small intestine. It is caused by a permanent intolerance to gluten proteins in individuals that are genetically susceptible (Freeman et al., 2011). Coeliac disease is one of the most common food-induced diseases in humans (Koehler et al., 2014). In the last three decades there has been significant increase in the adoption of a gluten-free lifestyle and the consumption of gluten-free foods in many parts of developing and developed countries (Niland and Cash, 2018). The choice of avoiding gluten diets, that is, non-wheat, rye and barely based foods, is based on several factors such as allergic reaction, belief that gluten ingestion leads to harmful health effects, inflammation of the small intestine epithelium cells, which leads to malabsorption of most essential nutrients like iron, folic acid, calcium, and fat-soluble vitamins; and their associated diseases like osteoporosis, anaemia, etc. (Pruska-Kędzior et al., 2008; Niland and Cash, 2018). The only treatment for patients with coeliac disease is

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the strict adherence to a gluten-free diet (Schoenlechner et al., 2010). Hence, this has necessitated the needs for the production of gluten free foods made from non-wheat based food materials like plantain, rice, etc. (Gallagher et al., 2002), which are safe and do not harm the small-intestinal mucosa. The production of gluten-free foods has significantly increased over the last three decades (Chillo et al., 2011; Obi and Opara, 2017).

Plantain is widely grown in the Southern parts of Nigeria and other African countries. In different parts of many African countries plantain is consumed as a cheap source of energy and also used to control weight and diabetes mellitus, due to its low glycaemic index properties (Akubor, 2003; Mendosa, 2009). Plantain, particularly unripe, is a good source of potassium and dietary fiber (Randy et al., 2007). It is rich in carbohydrates, dietary fibers, iron, vitamins, and minerals (Tribess et al., 2009). Plantain contains small amounts of serotonin, which has the ability to dilate the arteries and improve blood circulation. Its regular consumption helps to cure anaemia (low blood level) and maintain a healthy heart (USDA Nutrient Database, 2010). Plantain flour has been successfully added to cereals to produce bread (Juárez-García et al., 2006), spaghetti (Ovando-Martínez et al., 2009; Schoenlechner et al., 2010; Mastromatteo et al., 2011) and other food products, demonstrating that its addition results in higher resistant starch (RS) content and lower starch digestion rate.

Tigernut (CyperusesculentusLativum) is a perennial grass-like plant, belonging to the division—Magnoliophyta, class—Liliopsida, order—cyperales, family—Cyperaceae and genus as the papyrus plant (Belewu and Belewu, 2007). Tigernut is an underutilised tuber that produces sweet nut-like taste (Coşkuner et al., 2002), widely grown in tropical and Mediterranean regions (Adejuyitan, 2011). The tuber serves as a potentially valuable food for both humans and animals in Southern Europe and many parts of developing countries (Pascual et al., 2000). The tubers contained appreciable amount of essential phytonutrients and phytochemicals, which are effective in the treatment and prevention of many diseases like coronary heart diseases, obesity, diabetes, and gastrointestinal diseases (Sabiu et al., 2017).

Soybean (Glycine max (L) Merrill) belongs to the family of leguminoisae and sub-family papilionnideae. Soy protein is a major component of the food for animals and is increasingly important in the human diet. Soy protein is not an ideal protein, because it is deficient in methionine, but high in lysine. Hence, there is a need to complement soybean based food products with cereals, which are high in lysine, but low in methionine (Coulibaly et al., 2012). In Nigeria, soybean is used in various food products such as soymilk, soyogi, soy-daddawa, soy-akara, soy-gari, soy-soup, and hot soy-drink (Coulibaly et al., 2012; Samson, 2014; Usman et al., 2016).

## Materials and methods

### *Source of food materials*

Tiger nuts (Cyperus esculentus) yellow variety and matured, unripe fruits of plantain were purchased from Erekesan market, Akure and Owena market, Ondo, Nigeria, respectively.

### *Tiger nut tuber flour processing*

Tiger nut tuber was processed into flour using the method of Oladele and Aina (2017) with slight modification. Yellow tiger nut tubers were sorted to remove unwanted materials like stones, pebbles and other foreign seeds, washed with double distilled water and drained. The tubers were oven dried at 60 °C for 20 h using a hot-air oven (Plus11 Sanyo Gallenkamp PLC, Loughborough, Leicestershire, UK), milled with a laboratory blender (Model KM 901D; Kenwood Electronic, Hertfordshire, UK) and passed through a 60 mm mesh sieve (British Standard) to obtain tiger nut tuber flour. The flour was packed in a plastic container, sealed and stored at room temperature (~27 °C) until analysis.

### *Plantain flour processing*

The plantain flour was processed using method described by Mepba (2007) with slight modification. The plantain heads were cut into separate bunches which were subsequently de-fingered. The fingers were washed to remove adhering soil particles, peeled, cut into thin slices of about 2 cm thick, blanched in 1.25% $NaHS0_3$ solution at 80 °C for 5 min and drained. The blanched plantain slices were oven dried at 60 °C for 20 h using a hot-air oven (Plus11 Sanyo Gallenkamp PLC, Loughborough, Leicestershire, UK), milled with a laboratory blender (Model KM 901D; Kenwood Electronic, Hertfordshire, UK) and passed through a 60 mm mesh sieve (British Standard) to obtain plantain flour. The flour was packed in a plastic container, sealed and stored at room temperature (~27 °C) until analysis.

*Defatted Soycake flour processing*

The defatted soycake flour was processed using method described by Ijarotimi and Owoeye (2017). The defatted soybean cake was oven dried at 60 °C for 20 h using a hot-air oven (Plus11 Sanyo Gallenkamp PLC, Loughborough, Leicestershire, UK), milled with a laboratory blender (Model KM 901D; Kenwood Electronic, Hertfordshire, UK) and passed through a 60 mm mesh sieve (British Standard) to obtain plantain flour. The flour was packed in the plastic container, sealed and stored at room temperature (~27 °C) until analysis.

*Formulation of food samples*

The plantain, tiger nut tubers and soybean cake flour were blended with reference to 50% recommended daily intakes (RDI) of protein (56 g/day) and fat (20 g/day) for adult using material balance equations. The following food combinations were thereafter obtained, that is, PSB (plantain flour, 64.5% & soycake, 35.5%), TNS (tiger nut flour, 59.8% & soycake 40.2%), PTS (plantain flour 51.1%, tigernut flour 11.5% & soycake flour 37.4%), PLT (100% plantain flour), TNT (100% tigernut flour) and a commercial dough meal flour (control) (CNT).

*Determination of proximate composition flour blends*

Proximate compositions, that is, moisture content, ash, crude fiber, crude fat and crude protein content of experimental food samples were determined using the standard methods (AOAC, 2012). Carbohydrate content was determined by difference as follows:
Carbohydrate (%) = 100-(%Moisture + %Fat + %Ash + %Crude fibre + %Crudeprotein)
The gross energy values of the samples were determined (MJ/kg) by using Gallenkamp Adiabatic bomb calorimeter (Model CBB-330-01041; UK).

*Determination of anti-nutritional factor of flour blends*

Determination of flavonoids was carried out using the method described by Boham and Kocipal-Abyazan (1994). Tannin concentration in the samples was determined as described by Jaffe (2003). Phenolconcentration was determined as described by George et al. (2005). Saponin was determined using the method described by Obadoni and Ochuko (2001). Phytate was determined using spectrophotometric method of AOAC (2012). Oxalate was determined according to the method of Munro (2000). Trypsin inhibition activity was determined as described by Griffiths (2000).

*Determination of mineral composition of flour blends*

Mineral compositions of calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu) and zinc (Zn) were determined using Atomic Absorption Spectrophotometer (AAS Model SP9). Sodium (Na) and potassium (K) in the food samples were determined using flame emission photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK) with NaCl and KCl as the standards (AOAC 2012). Phosphorus was determined using Vanodo-molybdate method.

*Calculation of mineral molar ratios and bioavailability index*

The Na/K, Ca/P, Ca/Mg, [K/Ca+Mg], Phytate: Zn, Ca: Phytate and [Ca][Phytate]/[Zn] molar ratios were calculated as described by Ferguson et al. (1988).

*Amino acid compositions*

The amino acid profiles of the experimental samples were determined according to the method described by AOAC (2012). The experimental samples were digested using 6N HCl for 24 h. Amino acids were determined using the Beckman Amino Acid Analyzer (model 6300; Beckman Coulter Inc., Fullerton, Calif., USA) employing sodium citrate buffers as step gradients with the cation exchange post-column ninhydrin derivatization method. The data were calculated as grams of amino acid per 100 g crude protein of flour sample.

*Determination of fatty acids compositions of flour blends*

The composite flour samples were extracted with chloroform:methanol (2:1 v/v) and solid non-liquid material was removed by filtration. The total extracted lipid material was recovered after solvent removal in a stream of nitrogen. The samples were re-dissolved in anhydrous chloroform/methanol (19:1 v/v), and clarified by centrifugation at 10,000 x g for 10 min. Tranmethylation was performed using 14% (w/v) boron triflouride ($BF_3$) in methanol (Solomon and Owolawashe, 2007). Fifty nanograms of heptadecanoic acid (internal standard) and 1 mL aliquot of each sample were transferred to a 15 mL

Teflon-lined screw-cap tube. After removal of solvent by nitrogen gassing, the samples were mixed with 0.5 mL of $BF_3$ reagent (14% w/v), placed in warm bath at 100 °C for 30 min and cooled. After the addition of saline solution, the transmethylated fatty acids were extracted into hexane. A calibration mixture of fatty acid standards was processed in parallel. Aliquots of the hexane phase were analysed by gas chromatography. Fatty acids were separated and quantified using a Hewlett-Packard gas chromatograph (5890 Series II) equipped with a flame-ionization detector. Two microliter aliquot of the hexane phase was injected in split-mode onto a fused silica capillary column (Omegawax: 30 m x 0.32 mm ID, Supleco, Bellefonte, PA). The injector temperature was set at 200 °C, detector at 230 °C, oven at 120 °C initially, then 120-205 °C for 18 min. The carrier gas was helium and the flow rate was approximately 50 cm/sec. Electronic pressure control in the constant flow mode was used. The internal standard (heptadecanoic acid, C17:0) and calibration standards (NuCheck, Elysian, MN) were used for quantitation of fatty acids in the lipid extracts. The reported fatty acids represent the average of three determinations.

*Determination of functional properties of flour blends*

*Swelling index (%)*

This was determined with the method described by Alawode et al. (2017) with modification for small samples. One gram (1.0 g) of the flour sample was mixed with 10 mL distilled water in a centrifuge tube and heated at 80 ºC for 30 min. This was continuously shaken during the heating period. After the heating, the suspension was centrifuged at 1000 x g for 15 min. The supernatant was decanted and the weight of the paste taken. The swelling power was calculated as follows:

$$\text{Swelling index (\%)} = \frac{\text{weight of sample paste}}{\text{weight of dry flour}} \times 100$$

*Bulk density*

A 50 g flour sample was put into a 100 mL measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density (g/cm3) was calculated as weight of flour (g) divided by flour volume ($cm^3$) (Okaka et al., 1979)

$$\text{Bulk density} = \frac{\text{weight of sample}}{\text{volume of sample after tapping}} \times 100$$

*Water absorption capacity (WAC)*

The method described by Onwuka (2005) was used. One gram of the flour sample was weighed into a 15 mL centrifuge tube and suspended in 10 mL of water. It was shaken on a platform tube rocker for 1 min at room temperature. The sample was allowed to stand for 30 min and centrifuged at 1200 x g for 30 min. The volume of free water was read directly from the centrifuge tube.

$$\text{WAC} = \frac{\text{amount of water added} - \text{free water}}{\text{weight of sample}} \times \text{density of water} \times 100$$

*Gelation capacity*

The least gelation concentration was determined by a modification of the method of Sathe et al. (1982). The flour dispersions of 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20% (w/v) were prepared in 5 mL distilled water in test tubes, which were heated at 90 ºC for 1 hour in water bath (Gallenkamp). The heated dispersions were cooled rapidly under running tap water and then at 4 ºC for 2 h. The least gelation concentration was determined as that concentration when the sample from the inverted tube did not slip or fall.

*Evaluation of sensory attributes of dough meal samples*

All sensory analyses were conducted in a sensory laboratory with adequate lighting and no odour environment. Panellists were selected based on their familiarity with control samples, recognition and perception of common odours. The dough meal samples were prepared by stirring flour in boiling water 1:4 (v/v) of flour to water dispersion at 100 ºC for 30 min. The reconstituted formulated food samples and the control food samples were coded and presented to 30 untrained panellists. The panel members were assigned individually to illuminate laboratory booths well and the prepared dough meals were served at 40 ºC coded with random three digits. Water at room temperature was provided for mouth rinsing in between successive evaluation. Sample attributes (colour, texture, taste, aroma, mouldability, etc.) were rated on a scoring scale of 1 to 9, where 1 = dislike extremely and 9 = like extremely. Panellists made their responses on score sheets, which were designed in line with the test procedures (Olapade et al., 2014).

*Statistical analysis*

All data were expressed as mean ± standard error of mean (SEM) using the statistical analysis programme for social sciences (SPSS) (30). Significant differences among the means were determined using coefficient of variations (CV %). Graphs were plotted using GraphPad Prism 6. Results were considered to be significant at $p \leq 0.05$.

## Results and discussion

*Chemical composition of plantain, tigernut and defatted soycake composite flour and control samples*

The macronutrient and mineral composition of plantain, tigernut and defatted soycake composite flour and control samples are presented in Table 1. The moisture content (MC) of blended flour samples ranged from 6.08 g/100 g in TNT to 7.29 g/100 g in PTS, and the values were significantly (p<0.05) lower when compared with the control sample (CNT) (9.29 g/100 g). The MC of experimental flour samples in this present study agreed with FAO recommended value for flour sample (<10%) (FAO, 2003) and the values were comparatively similar to what obtained for plantain-based dough meal enriched with soybean and cassava fibre (7.18 – 7.80 g/100 g) (Famakin et al., 2016) and plantain-based complementary foods enriched with fermented Bambara groundnut (Ijarotimi, 2008). The variation between moisture content in this study, experimental food samples, control food sample (CNT) and other reported plantain-based food products could be attributed to processing methods and composition of blended food materials. Scientific study has shown that high moisture content in flour sample enhances microbial activities, spoilage, and thereby reduces flour shelf life (Madukwe et al., 2013).

The protein content of blended flour samples ranged from 16.22 g/100 g in PSB to 29.72 g/100 g in PTS, and was significantly (p<0.05) higher than PLT (100% plantain) (9.45 g/100 g) and CNT (14.29 g/100 g). The protein content in experimental food samples was comparatively higher than what was reported by Famakin et al. (2016) for plantain-based enriched with soycake and rice bran. Nutritionally, the protein content of the blended flour samples, particularly PSB and PTS, would be suitable to provide half of daily protein requirement of adult (56 g/kg body weight), and also for the growth and development of children.

The crude fiber content of the composite flour samples ranged from 1.26 g/100 g in PSB to 5.79 g/100 g in TNT, and was significantly (p<0.05) higher than PLT (3.55 g/100 g) and CNT (0.23 g/100 g). Comparatively, the crude fiber content of melon seed flour obtained in this present study was similar to the plantain-based composite flour enriched with soycake and rice bran reported by Famakin et al. (2016). Epidemiological studies have shown that dietary fiber intake promotes good health, for instance, dietary fiber is beneficial for the treatment of Type 2 diabetes mellitus (American Diabetes Association, 2013) by delaying digestion and absorption of carbohydrates in gastro-intestinal tract (Post et al., 2012). Hence, it reduces the risk of diabetes and other degenerating diseases.

**Table 1** Proximate composition (g/100 g) of plantain, tigernut and soycake composite flour and control samples

| Samples | PLT | TNT | TNS | PSB | PTS | CNT | FAO |
|---|---|---|---|---|---|---|---|
| Moisture | $8.72^{b}\pm0.08$ | $6.08^{e}\pm0.19$ | $6.63^{d}\pm0.14$ | $7.13^{cd}\pm0.09$ | $7.29^{c}\pm0.21$ | $9.29^{a}\pm0.28$ | 10 |
| Ash | $0.96^{c}\pm0.05$ | $1.87^{b}\pm0.01$ | $2.81^{a}\pm0.07$ | $1.94^{b}\pm0.01$ | $2.90^{a}\pm0.06$ | $0.98^{c}\pm0.01$ | - |
| Fat | $10.51^{e}\pm0.12$ | $28.77^{a}\pm0.40$ | $23.83^{b}\pm0.40$ | $12.43^{d}\pm0.23$ | $15.69^{c}\pm0.06$ | $10.33^{e}\pm0.06$ | - |
| Fibre | $3.55^{c}\pm0.03$ | $5.79^{a}\pm0.09$ | $4.34^{b}\pm0.05$ | $1.26^{e}\pm0.04$ | $1.45^{d}\pm0.01$ | $0.23^{f}\pm0.01$ | - |
| Protein | $9.45^{f}\pm0.06$ | $10.65^{e}\pm0.06$ | $26.28^{b}\pm0.08$ | $16.22^{c}\pm0.22$ | $29.72^{a}\pm0.02$ | $14.29^{d}\pm0.07$ | 16.70 |
| Carbohydrate | $66.81^{a}\pm0.09$ | $46.84^{d}\pm0.31$ | $36.11^{f}\pm0.23$ | $61.01^{c}\pm0.19$ | $42.95^{e}\pm0.26$ | $64.88^{b}\pm0.30$ | - |
| Energy (Kcal/100g) | $399.63^{f}\pm0.84$ | $488.86^{a}\pm2.22$ | $464.02^{b}\pm2.90$ | $420.83^{d}\pm1.11$ | $431.88^{c}\pm1.34$ | $409.62^{e}\pm1.03$ | 344 |
| Cu | $0.01^{b}\pm0.00$ | $0.01^{b}\pm0.00$ | $0.04^{a}\pm0.01$ | $0.01^{b}\pm0.00$ | $0.01^{b}\pm0.00$ | $0.01^{b}\pm0.00$ | |
| Pb | $0.00^{b}\pm0.00$ | $0.01^{a}\pm0.00$ | $0.01^{a}\pm0.00$ | $0.01^{a}\pm0.00$ | $0.00^{b}\pm0.00$ | $0.01^{a}\pm0.00$ | |
| Zn | $0.02^{e}\pm0.00$ | $0.10^{b}\pm0.02$ | $0.04^{d}\pm0.01$ | $0.29^{a}\pm0.05$ | $0.07^{c}\pm0.01$ | $0.10^{b}\pm0.02$ | |
| Fe | $0.12^{c}\pm0.02$ | $0.23^{ab}\pm0.04$ | $0.25^{a}\pm0.04$ | $0.30^{a}\pm0.05$ | $0.16^{b}\pm0.03$ | $0.14^{bc}\pm0.02$ | |
| Mn | $0.02^{b}\pm0.00$ | $0.02^{b}\pm0.00$ | $0.02^{b}\pm0.00$ | $0.03^{a}\pm0.01$ | $0.02^{b}\pm0.00$ | $0.02^{b}\pm0.00$ | |
| P | $13.12^{d}\pm0.22$ | $14.49^{c}\pm0.24$ | $20.44^{a}\pm0.34$ | $5.08^{f}\pm0.08$ | $8.18^{e}\pm0.14$ | $19.22^{b}\pm0.32$ | |
| K | $9.12^{b}\pm0.15$ | $8.28^{c}\pm0.14$ | $10.43^{a}\pm0.17$ | $6.34^{d}\pm0.10$ | $6.39^{d}\pm0.11$ | $9.50^{b}\pm0.16$ | |
| Na | $5.30^{b}\pm0.09$ | $6.24^{a}\pm0.10$ | $4.55^{c}\pm0.08$ | $3.20^{d}\pm0.05$ | $4.37^{c}\pm0.07$ | $4.39^{c}\pm0.07$ | |
| Ca | $5.35^{b}\pm0.09$ | $4.23^{c}\pm0.07$ | $6.24^{a}\pm0.10$ | $5.49^{b}\pm0.09$ | $4.37^{c}\pm0.07$ | $3.76^{d}\pm0.06$ | |
| Mg | $2.09^{cd}\pm0.03$ | $2.37^{b}\pm0.04$ | $2.75^{a}\pm0.05$ | $2.03^{d}\pm0.03$ | $2.18^{c}\pm0.04$ | $1.99^{d}\pm0.03$ | |
| Na/K | $0.99^{c}\pm0.00$ | $1.28^{a}\pm0.00$ | $0.74^{f}\pm0.00$ | $0.86^{d}\pm0.00$ | $1.16^{b}\pm0.00$ | $0.78^{e}\pm0.00$ | |
| Ca/P | $0.32^{c}\pm0.00$ | $0.23^{d}\pm0.00$ | $0.24^{d}\pm0.00$ | $0.84^{a}\pm0.00$ | $0.41^{b}\pm0.00$ | $0.15^{e}\pm0.00$ | |

*Means (±SEM) with different alphabetical superscripts in the same row are significantly different at P<0.05; Key: PLT: 100% Plantain; TNT: 100% Tigernut; CNT: 100% Commercial dough meal; TNS: Tigernut:Soycake (59.83:40.17)%; PSB: Plantain:soycake (64.46:35.54)%; PTS: Plantain: Tigernut: Soycake (51.07:11.50:37.43)%.*

Energy values of the composite flour samples ranged from 420.83 kcal/100 g in PBS to 488.86 kcal/100 g in TNT. Statistically, the energy values of experimental flour samples were significantly ($p<0.05$) higher when compared with PLT (399.63 kcal/100 g), CNT (409 Kcal/100 g), and that of FAO recommended energy value (344 Kcal/day). This implies that the flour samples may be suitable to provide daily energy requirement for both children and adults. The observed high energy values of these experimental composite flours could be attributed to high fat content of tigernut, protein content of defatted soycake and carbohydrate of plantain, which agreed with other studies that plants like plantain, soybean, etc. are inexpensive sources of energy (Adejuyitan et al., 2009; Akubor and Ishiwu, 2013; Famakin et al., 2016).

The mineral compositions of plantain, tigernut and defatted soycake based dough meal flour are presented in Table 1. The mineral compositions of flour samples had phosphorous as the most abundant element, except in PSB, with values ranged from 5.08±0.08 to 20.44±0.34 mg/100 g. Statistically, the concentration of phosphorus, iron, zinc and manganese in the composite flour samples was significantly higher ($p<0.05$) than in PLT (100% plantain flour), but was either equal or higher than in the control sample (CNT). Hence, in this present study, it could be inferred that the experimental flour samples contain appreciable amount of essential minerals like iron, zinc and magnesium, which are very essential for diabetic patients. Scientific studies have reported that zinc, magnesium and calcium play important role in glucose metabolism by serving as cofactors or components for enzyme involved in glucose metabolism, and thereby enhancing insulin action by activation of insulin receptor (Mamza et al., 2016; Ramaswamy et al., 2016).

The range values of Na/K and Ca/P molar ratios of the composite flour were 0.74 – 1.28 and 0.23 – 0.84, respectively. The Na/K molar ratios in this report were lower than recommended value of <1.00, except TNT and PTS samples, hence, these composite flour samples may be suitable for individuals with high blood pressure. The Ca/P molar ratios of composite flour samples were higher when compared with PLT (100% plantain) (0.32), CNT (commercial flour) (0.15) and FAO recommended value of >1.0. Hence, there is a need to complement intake of these composite flours with calcium supplement in order to prevent osteoporosis in adults and rickets in children (Nieman et al., 1992).Amino acid profile of plantain, tigernut and soycake composite flour samples and control sample are presented in Table 2. Total amino acid profile of the flour samples ranged from 63.48 mg/100 g protein in TNS to 74.25 mg/100 g of protein in PSB, and these values were significantly ($p<0.05$) higher than in CNT (60.91 mg/100 g protein). For total essential amino acids, the range values were from 26.58 mg/100 g protein in PTS to 29.27 mg/100 g protein in PSB, and were higher than PLT (25.86 mg/100 g protein), except in TNS (23.90 mg/100 g protein), but were comparable to that of CNT (28.27 mg/100 g of protein). This finding agreed with the report that combinations of two or more local food materials usually improved nutritional status of the final food products (Omueti et al., 2009). The essential amino acids in the experimental flour samples may be adequate to support growth and development in children and adults. Besides, studies have reported that the plasma concentrations of essential amino acids like valine, leucine and isoleucine (branched chain amino acids) are prognostic for the onset and progress of Type 2 diabetes (Wang et al., 2011; Melnik et al., 2012; Floegel et al., 2013). The essential amino acid scores of the experimental flour samples showed that methionine was the limiting amino acid, while arginine was the most abundant amino acid. The amount of arginine in these composite flour samples is highly beneficial in the management of high blood pressure. For instance, it is evident that arginine plays an important role in the production of nitric oxide in the body, which helps in the relaxation of the arteries to enhance easy flow of blood and thereby reduces the risk of hypertension or high blood pressure (Tejero et al., 2008).

Fatty acid composition of the composite flour samples and control flour sample are presented in Table 3. The range values of total saturated fatty acids (SFA) and polyunsaturated fatty acids were 14.86 mg/100 g in TNS to 17.01 mg/100 g in PTS and 55.14 mg/100 g in PTS to 56.62 mg/100 g in PSB; while those of the control sample were 25.65 mg/100 g and 37.29 mg/100 g, respectively. Statistically, the saturated fatty acid and polyunsaturated fatty acid of the composite flour samples were significantly lower ($p<0.05$) than commercial control sample (CNT). The polyunsaturated fatty acid/saturated fatty (P/S) molar ratio of the composite flour samples ranged from 1.54 in PTS to 1.92 in TNS, and was significantly higher than that of PLT (1.27) and CNT (1.40). Comparatively, the values of P/S molar ratio of experimental flour samples were higher than recommended FAO/WHO (1991) of >1.00; and this implies that there are more of polyunsaturated fatty acids in the composite flour samples than saturated fatty acids. It is well established that such high dietary fat containing food intakes may provide health benefits (Bożena et al., 2013). The consumption of unsaturated oils in diet is therefore recommended both to decrease high cholesterol intake and also to increase the ratio of polyunsaturated to saturated fatty acid in order to prevent atherosclerosis and cardiovascular diseases (Cutler, 1991; Bożena et al., 2013).

**Table 2** Amino acid profile (mg/100g protein) of plantain, tigernut and soycake composite flour and control samples

| Samples | PLT | TNT | TNS | PSB | PTS | CNT | *Adult | *Children |
|---|---|---|---|---|---|---|---|---|
| **Non-essential amino acids** | | | | | | | | |
| Glycine | 4.70[a] | 4.56[a] | 4.35[a] | 4.23[a] | 4.48[a] | 1.32[b] | - | - |
| Alanine | 3.92[b] | 4.42[a] | 4.00[a] | 3.61[b] | 3.84[b] | 2.67[c] | - | - |
| Serine | 1.97[b] | 2.33[a] | 1.79[b] | 2.20[a] | 2.01[a] | 1.76[b] | - | - |
| Proline | 2.19[b] | 3.53[a] | 2.07[b] | 2.52[b] | 2.48[b] | 1.26[c] | - | - |
| Aspartic | 8.16b | 5.54c | 8.42b | 9.21a | 8.56[b] | 5.91c | - | - |
| Cysteine | 0.83[c] | 3.70[a] | 0.75[d] | 0.99[c] | 0.87[c] | 1.44[b] | - | - |
| Glutamic | 13.16[c] | 17.92[a] | 12.54[d] | 14.34[b] | 13.25[c] | 11.81[e] | - | - |
| Tyrosine | 1.54[c] | 2.16[a] | 1.43[c] | 1.92[b] | 1.48[c] | 1.26[c] | - | - |
| Arginine | 4.92[b] | 3.66[c] | 4.23[b] | 5.96[a] | 4.98[b] | 5.21[a] | - | - |
| ΣNEAAs | 41.39[c] | 47.82[a] | 39.58[d] | 44.98[b] | 41.95[c] | 32.64[e] | - | - |
| **Essential amino acids** | | | | | | | | |
| Phenylalanine | 2.45[d] | 4.98[b] | 1.93[e] | 3.86[c] | 2.50[d] | 7.01[a] | 2.5 | 6.9 |
| Histidine | 1.36[b] | 1.55[b] | 1.29[b] | 2.06[a] | 1.64[b] | 1.62[b] | - | 1.0 |
| Metheonine | 0.62[b] | 1.22[a] | 0.61[b] | 0.92[b] | 0.72[b] | 0.43[c] | 1.5 | 2.7 |
| Valine | 3.36[b] | 3.78[b] | 2.97[c] | 4.89[a] | 4.20[a] | 3.59[b] | 2.6 | 3.8 |
| Tryptophan | 0.60[b] | 1.11[a] | 0.53[b] | 0.71[b] | 0.67[b] | 0.51[b] | 0.4 | 1.25 |
| Threonine | 2.64[b] | 2.71[b] | 2.35[b] | 3.05[a] | 3.11[a] | 1.72[c] | 1.5 | 3.7 |
| Isoleucine | 3.48[b] | 3.12[b] | 2.91[c] | 3.59[b] | 3.16[b] | 4.83[a] | 2.0 | 3.1 |
| Leucine | 6.52[a] | 5.24[c] | 6.37[a] | 6.64[a] | 6.44[a] | 6.65[a] | 3.9 | 7.3 |
| Lysine | 4.83[b] | 5.51[a] | 4.94[b] | 3.55[c] | 4.14[b] | 1.91[d] | 3.0 | 6.4 |
| ΣEAAs+His | 25.86[d] | 29.22[a] | 23.9[e] | 29.27[a] | 26.58[c] | 28.27[b] | - | - |
| **Predicted nutritional quality** | | | | | | | | |
| TAA | 67.25[d] | 77.04[a] | 63.48[e] | 74.25[b] | 68.53[c] | 60.91[f] | - | - |
| TEAA/TNEAA | 0.62[b] | 0.61[b] | 0.60[b] | 0.65[b] | 0.63[b] | 0.87[a] | - | - |
| ΣSAA(Meth+Cys) | 1.45[c] | 4.92[a] | 1.36[c] | 1.91[b] | 1.59[b] | 1.87[b] | - | - |
| ΣArAA(Phe+Tyr) | 3.99[d] | 7.14[b] | 3.36[d] | 5.78[c] | 3.98[d] | 8.27[a] | - | - |
| Arginine/Lysine | 1.02[c] | 0.66[e] | 0.86[d] | 1.68[b] | 1.20[c] | 2.73[a] | - | - |
| BCAAs | 13.36[b] | 12.14[c] | 12.25[c] | 15.12[a] | 13.8[b] | 15.07[a] | - | - |
| LAAS | Methionine | Methionine | Methionine | Methionine | Methionine | Lysine | | |
| AAAS | Arginine | Arginine | Arginine | Arginine | Arginine | Phenyl-alanine | | |

Key: PLT: 100% Plantain; TNT: 100% Tigernut; CNT: 100% Commercial dough meal; TNS: Tigernut: Soycake (59.83:40.17)%; PSB: Plantain:soycake (64.46:35.54)%; PTS: Plantain: Tigernut: Soycake(51.07:11.50:37.43)%.*RDA of essential amino acids ((mg/100g b.w)) for Adult and Children (<5 yrs.) (FAO/WHO, 1991; FAO/WHO/UNU, 2007); Total essential amino acids (ΣEAA), Total non- essential amino acids (ΣNEAA), Total sulphur amino acid (ΣSAA), Total Aromatic amino acids (ΣArAA), Limiting amino acid (LAA), Abundant amino acid (AAA), Branched chain amino acids (ΣBCAAs=Leu.,Isoleu., Valine)

The anti-nutritional composition of composite flour samples is shown in Table 4. Trypsin had the highest concentration with range values of 8.42 – 16.38 mg/ g, while oxalate had the lowest concentration (0.03 – 3.84 mg/ g) and these values were significantly lower when compared with CNT (27.63 and 0.11 mg/ g, respectively). However, the anti-nutritional composition of composite flour samples were generally lower when compared with tolerable levels and this could be attributed to the effects of processing methods adopted during sample preparation. Series of studies have reported that various domestic processing methods like dehulling, sprouting, blanching, cooking, etc. usually brings about reductions in anti-nutritional composition of final food products (Gilani et al., 2005; Ijarotimi and Keshinro, 2012, Temesgen, 2013). Epidemiological studies have reported on the nutritional and health benefits of some phytochemicals in plants. For instance, it is well established that dietary polyphenols have properties that inhibit carbohydrate digestion and glucose absorption in the intestine, stimulate insulin secretion from the pancreatic β-cells, modulate glucose release from the liver, activate insulin receptors and glucose uptake in insulin-sensitive tissue and modulate intracellular signaling pathways and gene expression (Carter et al., 2010; Hanhineva et al., 2010; Firdous, 2014). Table 4. shows the relationship between the phytate and the bioavailability of selected minerals such as calcium, zinc and iron in the composite flour samples and the control samples. The range values of phytate: calcium (0.003 - 0.004), phytate: zinc (0.104 - 1.081), phytate: iron (0.086 - 0.131) and phytate: calcium: zinc (0.014 - 0.169) molar ratios were lower than that of critical values (Bindra et al., 1986; Gibson et al., 1995). This observation implies that the mineral composition of the composite flour samples would be less interfered with the phytate, and thereby enhances the bioavailability of minerals like calcium, zinc and iron in the gastro-intestinal tract (Walter et al., 2002). Nutritionally, zinc and calcium are essential elements in human nutrition particularly in glucose metabolism by enhancing insulin production. Hence, these elements play important roles in diabetes patients (Mamza et al., 2016; Ramaswamy et al., 2016).

**Table 3** Fatty acid profile ( %) of plantain, tigernut and soycake composite flour and control samples

| Samples | PLT | TNT | TNS | PSB | PTS | CNT |
|---|---|---|---|---|---|---|
| **Saturated (SFA)** | | | | | | |
| Caprylic acid (C8:0) | 0.00[b] | 0.09[a] | 0.00[b] | 0.00[b] | 0.00[b] | 0.00[b] |
| Capric acid (C10:0) | 0.00[b] | 0.09[a] | 0.00[b] | 0.00[b] | 0.00[b] | 0.00[b] |
| Lauric acid (C12:0) | 0.00[b] | 0.08[a] | 0.00[b] | 0.00[b] | 0.00[b] | 0.00[b] |
| Myristic acid (C14:0) | 0.25[a] | 0.11[c] | 0.15[b] | 0.26a | 0.15[b] | 0.00[d] |
| Palmitic acid (C16:0) | 13.89[c] | 16.31[b] | 10.34[e] | 10.89[e] | 11.41[d] | 17.98[a] |
| Margaric acid (C17:0) | 0.04[b] | 0.07[a] | 0.02[d] | 0.04[b] | 0.02[d] | 0.03[c] |
| Stearic acid (C18:0) | 5.82[b] | 3.05[d] | 3.82[d] | 4.67[c] | 4.79[c] | 6.64[a] |
| Behenic acid (C22:0) | 0.33[a] | 0.08[c] | 0.21[b] | 0.39[a] | 0.21[b] | 0.21[b] |
| Lignoceric acid (C24:0) | 0.16[b] | 0.65[a] | 0.10[c] | 0.19[b] | 0.10[c] | 0.10[c] |
| Arachidic acid (C20:0) | 0.46[c] | 0.76[a] | 0.32[d] | 0.22[e] | 0.33[d] | 0.69[b] |
| **∑SFA** | 20.95[c] | 21.29[b] | 14.86[f] | 16.66[e] | 17.01[d] | 25.65[a] |
| **Monounsaturated (MUFA)** | | | | | | |
| Palmitoleic acid (C16:1) | 0.26[d] | 1.16[b] | 0.17[e] | 0.31[c] | 0.17[e] | 4.28[a] |
| Oleic acid (C18:1) | 51.85[c] | 54.59[b] | 56.24[a] | 55.02[b] | 54.81[b] | 30.29[d] |
| Erucic acid (C22:1) | 0.24[b] | 0.33[a] | 0.15[c] | 0.29[b] | 0.16[c] | 0.03[d] |
| **∑MUFA** | 52.35[c] | 56.08[a] | 56.56[a] | 55.62[b] | 55.14[b] | 34.60[d] |
| **Polyunsaturated (PUFA)** | | | | | | |
| Linoleic acid (C18:2) | 25.96[d] | 22.44[e] | 27.99[b] | 26.80[c] | 27.35[b] | 31.55[a] |
| Linolenic acid (C18:3) | 0.69[b] | 0.55[c] | 0.44[d] | 0.83[a] | 0.45[d] | 8.10[a] |
| Arachidonic acid (C20:4) | 0.06[c] | 0.15[a] | 0.04[d] | 0.07[b] | 0.04[d] | 0.07[b] |
| ∑PUFA | 26.71[d] | 23.14[e] | 28.47[b] | 27.70[c] | 27.84[c] | 37.29[a] |
| MUFA/PUFA | 1.96[c] | 2.42[a] | 1.99[c] | 2.01[b] | 1.98[c] | 0.93[d] |
| PUFA/SFA | 1.27[e] | 1.09[f] | 1.92[a] | 1.66[b] | 1.54[c] | 1.40[d] |
| (PUFA+MUFA)/SFA | 3.77[c] | 3.72[c] | 5.72[a] | 5.00[b] | 4.88[b] | 2.80[d] |

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at P<0.05. Key: PLT: 100% Plantain; TNT: 100% Tigernut; CNT: 100% Commercial dough meal; TNS: Tigernut: Soycake (59.83:40.17)%; PSB: Plantain:soycake (64.46:35.54)%; PTS: Plantain: Tigernut: Soycake (51.07:11.50:37.43)%.

**Table 4** Anti-nutrient compositions (mg/g) of plantain, tigernut and soycake composite flour and control samples

| Parameters | PLT | TNT | TNS | PSB | PTS | CNT | *C |
|---|---|---|---|---|---|---|---|
| Tannin | 1.27[e]±0.01 | 2.02[c]±0.01 | 2.59[b]±0.07 | 1.65[d]±0.17 | 3.25[a]±0.02 | 1.14[e]±0.01 | 3.0 mg/100g |
| Phenol | 1.24[d]±0.05 | 1.15[e]±0.01 | 1.91[a]±0.01 | 1.46[c]±0.01 | 1.82[b]±0.01 | 1.02[f]±0.02 | - |
| Oxalate | 0.03[d]±0.00 | 0.08[b]±0.00 | 0.07[c]±0.00 | 0.11[a]±0.00 | 0.06[c]±0.00 | 0.11[a]±0.00 | 0.25g/100g |
| Phytate | 1.92[d]±0.27 | 3.3[bc]±0.00 | 3.84[bc]±0.27 | 3.02[c]±0.27 | 3.02[c]±0.27 | 4.13[a]±0.01 | 5-6g/100g |
| Saponin | 2.81[bc]±0.65 | 2.68[bc]±0.10 | 3.15[b]±0.00 | 2.21[c]±0.01 | 3.21[b]±0.01 | 4.05[a]±0.03 | - |
| Flavonoid | 2.69[a]±0.06 | 1.95[c]±0.02 | 2.48[b]±0.05 | 1.43[d]±0.04 | 2.03[c]±0.04 | 2.81[a]±0.01 | - |
| Trypsin | 13.07[c]±0.06 | 8.42[f]±0.19 | 9.77[e]±0.00 | 10.63[d]±0.00 | 16.38[b]±0.33 | 27.63[a]±0.32 | 0.25g/100g |
| **Phytate/mineral (Ca, Zn & Fe) molar ratios** | | | | | | | |
| *Phytate/calcium | 0.003[a] | 0.005[a] | 0.004[a] | 0.003[a] | 0.004[a] | 0.005[a] | 0.24 |
| *Phytate/zinc | 1.293[a] | 0.335[b] | 1.081[a] | 0.104[c] | 0.451[b] | 0.289[c] | 15 |
| *Phytate/iron | 0.221[a] | 0.122[a] | 0.131[a] | 0.086[a] | 0.159[a] | 0.184[a] | >1.0 |
| *Phy*Ca/Zn | 0.173[a] | 0.035[a] | 0.169[a] | 0.014[a] | 0.049[a] | 0.027[a] | 200 |

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at P<0.05.
Key: PLT: 100% Plantain; TNT: 100% Tigernut; CNT: 100% Commercial dough meal; TNS: Tigernut:Soycake (59.83:40.17)%; PSB: Plantain:soycake (64.46:35.54)%; PTS: Plantain: Tigernut: Soycake (51.07:11.50:37.43)%.
*Critical molar ratios; Phytate:calcium = 0.24 (Morris and Ellis, 1985); Phytate:zinc = 15 (WHO, 1996); Phytate:iron = > 1 (Hurrell, 2003); phytate: calcium/zinc > 200 (Hemalatha et al., 2007).

*Functional properties of plantain, tigernut and defatted soycake composite flour and control samples*

The functional properties of formulated composite flour and control samples are presented in Table 5. Bulk density of the composite flour samples ranged from 0.41 g/mL in TNS to 0.43 g/mL in PTS and was significantly higher (p<0.05) than CNT (a commercial market sample) (0.37 g/mL), but lower when compared with PLT (0.58 g/mL). Bulk density value is important in packaging (Sharma et al., 2012; Adebayo et al., 2013). The low bulk density observed in this study implies that less quantity of the flour samples would be required in packaging, hence ensuring an economical packaging (Osundahunsi and Aworh, 2002). Water absorption capacity of the composite flour samples ranged from 2.43 mg/g in TNS to 2.75 mg/g in PSB, and was significantly ($p<0.05$) higher than CNT (2.20 mg/g) and PLT (2.50 mg/g). Water absorption capacity (WAC) is an index of the amount of water that a food product can absorb and retain. The WAC of the flour samples in this present study was lower, and this is desirable for making thinner gruels that will enhance more intake of nutrients (Kulkarni et al., 1991); and lowering the microbial activities of the food products, thereby, prolong the shelf life of the flour samples (Giami and Bekeham, 1992). Swelling index of the formulated composite flour ranged from 68.50% in TNS to 90.42% in PSB, while that of CNT was 58.89% and PLT was 94.67%. Swelling capacity is an important factor used in determining the expansion accompanying of solvent. According to Kinsella (1976), swelling causes changes in hydrodynamic properties of the food sample, thus imparting characteristics such as body, thickness and reduced viscosity of the food, plasticity and electricity. Hence, these properties are desirable for a good dough meal. The least gelation of composite flour ranged from 8.00% in PSB to 10.00% in PTS, and the values were significantly ($p<0.05$) higher than CNT (6.00%) and PLT (8.00%). The least gelation is the ability of a food sample to form a gel at a higher concentration. This implies that these experimental flour samples have poor gelating ability, hence it will not form a good gel, and this is a good functional process for a functional food. This means that the diet will have a low dietary bulk.

*Sensory attributes of dough meal made from plantain, tigernut and defatted soycake composite flour and control sample*

The sensory attributes of dough meals made from plantain, tigernut and defatted soycake flour samples, and the control samples are presented in Table 6. The appearance, taste and aroma of formulated dough meals were significantly ($p<0.05$) higher than PLT (100% plantain flour) dough meal, but scored lower when compared with the control sample (CNT). For mouldability and overall acceptability, TNS was insignificantly ($p<0.05$) higher when compared with other experimental food samples, but significantly lower than CNT (a commercial dough meal flour). The disparity between formulated dough meals and CNT could be due to the difference in food composition, processing techniques and familiarity to the control sample of the panellists.

**Table 5** Functional properties of plantain, tigernut and soycake composite flour and control samples

| Sample | Bulk density (g/mL) | Water absorption capacity (mg/g) | Swelling index (%) | Least gelation (%) |
|---|---|---|---|---|
| PLT | $0.58^{a}\pm0.03$ | $2.50^{c}\pm0.03$ | $94.67^{a}\pm2.11$ | $8.00^{c}\pm0.00$ |
| TNT | $0.41^{d}\pm0.00$ | $2.30^{e}\pm0.10$ | $89.82^{c}\pm3.04$ | $12.00^{a}\pm0.00$ |
| TNS | $0.41^{d}\pm0.00$ | $2.43^{d}\pm0.00$ | $68.50^{d}\pm0.74$ | $10.00^{b}\pm0.00$ |
| PSB | $0.51^{b}\pm0.00$ | $2.75^{a}\pm0.05$ | $90.42^{b}\pm0.40$ | $8.00^{c}\pm0.00$ |
| PTS | $0.43^{c}\pm0.01$ | $2.62^{b}\pm0.03$ | $69.98^{d}\pm3.32$ | $10.00^{b}\pm0.00$ |
| CNT | $0.37^{e}\pm0.00$ | $2.20^{f}\pm0.11$ | $58.89^{e}\pm1.02$ | $6.00^{d}\pm0.00$ |

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at $P<0.05$; Key: PLT: 100% Plantain; TNT: 100% Tigernut; CNT: 100% Commercial dough meal; TNS: Tigernut: Soycake (59.83:40.17)%; PSB: Plantain:soycake (64.46:35.54)%; PTS: Plantain: Tigernut: Soycake (51.07:11.50:37.43)%.

**Table 6** Sensory attributes of formulated dough meals made from plantain, tigernut and soybean cake flour

| Sample | CNT | PLT | TNT | PSB | TNS | PTS |
|---|---|---|---|---|---|---|
| Colour | $8.00^{a}\pm1.12$ | $5.90^{c}\pm1.99$ | $7.50^{ab}\pm1.00$ | $6.50^{bc}\pm1.85$ | $7.15^{ab}\pm0.75$ | $6.70^{bc}\pm1.66$ |
| Texture | $8.05^{a}\pm0.89$ | $6.55^{b}\pm1.50$ | $6.90^{b}\pm1.65$ | $6.60^{b}\pm1.39$ | $6.70^{b}\pm1.38$ | $6.35^{b}\pm1.93$ |
| Mouldability | $8.35^{a}\pm0.81$ | $6.70^{b}\pm1.75$ | $6.65^{b}\pm1.49$ | $6.85^{b}\pm1.63$ | $6.90^{b}\pm1.29$ | $6.30^{b}\pm1.72$ |
| Taste | $7.75^{a}\pm1.25$ | $5.90^{c}\pm1.45$ | $7.10^{ab}\pm1.51$ | $6.55^{bc}\pm1.32$ | $6.80^{abc}\pm1.24$ | $6.70^{bc}\pm1.80$ |
| Aroma | $7.55^{a}\pm1.28$ | $5.75^{c}\pm1.55$ | $6.90^{ab}\pm1.37$ | $5.75^{c}\pm1.62$ | $6.95^{ab}\pm1.19$ | $6.25^{bc}\pm1.45$ |
| Overall acceptability | $8.35^{a}\pm1.39$ | $6.45^{b}\pm1.43$ | $7.00^{b}\pm0.97$ | $6.70^{b}\pm1.53$ | $7.20^{b}\pm0.89$ | $6.35^{b}\pm1.46$ |

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at $P<0.05$

## Conclusion

The present study established that composite flour samples produced from plantain, tigernut and defatted soycake were rich in essential nutrients like amino acids, minerals and energy values, but low in antinutritional factors. Hence, the composite flours, particularly TNS, may be suitable as functional food for the treatment or management of diabetes and coeliac disease.

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