



Research article

Sensory and physicochemical properties of biscuit produced from blends of whole wheat, soy *okara* and tigernut residue flours

Helen Obioma Agu^{*}, Jennifer Chikamara Ihionu, Joy Chinenye Mba

Department of Food Science and Technology, Nnamdi Azikiwe University, Awka P.M.B., 5025, Awka, Anambra State, Nigeria



ARTICLE INFO

Keywords:

Soy *okara*
Whole wheat
Tigernut residue
Composite flours
Biscuits

ABSTRACT

Biscuits are popular ready to eat, cheap and convenient food products that are consumed globally. Supplementation of wheat flour with inexpensive staples from other cereals, legumes, roots and tubers will help in improving the nutritional quality of wheat products. Therefore, this study investigated the sensory and physicochemical properties of biscuits produced from blends of whole wheat, soy *okara* and tigernut residue flours. The sensory qualities of the twelve whole wheat, soy *okara* and tigernut residue flour biscuits at $p < 0.05$ ranged from 5.36 to 7.68 (color), 5.60–7.64 (appearance), 4.48–7.96 (mouthfeel), 4.28–7.76 (aroma), 3.96–8.32 (taste), 3.64–8.20 (crunchiness), 3.56–7.56 (crispiness), and 5.08–8.36 (overall acceptability). Physical, proximate and mineral analysis were carried out on the best five biscuit samples containing 100:0:0 (MVP), 60:20.98:19.02 (ISP), 50.75:39.25:10 (JAR), 53.79:22.57:23.64 (GEN) and 56.32:27.39:16.29 (XEC) whole wheat, soy *okara* and tigernut residue flours respectively. The physical analysis showed that diameter (38.13–38.17 mm), height (37.73–37.76 mm) and thickness (6.10–6.17 mm) were not significantly different, but the weight (7.30–7.73 g), spread ratio (5.73–6.10 mm) and breaking strength (600–643 g) significantly ($p < 0.05$) differed among the biscuit samples. The proximate composition of the biscuits ranged from; ash (1.70–1.90%), moisture (4.00–5.70%), fiber (7.00–11.30%), fat (16.20–17.30%), protein (6.50–12.00%), carbohydrate (56.94–59.20%) while mineral content ranged from; magnesium (122.00–134.00 mg/100 g), sodium (16.00–28.00 mg/100 g), calcium (12.00–24.00 mg/100 g), iron (2.30–3.50 mg/100 g) and phosphorus (100.00–121.00 mg/100 g). The study showed that substitution of wheat flour with soy *okara* and tigernut residue flour at a ratio of 60:20.98:19.02 yielded the most acceptable biscuits in all the sensory attributes assessed. This implies that biscuits produced from this composite blend contain sufficient amounts of protein, fat, fiber and carbohydrate. Hence, they can serve as relief for malnutrition.

Practical application

This study demonstrates the possibility of producing biscuits from whole wheat, soy *okara* and tigernut residue flours, especially where the conventional wheat flour is not financially feasible. The optimized process can be used for commercial production of biscuits for nutritional, health benefits, food security, and economic impact.

* Corresponding author.

E-mail address: ho.agu@unizik.edu.ng (H.O. Agu).<https://doi.org/10.1016/j.heliyon.2023.e15318>

Received 5 December 2022; Received in revised form 26 March 2023; Accepted 3 April 2023

Available online 8 April 2023

2405-8440/© 2023 Published by Elsevier Ltd.

This is an open access article under the CC BY-NC-ND license

(<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

In recent years, nutritional modification of food products has gained attraction due to increased consumer interest in healthy foods. Biscuit is one of the most important and widely consumed cereal-based staple foods worldwide. It is low in protein and other macronutrients while high in carbohydrates, with a high glycemic index that can lead to obesity and susceptibility to diabetes and bile duct cancer [1]. However, the consumption of biscuits in many countries, especially Nigeria, is increasing due to urbanization, but there is a challenge to meeting the supply and demand of the product to meet the eating habits of consumers. Wheat flour, the main ingredient used in biscuit making, is imported into the country, which involves huge foreign exchange spending, resulting in a high cost of baked goods.

Protein-energy malnutrition (PEM) and micronutrient deficiencies are also one of the predominant problems in many developing countries, including Nigeria. This has led to high costs and inadequacies in the production of protein-rich foods, affecting children, the sick and the elderly who are in dire need of a balanced diet. Therefore, efforts are being made to improve the nutritional composition of foods to meet the nutritional needs of consumers [2].

The strategy of converting waste into valuable material is also an innovative means of replacing wheat flour wholly/partly with locally available nutrient-rich raw materials in baked goods. Such a replacement will significantly reduce the cost of raw materials and provide consumers with alternatives. This research therefore aimed to determine the physicochemical and sensory properties of biscuits made from whole wheat, soy and tigernut residue flours.

Soybeans are an important oilseed consumed worldwide [3]. Among plant-based protein ingredients, the soybean has high nutritional value [4], but contains several anti-nutritional substances, such as phytic acid, protease inhibitors and saponins, which often limit their dietary intake. Consumption of soy products is increasing worldwide, either as a whole or as an ingredient in soy drinks and tofu. As a result, the food industry generates large amounts of by-products that are often discarded but can still be valuable sources of nutrients and natural antioxidants in human nutrition and animals.

Soybean residue (*okara*) is a white-yellowish puree that remains after filtration of the crushed soybean seeds used to make soymilk [5] and is produced in large quantities (about 1.1 kg per kilogram of soybeans processed into soy milk production) [6]. This by-product has a high moisture content (70–80%), making it prone to spoilage and often discarded, but dried *okara* is still high in protein (about 30%), lipid (10–20%), and high in polyunsaturated fatty acids and dietary fiber content (20–50%). It also contains isoavone, minerals and oligosaccharides (raffinose and starchyose) [7,8]. Under certain conditions, the nutritional value can even be increased [9].

In addition, and unlike soybeans, which have many anti-nutritional factors, the production of *okara* involves a thermal process that reduces most anti-nutritional factors [5]. Several health benefits have been attributed to *okara*, including antioxidant capacity, prevention of obesity and liver fat accumulation, lowering of plasma cholesterol and prevention of cardiovascular disease [7,10,11]. These properties make it an inexpensive source of functional ingredients [6].

Tigernut (*Cyperus esculentus*) is a monocot belonging to the *Cyperaceae* family and is underutilized [12]. It is a tuber that grows freely and is widespread in Nigeria, other parts of West Africa, East Africa, parts of Europe, especially Spain, and the Arabian Peninsula [13]. Tigernut residues are a good source of carbohydrates, as shown by their high carbohydrate content. Researchers have reported that tigernut residues, which are often considered waste, are rich in iron (for blood formation), calcium (for healthy bone and tooth formation), magnesium and sodium, which improve human well-being [14].

The importance of vitamins in maintaining good health cannot be overstated and these residues can provide another source of essential vitamins such as vitamin C, vitamin B1 and vitamin B2 [14]. The low content of antinutrients in these residues not only represents an advantage in terms of use in feed production, but also points to possible health applications. Adejuyitan et al. [15] also reported that tigernut tubers may help reduce the risk of colon cancer due to their high glucose composition. In addition, it is suitable for people with diabetes and gluten allergy [16].

2. Materials and methods

2.1. Source of material

Soybean, tigernut tubers, whole wheat flour and other baking materials such as butter (King's), Dangote granulated sugar, baking powder (Double crown), full cream milk powder (Dano), vanilla flavor (Foster Clark) and Dangote salt were purchased from Eke Awka market, Awka, Anambra State, Nigeria, in 2021. All reagents and equipment used were of analytical grade.

2.2. Experimental design

The experiment was a mixture design obtained using Design Expert 12. The experiment had a total of 12 runs. The design key is

Table 1
Design key.

Factor	Name	Unit	Low	High
X1	Wheat flour	g	40	100
X2	<i>Okara</i> flour	g	20	40
X3	Tigernut residue flour	g	10	30

shown in Table 1. The mixture components, A (wheat flour), B (*okara* flour), C (tigernut residue flour) were summed up to 100 as shown in Table 2. Analysis was carried out on the best five (5) samples from sensory evaluation.

2.3. Production of whole wheat flour

The method described by Ndife et al. [17] was used to make whole wheat flour as shown in Fig. 1 and packaged in an airtight container until needed for analysis.

2.4. Production of soybean residue flour

A method for making soybean residual flour was developed by Mbaeyi-Nwaoha and Uchendu [18]. The method was used but with slight modification as shown in Fig. 2 and packaged in an airtight container.

2.5. Production of tigernut residue flour

The method described by Senya et al. [19] was used to prepare tigernut residue flour as shown in Fig. 3 and stored in an airtight container at room temperature for later use.

2.6. Production of the biscuits

In the manufacturing of the whole wheat/soy *okara*-tigernut residue flour biscuits, the method given by Makanjuola and Adebo-wale [20] was used with slight modification as shown in Fig. 4.

2.7. Sensory evaluation

A semi-trained panel of 25 judges made up of male and female staff and students of the Department of Food Science and Technology, Nnamdi Azikiwe University, Awka was used. The average age of the panelists was 35 years. Participants evaluated the products seated in individual booths under cool, natural, fluorescent lights. The panelists were educated on the respective descriptive terms of the sensory scales and requested to evaluate the various biscuit samples for taste, appearance, texture, aroma, and overall acceptability using a 9-point Hedonic scale, where 9 was equivalent to like extremely and 1 equivalent to dislike extremely. Presentation of coded samples was done randomly and portable water was provided for rinsing of the mouth in between the respective evaluations [21].

2.8. Ethics approval and consent to participate

The researchers applied the principle of voluntary participation confidentiality and anonymity in the study to ensure that the rights of the panelists were respected. A letter of approval for the study was obtained from the Department of Food Science and Technology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria and informed consent (verbal) was obtained from each of the panelists before the sensory evaluation was conducted.

2.9. Determination of physical properties of biscuits

Physical characteristics of biscuit samples were evaluated by measuring the height, weight, diameter, thickness, break strength and spread ratio as described in the study of Bunde-Tsegba et al. [22].

Table 2

Formulation of composite flour.

Run	Component 1 A: whole wheat flour (g)	Component 2 B: soy <i>okara</i> flour (g)	Component 3 C: Tigernut residue flour (g)
1	100.0	0.00	0.00
2	50.02	29.47	20.51
3	53.79	22.57	23.64
4	45.90	26.35	27.74
5	57.05	32.94	10.00
6	44.08	40.00	15.92
7	56.32	27.39	16.29
8	50.00	20.00	30.00
9	60.00	21.00	19.02
10	40.00	31.50	28.50
11	50.75	39.25	10.00
12	43.64	34.42	21.94

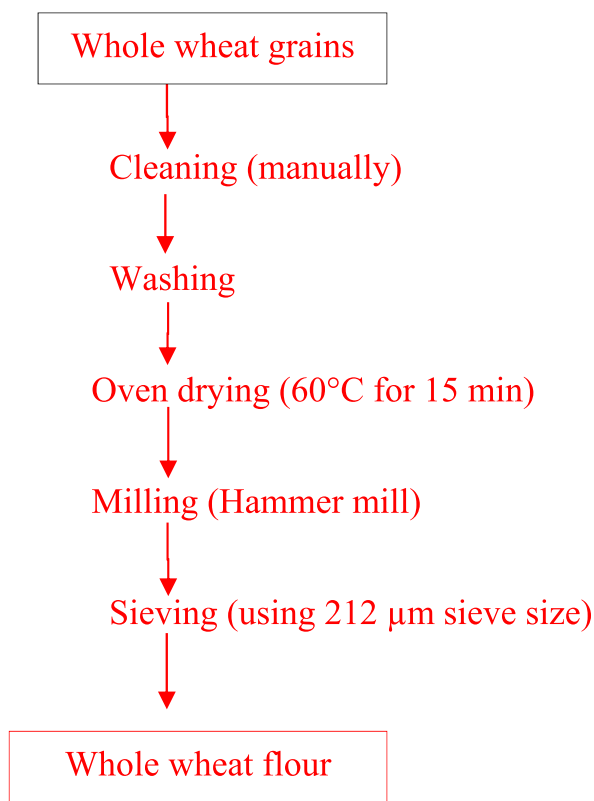


Fig. 1. Production of whole wheat flour.

2.10. Determination of proximate composition

The proximate compositions (moisture, fat, protein, fiber, ash) of the biscuit samples were determined by the standard methods described by the AOAC [23]. Carbohydrate content was determined by difference [100 - (% Moisture + % Protein + % Fat + % Ash + % Fiber)] [24].

2.11. Mineral analysis

The mineral (Magnesium, Calcium, Iron, Phosphorus and Sodium) contents of the biscuit samples were determined using the standard methods described by the AOAC [23].

2.11.1. Digestion of sample

Twenty (20) grams of the samples were digested for 25 min (as in ash determination) and the resulting ash was dissolved in 100 mL of dilute hydrochloric acid (1 mL HCL) and diluted to a 100 mL volumetric flask using distilled water. The solution was used for the various analysis of a mineral.

2.11.2. Determination of magnesium

Twenty (20) mL of the sample filtrate was, pipetted into a 250 mL conical flask, after which 25 mL of ammonia buffer solution was added and mixed properly. Then a pinch of Erichrome black T indicator was added and titrated with 0.02 N of EDTA until the color of the solution changed from wine-red to blue. The magnesium contents were calculated using equation (1).

$$\text{Magnesium (mg / 100 g)} = \frac{(Tv \times 0.2432 \times 1000)}{\text{Vol.of sample used}} \quad \text{equation 1}$$

2.11.3. Determination of calcium

The calcium content of the test samples was determined by the EDTA complex isometric titration. Twenty (20) mL of each extract was dispersed into a conical flask and panels of the masking agents, hydroxytannin, hydrochlorate, and potassium cyanide were added, followed by 20 mL of ammonia buffer (pH 10.0). A pinch of the indicator-Ferrochrome black was added and the mixture was shaken very well. It was titrated against 0.02 N EDTA solution until a permanent blue color was observed, then the reading was taken. The

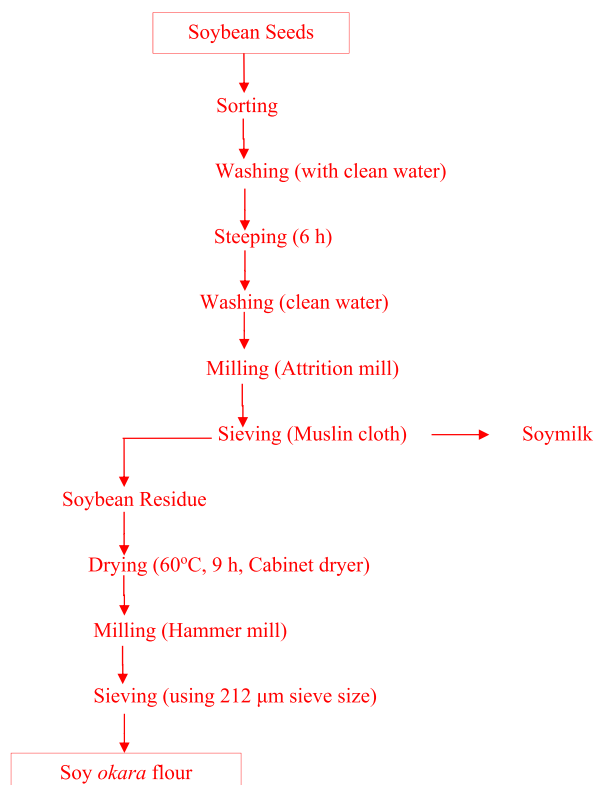


Fig. 2. Processing of soy okara flour.

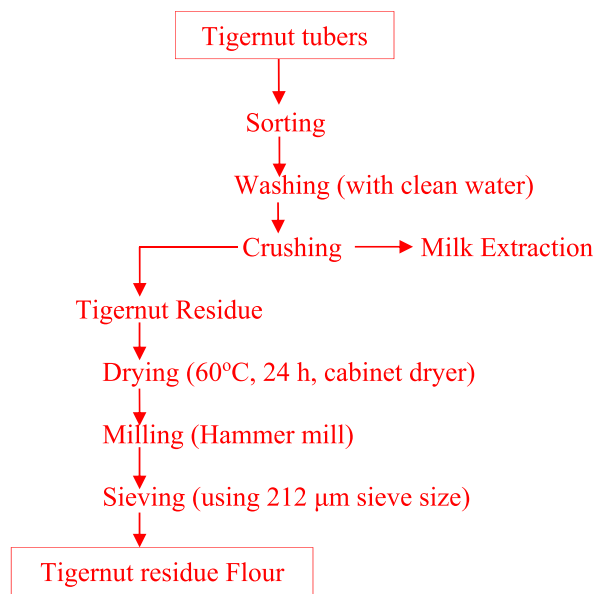


Fig. 3. Processing of tigernut residue flour.

calcium contents were calculated using equation (2).

$$\text{Calcium (mg / 100 g)} = \frac{(Tv \times 0.4008 \times 1000)}{\text{Vol.of sample used}}$$

equation 2

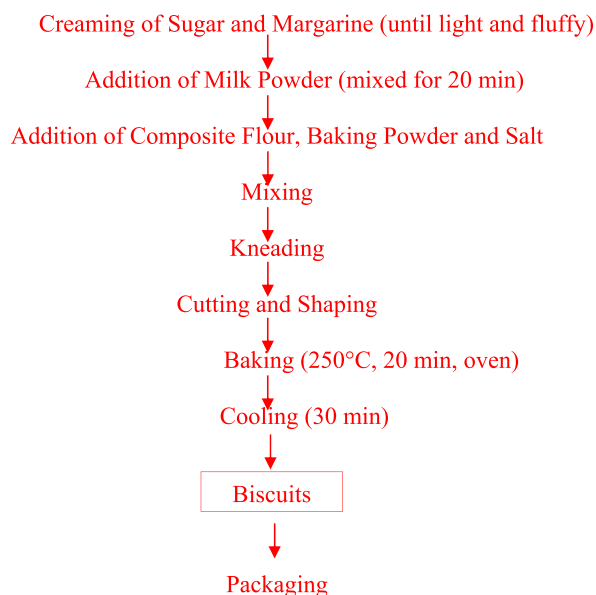


Fig. 4. Production of biscuit.

2.11.4. Determination of iron

The concentration of iron (ppm) was analyzed using an atomic absorption spectrophotometer at a wavelength of 243 nm and the concentration at mg/100 g was calculated using equation (3):

$$\text{Iron (Fe) (mg / 100 g)} = \frac{\text{Concentration (ppm)} \times \text{Dilution factor}}{\text{Wt.of sample}} \times 1000 \quad \text{equation 3}$$

2.11.5. Determination of phosphorus

A sample solution (20 mL) was put in a 100 mL volumetric flask. The solution was neutralized with ammonia and nitric acid solution (1:2). Twenty (20) mL of vanadate molybdate reagent was added and diluted to the mark and then allowed to stand for 10 min and absorbance was read at 470 nm in the ultra violet region and the mineral concentration at mg/100 g was calculated using equation (4):

$$\text{Phosphorus (mg / 100 g)} = \frac{\text{Concentration (ppm)} \times \text{Dilution factor}}{\text{Wt.of sample}} \times 100 \quad \text{equation 4}$$

2.11.6. Determination of sodium

The concentrations of Sodium (ppm) were analyzed using a UV- spectrophotometer at a wavelength of 443.5 nm, and the concentration in mg/100 g was calculated using equation (5):

$$\text{Sodium (mg / 100 g)} = \frac{\text{Concentration (ppm)} \times \text{Dilution factor}}{\text{Wt.of sample}} \times 1000 \quad \text{equation 5}$$

2.12. Statistical analysis

Data generated from the respective analysis was compiled appropriately and subjected to Analysis of Variance (ANOVA). The mean of other data was separated by using the Duncan Multiple Range test (Statistical Package for Social Science, version 25.0).

3. Results and discussion

3.1. The sensory evaluation of whole wheat, soy okara and tigernut residue biscuits

Table 3 depicts the sensory evaluation of biscuits produced from whole wheat, soy okara and tigernut residue flours (Fig. 5). The result showed that sample MVP (100:0:0) significantly.

JAR: 50.75:39.25:10; VET: 44.08:40.0:15.92; ZKT: 43.64:34.42:21.94; IOI: 40.0:31.50:28.50; MVP: 100:0:0; XEC: 56.32:27.39:16.29; GEN: 53.79:22.57:23.64; XRP: 50:20:30; BCA: 57.05:32.95:10; XNL: 45.90:26.35:27.74; ISP: 60:20.98:19.02; NBC: 50.02:29.47:20.51; whole wheat-soy okara-tigernut residue flour biscuits respectively.

Differed ($p < 0.05$) from the rest of the biscuit samples in all the quality attributes assessed. The mean scores for the sensory

Table 3The sensory evaluation of whole wheat-soy *okara*-tigernut residue flour biscuits.

Samples	MVP	NBC	GEN	XNL	BCA	VET	XEC	XRP	ISP	IOI	JAR	ZKT
WH: SO:TR (%)	100: 0: 0	50.02:29.47: 20.51	53.79:22.57: 23.64	45.90:26.35:27.74	57.05:32.95: 10	44.08:40:15.92	56.32:27.39: 16.29	50:20:30	60:20.98:19.02	40:31.50:28.50	50.75:39.25:10	43.64:34.42:21.94
Color	7.68 ^a ±1.14	7.68 ^a ±1.14	6.20 ^{cde} ± 1.15	6.20 ^{cde} ± 1.47	6.40 ^{bcd} ± 1.58	5.64 ^{de} ± 1.38	6.44 ^{bcd} ± 0.9	5.36 ^e ±1.29	7.16 ^{ab} ± 1.28	5.68 ^{de} ± 1.25	6.76 ^{bc} ±1.30	5.92 ^{cde} ± 1.85
Appearance	7.64 ^a ±0.99	5.96 ^c ±1.24	6.20 ^{bc} ±1.26	6.24 ^{bc} ±1.42	6.16 ^{bc} ±1.49	5.72 ^c ±1.43	6.44 ^{bd} ± 0.71	5.60 ^e ±1.61	6.92 ^{ab} ± 1.38	5.76 ^c ±1.16	6.96 ^{ab} ± 0.98	5.68 ^c ±1.95
Mouthfeel	7.96 ^a ±0.93	5.68 ^{bcd} ± 1.49	6.12 ^{bc} ±1.72	5.56 ^{bcd} ± 1.66	5.48 ^{bcde} ± 1.98	4.80 ^{def} ±1.61	5.56 ^{bcd} ± 1.08	4.48 ^f ±1.33	7.32 ^a ±1.60	4.60 ^{ef} ±1.38	6.36 ^b ± 1.32	5.40 ^{cde} ± 1.04
Aroma	7.76 ^a ±1.09	5.52 ^c ±1.23	5.68 ^c ±1.35	5.20 ^{cd} ± 1.55	5.52 ^c ±1.71	4.24 ^e ±1.59	5.68 ^c ±1.14	4.52 ^{de} ± 1.19	6.64 ^b ± 1.58	4.28 ^e ±1.31	5.88 ^{bc} ±1.27	5.12 ^{cd} ± 1.69
Sweetness	8.32 ^a ±0.90	5.56 ^{cde} ± 1.75	6.16 ^c ±1.49	5.20 ^{de} ± 1.47	5.80 ^{cde} ± 1.68	4.32 ^{fg} ± 1.63	6.12 ^{cd} ± 1.33	4.16 ^g ± 1.52	7.20 ^b ± 1.35	3.96 ^g ± 1.14	5.92 ^{cde} ± 1.85	5.04 ^{ef} ±1.56
Crunchiness	8.20 ^a ±1.04	4.16 ^{de} ± 1.46	5.60 ^{bc} ±1.53	5.44 ^{bc} ±1.83	3.80 ^e ±1.76	3.64 ^e ±1.50	4.84 ^{cd} ± 1.34	3.80 ^e ±1.32	7.40 ^a ±1.47	4.24 ^{de} ± 1.23	6.36 ^b ± 1.70	5.36 ^{bc} ±1.35
Crispiness	7.56 ^a ±1.64	4.72 ^{cd} ± 1.65	5.44 ^{bc} ±1.56	5.48 ^{bc} ±1.66	3.80 ^e ±1.66	3.56 ^e ±1.56	4.88 ^{cd} ± 1.20	3.72 ^e ±1.17	7.12 ^a ±1.22	4.16 ^{de} ± 1.25	6.04 ^b ± 1.84	5.32 ^{bc} ±1.65
Overall Acceptability	8.36 ^a ±0.70	5.60 ^{de} ± 1.63	6.08 ^{cd} ± 1.29	5.44 ^{de} ± 1.78	5.08 ^{efg} ±2.04	4.56 ^{fg} ± 1.42	5.84 ^{cde} ± 1.11	4.52 ^g ± 1.29	7.52 ^b ± 1.19	4.40 ^g ± 1.32	6.64 ^c ±1.50	5.40 ^{def} ±1.66

*Values are means ± standard deviation. Means with different superscript in the same row are significantly different ($p < 0.05$). WH = Whole wheat flour, SO = Soy *okara* flour, TR = Tigernut residue flour.



Fig. 5. Production of whole wheat + soy okara + tigernut residue biscuits.

attributes of the samples ranged from 5.36 to 7.68 for color, 5.60–7.64 for appearance, 4.48–7.96 for mouthfeel, 4.24–7.76 for aroma, 3.96–8.32 for taste, 3.46–8.20 for crunchiness, 3.56–7.56 for crispiness and 5.08–8.36 for overall acceptability. The mean scores (5.08–8.36) for the overall acceptability of the whole wheat/soy *okara*-tigernut residue biscuits were above the average (5), indicating high acceptability of the samples. The control sample (MVP) had the highest value (8.36), closely followed by samples ISP (60:20.98:19.02) (7.52), JAR (50.75:39.25:10) (6.54), GEN (53.79:22.57:23.64) (6.08) and XEC (56.23:27.39:16.29) (5.84) while sample BCA (57.05:32.95:10) had the least value (5.08). According to Nwatum et al. [25], the baking conditions (temperature and time variables); the state of the biscuit constituents, such as fiber, starch, protein (gluten), whether damaged or undamaged and the amounts of absorbed water during dough mixing, all contribute to the outcome of the overall acceptability. It was based on the high preference of the five samples that were selected for chemical and physical analysis.

Table 4
Physical properties (mm) of the whole wheat-soy *okara*-tigernut residue flour biscuits.

Samples	WH:SO:TR	Thickness	Diameter	Height	Spread Ratio	Weight (g)	Break Strength
MVP	100:0:0	6.10 ^b ± 0.02	38.14 ^a ±0.03	37.75 ^a ±0.03	6.10 ^a ±0.01	7.40 ^b ± 0.10	600.00 ^d ± 1.01
ISP	60:20.98:19.02	6.17 ^a ±0.03	38.16 ^a ±0.03	37.73 ^a ±0.03	6.07 ^b ± 0.01	7.47 ^b ± 0.06	643.00 ^a ±2.65
JAR	50.75:39.25:10	6.15 ^{ab} ± 0.02	38.13 ^a ±0.03	37.76 ^a ±0.02	6.03 ^c ±0.01	7.73 ^a ±0.15	640.00 ^{ab} ± 2.5
GEN	53.79:22.57:23.64	6.14 ^{ab} ± 0.03	38.15 ^a ±0.03	37.74 ^a ±0.03	5.83 ^d ± 0.01	7.30 ^b ± 0.10	637.00 ^b ± 2.65
XEC	56.32:27.39:16.29	6.12 ^b ± 0.03	38.17 ^a ±0.03	37.77 ^a ±0.03	5.73 ^c ±0.03	7.50 ^b ± 0.10	630.00 ^c ±2.65

*Values are means ± standard deviation of triplicate determinations. Means with different superscript in the same column are significantly different ($p < 0.05$). WH = Whole wheat flour, SO = Soy *okara* flour, TR = Tigernut residue flour.

3.2. Physical properties (mm) of whole wheat-soy okara-tigernut residue flour biscuits

Table 4 shows the physical properties of the most preferred whole wheat-soy okara-tigernut residue flour biscuits (Fig. 6). The result revealed that incorporation of soy okara and tigernut residue significantly affected some of the physical properties of biscuit samples although no definite trend was observed. There was no significant difference ($p > 0.05$) in the diameter and height of the biscuit samples, which recorded values ranging from 38.13 mm to 38.17 mm and 37.73 mm–37.77 mm respectively. Some significant differences ($p < 0.05$) however, existed in the thickness (6.10–6.17 mm), spread ratio (5.73–6.10 mm), weight (7.30–7.73 g) and breaking strength (600–643 g).

The result of the physical properties of biscuits showed that supplementation of whole wheat flour with flours from soy okara and tigernut residue gave no significant difference ($p > 0.05$) in the diameter (38.13–38.17 mm) and height (37.73–37.76 mm) of the samples as they all compared favorably with the control, whereas this effect slightly affected the thickness of the supplemented biscuits from 6.10 mm to 6.17 mm, although some significant differences ($p < 0.05$) were observed. Similar observations were reported for cookies made with wheat, walnut, and carrot flour [26].

MVP: 100:0:0; **ISP:** 60:20.98:19.02; **JAR:** 50.75:39.25:10; **GEN:** 53.79:22.57:23.64; **XEC:** 56.32:27.39:16.29 whole wheat-soy okara-tigernut residue flour biscuits respectively.

The spread ratio is an important characteristic for determining the quality of biscuits. Biscuits with higher spread ratios are the most desirable [27]. It was observed that incorporation of wheat flour with soy okara and tigernut residue flour significantly ($p < 0.05$) reduced the spread ratio from 6.10 mm in the control sample (100:0:0) to 5.73 mm in sample XEC (56.23:27.39:16.29). This is contrary to the report of Porcel et al. [28] who reported that the inclusion of soy okara provoked an increase in the spread ratio of cookies. A slightly higher spread ratio (6.73–7.32 mm) was also reported by Eke-Ejiofor and Deedam [29], for wheat-tigernut residue biscuits. Processing methods adopted as well as differences in the raw materials used could be possible reasons for this variation in the spread ratio of the samples.

Also, there was no significant difference ($p > 0.05$) in the weight of the biscuit samples except for sample JAR (50.75:39.25:10). The values ranged from 7.30 g in sample GEN (53.79:22.57:23.64) to 7.73 g in sample JAR (50.75:39.25:10). The results revealed that incorporation of soy okara and tigernut residue in the biscuit samples did not significantly affect the weight of the samples. The value of the weight of the biscuit samples obtained in this was lower than 9.69–18.20 g reported for wheat-sorghum-defatted coconut cookies as noted by Ref. [30]. This could be attributed to differences in the raw materials used.

The breaking strength of the cookie samples significantly differed ($p < 0.05$) from one another with values ranging from 600 to 643 g. The control sample (100:0:0) had the least breaking strength while sample ISP (60:20.98:19.02) had the highest breaking strength. These values were lower compared to 1827–2164 g reported by Okpala and Ofoedu [31]. The varied results could be due to differences in raw materials used as well as the formulation recipe used.

3.3. Proximate composition (%) of the whole wheat/soy okara-tigernut residue flour biscuits

The proximate composition results of the most preferred biscuits (Fig. 6) are presented in Table 5. There were some significant differences ($p < 0.05$) in the quality parameters of the biscuit samples. The ash content of the samples ranged from 1.70 to 1.90%, moisture content ranged from 4.00 to 5.70%, fat ranged from 16.20 to 17.30%, fiber ranged from 7.00 to 11.30%, protein ranged from 6.50 to 12.00% and carbohydrate content ranged from 57.20 to 59.20%. As observed in Table 5, incorporation of soy okara and tigernut residue flour in the biscuit samples slightly reduced their ash, moisture and protein content while the fat, fiber and carbohydrate content of the biscuit samples increased slightly.

Because ash is the inorganic residue left after the water and organic materials have been removed by heating in the presence of an oxidizing agent, the ash content of a food material could be used as an indication of mineral elements of the food [26]. As shown in Table 5, the ash contents of the supplemented biscuits were lower than that of the control biscuit product. Sample ISP had a value of 1.86% followed by sample JAR (50.75:39.25:10) (1.80%), sample GEN (53.79:22.57:23.64) (1.74%), sample XEC (56.23:27.39:16.29) (1.70%) and the control (100:0:0) with the highest value of 1.90%. The result showed that incorporation of soy okara and tigernut



Fig. 6. Best five (5) biscuit samples from sensory evaluation result.

Table 5
Proximate composition (%) of whole wheat-soy *okara*-tigernut residue flour biscuits.

Samples	WH:SO:TR	Ash	Moisture	Fat	Fiber	Protein	Carbohydrate
MVP	100:0:0	1.90 ^a ±0.01	5.70 ^a ±0.26	16.20 ^b ± 0.26	7.00 ^c ±2.65	12.00 ^a ±1.00	57.20 ^d ± 0.26
ISP	60:20.98:19.02	1.86 ^b ± 0.01	5.50 ^a ±0.26	16.40 ^{ab} ± 0.26	8.30 ^{bc} ±0.26	11.00 ^a ±1.00	56.94 ^c ±0.03
JAR	50.75:39.25:10	1.80 ^c ±0.01	5.00 ^b ± 0.26	16.63 ^{ab} ± 0.25	9.40 ^{ab} ± 0.26	9.00 ^b ± 1.00	58.20 ^b ± 0.03
GEN	53.79:22.57:23.64	1.74 ^d ± 0.01	4.70 ^b ± 0.26	17.00 ^{ab} ± 1.00	10.47 ^{ab} ± 0.29	7.00 ^c ±1.00	59.06 ^a ±0.03
XEC	56.32:27.39:16.29	1.70 ^e ±0.01	4.00 ^c ±0.26	17.30 ^a ±0.26	11.30 ^a ±0.26	6.50 ^c ±0.10	59.20 ^a ±0.10

*Values are means ± standard deviation of triplicate determinations. Means with different superscript in the same column are significantly different ($p < 0.05$). WH = Whole wheat flour, SR = Soy *okara* flour, TR = Tigernut residue flour.

residue flour slightly decreased the ash content of the product. Ilelaboye and Jesusina [32] reported a similar decrease (3.00–2.70%) in the ash content of plantain-sorghum composite biscuits fortified with soy *okara* although their values were quite higher than the ones obtained in this study.

In a related study by Eke-Ejiofor and Deedam [29], slightly lower ash content ranging from 1.34 to 1.84% was reported for wheat-tigernut residue composite biscuits. The variations in these results could be due to differences in the raw materials used as well as differences in the blending proportions.

There was no significant difference ($p > 0.05$) in the moisture content of samples MVP (100:0:0) (5.70%) and ISP (60:20.98:19.02) (5.50%) and those of samples JAR (50.75:39.25:10) (5.00%) and GEN (53.79:22.57:23.64) (4.70%) but they varied significantly ($p < 0.5$) from that of Sample XEC (56.23:27.39:16.29) (4.00%). The influence of incorporation of soy *okara* and tigernut residue on the moisture content of the biscuit samples was clear as all the composite samples had lower moisture compared to the control sample. Similar values ranging from 3.70 to 4.60% was reported, as the moisture content of biscuits produced from blends of maize and tigernut flours [33]. Alebiosu et al. [30] found that cookies made from composite flours of wheat, sorghum, and defatted coconut flour had increased moisture content, ranging from 7.10 to 10.89%. Differences in the raw materials utilized, as well as environmental and experimental conditions, can explain the variation in moisture content [34]. If the biscuits were protected from absorbing moisture by adequate packaging, the low moisture content obtained in this study was beneficial for preventing microbiological activity and extending the shelf-life of the biscuits.

There was a slight increase in the fat content of the fortified biscuits when compared to the control sample. The percentage fat content of the biscuit samples ranged from 16.20% in sample MVP (100:0:0) to 17.30% in sample XEC (56.23:27.39:16.29). The fat content of samples ISP (60:20.98:19.02), JAR (50.75:39.25:10) and GEN (53.79:22.57:23.64) were statistically the same ($p < 0.05$) although they significantly differed ($p < 0.05$) from those of samples MVP (100:0:0) and XEC (56.23:27.39:16.29). The percentage fat content obtained in this study was within range (9.95–20.45%) reported by Nwatum et al. (2020) for biscuits produced from wheat, defatted peanut, and avocado flour blends but lower than 3.20–4.20% reported by Ilelaboye and Jesusina [32] for plantain-sorghum composite biscuits fortified with soy *okara*. The variances in the basic materials utilized could be to blame for the varying results. It could also be due to the function of the butter used in the biscuit making process [33]. Although fat increases absorption of fat-soluble vitamins, offers vital fatty acids, and crucial volatile chemicals for flavor and sensory aspects, high-fat content in food, particularly baked goods, might facilitate rancidity during storage [35].

As was expected, there was significant increase in the fiber content of the biscuit samples. The values increased from 7.00% in sample MVP (100:0:0) to 11.30% in sample XEC (56.23:27.39:16.29). This agrees with the study of Eke-Ejiofor and Deedam [29] who reported a similar increase (1.06–3.13%) in fiber content of biscuits produced from wheat-tigernut residue composite flour. Adeoye et al. [36] also reported an increase in fiber content (0.48–1.03%) of wheat biscuit fortified with pineapple peel flour although their values were lower than the ones obtained in this study. Crude fiber composition is a measure of the quality of indigestible cellulose, pentose, lignin, and other indigestible materials [37]. Although crude fiber has minimal nutritional value, it aids in the increased utilization of nitrogen and absorption of some other micronutrients, as well as providing bulk for peristaltic activity in the intestine [33].

The protein content of the biscuit samples decreased significantly ($p < 0.05$) with inclusion of soy *okara* and tigernut residue flour. Protein content was highest (12.00%) in the control sample and least (6.50%) in sample XEC (56.23:27.39:16.29). The decrease in the protein content of all the fortified samples was expected as the protein fractions of soybean and tigernut were largely removed during processing and the resulting residue composed of mainly roughages [38]. This observation was in line with the report of Porcel et al. [28] who noted a similar decrease in the protein content of wheat biscuits fortified with dry tigernut residue. The values of protein obtained in the present study appear less than the recommended daily requirement for protein (25–30 g/day) for ages 15 and 19 years as recommended by WHO [39] cited in Kiin-Kabari et al. [26]. This indicates that the frequent eating of this snack may serve to alleviate the problem of protein deficiencies in children, of which are the targets for production of this nutritionally improved product, and for adults who may want to snack on healthy food products.

The carbohydrate content of the samples varied significantly ($p < 0.05$) from 56.94 to 96.20%. Sample XEC (56.23:27.39:16.29) had the highest carbohydrate content, while Sample ISP (60:20.98:19.02) had the least. The carbohydrate content of the whole wheat-soy *okara*-tigernut residue biscuit was like 55.52–66.27% reported for maize-tigernut flour [33] but lower than 74.70–80.80% reported for plantain-sorghum biscuits fortified with soy *okara* [32]. This may be attributed to the differences in the raw materials used. According to Okache et al. [40], carbohydrate content contributes to the energy value of food formulations. The high carbohydrate in

these biscuits makes them ideal for all age groups, most especially infants, since they require energy for their rapid growth.

3.4. Mineral composition (mg/100 g) of whole wheat-soy okara-tigernut residue flour biscuits

The mineral composition of biscuits produced from composite flours of whole wheat-soy okara-tigernut residue flour is shown in Table 6. Significant differences ($p < 0.05$) exist amongst the samples in their mineral content. The results revealed that inclusion of soy okara and tigernut residue flour increased the magnesium, sodium and iron content of the biscuit samples from 122.00 mg/100 g to 134.00 mg/100 g, 16.00 mg/100 g to 28.00 mg/100 g and 2.30 mg/100 g to 3.50 mg/100 g respectively. However, the calcium and phosphorus content of the samples decreased from 24.00 mg/100 g to 12.00 mg/100 g and 121.00 mg/100 g to 100.00 mg/100 g respectively.

There was significant difference ($p < 0.05$) in the magnesium content of the samples which ranged from 122.00 mg/100 g to 134.00 mg/100 g. The highest magnesium content was recorded for sample MVP (100:0:0) while sample XEC (56.23:27.39:16.29) had the least value of magnesium. It was observed that inclusion of soy okara and tigernut residue flour in the biscuit formulation generally improved the magnesium content of all the composite samples.

The values obtained for magnesium in this study are higher than the range of values (78.55–98.88 mg/100 g) reported for the wheat-defatted peanut-avocado biscuit [25] although the study agreed to the fact that inclusion of byproducts improved the magnesium content of the biscuits. The varied results may be attributed to differences in the raw materials used. Magnesium has been shown to be an activator of a variety of enzyme systems as well as a regulator of nerve electrical potential. Magnesium works with calcium to help in muscular contraction, blood clotting, blood pressure management, and lung function [41]. Because the biscuits had a large amount of the element, they could be an ideal snack for both men and women.

The sodium content of the biscuits ranged from 16.00 mg/100 g to 28.00 mg/100 g and there was significant difference ($p < 0.05$) among the values obtained. These values do not meet the United State Department of Agriculture (USDA) recommendation for sodium (1500 mg/g) [42]. The values were however, higher than 14.11–16.08 mg/100 g reported by Ilelaboye and Jesusina [32] for the sodium content of cookies produced from flour blends of wheat, walnut, and carrots. Differences in the raw materials used could be the reason for the varied results. Sodium is an electrolyte compound which helps in balancing fluids in the human body system. It is also required for nerve and muscle functioning but over-consumption can lead to kidney damage and increased chances of high blood pressure [43].

The Calcium content of the biscuits significantly decreased ($p < 0.05$) from 24.00 mg/100 g in the control sample (100:0:0) to 12.00 mg/100 g in sample XEC (56.23:27.39:16.29). Inclusion of soy okara and tigernut residue flour in the formulated biscuits significantly reduced their calcium content. These values were lower than that (101.7–259.1 mg/100 g) reported by Ref. [30] for cookies produced from wheat, sorghum and defatted coconut composite flours. The U.K. Department of Health recommended nutrient intake of 1000 mg/day of calcium for adult and 550 mg/day for infants and children [44]. Thus, to meet the recommended reference intake of calcium, the biscuits should be consumed in accompaniment with other calcium-rich or fortified beverages such as milk. Calcium aids in the development of bones and provides skeletal bones with support and rigidity. It aids in the regulation of cardiac tone and contractility, as well as acting as an antidote to potassium's depressive effects [44].

There was an improvement in the iron content of biscuit products as all the supplemented samples had values higher than the control and ranged from 2.30 mg/100 g to 3.50 mg/100 g with no significant difference ($p > 0.05$) among the samples except in samples GEN (53.79:22.57:23.64) and XEC (56.23:27.39:16.29). Alebiosu et al. [30], also reported improvement in iron content (3.73 mg/100 g–6.50 mg/100 g) of cookies produced from Wheat-sorghum-defatted coconut composite flour. Iron is an essential trace element which plays vital roles such as hemoglobin formation and oxidation of fats, protein, and carbohydrates [26]. The WHO [39] daily recommended intake of iron for children (6–59 months) is 5.8 mg/100 g. Hence, children can get the required iron from consuming samples together with other foods.

The phosphorus content of the formulated biscuits samples ranged from 100 to 121 mg/100 g. There were significant ($p < 0.05$) differences among the samples with regards to phosphorus content. The highest value was observed in the control sample (100:0:0) while the least value was observed in sample XEC (56.23:27.39:16.29). The results obtained were less than the values (176.37–221.36 mg/100 g) recorded for biscuits made from blends of wheat, defatted peanut, and avocado composite flour [25]. The variation in the results could be attributed to the differences in the raw materials used. Phosphorus is a mineral that is necessary for the growth and repair of body cells and tissues. Calcium and phosphorus work together to provide structure and strength. Phosphorus is also needed for several metabolic processes, including energy production and control [45].

Table 6

Mineral composition (mg/100 g) of whole wheat-soy okara-tigernut residue flour biscuits.

Samples	WH:SR:TR	Magnesium	Sodium	Calcium	Iron	Phosphorus
MVP	100:0:0	122.00 ^d ± 2.65	16.00 ^d ± 2.65	24.00 ^a ±2.18	2.30 ^b ± 0.26	121.00 ^a ±2.5
ISP	60:20.98:19.02	126.00 ^{cd} ± 2.65	20.00 ^{cd} ± 2.65	22.00 ^{ab} ± 2.65	2.50 ^b ± 0.26	118.00 ^{ab} ± 2.65
JAR	50.75:39.25:10	128.00 ^{bc} ±2.65	22.00 ^{bc} ±2.65	18.00 ^{bc} ±2.65	2.70 ^b ± 0.26	116.00 ^{ab} ± 2.65
GEN	53.79:22.57:23.64	132.00 ^{ab} ± 2.65	25.00 ^{ab} ± 2.65	16.00 ^{cd} ± 2.65	3.30 ^a ±0.26	113.00 ^b ± 2.5
XEC	56.32:27.39:16.29	134.00 ^a ±2.65	28.00 ^a ±0.99	12.00 ^d ± 3.12	3.50 ^a ±0.10	100.00 ^c ±2.64

*Values are means ± standard deviation of triplicate determinations. Means with different superscript in the same column are significantly different ($p < 0.05$). WH = Whole wheat flour, SR = Soybean residue flour, TR = Tigernut residue flour.

4. Conclusion

The study showed that substitution of wheat flour with soy *okara* and tigernut residue flour at a ratio of 60:20.98:19.02 yielded the most acceptable nutritious biscuit and compared favorably with a 100% whole wheat biscuit in all the sensory attributes assessed. The biscuits produced from this composite blend contain sufficient amounts of protein, good fat, minimal carbohydrate, and sufficient fiber, as well as magnesium, sodium and iron - hence can serve as relief for malnutrition. Also, the inclusion of these byproducts did not adversely affect the physical properties of the formulated biscuits. Soy *okara* and tigernut residue are therefore viable substitutes for wheat flour since a huge percentage of our foreign reserves is utilized in the importation of wheat. Additionally, these byproducts, which are expected waste, can be turned to wealth and diversification in terms of usage. Thus, judicious incorporation of these byproducts in suitable proportions into bakery products to enhance dietary quality should therefore be encouraged. This could serve as a means of tackling and combating protein-energy malnutrition and improve the health status of vulnerable groups.

Author contribution statement

Helen Obioma Agu: Conceived and designed the experiments; Performed the experiments; Wrote the paper. Jennifer Chikamara Ihionu: Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper. Joy Chinenye Mba: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Data included in article/supplementary material/referenced in article.

Additional information

No additional information is available for this paper.

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.

Acknowledgements

The authors acknowledge the Department of Food Science and Technology, Nnamdi Azikiwe University Awka, Anambra State, Nigeria and, Federal Ministry of Health, National Arbovirus and Vector Research centre, Enugu, Enugu State, Nigeria where the research was carried out.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.heliyon.2023.e15318>.

References

- [1] M. Mudau, S.E. Ramashia, M.E. Mashau, H. Silungwe, Physicochemical characteristics of bread partially substituted with finger millet (*Eleusine corocana*) flour, *Braz. J. Food Technol.* 24 (2021) 1–14.
- [2] M.C. Temba, P.B. Njobeh, O.A. Adebo, A.O. Olugbile, E. Kayitesi, The role of compositing cereals with legumes to alleviate protein energy malnutrition in Africa, *Int. J. Food Sci. Technol.* 51 (2016) 543–554.
- [3] K. Nishinari, Y. Fang, S. Guo, G.O. Phillips, Soy proteins: a review on composition, aggregation, and emulsification, *Food Hydrocolloids* 39 (2014) 301–318.
- [4] K. Dajanta, A. Apichartsrangkoon, E. Chukeatirote, R.A. Frazier, Free-amino acid profiles of thua nao, a Thai fermented soybean, *Food Chem.* 125 (2011) 342–347.
- [5] S.P. Stanovic, M.B. Barac, M.B. Pesic, V.S. Jankovic, B.V. Vucelic-Radovic, Bioactive proteins and energy value of *okara* as a byproduct in hydrothermal processing of soy milk, *J. Agric. Food Chem.* 61 (2013) 9210–9219.
- [6] Y. Li, J. Hao, Y. Cheng, R. Zhao, L. Yin, L. Li, Improvement of *okara* mouthfeel by *Aspergillus niger* and *Aspergillus oryzae* fermentation, *Agric. Eng.* 28 (2012) 248–253.
- [7] A. Jimenez-Escrig, M.D. Tenorio, I. Espinosa-Martos, P. Ruperez, Health-promoting effects of a dietary fiber concentrate from the soybean byproduct *okara* in rats, *J. Agric. Food Chem.* 56 (2008) 7495–7501.
- [8] D. Song, S.K.C. Chang, A.A. Ibrahim, Effect of fermentation substrates on enzyme production and degradation of oligosaccharides in pinto bean flour as affected by particle size, *J. Food Process. Preserv.* 33 (2009) 527–546.

- [9] G.B. Voss, L.M. Rodríguez-Alcalá, L.M.P. Valente, M.M. Pintado, Impact of different thermal treatments and storage conditions on the stability of soybean byproduct (*okara*), *J. Food Meas. Char.* 12 (2018) 1981–1996, 2018.
- [10] R. Bedani, E.A. Rossi, D.C. Cavallini, R.A. Pinto, R.C. Vendramini, E.M. Augusto, Influence of daily consumption of symbiotic soy-based product supplemented with *okara* soybean by-product on risk factors for cardiovascular diseases, *Food Reserve Int.* 73 (2015) 142–148.
- [11] W.C. Vong, S.Q. Liu, Biovalorisation of *okara* (soybean residue) for food and nutrition, *Trends Food Sci. Technol.* 52 (2016) 139–140.
- [12] C. Ekeanyanwu, I. Ononogbu, Nutritive value of Nigerian *tigernut* (*Cyperus esculentus* L.), *Agric. J.* 5 (2010) 297–302.
- [13] R. Abaejoh, I. Djomdi, R. Ndojounkeu, Characteristics of tigernut (*Cyperus esculentus*) tubers and their performance in the production of a milky drink, *J. Food Process. Preserv.* 30 (2006) 145–163.
- [14] Wayah S and Shehu S, Assessment of the nutritional and antinutritional components of *tigernut* residues. *Int. J. Sci. Res.* 4(6): 342-344.
- [15] J.A. Adejuyitan, E.T. Otunola, E.A. Akande, I.F. Bolarinwa, F.M. Oladokun, Some physicochemical properties of flour obtained from fermentation of *tigernut* (*Cyperus esculentus*) sourced from a market in Ogbomosho, Nigeria, *Afr. J. Food Sci.* 3 (2009) 51–55.
- [16] O. Borges, B. Goncalves, L. Sgeoeiro, P. Correia, A. Silva, Nutritional quality of chestnut cultivars from Portugal, *Food Chem.* 106 (2008) 976–984.
- [17] J. Ndife, F. Kida, S. Fagbemi, Production and quality assessment of enriched cookies from whole wheat and full fat soya, *Eur. J. Food Sci. Technol.* 2 (1) (2014) 19–28.
- [18] I.E. Mbaeyi-Nwaoha, N.O. Uchendu, Production and evaluation of breakfast cereals from blends of acha and fermented soybean paste (*okara*), *J. Food Sci. Technol.* 53 (1) (2016) 50–70.
- [19] E.K. Senya, F. Kwaatema, K.R. Sitsofe, Production and acceptability of tit-bits made from wheat and *tigernut* flour blends, *Int. J. Appl. Agric. Res.* 5 (1) (2021) 142–147.
- [20] O.M. Makanjuola, O.J. Adebawale, Vitamins, functional and sensory attributes of biscuit produced from wheat-cocoyam composite flour, *J. Sci. Innovat. Res.* 9 (2) (2020) 77–82.
- [21] M.O. Iwe, G.O. Okereke, A.N. Agiriga, Production and evaluation of bread made from modified cassava starch and wheat flour blends, *Agrotechnology* 4 (1) (2014) 133–139.
- [22] C.M. Bunde-Tsegba, V. Okeke, I.A. Sengeve, Effect of soybean addition on the quality of plantain-based biscuits, *Food Sci. Nutr. Res.* 4 (1) (2021) 1–6.
- [23] AOAC, Official Methods of Analysis, eighteenth ed., Association of official analytical chemists, Washington, D.C., U.S.A, 2010.
- [24] G.I. Onwuka, Food Analysis and Instrumentation Theory and Practice: Analytical Techniques, second ed., Naphthali prints, Surulere, 2018, pp. 229–230.
- [25] I.A. Nwatum, M.T. Ukeyima, M.O. Eke, Production and quality evaluation of cookies from wheat defatted peanut and avocado composite flour, *Asian Food Sci. J.* 15 (4) (2020) 1–12.
- [26] D.B. Kiin-Kabari, C.U. Mbanefo, O.M. Akusu, Production, nutritional evaluation and acceptability of cookies made from a blend of wheat, African walnut, and carrot flours, *Asian Food Sci. J.* 20 (6) (2021) 60–76.
- [27] A. Chauhan, D.C. Saxena, S. Singh, Physical, textural and sensory characteristics of wheat and amaranth flour blend cookies, *Cogent Food Agric.* 2 (2016) 112–773.
- [28] M.V.O. Porcel, A.N. Rinaldoni, L.T. Rodríguez Furlan, M.E. Campderrós, Influence of the particle size and level of substitution of *okara* flour in the development of gluten-free cookies, *Int. J. Res. Advent Technol.* 4 (8) (2016) 82–92.
- [29] J. Eke-Ejiofor, J.N. Deedam, Effect of *tigernut* residue flour inclusion on the baking quality of confectionaries, *J. Food Res.* 4 (5) (2015) 172–180.
- [30] M.O. Alebiosu, B.A. Akinbode, I.S. Oni, J.O. Oladele, Quality evaluation of cookies produced from wheat, sorghum and defatted coconut flour blends, *Asian Food Sci. J.* 17 (3) (2020) 11–21.
- [31] L.C. Okpala, P.I. Ofoedu, Quality characteristics of cookies produced from sweet potato and wheat flour blend fortified with brewer's spent grain flour, *Curr. Res. Nutr. Food Sci.* 6 (1) (2018) 113–119.
- [32] N.O. Ilelaboye, T.I. Jesusina, Proximate composition, functional properties and sensory evaluation of cracker biscuit from *okara* fortified plantain-sorghum flour blend, *J. Women Tech. Educ. Employ.* 1 (1) (2020) 17–27.
- [33] P.C. Obinna-Echem, H.I. Wachukwu-Chikaodi, A.D. Okwagwung, Functional properties of tigernut and cowpea flour blends, *Eur. J. Agric. Food Sci.* 2 (6) (2020) 1–5.
- [34] N.E. Obasi, N. Uchechukwu, E. Eke-Obia, Production and evaluation of biscuits from African yam bean (*Sphenostylis stenocarpa*) and wheat (*Triticum aestivum*) flours, *Food Sci. Qual. Manag.* 7 (2012) 5–12.
- [35] A. Musa, T. Lawal, Proximate composition of ten types of biscuits and their susceptibility to *tribolium castaneum* herbst (*Tenebrionidae bostrichidae*) in Nigeria, *Food Sci. Qual. Manag.* 14 (2013) 33–40.
- [36] B.K. Adeoye, A.I. Alao, J.A. Famurewa, Quality evaluation biscuits produced from wheat and pineapple peel flour, *Appl. Trop. Agric.* 22 (2) (2017) 210–217.
- [37] L.O. Akajiaku, N.O. Kabuo, S.O. Alagbaoso, I.G. Orji, A.S. Nwogu, Proximate, mineral and sensory properties of cookies made from tiger-nut flour, *J. Nutr. Diet Pract.* 2 (1) (2018) 1–5.
- [38] A. V'azquez-Ovando, G. Rosado-Rubio, L. Chel-Guerrero, D. Betancur-Ancona, Physicochemical properties of a fibrous fraction from chia (*Salvia hispanica* L.), *Food Sci. Technol.* 42 (2009) 168–173.
- [39] World Health Organization, Make Every Mother and Child Count, World Health Organization, Geneva, Switzerland, 2005.
- [40] T.A. Okache, J.K. Agomuo, I.Z. Kaida, Production and evaluation of breakfast cereal produced from finger millet, wheat, soybean, and peanut flour blend, *Res. J. Food Sci. Qual. Control* 6 (2) (2020) 9–19.
- [41] R. Swaminathan, Magnesium metabolism and its disorders, *Clin. Biochem. Rev.* 24 (2) (2013) 47–66.
- [42] USDA, World Soybean Production 2007 Soy Stats, American Soybean Association, 2010. Annual report. 2 pages.
- [43] G.M. Wardlaw, Perspectives in Nutrition, sixth ed., McGraw Hill Companies, New York, U.S.A, 2004, pp. 1–72.
- [44] P. Pravina, D. Sayaji, M. Avinash, Calcium and its role in human body, *Int. J. Res. Pharm. Biomed. Sci.* 4 (2) (2013) 659–668.
- [45] N.E. Odimegwu, C.E. Ofoedu, G.C. Omeire, M.C. Umelo, C.N. Eluchie, S.O. Alagbaoso, N.E. Njoku, P.O. Ozoani, Production and evaluation of breakfast cereals from flour blends of maize (*Zea mays*) and jackfruit (*Artocarpus heterophyllus*) seeds, *Arch. Curr. Res. Int.* 16 (3) (2019) 1–16.