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Nutritional quality and physicochemical properties of biscuit from composite flour of wheat, African yam bean and tigernut

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ABSTRACT

This study investigated the effect of the supplementation of wheat flour with flour blends of African yam bean (AYB) and tigernut for the production of biscuits and evaluated the sensory characteristics. The composite flours were of ratio 70:25:5 (TWB), 70:20:10 (ATW), 70:15:15 (BTT) for wheat: AYB: tigernut, respectively, while 100 % wheat flour served as control (WTY). The composite flour samples were analyzed for proximate, functional and pasting properties. The physical and chemical properties and sensory attributes of the developed biscuits were carried out. The moisture, protein, fat, ash, crude fiber, carbohydrate, and energy contents of the composite flour ranged from 6.63 to 8.13 %, 11.22–18.36 %, 13.27–19.15 %, 0.98–0.99 %, 3.96–7.43 %, 59.97–62.55 % and 400.89 to 410.40 Kcal/100g, respectively. The results showed that protein fat, ash and crude fiber of the biscuit were improved. The water and oil absorption capacity of composite flour was low while the pasting properties of the composite flour blends reduced as the AYB flour increased. All the composite flour blend biscuit samples possessed high essential nutrients and antioxidant potential. All the biscuits samples were accepted by the panelists, however, sample BTT (70 % wheat flour+15 % AYB flour+ 15 % tigernut flour) was most accepted in appearance, aroma, taste, crispness and overall acceptability. Therefore, biscuits from the flour blends of wheat, AYB and tigernut could be nutritionally beneficial and good for adults.

1. Introduction

Biscuits are snacks widely consumed by people of all age groups [1]. It is a baked product that can be called a cookie made from flour, water, fat, and sugar [2,3]. Wheat flour is a major ingredient for biscuit production because gluten is not available in other cereals. Biscuits have some advantages compared with other snacks, are cheaper, good shelf life, and are available in different sizes, tastes, colors, and packs [4].

African yam bean (*Sphenostylis stenocarpa)* (AYB), is an herbaceous leguminous and annual crop that contains bean seeds that are usually enclosed in a pod-like cowpea. It is usually grown in tropical Africa commonly in Central and Western Africa, and grown widely in the Eastern part of Nigeria [5]. AYB is rich in protein, dietary fiber, vitamins, and minerals [6,7]. However, constraints to its cultivation and utilization include the presence of a high content of anti-nutritional factors such as trypsin inhibitor, phytate, tannin, oxalate and alkaloids and long cooking time [8]. Adegboyega et al. [9] reported that processing of AYB seed could reduce the

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Table 1
Formulation of composite flour blends of wheat, African yam bean and tigernut flour.

Samples	Wheat flour (%)	African yam bean flour (%)	Tigernut flour (%)
WTY	100	–	–
TWB	70	25	5
ATW	70	20	10
BTT	70	15	15

WTY – 100 % wheat flour, TWB – 70 % wheat flour + 25 % African Yam bean flour + 5 % tigernut flour, ATW - 70 % wheat flour + 20 % African yam bean flour + 10 % tigernut flour, BTT - 70 % wheat flour + 15 % African yam bean flour + 15 % tigernut flour.

anti-nutritional factors which could have had a low effect on the nutritional value. It has been reported that AYB contains bioactive compounds of phenolic and flavonoid acids [10]. This legume has also been reported to be of importance in the management of chronic diseases like diabetes, hypertension and cardiovascular diseases because of its high dietary fiber content [11].

Tigernuts (*Cyperus esculentus)* are an underutilized crop and three varieties (black, brown and yellow) are majorly cultivated [12]. The yellow variety is preferred among the varieties because of its size, attractive yellow color and freshness [13]. Tigernut is a rich source of dietary fiber, minerals, vitamins, protein, and carbohydrates [14,15]. Tigernuts also contain some phytochemicals such as sterols, alkaloids, tannins and saponin etc which have antioxidant potential [16]. Also, studies have shown that adding tigernut flour could increase the fiber contents and antioxidant properties of food [17,18]. Tigernut can be eaten raw, roasted, or grated to make refreshing beverages and processed [19]. It can be used in the production of baked products and any other confectioneries [20]. Ade-Omowaye et al. [21] and Chinma et al. [22] reported of addition of tigernut to wheat flour for bread and biscuit production, respectively.

The major flour for baking biscuits is refined wheat flour and this is because of its unique gluten content. However, wheat flour is high in starch but low in other important nutrients such as dietary fiber, minerals and proteins which may be reduced to a greater amount during the refining process [23]. With the nutritional value and bioactive compounds present in AYB and tigernut will be useful in increasing the nutritional composition of wheat flour. Studies have shown that composite flours produced from a combination of cereals, legumes, or tubers could contain more nutritional value than those produced from single cereals, legumes, or tubers and thus this may improve overall nutrition [24]. AYB and tigernut have been used alone with other cereals such as wheat, acha, maize, etc to make biscuits and snacks [18,25–27]. There is little information about the combination of AYB and tigernut for the production of biscuits. Therefore, this study aimed to evaluate the physical, chemical properties and sensory quality of biscuits produced from wheat flour, AYB, and tigernut flour.

2. Materials and methods

2.1. Materials

Wheat flour, African yam bean, tigernut and other ingredients such as margarine, sugar, eggs, skimmed milk powder and salt were purchased from Oba market in Akure, Ondo State, Nigeria. All other chemicals used were of analytical grade and were obtained from Sigma-Aldrich, London, United Kingdom.

2.2. Methods

2.2.1. Preparation of African yam bean flour (AYB)

AYB was processed to flour by using the method described by Abiodun & Adepeju [28]. AYB was cleaned and soaked in clean water for 24 h. It was dehulled manually and dried in an air oven (Plus11 Sanyo Gallenkamp PLC, Loughborough, UK) at 70 °C for 12 h. It was milled using a locally fabricated attrition mill and sieved through 45 μm mesh sieve, packaged in high-density polyethylene bag and stored at 4 °C in refrigerator condition for further analysis.

2.2.2. Preparation of tigernut flour

The method described by Ayo et al. [29] was used for the preparation of tigernut flour. The tigernuts were cleaned, washed, drained and dried in an air oven (Plus11 Sanyo Gallenkamp PLC, Loughborough, UK) at 70 °C for 8 h. It was then milled in a locally fabricated attrition mill and sieved using 45 μm mesh sieve, packaged in a high polyethylene bag and stored at 4 °C in refrigerator condition for further analysis.

2.2.3. Production of biscuit

The biscuit was produced by using the method described by Ayo et al. [18]. The composite flour blends are shown in Table 1. These were the recipe used: margarine (20 g) and sugar (30 g) were mixed together in a Kenwood mixer (Model KM 901 D, Hertfordshire) for 30 min, eggs (3), 7.5 g of skimmed milk powder and 0.1 g of salt were added. Then, 100 g of composite flour with 2 g of baking powder mixed together was poured into the mixture in the Kenwood mixer (Model KM 901 D, Hertfordshire) and mixed properly to form a dough. The dough was kneaded and rolled with a roller and cut using a locally fabricated biscuit round cutter. It was then baked in an oven at 180 °C for 15 min. The biscuit was removed from the oven (LG Electronics, India), cooled (Fig. 1), packaged and stored in

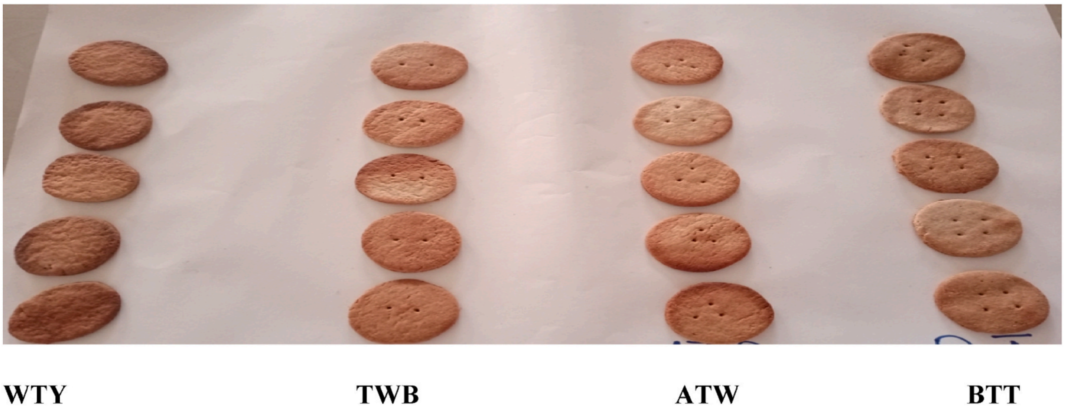

Fig. 1. Biscuit samples
WTY – 100 % wheat flour, TWB – 70 % wheat flour +25 % African yam bean flour +5 % tigernut flour, ATW - 70 % wheat flour +20 % African yam bean flour +10 % tigernut flour, BTT - 70 % wheat flour +15 % African yam bean flour +15 % tigernut flour.

air-tight containers at ambient temperature (26 ± 2 °C) for further analysis.

2.3. *Analyses*

2.3.1. *Determination of proximate composition of composite flour and cookie samples*

The moisture, protein, ash, fat, crude fiber and carbohydrate by difference were carried out according to the method described by AOAC [30]. The carbohydrate was calculated by subtracting the summation of moisture, protein, fat, ash and crude fiber content from 100. The energy value was calculated using the Atwater method by finding the summation of fat multiplied by nine (9); protein multiplied by four (4); carbohydrate multiplied by four (4) [31].

2.3.2. *Determination of pasting properties of composite flour*

Pasting properties for each of the samples were determined using Rapid Visco Analyzer (Model RVA series 4; Newport Scientific Pty Ltd., Warriewood, Australia). In an RVA canister, the composite flour sample (3 g) was mixed with distilled water to make a 28 g suspension. The suspension was heated to 95 °C for 3 min after being held at 50 °C for 1 min. It was held at 95 °C for 3 min, then cooled to 50 °C for 4 min and held there at that temperature for 2 min. Peak viscosity, trough, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature were read from the pasting profile with the aid of a window's software connected to the computer.

2.3.3. *Determination of mineral composition of biscuit*

Calcium, magnesium, iron and zinc were determined using an Atomic Absorption Spectrophotometer (AAS model SP9). Standard stock solutions were prepared for each metal using suitable metal salts of each metal to prepare a standard curve. Potassium and sodium were determined by using a Flame Emission Photometer (Sherwood Flame Photometer 410, Sherwood Scientific Limited, UK). The standard solutions were prepared separately using sodium chloride and potassium chloride for sodium and potassium determinations, respectively. The values obtained from the flame photometer were plotted against the strength of various solutions. The digests were determined from a flame photometer. The values obtained were plotted in the respective standard value to read the original values of the concentration of the elements. Phosphorus was determined by using the Vanado-molybdate method [30].

2.3.4. *Determination of amino acid profile of biscuit*

The amino acid profile was determined according to the method described by AOAC [32]. Amino acids were carried out by using the Berkman Amino Acid Analyzer (model 6300, Berkman Coulter, Inc., Fullerton, Calif., USA). The samples were hydrolyzed with 6 M HCl for 24 h in a sealed pipe and the hydrolysate was eluted ranging from 0.2 M, pH 3.25 to 0.35 M, pH 5.25. The data were calculated as grams of amino acid per 100 g crude protein of the flour sample.

2.3.5. *Determination of antinutritional factors of biscuit*

2.3.5.1. Phytate content determination. The phytate content was determined by using the method described by Wu et al. [33]. The sample (8 g) was added to 200 mL of 2 % HCl for extraction. The dispersion sample was extracted, and then it was filtered. 50 mL of the filtrate was then mixed with 10 mL of 0.3 % ammonium cyanide (NH_4SCN), diluted with 10 ml of distilled water. The extract was titrated against a ferric chloride solution of 0.00195 g/mL until the brownish-yellow color persisted.

2.3.5.2. Oxalate content determination. Oxalate was determined according to the method described by Siener et al. [34]. A known weight (1.0 g) of the sample was used and 75 mL of 15 N H_2SO_4 was added stirred with a magnetic stirrer vigorously for 1 h and filtered with Whatman No 1 filter paper. Then, 25 mL of the filtrate was taken and titrated against 0.1 N $KMnO_4$ solution till a faint pink color appeared and persisted for 30 s.

2.3.5.3. Tannin content determination. The tannin content was determined using the method described by Khasnabis et al. [35]. In a 250 mL conical flask, two (2) g of the sample were weighed. A 200 mL of 0.004 M $K_3Fe(CN)_6$ and 10 mL of 0.008 M $FeCl_3$ in 0.008 M HCl were added. The flask was left to stand for 20 min with periodic stirring at 10 min intervals, after which 1 mL of an aliquot was taken out. A10 mL of 0.00015 M $K_3Fe(CN)_6$ and 2 mL of 0.008 M $FeCl_3$ in 0.008 M HCl were added to this aliquot. The absorbance was then read at 720 nm after 30 s against a blank following the addition of the last reagent.

2.3.5.4. Trypsin inhibitor determination. The trypsin inhibitor was determined according to the method described by Ijarotimi and Kenshinro [36]. One (1) g of the sample was mixed with 50 mL of 0.01 N NaOH, which had a pH range of 8.4–10.00, and the mixture was left to stand for 3 h while being stirred at intervals. The test tubes were then placed in a water bath set at 37 °C, to which 2 mL of the diluted extract had been added, along with 2 mL of a cold trypsin solution (4 mg in 200 mL of 0.001 M HCl). After that, each tube received 5 mL of Benzoyl- DL-arginine-P-nitro anilide hydrochloride (BAPNA) (40 mg dissolved in 1 mL of dimethyl sulfoxide, diluted to 100 mL with tris buffer 0.05 M, pH 8, and diluted to 100 mL with tris buffer 0.05 M, pH 8.2, pre-warmed at 37 °C). 30 % acetic acid was added to stop the reaction after 10 min, and the contents of each tube were well mixed. After centrifuging the contents of each tube at 3000 rpm, the filtrate's absorbance was measured at 410 nm against the reagent blank. The reference was prepared in the same way as the sample, but the extract was replaced with 2 mL of distilled water.

2.3.6. Determination of functional properties of composite flour

2.3.6.1. Bulk density determination. The bulk density was determined according to the method described by Joshi et al. [37]. The 50 mL graduated cylinder containing the flour mix sample (10 g) was gently tapped on the bench top ten times and the volume of the samples was recorded. For every sample, it was carried out three times, and bulk density was calculated.

2.3.6.2. Water absorption capacity determination. Water absorption capacity was determined by using the method described by Okoye et al. [38]. The centrifuge tube was filled with one (1 g) sample, 10 mL of distilled water, and agitated. Centrifuging the suspension that resulted was done for 30 min at 3500 rpm. The supernatant was transferred to a 10 mL graduated cylinder. The amount of water that was absorbed was determined by subtracting the volume of the supernatant from the initial volume of water added to the sample.

2.3.6.3. Oil absorption capacity determination. The oil absorption capacity (OAC) was determined by the method described by Ajibola et al. [39]. One gram (1 g) of the sample was placed in a beaker with 10 mL of the oil with known specific gravity. For 3 min, a magnetic stirrer was used to mix the suspension. The acquired suspension was then centrifuged at 3500 rpm for 30 min, and the supernatant was measured into a 10 mL graduated cylinder. The oil had a density of 0.931 g/mL. The amount of oil absorbed was determined by subtracting the original oil volume from the final supernatant volume.

2.3.6.4. Swelling capacity determination. The swelling capacity was determined by the method described by Okoye et al. [38]. The 0.2 g of flour was homogenously dispersed in 10 mL of distilled water. In a thermally controlled water bath, the slurry was heated to 60 °C. The mixture was centrifuged for 15 min at 2200 rpm after being cooled to room temperature. After centrifugation, the remaining residue and retained water were reweighed, and swelling capacity was calculated.

2.3.6.5. Least gelation concentration. The least gelation concentration was determined by the method described by Okoye et al. [38]. With 5 mL of distilled water, sample suspensions of 2–20 % (w/v) were prepared. The test tubes holding these suspensions were immediately chilled in ice after being heated for 1 h in boiling water at 100 °C. The test tubes were then cooled for 24 h at 4 °C, and the least gelation concentration was taken as the concentration when the sample from the inverted test tube did not fall or slip.

2.3.7. Determination of antioxidant properties of biscuit

2.3.7.1. Total phenol content determination. Total phenol content was determined according to the method described by Parsaei et al. [40]. The extracts of the flour blends were oxidized with 2.5 mL of 10 % Folin-Ciocalteu's reagent and neutralized by using 2 mL of 7.5 % sodium carbonate. The reaction mixture was then incubated for 40 min at 45 °C, and the absorbance was measured in a spectrophotometer at 765 nm. Then, using Gallic acid as a standard, the total phenol concentration was calculated.

2.3.7.2. Total flavonoid content determination. The total flavonoid content was determined according to the method described by Derakhshan et al. [41]. The sample was measured to be 0.5 mL, mixed with 0.5 mL of methanol, 50 μl of 10 % $AlCl_3$, 50 μL of 1 mol/L potassium acetate, and 1.4 mL of water, and incubated at room temperature for 30 min. The reaction mixture's absorbance was then measured in the spectrophotometer at 415 nm. Quercetin is used as a standard for the calculation of the total flavonoid content.

2.3.7.3. 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay. The free radical scavenging ability of the extracts of biscuit was used against

Table 2
Proximate composition (%) and energy value (Kcal/100) of composite flour and biscuit samples from wheat, African yam bean and tigernut.

Samples	Moisture	Protein	Fat	Ash	Crude fiber	Carbohydrate	Energy
Composite flour							
WTY	8.40 ± 0.65^{a}	9.45 ± 0.10^{d}	7.23 ± 0.55^{d}	0.94 ± 0.02^{b}	2.36 ± 0.01^{d}	71.62 ± 0.23^{a}	389.35 ± 3.05^{c}
TWB	6.63 ± 0.55^{c}	18.36 ± 0.15^{a}	19.15 ± 0.57^{c}	0.99 ± 0.02^{a}	3.96 ± 0.05^{c}	62.55 ± 0.91^{b}	410.40 ± 4.03^{a}
ATW	7.27 ± 0.50^{b}	13.48 ± 0.15^{b}	11.81 ± 0.60^{b}	0.98 ± 0.02^{a}	4.55 ± 0.05^{b}	61.28 ± 0.22^{b}	400.89 ± 4.75^{b}
BTT	8.13 ± 1.10^{a}	11.22 ± 0.28^{c}	13.27 ± 0.58^{a}	0.98 ± 0.01^{a}	7.43 ± 0.06^{a}	59.97 ± 1.05^{c}	404.11 ± 4.67^{b}
Biscuit							
WTY	3.15 ± 0.15^{a}	7.51 ± 0.10^{d}	15.23 ± 0.55^{c}	1.10 ± 0.01^{d}	1.91 ± 0.01^{d}	71.10 ± 0.23^{a}	451.51 ± 8.01^{a}
TWB	2.93 ± 0.24^{b}	14.70 ± 0.26^{a}	20.75 ± 1.65^{a}	2.32 ± 0.24^{a}	2.21 ± 0.07^{c}	48.08 ± 1.19^{c}	437.80 ± 9.61^{d}
ATW	1.75 ± 0.12^{d}	10.12 ± 0.16^{b}	16.98 ± 0.56^{d}	1.97 ± 0.01^{b}	2.81 ± 0.01^{b}	50.86 ± 1.39^{b}	452.81 ± 9.99^{b}
BTT	2.20 ± 0.06^{c}	8.65 ± 0.02^{c}	19.79 ± 0.51^{b}	1.66 ± 0.94^{c}	3.70 ± 0.52^{a}	50.00 ± 0.88^{b}	444.64 ± 8.05^{c}

Values are means ± standard deviation of three determinations. Means in the same column with different superscript are significantly different ($p < 0.05$). WTY – 100 % wheat flour, TWB – 70 %, wheat flour +25 % African yam bean flour +5 % tiger nut flour, ATW - 70 % wheat flour +0 % African yam bean flour +10 % tiger nut flour, BTT - 70 % wheat flour +15 % African yam bean flour +15 % tigernut flour.

DPPH (1, 1-diphenyl-2-picrylhydrazyl) free radical according to the method described by Sethi et al. [42]. A suitable dilution of the extracts (1 mL) was mixed with 1 mL of 0.4 mol/L methanolic solution containing DPPH radicals. For 30 min the mixture was kept in the dark (until stable absorption values were obtained). Afterward, the bleaching of the purple methanol solution was evaluated to indicate the decrease of the DPPH radical, and the absorbance was measured with a spectrophotometer at 517 nm. The DPPH radical scavenging ability was subsequently calculated as a percentage of DPPH.

2.3.7.4. ABTS assay. The method described by Sridhar & Charles [43] was used to determine the ABTS scavenging activity of the biscuit. As the working solution, two stock solutions of 7 mm ABTS and 2.4 mM potassium persulphate v/v were mixed together and allowed to react for 12 h at room temperature in the dark. This was further diluted by mixing it with 1 mL of freshly prepared ABTS solution to obtain an absorbance of 0.706 ± 0.001 units at 734 nm using a spectrophotometer. After allowing biscuit extracts to react with 1 mL of the ABTS + at various concentrations (0.2–1.0), the absorbance was measured at 734 nm after 7 min %ABTS + inhibition by the extract was calculated and compared with BHT and rutin using the equation

% ABTS + scavenging activity = Abs (control)-Abs (sample) / x 100

Where Abs (control) is the absorbance of ABTS radical + methanol, and Abs (sample) is the absorbance of ABTS radical + sample extract or standard.

2.3.7.5. Ferric reducing antioxidant property (FRAP) assay. The ferric reducing antioxidant property was determined by using the method described by Sethi et al. [42]. Briefly, 250 μL of sodium phosphate buffer (200 mM; pH 6.6), 250 μl of potassium ferrocyanide (1 %), and 0–250 μl of stock of the extract from biscuit were mixed together. The mixture was then incubated at 50 °C for 20 min. Then, 250 μL of 10 % trichloroacetic acid was added, and the mixture was centrifuged for 10 min at 650 rpm. After, 1000 μL of the supernatant was mixed with an equal volume of water and 100 μL of ferric chloride (0.1 % (w/v). The absorbance was then measured at 700 nm. A higher absorbance indicates a higher reducing power.

2.3.8. Determination of physical characteristics

The biscuit diameter, height, weight and spread ratio were evaluated. The diameter and height were measured by placing three biscuits edge on edge then an vernier caliper was used to measure it. The weight of an average value of three individual biscuit samples was determined using the electronic weight balance as described by Ayo et al. [44]. The spread ratio of biscuit samples was determined using the Ayo et al. [44] method. The spread ratio was calculated as the diameter/height of the biscuits.

2.3.9. Determination of color attributes

The color of the biscuit was measured using a Hunter Colorimeter (Hunter Associates Laboratory Inc, Reston, VA, USA) and the values expressed on the L*, a*, b* tristimulus scale. The L*-value represents the lightness index; the a*-value represents the degree of redness (-a*) or greenness (+a*); and the b*-value represents the degree of yellowness (-b*) or blueness (+b*). The browning index was calculated using the following equation

$$\text{Browning index} = \frac{100(x-0.31)}{0.17} \qquad \text{equation 1}$$

Where x= (a*+1.75L*)/(5.645L*+a*- 0.3012b*) [45].

2.3.10. Determination of sensory attributes

Thirty semi-untrained panelists voluntarily participated from the University community. The biscuits were evaluated for appearance, flavor, texture, crispness, and general acceptability using a nine-point hedonic scale where 9 represents 'like extremely' and 1, 'dislike extremely'. Samples were identified with three-digit code numbers and presented to regular biscuit consumers as

Table 3
Functional properties of composite flour from wheat, African yam bean and tigernut.

Sample	Bulk density (g/ml)	Water absorption capacity (%)	Oil absorption capacity (%)	Swelling capacity (%)	Least gelation concentration (%)
WTY	0.74 ± 0.02^{b}	233.00 ± 0.05^{a}	184.00 ± 0.02^{a}	5.00 ± 0.01^{a}	16.82 ± 0.42^{a}
TWB	0.71 ± 0.01^{c}	170.00 ± 0.01^{c}	150.00 ± 0.01^{d}	4.00 ± 0.01^{b}	8.96 ± 0.38^{d}
ATW	0.72 ± 0.02^{c}	180.00 ± 0.01^{bc}	160.00 ± 0.01^{c}	4.00 ± 0.02^{b}	10.85 ± 0.28^{c}
BTT	0.77 ± 0.01^{a}	200.00 ± 0.01^{b}	180.00 ± 0.02^{b}	3.00 ± 0.02^{c}	11.52 ± 0.58^{b}

Values are means ± standard deviation of three determinations. Means in the same column with different superscript is significantly different ($p < 0.05$). WTY – 100 % wheat flour, TWB – 70 % wheat flour +25 % African yam bean flour +5 % tigernut flour, ATW - 70 % wheat flour +20 % African yam bean flour +10 % tigernut flour, BTT - 70 % wheat flour +15 % African yam bean flour +15 % tigernut flour.

panelists. The panelists were given questionnaires and instructed to rinse their mouths with water after every sample. Each panelist was required to evaluate all the samples prepared individually without a biased mind [46].

2.4. *Statistical analysis*

All data obtained in triplicate were analyzed and subjected to analysis of variance (ANOVA), using statistical package for social science (SPSS) (version 21.0 IBM Inc Quarry Bay, Hong Kong). Means were separated by using the Duncan Multiple Range Test (DMRT). Values of $p < 0.05$ were considered as statistically significant.

3. Results and discussion

3.1. *Proximate composition of composite flour*

The result of the proximate composition of the composite flour of wheat, AYB and tigernut are presented in Table 2. The moisture content ranged from 6.63 to 8.13 %, the low moisture content observed could be as a result of the drying method used and they were in accordance with the standard of less than 10 % for flour. The moisture contents were similar to values reported by El-Naggar [47] who obtained low moisture content in tigernut flour. Also, Bamigbola et al. [48] observed low moisture content ranging from 5.63 to 6.93 g/100g for wheat-based composite flour. The low moisture content in food samples increased the shelf life of the food products [48]. The protein contents ranged from 11.22 to 18.36 %. It was observed that sample ATW had the highest value. The high amount of protein content may be attributed to the addition of AYB flour. The fat contents ranged from 9.10 to 13.27 %. BTT (70 % wheat flour + 15 % AYB flour + 15 % tigernut flour) had the highest value which could be because of the percentage AYB and tigernut used. The ash contents ranged from 0.98 to 0.99 %, it was observed that TWB had the highest ash content. A similar observation of ash contents was reported by Odenigbo et al. [49] for wheat and plantain flour blends. The crude fiber ranged from 3.96 to 7.43 %. The highest value was obtained in BTT (70 % wheat flour + 15 % AYB flour + 15 % tigernut flour) which could be a result of the high inclusion of AYB and tigernut. This was in line with the report of Akubor & Badifu [50] on African breadfruit and wheat flour blends that obtained high crude fiber. The carbohydrate contents ranged from 59.97 to 62.55 %, WTY (100 % wheat flour) had the highest carbohydrate content. The carbohydrate contents of the samples are indications that they are good sources of energy. The energy values ranged from 400.89 to 410.40 Kcal/100g. The highest value was obtained in sample TWB (70 % wheat flour + 25 % AYB flour + 5 % tigernut flour).

The moisture, protein, fat, ash, crude fiber, carbohydrate and energy of composite flour biscuit samples ranged from 1.75 to 2.93 %, 8.65–14.70 %, 16.98–20.75 %, 1.66–2.32 %, 2.21–3.70 %, 48.08–50.86 % and 437.80 to 452.81 Kcal/100g, respectively. The result showed that the control had low values for protein, fat, ash and crude fiber contents which could be because 100 % wheat flour was used. However, the highest values of protein, fat and ash contents were observed in sample TWB (70 % wheat flour + 25 % AYB flour + 5 % tigernut flour), this could be a result of the amount of AYB added. The values obtained for moisture were low which could be a result of baking and this may increase the shelf life and protect against microbial attack. Yadav et al. [51] obtained similar low moisture contents in wheat, plantain and chickpea biscuits. Also, the low moisture content observed agrees with the report of Farzana & Mohajan [52] for soy-mushroom biscuits. It was observed that the protein content of the biscuit decreased compared with composite flour blends which could be a result of baking. However, the fat content increased which could be as a result of margarine being used as one of the ingredients. Similar results were reported by Bello et al. [53] for cookies made from flour blends of wheat, unripe plantain and fluted pumpkin seeds. High-fat content has been reported by Farzana & Mohajan [52] for soy-mushroom biscuits. Also, the crude fiber decreased compared with composite flour blends which could be a result of the baking process.

3.2. *Functional properties of composite flour*

The functional properties of composite flour of wheat, AYB and tigernut, and control are presented in Table 3. The bulk density ranged from 0.71 to 0.77 g/mL. There was a significant difference observed in the samples except for TWB (70 % wheat flour + 25 % AYB flour + 5 % tigernut flour) and ATW (70 % wheat flour + 20 % AYB flour + 10 % tigernut flour) there was no significant difference. However, the bulk density was high in all the samples which implies that such flour may be used as a thickener in food. Bulk density is very important and used to determine the packaging requirement of food [54]. Water absorption capacity (WAC) ranged from 170 to 233 %. WAC obtained was similar to the report of Kaushal et al. [55] for taro, rice and pigeon pea flour blends. However,

Table 4

Pasting properties of composite flour from wheat, African yam bean and tigernut.

Sample	WTY	TWB	ATW	BTT
Peak viscosity (cp)	1240.00 ± 0.50^{b}	833.33 ± 0.58^{d}	1042.00 ± 1.73^{a}	913.33 ± 3.06^{c}
Trough (cp)	719.67 ± 0.45^{a}	491.33 ± 0.58^{c}	626.00 ± 4.58^{b}	474.00 ± 1.73^{d}
Breakdown (cp)	520.33 ± 0.52^{c}	391.67 ± 0.59^{c}	416.00 ± 0.01^{b}	439.00 ± 2.65^{a}
Setback (cp)	590.00 ± 0.53^{a}	489.00 ± 3.00^{d}	582.33 ± 0.58^{b}	515.33 ± 0.58^{c}
Time (min)	5.77 ± 0.02^{a}	5.33 ± 0.03^{b}	5.37 ± 0.15^{b}	5.13 ± 0.02^{c}
Temperature (^{o}C)	88.35 ± 0.03^{a}	86.37 ± 0.06^{b}	85.55 ± 0.04^{c}	86.45 ± 0.04^{b}

Values are means ± standard deviation of three determinations. Means in the same row with different superscript are significantly different ($p < 0.05$). WTY – 100 % wheat flour, TWB – 70 % wheat flour +25 % African yam bean flour +5 % tigernut flour, ATW - 70 % wheat flour +20 % African yam bean flour +10 % tigernut flour, BTT - 70 % wheat flour +15 % African yam bean flour +15 % tigernut flour.

Table 5

Mineral composition and antinutritional factor (mg/100g) of biscuit from composite flour of wheat, African yam bean and tigernut.

Sample	WTY	TWB	ATW	BTT
Mineral				
Sodium	6.11 ± 0.01^{b}	5.33 ± 0.02^{d}	5.98 ± 0.02^{c}	6.41 ± 0.01^{a}
Potassium	9.73 ± 0.02^{c}	9.56 ± 0.02^{d}	10.41 ± 0.02^{a}	9.81 ± 0.01^{b}
Calcium	4.25 ± 0.01^{d}	5.10 ± 0.01^{a}	4.53 ± 0.01^{c}	4.79 ± 0.01^{b}
Phosphorus	0.13 ± 0.00^{c}	0.20 ± 0.01^{a}	0.12 ± 0.01^{c}	0.19 ± 0.01^{b}
Magnesium	1.73 ± 0.01^{b}	1.58 ± 0.01^{c}	1.50 ± 0.01^{c}	1.90 ± 0.01^{a}
Iron	0.10 ± 0.01^{b}	0.10 ± 0.01^{b}	0.14 ± 0.02^{a}	0.10 ± 0.01^{b}
Zinc	0.04 ± 0.01^{c}	0.06 ± 0.01^{a}	0.04 ± 0.01^{c}	0.05 ± 0.01^{b}
Antinutrient				
Tannin	0.26 ± 0.08^{a}	0.09 ± 0.01^{b}	0.06 ± 0.02^{c}	0.09 ± 0.01^{b}
Phytate	0.20 ± 0.02^{c}	0.28 ± 0.01^{a}	0.25 ± 0.01^{b}	0.22 ± 0.05^{c}
Oxalate	0.12 ± 0.02^{c}	0.15 ± 0.01^{b}	0.18 ± 0.02^{a}	0.17 ± 0.01^{b}
Trypsin Inhibitor	0.34 ± 0.01^{c}	0.44 ± 0.03^{b}	0.96 ± 0.02^{a}	0.49 ± 0.02^{b}

Values are means ± standard deviation of three determinations. Means in the same row with different superscript are significantly different ($p < 0.05$). WTY – 100 % wheat flour, TWB – 70 % wheat flour +25 % African yam bean flour +5 % tigernut flour, ATW - 70 % wheat flour +20 % African yam bean flour +10 % tigernut flour, BTT - 70 % wheat flour +15 % African yam bean flour +15 % tigernut flour.

WTY (100 % wheat flour) had higher WAC compared with composite flour. WAC is the amount of water absorbed by food or flour in order to achieve the desired consistency and also to produce a high-quality food product [56]. A high WAC will lead to product cohesiveness [57], which also reveals that these composite flours could be useful for bakery products. The oil absorption capacity (OAC) ranged from 150.00 to 184.00 %. The values obtained for OAC agree with the report of Okpala et al. [58] for the blends of germinated pigeon pea, fermented sorghum and cocoyam flours. The control (100 % wheat flour) had the highest value. OAC has been reported to improve flavor retention, palatability and shelf life of flour products [59]. The swelling capacity ranged from 3.00 to 5.00 %. There was a significant difference in the samples. The swelling capacity is the amount of water absorbed by the flour granules during heating [60]. The least gelation concentration (LGC) is the lowest protein concentration at which gel remains in the inverted tube, this ranged from 8.96 to 16.82 %. The lower least gelation concentration the better the gelating ability of the sample. It was observed that sample TWB (70 % wheat flour + 25 % AYB flour + 5 % tigernut flour) had the lowest value which implies that it had better gelating ability compared with other samples. Also, results showed that as AYB and tigernut increased the LGC increased. This is in line with the report of Aluge et al. [61] for wheat-sorghum-soybean composite flour.

3.3. *Pasting properties of composite flour*

Table 4 shows the pasting properties of the flour blends of wheat, AYB and tigernut, and control. The peak viscosity of flour blends ranged from 883.33 to 1240.00 cp. Peak viscosity is the point at which gelatinized starch develops maximum viscosity during dough heating in water. It provides an indication of viscous load that may occur during mixing and some correlation with the quality of the final product [62]. If there is a high peak viscosity in the flour sample this could result in a higher swelling index, while low peak viscosity leads to high solubility due to starch degradation [63]. The values obtained in peak viscosity agreed with the report of Bakare et al. [64] for composite flour of breadfruit and wheat. The trough is the period in which the starch samples undergo constant temperature and mechanical shear stress with the viscosity breakdown. Trough viscosity ranged from 474.00 to 719.67 cp. It was revealed that sample BTT (70 % wheat flour + 15 % AYB flour + 15 % tigernut flour) had the lowest value which implies that it will be a more stable gel during cooking. Makinde & Eyitayo [65] reported trough ranged from 750.5 to 964.0 RVU for wheat coconut flour blends. Breakdown viscosity is an index of the stability to rupture swollen starch granules when held at high temperatures with continuous shearing [66]. The breakdown viscosity ranged from 391.67 to 520.33 cp. The final viscosity ranged from 980.00 to 1309.67 cp. It was observed that WTY had the highest final viscosity which could be because it was 100 % wheat flour. It indicates the ability of samples to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear force during stirring [67]. Setback

Table 6
Amino profile (g/100 g of protein) of biscuit produced from composite flour of wheat, African yam bean and tigernut.

Sample	WTY	TWB	ATW	BTT
Essential amino acid				
Leucine	6.13^{d}	6.30^{c}	7.12^{a}	6.65^{b}
Lysine	2.07^{d}	2.12^{c}	2.31^{a}	2.20^{b}
Isoleucine	2.68^{d}	2.88^{c}	3.24^{a}	2.98^{b}
Phenylalanine	2.48^{c}	2.57^{b}	3.02^{a}	2.48^{c}
Tryptophan	0.60^{c}	0.66^{b}	0.63^{c}	0.71^{a}
Valine	2.22^{d}	3.16^{c}	3.39^{a}	3.27^{b}
Methionine	1.15^{c}	1.12^{c}	1.26^{b}	1.31^{a}
Histidine	1.41^{d}	1.50^{c}	1.73^{b}	2.01^{a}
Threonine	1.05^{c}	1.17^{b}	1.28^{a}	1.19^{b}
TEAA	19.79	21.48	23.14	23.64
Non-essential amino acid				
Proline	3.25^{c}	3.35^{b}	3.35^{b}	3.47^{a}
Arginine	2.67^{c}	2.58^{d}	2.84^{b}	2.92^{a}
Cysteine	1.21^{b}	1.21^{b}	1.33^{a}	1.33^{a}
Alanine	4.93^{c}	5.35^{b}	5.31^{b}	5.61^{a}
Glutamic acid	17.49^{d}	18.17^{c}	18.47^{b}	19.00^{a}
Glycine	4.37^{d}	4.96^{b}	4.61^{c}	5.01^{a}
Serine	4.27^{c}	4.29^{c}	4.67^{b}	5.13^{a}
Aspartic acid	5.15^{d}	5.89^{b}	5.68^{c}	6.61^{a}
TNEAA	43.34	45.80	46.26	49.08
TEAA + His + Arg/TAA	37.80	37.90	39.90	39.90
TEAA/TAA	31.30	31.90	33.3	32.5
TNEAA/TAA	68.6	68.07	66.60	67.40
TSAA(Meth + Cyst)	2.36	2.33	2.59	2.64
ArAA (Phe + His + Arg + Tryp)	7.16	7.31	8.22	8.12
TEAA/TNEAA	0.46	0.47	0.50	0.48
Limiting amino acid	Tryptophan	Tryptophan	Tryptophan	Tryptophan
Abundant amino acid	Glutamic acid	Glutamic acid	Glutamic acid	Glutamic acid

Values are means of three determinations. Means in the same row with different superscript are significantly different ($p < 0.05$). WTY – 100 % wheat flour, TWB – 70 % wheat flour +25 % African yam bean flour +5 % tigernut flour, ATW - 70 % wheat flour +20 % African yam bean flour +10 % tigernut flour, BTT - 70 % wheat flour +15 % African yam bean flour +15 % tigernut flour, TNEAA- Total non-essential amino acid, TEAA- Total essential amino acid, TAA- Total amino acid, TSAA -Total sulphur amino acid, ArAA - Aromatic amino acid, His - Histidine, Arg - Arginine; Meth - Methionine, Phe - Phenylalanine, Tryp -Tryptophan.

viscosity indicates the tendency of dough to undergo retrogradation [68]. The values obtained for setbacks ranged from 489.00 to 590.00 cp. The higher the setback viscosity the higher the rate of retrogradation and undergo syneresis or weeping during freezing. The peak time ranged from 5.13 to 5.77 min, there was a significant ($p < 0.05$) difference in the samples. The peak time is used to measure the cooking time and when the peak viscosity occurred in minutes [69]. The pasting temperature ranged from 85.55 to 88.35 °C. The pasting temperature obtained was similar to the report of Mbata et al. [70] for maize flour supplement with Bambara groundnut.

3.4. Mineral composition and antinutritional factor of biscuit produced from composite flour of wheat, African yam bean and tigernut

The result of mineral composition and antinutrient of the biscuit produced from composite flour of wheat, AYB and tigernut, and control are presented in Table 5. The potassium, calcium, phosphorus, sodium, magnesium, iron and zinc ranged from 9.56 to 10.41 mg/100g, 4.25–5.10 mg/100g, 0.12–0.20 mg/100g, 5.33–6.41 mg/100g, 1.50–1.90 mg/100g, 0.10–0.14 mg/100g and 0.04–0.06 mg/100g, respectively. The most abundant mineral was potassium, ATW (70 % wheat flour + 20 % AYB flour + 10 % tigernut flour) had the highest potassium which could make this biscuit suitable for hypertensive patients. Potassium is required to maintain the osmotic balance of the body fluids and control glucose absorption [71]. The calcium helps in strong teeth and bone formation [72]. TWB had the highest calcium which could as a result of the percentage of AYB added. Phosphorus helps in the calcification of bones and plays an essential role in carbohydrate metabolism [73]. TWB had the highest phosphorus, however, there were significant differences $p < 0.05$ in samples. Sodium helps to keep the water and electrolyte balance of the body [74]. BTT had the highest sodium which could be because of the amount of AYB and tigernut. Magnesium plays a major role in glucose and insulin metabolism [75,76]. BTT had the highest magnesium while ATW had the lowest value. Zinc regulates the immune responses, and enhances growth and development. Iron helps in transporting oxygen in the haemoglobin of red blood cells around the body [77].

The tannin contents ranged from 0.09 to 0.26 mg/100g, this was reduced significantly which could be because of the soaking processing method used. A similar finding was reported by Nzeagwu & Onuwudiwe [78] for cookies made from tigernut flour. ATW (70 % wheat flour + 20 % AYB flour + 10 % tigernut flour) had the lowest tannin which could be because of the amount of AYB and tigernut flour added. Tannin inhibits the activities of some enzymes such as trypsin, amylase, and lipase to form insoluble complexes with protein and divalent ions like Fe^{2+} and Zn thereby reducing their absorption in the body [79]. Phytate contents ranged from 0.20 to 0.28 mg/100g. Results showed that TWB (70 % wheat flour + 25 % AYB flour + 5 % tigernut flour) had the highest phytate content which could be a result of the high amount of AYB added. Phytate may reduce the bioavailability of some minerals such as calcium,

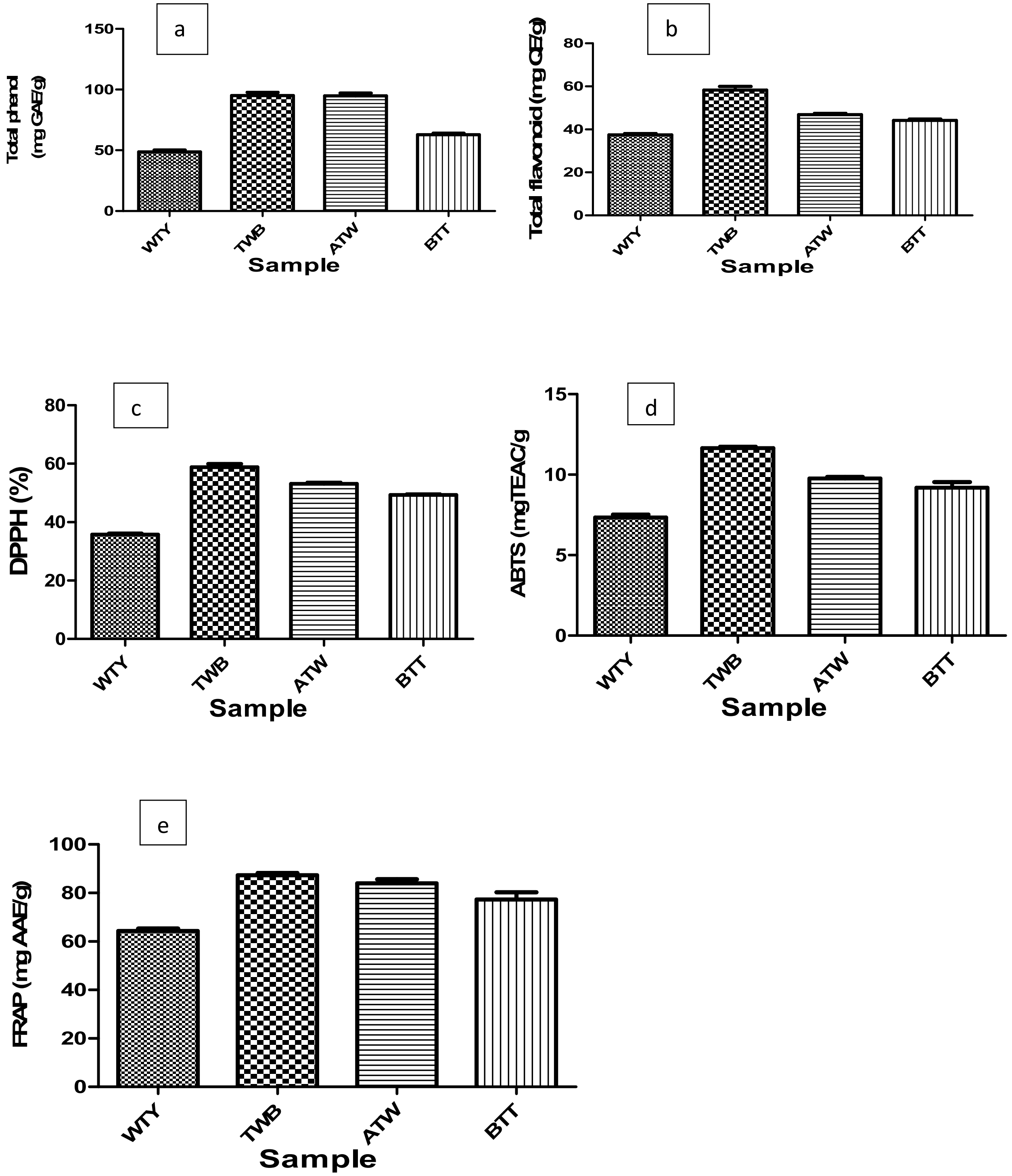

Fig. 2. a–e.
Antioxidant properties of biscuit produced from composite flour blends of wheat, African yam bean and tigernut. WTY – 100 % wheat flour, TWB – 70 % wheat flour +25 % African yam bean flour +5 % tigernut flour, ATW - 70 % wheat flour +20 % African yam bean flour +10 % tigernut flour BTT - 70 % wheat flour +15 % African yam bean flour +15 % tigernut flour.

magnesium and iron. Oxalate contents ranged from 0.12 to 0.18 mg/100g, the value obtained agrees with the report of Nzeagwu & Onuwudiwe [78] for cookies made from tigernut flour. The trypsin inhibitor ranged from 0.34 to 0.96 mg/100g. It was observed that all the antinutritional factors were greatly reduced, however, WTY (100 % wheat flour) had the lowest phytate, oxalate and trypsin

Table 7
Physical characteristics of biscuit produced from composite flour of wheat, African yam bean and tigernut.

Sample	Weight (g)	Height (cm)	Diameter (cm)	Spread ratio
WTY	12.00 ± 0.05^a	0.49 ± 0.01^c	5.51 ± 0.03^d	11.24 ± 0.15^c
TWB	12.60 ± 0.59^a	0.50 ± 0.01^c	5.73 ± 0.05^c	11.47 ± 0.11^b
ATW	12.60 ± 0.34^a	0.62 ± 0.03^b	6.14 ± 0.12^b	10.00 ± 0.40^d
BTT	13.10 ± 0.09^a	0.73 ± 0.06^a	9.20 ± 0.26^a	12.60 ± 0.61^a

Values are means ± standard deviation of three determinations. Means in the same column with different superscript are significantly different ($p < 0.05$). WTY – 100 % wheat flour, TWB – 70 % wheat flour +25 % African yam bean flour +5 % tigernut flour, ATW - 70 % wheat flour +20 % African yam bean flour +10 % tigernut flour, BTT - 70 % wheat flour +15 % African yam bean flour +15 % tigernut flour.

inhibitor. Studies have shown that processing methods such as soaking, boiling, germination, drying and fermentation reduced antinutrients [36].

3.5. Amino acid profile of biscuit produced from composite flour of wheat, African yam bean and tigernut

Table 6 shows the amino acid profile of biscuits produced from composite flour of wheat, AYB and tigernut, and control. The total essential amino acid ranged from 19.79 to 23.64 g/100g protein, total non-essential amino acid ranged from 43.34 to 49.08 g/100g protein. The most abundant essential and non-essential amino acids were leucine and glutamic acid, respectively. A similar observation of essential and non-essential amino acids was reported by Olagunju et al. [80] for acha–pigeon pea biscuit. Also, Sodipo et al. [81] reported high values of leucine and glutamic acid for extruded products from pearl millet and germinated pigeon peas. It was observed that the control (100 % wheat flour) biscuit had the lowest values of total essential and non-essential amino acids which could be because it contains little amount of protein. ATW (70 % wheat flour + 20 % AYB flour + 10 % tigernut flour) had the highest values of leucine, lysine, isoleucine, phenylalanine, valine, methionine and threonine. Results showed that sample BTT (70 % wheat flour + 15 % AYB flour + 15 % tigernut flour) had the highest values for the essential and non-essential amino acids. The total sulphur-containing amino acid ranged from 2.33 to 2.64 g/100g protein. BTT had the highest total sulphur-containing amino acid. The total aromatic amino acid ranged from 7.16 to 8.22 g/100g protein. ATW had the highest total aromatic amino acid. The limiting amino acid was tryptophan, however, glutamic acid was the abundant amino acid.

3.6. Antioxidant properties of biscuit produced from composite flour of wheat, African yam bean and tigernut

The results of antioxidant properties of biscuits produced from composite flour of wheat, AYB and tigernut, and control are presented in Fig. 2 a-e. The total phenol content ranged from 48.66 to 95.05 mg GAE/g. The control (100 % wheat flour) had the lowest value which could be attributed to 100 % wheat flour used. It was observed that as the AYB flour proportion increased the value obtained increased. It implies that these samples possessed strong antioxidants that can scavenge free radicals and thereby reducing the rate of oxidation. Total flavonoids ranged from 37.45 to 58.33 mg QE/g. It was observed that TWB (70 % wheat flour + 25 % AYB flour + 5 % tigernut flour) had the highest value which could attributed to the high amount of AYB flour added. However, Adefegha et al. [82] reported that phenolic compounds are powerful antioxidants that can protect the body against free radicals. Also, it was reported that flavonoids are active against many diseases such as cardiovascular diseases, cancer, and other age-related diseases [83]. The 2, 2′-azino-bis (−3 ethylbenzothiazoline-6-sulfonic acid) (ABTS) ranged from 7.35 to 11.66 mg TEAC/g. Sample BTT (70 % wheat flour + 15 % AYB flour + 15 % tigernut flour) had the highest scavenging activities which could be because of the inclusion of AYB and tigernut at 15 %. The ABTS antiradical assay measures the ability of antioxidants to scavenge ABTS·+ that is generated in the aqueous phase [84]. It is normally used because of some limitations in DPPH which is associated with color interference and sample solubility [85]. The value obtained for ferric reducing antioxidant power ranged from 64.32 to 87.2 mg AAE/g, it was observed that TWB (70 % wheat flour + 25 % AYB flour + 5 % tigernut flour) had more ability to reduce Fe^{3+} to Fe^{2+}, however, there were significant differences and control (100 % wheat flour) had the lowest ability to reduce Fe^{3+} to Fe^{2+}. The DPPH values ranged from 35.75 to 58.86 %. DPPH is one of the tests used to prove the ability of the components of the biscuit to act as donors of hydrogen atoms and to capture free radicals. The highest value was obtained in sample TWB (70 % wheat flour + 25 % AYB flour + 5 % tigernut flour) which could be attributed to the proportion of AYB included. This implies that TWB possessed the highest ability to scavenge DPPH.

3.7. Physical characteristics of biscuit produced from composite flour of wheat, African yam bean and tigernut

Physical characteristics of the biscuit produced from composite flour of wheat, AYB and tigernut, and control are presented in Table 7. The diameter, weight, height and spread ratio ranged from 5.51 to 9.20 cm, 12.00–13.10 g, 0.49–0.73 cm and 10.00 to 12.60, respectively. The diameter, height, and weight increased with an increase in AYB and tigernut flour. There was a significant difference ($p < 0.05$) observed in diameter, height and spread ratio of the biscuit samples while no significant difference was observed in weight. However, sample BTT (70 % wheat flour + 15 % AYB flour + 15 % tigernut flour) had the highest value of diameter, height, weight and spread ratio. The higher the value of spread ratio the better the acceptance of the biscuit [86]. The values obtained for the spread ratio agreed with the report of Oluwamukomi et al. [87] for wheat-cassava composite biscuits enriched with soy flour.

Table 8

Color attributes of biscuit produced from composite flour of wheat, African yam bean and tigernut.

Sample	L*	a*	b*	C	H	Browning Index
WTY	57.23 ± 0.05^c	13.40 ± 0.01^d	23.01 ± 0.05^d	26.63 ± 0.05^d	59.78 ± 0.05^d	17.65
TWB	59.52 ± 0.03^a	13.55 ± 0.01^b	24.61 ± 0.06^c	28.10 ± 0.05^b	61.16 ± 0.05^a	17.65
ATW	58.93 ± 0.07^b	13.98 ± 0.01^a	25.24 ± 0.07^b	28.86 ± 0.06^a	61.01 ± 0.06^b	17.65
BTT	56.90 ± 0.01^d	13.44 ± 0.01^c	27.28 ± 0.07^a	26.89 ± 0.05^c	60.00 ± 0.07^c	17.65

Values are means ± standard deviation of three determinations. Means in the same column with different superscript are significantly different ($p < 0.05$). WTY – 100 % wheat flour, TWB – 70 % wheat flour +25 % African yam bean flour +5 % tigernut flour, ATW - 70 % wheat flour +20 % African yam bean flour +10 % tigernut flour, BTT - 70 % wheat flour +15 % African yam bean flour +15 % tigernut flour.

Table 9

Sensory qualities of Biscuit produced from composite flour of wheat, African yam bean and tigernut.

Sample	Appearance	Aroma	Taste	Crispness	Overall acceptability
WTY	6.97 ± 1.69^a	6.70 ± 1.18^a	7.40 ± 1.35^a	7.43 ± 1.65^a	7.33 ± 1.32^a
TWB	6.90 ± 1.21^a	6.37 ± 1.33^a	6.83 ± 1.44^a	7.03 ± 1.43^a	7.17 ± 1.02^a
ATW	7.10 ± 1.37^a	6.80 ± 1.32^a	6.90 ± 1.95^a	6.83 ± 1.58^a	7.27 ± 1.20^a
BTT	7.60 ± 0.89^a	6.90 ± 1.60^a	7.60 ± 1.22^a	7.53 ± 1.46^a	7.70 ± 1.42^a

Values are means ± standard deviation of three determinations. Means in the same column with different superscript are significantly different ($p < 0.05$). WTY – 100 % wheat flour, TWB – 70 % wheat flour +25 % African yam bean flour +5 % tigernut flour, ATW - 70 % wheat flour +20 % African yam bean flour +10 % tigernut flour, BTT - 70 % wheat flour +15 % African yam bean flour +15 % tigernut flour.

3.8. *Color attributes of biscuit produced from composite flour of wheat, African yam bean and tigernut*

The results of color attributes of biscuits produced from composite flour of wheat, AYB and tigernut. and control are presented in Table 8. Color is an important parameter for the overall acceptability of biscuits. The color of the biscuits indicated whiteness (L) index ranged from 57.23 to 58.93. It was revealed that there was a significant difference ($p < 0.05$) among the samples. It was observed that sample TWB (70 % wheat flour + 25 % AYB flour + 5 % tigernut flour) had the highest value of L. The color values of a* and b* ranged from 13.40 to 13.98, and 23.01 to 27.28, respectively. There was a significant ($p < 0.05$) difference among all the biscuit samples. However, sample ATW (70 % wheat flour + 20 % AYB flour + 10 % tigernut flour) and BTT (70 % wheat flour + 15 % AYB flour + 15 % tigernut flour) had the highest intensity of redness and yellowness respectively. It was shown in the result that ATW had the highest chroma and TWB had the highest hunter. The color of the biscuit could change due to the degradation of pigment or the formation of brown-colored pigment during processing [88]. The brown pigment could be attributed to the enhanced antioxidative activity of the baked products [89]. The browning index of this biscuit had the same value of 17.65.

3.9. *Sensory attributes of biscuit produced from composite flour of wheat, African yam bean and tigernut*

The sensory scores of the samples from composite flour of wheat, AYB and tigernut, and control are presented in Table 9. The appearance, aroma, taste, crispness and overall acceptability ranged from 6.90 to 7.60, 6.37 to 6.90, 6.83 to 7.40, 6.83 to 7.53 and 7.17 to 7.70, respectively. It was shown from the result that BTT (70 % wheat flour + 15 % AYB flour + 15 % tigernut flour) had the highest value for appearance, aroma, taste, crispness and overall acceptability. There was no significant ($p > 0.05$) difference among the samples for appearance, aroma, taste, crispness and overall acceptability. However, sample BTT was most accepted in appearance, aroma, taste, crispness and overall acceptability compared with the control (100 % wheat). The values obtained were in accordance with the report of Akajiaku et al. [90] on cookies produced from tigernut flour. Also, Sodipo et al. [91] reported similar observations in cookies produced from unripe plantain, moringa seed and defatted sesame seed.

4. Conclusion

The wheat flour supplemented with African yam bean and tigernut to produce biscuits had high protein and crude fiber, as well as high energy. It was shown that the most abundant mineral in the biscuit was potassium. The most abundant essential and non-essential amino acid was leucine and glutamic respectively. The developed biscuit had high phenolic and flavonoid content, scavenged DPPH, and reduced Fe^{3+} to Fe^{2+}, which showed promising free radical scavenging properties. Sample BTT (70 % wheat +15 % African yam bean + 15 % tigernut flour) was most acceptable to the panelist compared with the control (100 % wheat flour). Therefore, this biscuit TWB (70 % wheat flour + 25 % African yam bean flour + 5 % tigernut flour) and BTT (70 % wheat flour + 15 % African yam bean flour + 15 % tigernut flour) considering nutritional values and acceptability could be suitable for children and adults.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Mopelola A. Dada: Supervision, Investigation. **Florence A. Bello:** Conceptualization. **Franca O. Omobulejo:** Writing – original draft, Methodology, Data curation. **Funmilayo E. Olukunle:** Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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