DOI : 10.2478/aucft-2024-0008

PHYSICOCHEMICAL CHARACTERISTICS OF BISCUITS PRODUCED FROM GLUTEN-FREE AMARANTH SEED AND TIGER NUT COMPOSITE FLOUR

– Research paper –

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Abstract: This study was carried out to advance the use of indigenous composite flour obtained from amaranth seed and tiger nut in the production of biscuits to increase access to a healthy and sustainable diet. Biscuit was produced from amaranth seed flour substituted with tiger nut flour at 0%, 10%, 20%, 30%, 40% and 50%. The functional and pasting properties of the flour samples were determined, the proximate composition was evaluated and selected minerals contents of flour and biscuit samples were also assessed using standard methods. The results showed that the protein, fat, ash and fibre content of amaranth seed flour increased from 13.86%, 4.12%, 1.77% and 1.26% respectively to a range of 13.86 – 16.16%, 4.47 – 5.18%, 2.18 – 2.65% and 2.35 – 3.96% respectively with the addition of tiger nut flour. An increase in protein, fat, ash and fibre was also recorded in the biscuit samples with the increased concentration of tiger nut flour. Flour and biscuits produced from 100% wheat had lower protein, fat and fibre content than 100% amaranth seed flour and the blends. The bulk density and water absorption capacity of 100% amaranth seed flour and the blends were significantly higher than 100% wheat flour. Biscuits produced from amaranth seed flour substituted with tiger nut flour at 50% had the highest content of sodium (202.59 mg/100g) and potassium (299.57 mg/100g). In comparison, 100% wheat biscuit and 100% amaranth biscuit had the highest calcium (186.67 mg/1000g) and iron content (4.13 mg/100g) respectively. The study concluded that amaranth seed and tiger nut flour blends could be utilized to produce high-nutritional quality gluten-free biscuits that will increase access to an affordable healthy and sustainable diet.

Keywords: Amaranth seed, tiger nut, pasting properties, proximate composition, gluten

INTRODUCTION

Consumption of food containing gluten can cause an immune disorder known as celiac disease which affects about 1% of the world population and non-celiac diseases such as dermatitis herpetiform, wheat allergy, and gluten ataxia (Foschia et al., 2016; Leonardo et al., 2017). Gluten is present in cereals such as wheat, barley, some species of oats, and rye (Cairano et al., 2018). These cereals are important in the production of breakfast cereals, cakes, biscuits, beer, and composite flours (Ikujenlola, 2014; Malomo and Popoola, 2020).
Biscuits are popular snacks consumed all over the world due to their desirable taste, flavor, accessibility, low cost, and convenience. The three major ingredients that are important in the production of biscuits are flour, sugar, and fat (Chinma et al., 2011). Wheat is usually used for biscuit production but because of gluten intolerance, it is important to explore other gluten-free cereals (Kiin-Kabari & Giami, 2015).

Received: 17.01.2024
Accepted in revised form: 25.06.2024

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Wheat is the second most imported food item in Nigeria. Central Bank of Nigeria reported that Nigeria spends over $2bn annually on over five million metric tonnes of wheat (CBN, 2021; Umar & Muhammad, 2021). The price of wheat has skyrocketed due to the war in Ukraine and Russia and also increase in the exchange rate in Nigeria leading to increase in prices of biscuits, bread, cakes and other wheat-based products. There is a need to explore indigenous crops that can be used to substitute wheat to increase the availability and affordability of baked products, especially for low- and middle-income earners. Biscuit has been produced from different composite flours with or without wheat such as maize, cowpea, soybean, pigeon pea, cassava, potato, tiger nut, sorghum, tomato peel, banana, millet, amaranth seed, and the likes (Chinma et al., 2011; Ikujenlola et al., 2014; Akubo and Owuse, 2020; Hussein et al., 2022; Singh & Pania, 2022) to promote intake of affordable functional snack with high nutritional benefits.
Tiger nut (*Cyperus esculentus*) is a perennial grasslike plant with an edible tuber. It is also called

ground almonds, or reed nuts, it is known *chufa* in Spain, *souchet* in France, and *erdmandel* in Germany. It is grown all over the world and is known for its nutritional and health benefits. It is mostly grown in northern Nigeria and called *aya* in Hausa language, *ofio* in Yoruba, and *Aki* in Igbo. (Imo et al., 2018; Nina et al., 2020; Babiker et al., 2021). Tiger nut flour has been reported to have 4.47 - 10.05% moisture, 5.62 - 11.25% protein, 6.04 - 22.06% fat, 5.10 – 8.16% fibre,1.95 - 3.17% ash and 58.92 - 66.1% carbohydrate content (Chinma *et al*., 2010). Tiger nut tuber is richer in protein than many root and tuber crops like yam, cassava, and potatoes and cereals such as rice and sorghum. It has the potential to contribute more than 17% and 26% of the daily recommended protein intake for adults and children respectively (Suleiman et al., 2018).

Tiger nut prevents heart attacks and thrombosis by enhancing the circulation of blood, reducing the risk of developing cancer of the colon and is effective in treating bacterial and urinary tract infections (Chinma et al., 2011; Imo et al., 2018) and aid liberation of insulin (Ogo et al., 2018). It has high carbohydrate content, the lipid is rich in oleic acid and the tiger nut is also valued for its high dietary fiber content (Malomo et al., 2023). It contains essential micronutrients such as calcium, magnesium, iron, sodium, and potassium which are important in the body for proper functioning of bones and tissues. It also contains a substantial quantity of vitamin B which is important in balancing the nervous system (Alaka et al., 2020).

Tiger nut can be used in the production of composite flour for baking bread and biscuits, as an adjunct in breweries for the production of beer and liquor, and as a natural sweetener in the production of confectionery due to its high carbohydrate content and nutty flavour (Jing *et al*., 2016; Ogo *et al*., 2018; Babiker et al., 2021). The flour obtained from tiger nut could have an advantage over flours obtained from other tuber crops because it could be useful in the prevention and treatment of both macronutrient and micronutrient deficiencies in children and adults, improve the health status of the consumers and also increase food security (Nina et al., 2019).

Amaranth seed spp is a pseudocereal that is cultivated globally for its leaves and seeds. Some species such as *A caudatus, A cruetus and A hypochondriacus* are cultivated for their seeds (Singh & Pania, 2020). The most popular species of amaranth seed in Nigeria is *Amaranthus viridis.* This species also known as "tete" among native Yorubas is usually grown for its leaves and succulent stem for making vegetable soup. Its cultivation has increased because of the high nutritional composition of both the leaves and seeds. The seeds are milled into flour, popped, and utilized in the production of pasta, noodles, breakfast cereal, food additives, bread, dumplings, crackers, biscuits, and pancakes (Olawoye & Gbadamosi., 2020).

Amaranth seed contains 14.60 – 14.69% protein, 5.80 - 8.28%, fat, 1.87 – 2.84% ash, and 61.43 – 71.00% carbohydrate. Zinc, Manganese, Magnesium, iron, and calcium are 6.27 mg/100 g, 5.96 mg/100 g, 18.23 mg/100 g, 11.00 mg/100 g and 33.29 mg/100 g (Tanimola et al., 2018; Singh & Punia, 2020).

Amaranth seed attracts attention due to its high content of essential amino acid lysine, higher protein content, vitamins, minerals, and phytochemicals compared to rice and wheat which are the major cereals consumed all over the world. It matures faster than most cereals, pseudocereals, roots, and tubers including tiger nut, and grows throughout the year which could be an advantage in combating malnutrition and nutritional-related diseases in low-income and medium-income countries (Tanimola et al., 2018). Its calcium content is higher than milk, its iron content is five times higher than wheat and is also richer and the level of vitamin C folic acid than cereal. Its oil content is about 6-10% which is high in oleic acid "unsaturated fatty acid" (Tibagonzeka, 2014). It is high in tocophenol, thiamine, riboflavin and pyridoxine. In addition to that, it can survive in harsh environments and matures faster than other cereals which could be important in sustaining food security (Tanimola et al., 2018). Substitution or replacement of major cereals like maize, wheat, or rice with highly nutritious pseudocereal such as amaranth seeds is receiving more attention because of the health benefits and change in dietary patterns (Singh & Punia, 2022).

Many authors have worked on the production of biscuits from composite flours but there is little of information on the functional, pasting, and nutritional properties of the gluten-free biscuit produced from amaranth seed and blends of amaranth seed flour and tiger nut flour. Hence, this study is carried out to determine the suitability of 100% Amaranth seed and blends of Amaranth seed and tiger nut in the production of highly nutritious and acceptable biscuits to increase access to good food and prevent nutritional-related diseases.

MATERIALS AND METHODS

Materials

Amaranth seeds (*Amaranthus virides*) were obtained from Teaching and Research Farm, Obafemi Awolowo University (O.A.U), Ile–Ife, Nigeria, Tiger nut (*Cyperus esculentus*) and wheat were purchased from the Wuse market in Abuja, Nigeria. The Amaranth seeds and tiger nut were taken to the herbarium at the botany Department, O.A.U. for identification. Microbial growth media (Lab M, United Kingdom) and chemicals used were of analytical grade (Sigma-Aldrich Chemical Company, St. Louis, Missouri, USA).

Production of amaranth seed flour

The Amaranth seeds were cleaned by removing the extraneous materials and rinsed in water. The water was drained and the seeds were thinly spread on trays and dried in a cabinet drier at 60 ºC for 6 h. The dried seeds were cooled, milled in a blender (USHA mixer grinder: MG2053N India), sieved through a sieve with 0.5 mm diameter, and stored in an airtight container at room temperature for further analyses.

Production of tiger nut flour

Brown tiger nuts were cleaned by removing the extraneous materials and rinsed in water. The water was drained, tiger nuts were thinly spread on trays and dried at 60 ºC in Gallenkamp Oven DS (7B 1074D; England) for 8h. The dried seeds were cooled, milled in a blender, sieved through a sieve with 0.5 mm diameter, and stored in an airtight container at room temperature for further analyses (Adejuyitan et al., 2009).

Production of biscuits

The ingredients used for the production of the biscuit were 100 g of flour (100% amaranth seeds and amaranth seed-tiger nut blends (Table 1)), 40 g of fat (Simas Cooking Margarine, Nigeria), 20 g of sugar, 0.5 g of salt, 5 g of powdered milk, 2 g of baking powder ($NaHCO_3$), and 25 ml of potable water. Fat, salt, and sugar were creamed in a mixer, and baking powder and flour were added to the mixture and manually creamed with a hand mixer (Model A700D Kenwood Chef). Water was added to obtain a dough, rolled and cut into circular shapes, placed in greased pans, and baked in a Gallenkamp oven (7B 1074D; England) at 180 ºC for 20 mins. The samples were cooled and stored in polythene bags for further analysis (Ishiwu et al., 2013).

Functional properties of amaranth seed flour and blends of amaranth seed and tiger nut flour

Bulk density, water absorption capacity, oil absorption capacity and swelling capacity of the flour and the blends were also determined.

Bulk Density

Each flour sample was gently dispensed into a graduated cylinder (10 ml) and tapped at the bottom until no further diminution of the sample was observed (Ikujenlola et al., 2010). Bulk density was calculated using the equation 1:

$$Bulk\ density = \frac{Weight\ of\ sample\ (g)}{Volume\ of\ sample\ (cm3)} \quad \text{eq. 1}$$

Water Absorption Capacity (WAC)

Each sample (1g) was weighed into centrifuge tube, mixed with 10 ml of distilled water and centrifuged at 5000 rpm for 30 mins (in Bosch Model No TDL-5, Germany). The supernatant was decanted and the sediment was weighed (Malomo and Abiose, 2019). Water absorption capacity was calculated according to the equation 2:

Water Absorption Capacity =

$$=\left(\frac{weight\ of\ sediment}{original\ weight\ of\ sample}\right) \quad \text{eq.2}$$

Table 1. Samples formulation

Sample	Flour and biscuit blends (g)	Salt (g)	Powdered milk (g)	Water (ml)	Margarine (g)	Sugar (g)	Baking powder (g)
A	100 g Amaranth seed (control)	0.5	5	25	40	20	2
B	90 g Amaranth seed: 10 g Tiger nut	0.5	5	25	40	20	2
C	80 g Amaranth seed: 20 g Tiger nut	0.5	5	25	40	20	2
D	70 g Amaranth seed: 30 g Tiger nut	0.5	5	25	40	20	2
E	60 g Amaranth seed: 40 g Tiger nut	0.5	5	25	40	20	2
F	50 g Amaranth seed: 50 g Tiger nut	0.5	5	25	40	20	2
G	100 g Whole wheat Flour (reference sample)	0.5	5	25	40	20	2

Oil Absorption Capacity (OAC)

Each flour sample (1 g) was weighed into a 50 mL centrifuge tube. Vegetable oil (30 mL) was slowly dispensed and swirled and, the mixture was heated for 30 min at 90 ºC with continuous stirring in a water bath (Gallenkomp, HH-S6, England) and thereafter centrifuged (Bosch Model No TDL-5, Germany) at 3000 x g for 10 mins. The supernatant was discarded and the tube containing the residue was dried in a hot air oven at 50°C for 30 min, cooled in a desiccator, and weighed (W3). Weight of centrifuge tubes plus sample (W2) (Adepeju et al., 2014). Equation 3 was used:

$$Oil\ absorption\ capacity\ = \left(\frac{weight\ of\ sediment}{original\ weight\ of\ sample}\right) \qquad \text{eq.3}$$

Swelling Capacity

Swelling capacity was determined using the modified method of Takashi and Sieb (1988). One gram of sample (W1) was weighed into a centrifuge tube (2 cm in diameter) and 10 ml distilled water was added, mixed gently using a glass stirring rod, and heated at a constant temperature (60, 70, 80, and 90 °C) in a water bath with continuous stirring for 15 mins. The tubes were centrifuged at 1788× g for 10 mins using a centrifuge (Bosch Model No TDL-5, Germany) and the supernatant was decanted immediately. The tubes were dried at 50°C for 30 min, cooled, and weighed (W3). Centrifuge tubes containing the sample were weighed before adding distilled water (W2). Swelling capacity was calculated as shown in Equation 4:

$$Swelling\ capacity = \left(\frac{W_3-W_2}{W_1}\right)\ g \qquad \text{eq.4}$$

where:

$W_3 = weight\ of\ tube\ +$ sample after centrifuging and drying

$W_2 =$ weight of tube $+$ sample before centrifuging

$W_1 =$ weight of sample

Pasting characteristics of the samples

The pasting characteristic was assessed in a Rapid Visco Analyser. Three grams of the sample was mixed with 25 ml of distilled water in a canister. The temperature was held at 50 ºC for 1 min for equilibrium to occur, heated 50 to 90 ºC for 3 mins and 45 s, then held at 95 ºC for 2.5 mins. The sample was cooled from 95 ºC to 50 at 6 ºC per min followed by maintaining the temperature for 2 mins at 50 ºC. The pasting characteristics measured are pasting temperature, trough viscosity, setback, breakdown and final viscosity (Adeyemi et al., 1992).

Determination of proximate composition

The proximate composition of the flour and biscuit samples produced from 100% amaranth seeds and blends of amaranth seed and tiger nut was determined using AOAC (2012), and Carbohydrate content was determined by difference. Gallenkamp ballistic bomb calorimeter (Gallenkamp ccb-330-010L UK) was used for the determination of gross energy value (AOAC, 2012).

Evaluation of selected minerals

Selected mineral contents of the flour and biscuit samples produced from 100% Amaranth seeds and blends of Amaranth seed and tiger nut were assessed using the method of AOAC (2012). Potassium (K) was evaluated using the standard flame emission photometer while Calcium (Ca), Sodium (Na) Phosphorus (P), and iron (Fe) were evaluated by an Atomic Absorption Spectrophotometer.

Sensory evaluation of biscuit samples

Organoleptic evaluation of the biscuit samples was carried out using 20 panelists between the ages of 17 to 26 selected from part five students of the Department of Food Science and Technology, Obafemi Awolowo University. These panelists are only familiar with biscuits made from wheat which is the most popular biscuit in the country. Samples were cooled to 30 ºC and the biscuits were evaluated based on appearance, taste, texture/crispiness, and overall acceptability using a 9-point hedonic scale where 1 represents "extremely dislike and 9 "extremely like". Each panelist evaluated and recorded his/her scores individually without the influence of another panelist and all panelists rinsed their mouth with potable water after tasting each sample. The results obtained from the panelists were analyzed using SPSS and the mean value was recorded.

Statistical Analysis

Samples were evaluated in triplicate and the data obtained were evaluated using the Statistical Package for Social Sciences (SPSS, Version 20), and the means obtained were separated using Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

Functional properties of amaranth seed and tiger nut flour blend

The result of the functional properties of amaranth seed and tiger nut flour blend is shown in Table 2. The bulk density of amaranth seed and tiger nut flour blends was between the range of 1.68 to 1.72 g/cm^3. There was no significant difference ($P > 0.05$) in the bulk density of amaranth seed flour and blends of amaranth seed and tiger nut flour. Bulk density of 100% wheat flour was significantly lower than flour obtained from amaranth seed and tiger nut. The lower bulk density of 100% wheat flour could be attributed to its low fibre content (Ade-Omowaye et al., 2008)

The WAC determines the cohesiveness of flour and improves the characteristics of mouthfeel (Nina *et al*., 2019). The variation in the WAC of the flour samples may be a result of protein concentration, hydrophilic property and conformational characteristics (Menon et al., 2015). The WAC of flour obtained from amaranth seed and blends of amaranth seed and tiger nut was within the range of 2.01 to 2.25 g/ml. It was highest in flour produced from 100% amaranth seed (2.25 g/ml) and lowest in 100% wheat flour (1.76 g/ml).

Oil absorption capacity (OAC) is connected to the physical entrapment of fat by protein through capillary attraction which is important because fat acts as a flavoring retainer and enhances the mouthfeel (Olawoye & Gbadamosi, 2017; Nina et al., 2019). The OAC of Amaranth seed and tiger nut flour ranged between 1.66 to 1.78 g/ml. Flour samples containing 20 – 50% tiger nut had higher OAC (1.69 – 1.78 g/g) than amaranth seed flour. The OAC in amaranth seed and tiger nut flour was significantly higher ($p < 0.05$) than 100% wheat flour (1.49 g/g). OAC improves the ability of flour protein to bind with fat which is desirable because fat serves as flavor retainer and improves mouth feel (Nina et al., 2019).

Swelling capacity is the capacity of granular starch to absorb water and swell freely when the temperature is raised (Olawoye & Gbadamosi, 2020). It is also a function of particle size, species, and processing (Chandra et al., 2015). The swelling capacity of amaranth seed and tiger nut flour blends was within the range of 3.42 to 4.32 g/g. The difference in the swelling capacity of amaranth seed flours and blends containing 10%, 20% and 30% tiger nut was not significant ($P > 0.05$) but amaranth substituted with 50% tiger nut and flour produced from 100% wheat had significantly lower ($P < 0.05$) swelling capacity.

Table 2. Functional properties of amaranth seed and tiger nut flour blends

Samples	Bulk density (g/cm^3)	Water absorption (g/g)	Oil absorption (g/g)	Swelling capacity (g/g)
A	1.68±0.06^a	2.25±2.12^a	1.67±0.56^{ab}	4.10±0.01^a
B	1.66±0.06^a	2.11±2.38^{ab}	1.66±0.61^{ab}	3.97±0.01^a
C	1.70±0.50^a	2.12±3.37^{ab}	1.70±0.05^a	4.07±0.02^a
D	1.72±0.14^a	2.20±0.78^{ab}	1.72±0.14^a	4.32±0.01^a
E	1.69±0.08^a	2.00±1.41^b	1.69±0.08^{ab}	3.58±0.03^{ab}
F	1.78±0.11^a	2.01±1.41^b	1.78±0.11^a	3.42±0.01^b
G	1.49±0.08^b	1.76±0.66^c	1.49±0.08^b	3.46±0.02^b

Means are significant with different superscripts in the same column at $p < 0.05$. A: 100% Amaranth seed; B: 90% Amaranth seed: 10% Tiger nut; C: 80% Amaranth seed: 20% Tiger nut; D: 70% Amaranth seed: 30% Tiger nut; E: 60% Amaranth seed: 40% Tiger nut; F: 50% Amaranth seed: 50% Tiger nut; G: Wheat biscuit (Control)

Table 3. Pasting properties of Amaranth seed and tiger nut flour blends

Samples	Final viscosity (RVU)	Peak 1 (RVU)	Setback (RVU)	Trough 1 RVU)	Breakdown (RVU)	Pasting Temperature (°C)	Peak time (min)
A	251.00^d	274.42^a	155.00^a	96.00^d	178.42^a	92.63^a	6.49^a
B	341.50^b	273.08^a	113.25^c	228.50^a	144.83^c	90.48^a	6.66^a
C	262.50^d	283.08^a	97.08^d	125.42^c	112.67^d	92.48^a	6.48^a
D	300.25^c	251.83^{ab}	80.17^e	220.08^a	131.75^c	93.35^a	5.58^b
E	249.25^d	197.37^c	98.33^d	158.92^b	138.45^c	91.75^a	6.25^{ab}
F	237.08^d	221.42^b	80.08^e	157.00^b	164.42^b	92.45^a	6.95^a
G	372.42^a	270.17^a	138.50^b	233.92^a	136.24^c	92.35^a	6.75^a

Means are significant with different superscripts in the same column at $p < 0.05$. A: 100% Amaranth seed; B: 90% Amaranth seed: 10% Tiger nut; C: 80% Amaranth seed: 20% Tiger nut; D: 70% Amaranth seed: 30% Tiger nut; E: 60% Amaranth seed: 40% Tiger nut; F: 50% Amaranth seed: 50% Tiger nut; G: Wheat biscuit (Control)

Pasting characteristics of amaranth seed and tiger nut flour blend

Pasting properties (Table 3) of the flours are very essential in assessing gelatinization behaviour during and after cooking. The final viscosity is the capacity of granular to produce gel while set back viscosity indicates the stability of gel and the ability of starch to retrograde. (Offia-Olua, 2014). The final viscosity of the amaranth seed tiger nut flour blends ranged from 237.08 to 372.42 rapid viscosity units (RVU). The 100% wheat flour (control sample) exhibited the highest final viscosity (372.42 RVU) while amaranth seed flour substituted with 50% tiger nut flour had the lowest final viscosity (237.06 RVU) which is not significantly different from sample E with 40% tiger nut. The values of the final viscosity reported in this study are however greater than the one reported by Chinma et al. (2014) and Chinma et al. (2010) (111.5 to 175.09 RVU and 81.23 to 230.37 RVU) for tiger nut-moringa blends and wheat-tiger nut blends respectively.

There was an initial increase in the final viscosity of the flour blends with an increase in the addition of tiger nut followed by a sharp decline when the level of tiger nut flour increased from 30% to 50% level of substitution. The decrease in the final viscosity of the flour blends in this study however, contradicts the report of Chinma et al. (2014) who reported an increase in the final viscosity of tiger nut moringa flour blends as the level of tiger nut flour increases. Amaranth seed flour (100%) had the highest peak viscosity (274.42 RVU) while amaranth seed flour substituted with 50% tiger nut flour exhibited the lowest peak viscosity (197.37 RVU). The difference in the peak viscosity of 100% wheat flour, 100% amaranth flour and amaranth flour substituted with 10% and 20% tiger nut flour was not significant. The peak viscosity of food is related to the capacity of starch to bind with water (Offia-Olua, 2014).

The setback viscosity of the amaranth seed-tiger nut flour blends as presented in Table 3 shows that 100% amaranth seed flour recorded the highest setback viscosity (155.00 RVU), followed by 100% wheat flour while amaranth seed flour substituted with 50% tiger nut flour was the lowest. Setback values have been reported to be the ability of starches to form semi-solid gel pastes. The addition of tiger nut to amaranth seed flour significantly decreased ($P < 0.05$) the setback viscosity. This reduction could be caused by an increase in the fibre content of the flour blends as tiger nuts increase (Table 3). Chinma et al. (2010) reported that fiber hinders the formation of gel in starch molecules and hence, leads to the reduction of setback viscosity

The trough viscosity was between 96 RVU and 233.92 RVU. It was significantly lower ($P < 0.05$) in 100% amaranth seed flour (96.00 RVU) than 100% wheat flour (2.33.92 RVU). Flours obtained from the blends of amaranth and tiger nut had significantly higher ($P > 0.05$) trough viscosity than 100% amaranth seed flour. Trough viscosity increased significantly ($p < 0.05$) with increase in tiger nut flour. Amaranth seed flour (100%) and amaranth seed flour with 30% tiger nut flour had the highest and lowest breakdown values of 178.42 and 112.67 RVU respectively. The value reported in this study is higher than those reported by Ade-Omowaye et al. (2008) and Chinma et al. (2014) for wheat-tiger nut blends and tiger nut-moringa flour blends respectively. Increase in the addition of tiger nut significantly decreased ($p < 0.05$) the breakdown viscosities of the composite flour. The breakdown measures the degree of disintegration of granular starch or paste stability.

The pasting temperature of the flour blends ranged between 90.48 and 93.35 ºC. Amaranth seed flour supplemented with 20% tiger nut flour recorded the lowest pasting temperature (90.48 ˚C) while Amaranth seed flour with 30% tiger nut flour exhibited the highest pasting temperature. However, there was no significant difference ($p < 0.05$) among the values recorded for the sample blends. The pasting temperatures were higher (63.07 to 63.60 ºC) than those of toasted tapioca reported by Ade-Omowaye et al. (2008). Pasting temperature determines the water absorption and swelling capacity of starch. The ratio of food constituents such as starch (amylose-amylopectin ratio) protein, lipids have a direct effect on the pasting temperature of flour (Olawoye & Gbadamosi., 2020).

The peak time of the amaranth seed-tiger nut flour blends ranged between 5.58 and 6.95 mins. Changes in peak times of the flour blends may be due to differences in the gelatinization temperature and variations in chemical composition. The peak time helps in measuring the time of formation of the paste during cooking (Chinma et al., 2014).

Proximate composition of amaranth seed, tiger nut flour and biscuit samples

The proximate composition of amaranth seed and amaranth seed - tiger nut biscuit and flour is presented in Table 4. The protein content of 100% amaranth flour was lower than amaranth seed- tiger nut flour blends. Flour produced from 100% amaranth seed had significantly higher protein content than 100% wheat flour. The protein content of amaranth seed flour was lower than 14.69% reported by Singh and Punia (2022) probably due to differences in the variety used, quality of soil and geographical location.

Table 4. Proximate composition of amaranth seed and tiger nut flour blends and biscuit (wet weight basis)

Sample	Protein (%)	Fat (%)	Ash (%)	Fibre (%)	Moisture (%)	Carbohydrate (%)	Energy (k/cal)
A	13.86±0.69^{b}	4.12±0.0^{b}	1.77±0.03^{ab}	1.26±0.01^{c}	9.98±0.05^{b}	69.01±0.88^{a}	439.57
B	14.47±0.03^{a}	4.47±0.01^{a}	2.18±0.01^{a}	2.35±0.01^{b}	10.26±0.01^{a}	66.28±0.05^{b}	416.29
C	14.95±0.14^{a}	4.97±0.02^{a}	2.37±0.01^{a}	2.90±0.03^{a}	10.67±0.03^{a}	64.14±0.20^{b}	417.12
D	15.43±0.07^{a}	4.96±0.02^{a}	2.38±0.03^{a}	3.14±0.06^{a}	10.86±0.03^{a}	63.23±0.03^{b}	417.55
E	15.87±0.13^{a}	5.18±0.02^{a}	2.45±0.01^{a}	3.58±0.02^{a}	11.36±0.03^{a}	61.58±0.11^{b}	419.19
F	16.16±0.04^{a}	4.86±0.04^{a}	2.65±0.02^{a}	3.96±0.02^{a}	11.47±0.04^{a}	60.09±0.25^{b}	418.82
G	11.87±0.05^{c}	1.86±0.01^{c}	1.43±0.01^{b}	0.69±0.01^{d}	10.24±0.01^{a}	73.91±0.87^{a}	392.90
				Biscuit			
A	16.67±0.03^{b}	6.49±0.01^{b}	3.53±0.03^{ab}	1.85±0.01^{b}	9.06±0.04^{b}	62.40±0.01^{a}	362.76
B	17.67±0.01^{a}	7.25±0.01^{ab}	3.63±0.02^{ab}	2.28±0.01^{ab}	9.59±0.02^{b}	59.98±0.04^{b}	360.35
C	18.96±0.01a	7.48±0.02^{ab}	3.94±0.02^{a}	2.95±0.02^{a}	10.21±0.03^{a}	56.46±0.01^{b}	366.37
D	19.04±0.01a	7.91±0.06^{a}	4.15±0.03^{a}	3.52±0.06^{a}	10.44±0.03^{a}	54.94±0.13^{b}	342.98
E	19.37±0.07^{a}	8.43±0.06^{a}	4.52±0.01^{a}	3.74±0.02^{a}	10.85±0.03^{a}	53.09±0.04^{b}	342.98
F	21.77±0.15^{a}	8.66±0.04^{a}	4.71±0.02^{a}	3.77±0.02^{a}	11.06±0.04^{a}	50.03±0.23^{b}	311.60
G	14.37±0.01^{c}	4.96±0.06^{c}	4.37±0.01^{a}	1.68±0.01^{c}	6.36±0.01^{c}	63.30±0.87^{a}	375.24

Means are significant with different superscripts in the same column at $p < 0.05$. A: 100% Amaranth seed; B: 90% Amaranth seed: 10% Tiger nut; C: 80% Amaranth seed: 20% Tiger nut; D: 70% Amaranth seed: 30% Tiger nut; E: 60% Amaranth seed: 40% Tiger nut; F: 50% Amaranth seed: 50% Tiger nut; G: Wheat biscuit (Control)

The protein content of biscuits made from 100% amaranth seed and amaranth seed - tiger nut flour blends (16.67 – 21.77%) was higher than 100% wheat biscuit (14.37%). Amaranth seed flour (100%) biscuit had more protein content than 100% wheat biscuits. It has been reported that the protein content of amaranth seed grain is higher than wheat, rice, and corn (Singh and Punia, 2020). The fat content of amaranth seed and tiger nut flour was between 4.12 to 5.18%. The fat content of the flour produced from amaranth flour was significantly lower ($p < 0.05$) than the blends. The fat content of biscuits produced from 100% amaranth seed and tiger nut blends was between the range of 6.49 to 8.66%. The fat content of 100% amaranth seed flour was significantly higher ($P < 0.05$) than 100% wheat flour (1.86%). The addition of tiger nut to amaranth seed flours significantly increased the fat content of flour and biscuit samples. The fat content of biscuits produced from 100% wheat flour (4.96%) was significantly lower than 100% amaranth seed flour (6.49%) biscuits. Ahmed et al. (2014) reported that the fat content of corn-tiger nut blend used in the formulation of gluten-free biscuits increased as the level of tiger nut flour increased. Fat is important in biscuits because retains flavour and improves the organoleptic characteristics of baked foods (Nina et al., 2019).

The ash content of flour samples generally increased with an increase in the concentration of tiger nut flour. It was within the range of 1.77 to 2.65% in the flour samples and 3.53 to 4.71% in the biscuit samples produced from amaranth seed and tiger nuts. The ash content of 100% wheat biscuit (4.37%) was higher than 100% amaranth seed biscuit (3.53%) but lower than biscuit produced from amaranth seed flour substituted with 40 and 50% tiger nut flour with values of 4.52 and 4.71% respectively but these differences were not significant ($P > 0.05$). Hussein et al. (2022) also reported an increase in ash content when tiger nut was added to wheat flour in the production of pan bread. Tiger nut has been reported by researchers to contain 1.95 - 3.17% ash content (Chinma et al., 2011) which is higher than the range reported for amaranth seed has 1.87 – 2.84% (Tanimola et al., 2018; Singh and Punia, 2020).

Flour produced from 50% amaranth seed and 50% tiger nut had the highest fibre content while flour produced from 100% wheat had the lowest. The fiber content of flour and biscuit produced from 100 % amaranth seed (1.26 – 1.85%) had significantly lower fiber content ($P < 0.05$) than the blends (2.28 – 3.96%) indicating that the addition of tiger nut had a significant effect ($P < 0.05$) on the increase in fibre content of the biscuit samples. This shows that tiger nut is rich in fibre content. Awolu et al. (2017) reported an increase in the crude fibre of maize-based snacks supplemented with tiger nut flour. Singh and Punia (2022) reported an increase in protein, fat, crude fibre, and ash content of chapatti with an increase in amaranth seed flour to wheat flour. Amaranth seed has higher dietary fibre and fat content than most cereal and contains between 50 and 60 g of starch per 100 g of grains (Singh and Punia, 2020). Consumption of tiger nuts could be effective in preventing and treatment of intestinal disorders due to high fibre content (Nina et al., 2019).

The moisture content of the flour blends was between 9.98 to 11.47%. However, there was no

significant difference ($p > 0.05$) in the moisture content of the 100 % wheat flour and the blends of amaranth seed and tiger nut flour. The addition of tiger nut was observed to cause an increase in the moisture content of the flour blends. This increase could be attributed to the hydrophilic nature of tiger nut flour thereby increasing the moisture content of the flour blends (Ade-Omowaye et al., 2008).
The result showed that the moisture content of the formulated biscuits varied between 6.36% and 11.06%. The moisture content of the biscuits produced from the blends was higher than 100% amaranth seed flour biscuit except in amaranth flour substituted with 10% tiger nut flour while the lowest moisture content was recorded in biscuit produced from 100% wheat flour. The higher moisture content of the blends could be attributed to the high fibre content of tiger nut. Fibre-rich foods have been reported to absorb moisture due to the presence of hydrophilic molecules. The result obtained in this study compared favorably with the result reported by Ade-Omowaye et al. (2008), Chinma et al. (2011) and Awolu et al. (2017) for wheat-tiger nut flour blend, maize-based snacks fortified with soybean and tiger nut, and wheat-based bread supplemented with moringa and tiger nut flour respectively. Moisture is important for the biochemical changes that may influence the sensory and shelf quality of the food products. The moisture content of the flour blends as well as the formulated biscuits falls within the recommended range for storage and processing as this increases storage stability. Low moisture content inhibits germination of spores and microbial growth can lead to spoilage and reduce consumers' acceptability (James, 1995; Barber et al., 2017).

The carbohydrate content ranged between 60.09% and 73.91% for the flour blends and between 50.03% and 63.30% for the biscuit. The carbohydrate content of 100% wheat flour and 100% amaranth seed flour was not significant ($P > 0.05$). The carbohydrate content of samples substituted with tiger nut flour was significantly lower ($P < 0.05$) than 100% amaranth seed and 100% wheat biscuit samples. The decrease in carbohydrate contents in the biscuits compared to the flours could be a result of heat treatment and the dilution effect of other ingredients (Tanimola et al., 2018). It has been reported that tiger nut can be used as raw material in baking and confectionary industries (Bibeker et al., 2021).
The energy value of food represents the number of calories that are available in food through oxidation. The calories depend on the protein, fat, and carbohydrate contents (Adeola and Ohizua, 2018). The energy value ranged from 392.9 to 439.57 kcal in flour blends and between 375.24 and 311.60 kcal in biscuits produced from amaranth seed and tiger nut flour blends. Flour from 100% amaranth seed flour and biscuits produced from it had the highest energy value. The energy value increased with an increase in the level of tiger nut flour substitution.

Mineral composition of amaranth seed and tiger nut flour and biscuit

Calcium content was within the range of 87.65 mg/100g to 163.54 mg/100g and 115.63 mg/100g to 186.67 mg/100 g for flour blends and biscuits respectively (Table 5).

Table 5. Mineral composition of flour blends from Amaranth seed and tiger nut and biscuit (mg/100g) (wet weight basis)

Samples	Calcium	Sodium	Phosphorus	Potassium	Iron
		Flour			
A	87.65 ± 1.84^{c}	174.26 ± 3.74^{a}	111.68 ± 3.74^{a}	230.14 ± 8.28^{a}	3.12 ± 0.01^{a}
B	98.355 ± 3.49^{b}	154.81 ± 3.18^{c}	99.66 ± 2.77^{b}	200.31 ± 5.75^{c}	2.86 ± 0.01^{b}
C	104.385 ± 2.16^{b}	145.56 ± 5.02^{c}	96.66 ± 4.05^{b}	196.67 ± 6.13^{c}	2.78 ± 0.06^{b}
D	116.45 ± 3.78^{b}	162.52 ± 3.91^{b}	100.36 ± 4.86^{b}	205.57 ± 4.75^{b}	3.06 ± 0.03^{a}
E	99.49 ± 2.37^{b}	168.33 ± 4.92^{ab}	101.05 ± 3.09^{b}	214.45 ± 7.04^{b}	3.13 ± 0.02^{a}
F	163.54 ± 5.92^{a}	181.24 ± 5.03^{a}	105.59 ± 3.64^{a}	225.58 ± 5.52^{a}	3.66 ± 0.01^{a}
G	100.48 ± 2.45^{b}	166.36 ± 6.42^{b}	82.45 ± 2.83^{c}	200.18 ± 7.63^{c}	3.86 ± 0.04^{a}
		Biscuit			
A	115.63 ± 1.07^{e}	173.50 ± 0.68^{b}	178.36 ± 1.73^{b}	226.34 ± 2.63^{c}	4.13 ± 0.03^{a}
B	128.36 ± 2.01^{d}	185.50 ± 0.47^{b}	196.04 ± 2.91^{a}	$269.35^{a}\pm1.91^{b}$	3.58 ± 0.09^{a}
C	138.87 ± 1.18^{c}	188.46 ± 0.35^{b}	154.47 ± 0.92^{c}	232.36 ± 2.60^{c}	3.71 ± 0.04^{a}
D	145.57 ± 1.03^{c}	175.07 ± 0.88^{b}	170.22 ± 1.47^{b}	265.57 ± 2.24^{ab}	2.92 ± 0.02^{b}
E	133.13 ± 1.92^{d}	196.11 ± 1.03^{a}	198.96 ± 2.64^{a}	252.23 ± 1.97^{b}	3.87 ± 0.02^{a}
F	153.96 ± 0.96^{b}	202.59 ± 0.91^{a}	193.66 ± 2.09^{a}	299.57 ± 3.42^{a}	1.68 ± 0.01^{c}
G	186.67 ± 2.38^{a}	197.92 ± 1.94^{a}	185.55 ± 2.11^{ab}	285.34 ± 2.77^{a}	1.02 ± 0.01^{c}

Means are significant with different superscripts in the same column at $p < 0.05$. A: 100% Amaranth seed; B: 90% Amaranth seed: 10% Tiger nut; C: 80% Amaranth seed: 20% Tiger nut; D: 70% Amaranth seed: 30% Tiger nut; E: 60% Amaranth seed: 40% Tiger nut; F: 50% Amaranth seed: 50% Tiger nut; G: Wheat biscuit (Control)

Among the flour blends studied, 100% amaranth seed had the lowest calcium content while flour blends containing 50% amaranth seed flour and 50% tiger nut flour had the highest calcium content. Calcium content of flour and biscuit produced from amaranth seed and tiger nut blends was higher than 100% amaranth seed. The calcium content of 100% wheat flour and biscuit was significantly higher than 100% amaranth seed. Chinma et al. (2011) also reported an increase in the calcium content of biscuit produced from pigeon peas with addition of tiger nut. A study conducted by Ahmed et al. (2014), showed an increase in calcium content with an increase in the tiger nut. The result also shows that the formulated biscuits from amaranth seed-tiger nut flour could be a significant source of calcium which is essential in the diet because it facilitates bone and teeth formation (Akubor & Owuse, 2020).
The sodium content ranged from 173.50 to 202.59 mg/100g in amaranth seed-tiger nut biscuits and 145.56 to 181.24 mg/100g in flour blends. A higher concentration of sodium in biscuit samples could be linked to the addition of table salt and $NaHCO_3$ to the recipe. Among the biscuit samples, biscuits produced from 60% amaranth seed flour and 40% tiger nut flour had the highest sodium content. Sodium content was generally higher in biscuits produced from amaranth seed and tiger nut flour blends than in 100% amaranth flour except in sample D. The result agrees with the study carried out by Ayo et al. (2018). All the biscuit samples are sufficient enough to provide a daily recommended intake (1200 mg/day) of sodium when consumed in a substantial amount (CODEX, 2007). Sodium is an essential micronutrient that is important in the maintenance of fluid balance, nerve transmission, and muscle contraction (Oyarekua, 2013). Food with higher levels of potassium with lower levels of sodium could be used in the formulation of a diet for hypertensive patients (Nina et al., 2019).
The phosphorus content ranged between 154.47 to 198.96 in formulated biscuits and 82.45 mg/100g to 111.68 mg/100 g for flour. Flour produced from amaranth seed flour (100%) had the highest phosphorus content while 100% wheat flour had the lowest. From the result, it was observed that the formulated biscuits had higher phosphorus content when compared with the flour blends, they were made from. This could be a result of other ingredients added in the course of production of the biscuits. These findings agree with the reports of Ade-Omowaye et al. (2008) and Chinma et al. (2011).
The potassium content of the flour blends and biscuits as affected by the level of tiger nut substitution is shown in Table 5. The potassium content ranged between 198.67 to 230.14 mg/100g in flour blend samples and 226.32 to 299.57 mg/100g in formulated biscuits samples. It was observed that flour blends sample C containing 80% Amaranth seed flour and 20% tiger nut flour had the lowest potassium content while amaranth seed flour substituted with 50% tiger nut flour had the highest level of potassium but the difference was not significant ($p > 0.05$). The concentration of potassium present in the biscuit produced from the blends was higher than 100% amaranth seed flour. Biscuit (Sample F) produced from 60% amaranth seed and 40% tiger nut had higher potassium content than 100% wheat biscuit. Ade-Omowaye et al. (2009) reported an increase in the concentration of potassium with the addition of tiger nut. Higher potassium content observed in the formulated biscuits could be due to the addition of other ingredients. This result is similar to other reports (Ade-Omowaye et al. (2009)(Chinma et al. (2011).
The iron content ranged between 2.78 to 3.66 mg/100g in flour blends and 1.68 to 4.13 mg/100g in biscuit samples. The iron content of the 100% amaranth seed flour and a blend of amaranth seed-tiger nut flour was higher than 100% wheat flour and the same observation was recorded in the biscuit produced from these flours. The iron content of biscuits produced from 100% amaranth seed flour was significantly higher than 100% wheat biscuits. This finding is in agreement with the result obtained by Singh and Pania (2021).
Increase in iron, zinc, potassium and phosphorus observed in the biscuit samples could also be due to the breakdown of phytic acid which has been reported to bind minerals. A study has attributed a decrease in phytic acid content to an increase in the availability of minerals (Lakra et al., 2020).

Sensory evaluation of biscuit from amaranth seed and tiger nut flour blends

Table 6 shows the scores for appearance, taste, flavor, texture/crispness, and overall acceptability of the biscuit blends. The score for appearance ranged between 5.90 and 6.80 with no significant difference ($p > 0.05$) among the samples. Sample B (90% amaranth seed flour and 10% tiger nut flour) was the most preferred with a mean score of 6.80 while biscuit produced from 60% amaranth seed flour and 40% tiger nut flour (sample E) was the least preferred in terms of appearance (5.90). Adebayo-Oyetoro et al. (2017) also reported an increase in the organoleptic characteristics of chin-chin produced from wheat flour with an increase in the addition of tiger-nut flour.

Table 6. Sensory evaluation of biscuit from amaranth seed and tiger nut flour blends

Samples	Appearance	Texture/Crispiness	Flavour	Taste	Overall Acceptability
A	5.40±0.12[a]	5.40±0.11[b]	6.00±0.13[a]	5.25±0.11[a]	5.40±0.11[a]
B	6.80±0.11[a]	5.70±0.14[a]	5.20±0.11[a]	5.25±0.11[a]	6.05±0.14[a]
C	6.60±0.11[a]	5.60±0.12[a]	5.70±0.12[a]	5.55±0.10[a]	5.80±0.12[a]
D	6.20±0.11[a]	5.90±0.11[a]	5.90±0.11[a]	5.60±0.14[a]	6.25±0.17[a]
E	5.90±0.13[a]	5.30±0.11[b]	4.90±0.13[b]	4.35±0.10[b]	5.05±0.11[b]
F	5.60±0.11[a]	5.70±0.13[a]	5.85±0.13[a]	5.55±0.13[a]	6.05±0.13[a]
G	6.10±0.11[a]	6.40±0.16[a]	6.50±0.11[a]	6.80±0.11[a]	6.75±0.15[a]

Means are significant with different superscripts in the same column at $p < 0.05$. A: 100% Amaranth seed; B: 90% Amaranth seed: 10% Tiger nut; C: 80% Amaranth seed: 20% Tiger nut; D: 70% Amaranth seed: 30% Tiger nut; E: 60% Amaranth seed: 40% Tiger nut; F: 50% Amaranth seed: 50% Tiger nut; G: Wheat biscuit (Control)

Biscuits produced from 100% amaranth seed had the highest score for flavour (6.00) compared with other amaranth seed-tiger nut biscuit samples but the score was lower than 100% wheat biscuit (6.50). The findings of this study also agree with the findings of Ayo et al. (2018). The taste scores ranged between 4.35 and 5.95 in the formulated biscuit. No significant differences ($p > 0.05$) were recorded among the samples based on this quality attribute except for biscuits made from 60% amaranth seed and 40% tiger nut flour which was significantly lower than ($P < 0.05$) other biscuit samples. Biscuits produced from wheat had the highest score for taste (6.80) which was not significantly higher ($p > 0.05$) than all amaranth seed-tiger nut biscuit samples except sample E. The texture of formulated biscuit samples was between 5.30 and 5.90. The texture/crispiness of all amaranth seed-tiger nut biscuit (5.30 – 5.90) was lower than 100% wheat biscuit (6.40). Biscuit produced from 100% amaranth had a significantly lower ($P < 0.05$) score for texture/crispness except for sample E. The Addition of tiger nut increased the score for taste except for sample E. There were no significant differences ($p > 0.05$) between the samples of amaranth seed-tiger nut biscuits in terms of overall acceptability. Biscuits made from 100% amaranth seed flour were the most acceptable overall acceptability in that it has the highest mean score. Increasing or decreasing the level of tiger nut did not have any significant effect on the consumer or panelist's overall acceptability of the biscuits formulated from the flour blends. The difference in scores of all amaranth seed-tiger nut biscuits and 100% wheat biscuits was not significant ($p > 0.05$) except for samples produced from 60% amaranth seed and 40% tiger nut. This may be due to inconsistency with human perception and individual preference. Thus, biscuits with desirable organoleptic properties can be produced from amaranth seed and tiger nut flour.

CONCLUSIONS

Utilization of amaranth seed and tiger nut flour in biscuits production significantly improved the protein, crude fiber, ash, and energy values of the biscuit samples compared to 100% wheat. The sensory assessment of the biscuit samples shows no significant difference between the biscuit samples produced from amaranth seed flour and blends of amaranth seed flour and tiger nut. The appearance, flavour, taste and colour of 100% amaranth biscuit and the blends were also not significantly different ($p > 0.05$) from 100% wheat biscuit showing that these flours can have great potential in biscuit production. This study therefore suggests the use of amaranth seed and tiger nut flour in the production of biscuits with high nutritional quality to combat malnutrition, increase the utilization base of Amaranth seed and tiger nut in providing essential nutrients for vulnerable groups especially those living with gluten intolerance, and prevent nutritionally related diseases.

AKNOWLEDGEMENTS

I appreciate Mr. O. Alakija for his technical support during this project.

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