

Chemical Composition and Sensory Properties of Wheat, African Yam Bean and Tiger Nut Residue Composite Flour Cookies

ABSTRACT

This study looked into the use of a blend of Wheat, African yam bean and tiger nut residue flours for the production of cookies and assessment of its chemical and sensory properties. The experiment used a completely randomized design, a total of 5 samples of the composite flour and one control (100% wheat flour) were obtained and used to bake the cookies. Proximate composition, mineral and sensory properties of the cookies were evaluated; the moisture content of the cookies ranged from 5.43 % to 6.91 %, ash content ranged from 1.33 % to 2.10 %, fat contents ranged from 6.70 % to 12.20 %, crude fibre content ranged from 3.85 % to 7.65 %, crude protein contents ranged from 11.20% to 15.08% while carbohydrate content ranged from 57.33 % to 71.48 %. The result of the mineral revealed that magnesium, calcium, iron, phosphorus and sodium ranged from 67.33 to 79.50, 29.00 to 43.03, 2.30 to 3.26, 117.00 to 139.66, 117.00 to 139.66 mg/100g respectively. The sensory attributes of the cookie samples varied significantly ($p < 0.05$) in terms of colour, crispiness, taste, texture and overall acceptability. Notably, the study found that cookies supplemented with 15% African yam bean and 15% tiger nut residue were well-accepted. It is anticipated that these products can lessen food insecurity. The results of the sensory attributes indicate that incorporation of African yam bean flour and tiger nut residue did not adversely affect these attributes.

Keywords: African Yam bean, Chemical composition, cookies, sensory properties, Tiger nut residue.

1. INTRODUCTION

Cookies are categorized as a type of confectionery treat that has been dried to have little moisture [1]. It is a nutritious snack made from a single or composite dough that has been heated in the oven to produce goods that are more digestible and pleasant [2]. They often contain flour, sugar, and some sort of oil or fat and are typically larger and softer than other types of biscuits [3]. Cookies are characterized by a recipe that features minimal water but abundant sugar and shortening [4]. Due to their lower moisture content in comparison to baked items like bread and cakes, cookies exhibit greater resistance to microbial spoilage and enjoy an extended shelf life [5]. Wheat flour, fat (margarine), sugar, and water are the essential components of cookies; however, they can also contain additional ingredients such salt, milk, aerating agents, emulsifiers, flavorings and colours. In order to satisfy certain dietary or therapeutic demands of consumers, they can also be strengthened or enriched with additional substances [4]. They are widely consumed as snacks around the world, especially in less developed countries where protein-energy malnutrition, especially in children and adolescents, is a problem [6].

Modern-day cookies are conventionally made from soft wheat, a grain cultivated in various regions globally but imported by nations like Nigeria, which experience unfavorable climatic

conditions for wheat cultivation [7]. Wheat (*Triticum aestivum* L.), despite being scarcely grown in Nigeria, boasts a wealth of carbohydrates and also contains protein, fat, ash, fiber, vitamins, and minerals such as sodium, potassium, calcium, magnesium, iron, phosphorus, copper, zinc and manganese [8]. The importation of wheat results in competition and depletion of scarce foreign exchange resources. Therefore, there is a compelling need to identify local alternatives to wheat in baked products. To this end, the promotion of composite flour usage has been advocated as it can reduce wheat importation. The incorporation of locally available, cost-effective crops like African yam bean and tiger nut, which can partially replace wheat flour without negatively impacting product acceptability, represents a promising avenue for product development. This approach can enhance overall nutritional content, stimulate the agricultural sector, diversify the range of cookies available, and reduce reliance on wheat flour, ultimately leading to lower production costs [9].

African yam bean primarily thrives in the southern regions of Nigeria and is referred to as "Okpodudu," "Ijiriji," or "Azama" by the Ibo people in the southeastern part of the country. Its seeds can be cooked by boiling and enjoyed with natural seasonings, roots, tubers and fruits, or processed into a paste to create a type of "moimoi" [9]. This legume, despite being lesser-known and underutilized, boasts a rich composition of protein, carbohydrates, vitamins and minerals [10]. The protein content of African yam bean consists of over 32 percent essential amino acids, with lysine and leucine being the predominant ones [11]. Moreover, African yam bean seeds can be roasted and consumed with palm kernel as a snack or boiled and paired with local seasonings, starchy root crops, and fruits [12]. Furthermore, it has been reported that African yam bean seeds can undergo processing to produce flour, which can be employed in the creation of bakery and confectionery items such as bread, biscuits, cookies, doughnuts, pie, crusts, and cakes [11].

Tiger nut (*Cyperus esculentus*) represents an underappreciated and underutilized crop, many varieties of which hold significant potential as both human and animal food sources, and it is extensively cultivated in Northern Nigeria [13]. In Nigeria, it goes by various names, including "Aya" in Hausa, "Ofio" in Yoruba, and "Akiausa" in Igbo [14]. Tiger nuts are notable for their high calcium, sodium, and phosphorus content, while their magnesium, manganese, iron, zinc, and copper levels are comparatively low [15]. The elevated calcium levels in tiger nuts are particularly valuable for promoting bone and tooth development in infants, and the presence of other minerals, such as iron, is crucial due to its role in blood formation [16].

Prior research has documented the production of cookies using composite flours, including blends of wheat, fonio and cowpea [17], lima bean, sorghum and wheat [18], and wheat, cocoyam and pigeon pea [19], among others. However, there is a scarcity of reports on the use of composite flours composed of wheat, African yam bean (*Sphenostylis stenocarpa*) and tiger nut (*Cyperus esculentus*) residue in cookie production. Therefore, the primary objective of this study was to develop cookies that meet acceptable standards by utilizing a combination of African yam bean, tiger nut residue and wheat flour.

2. MATERIALS AND METHODS

2.1 Material Procurement

Wheat flour, Tiger nut, African yam bean and other ingredients were purchased from Eke-Awka market, Anambra state, Nigeria.

2.2 Preparation of African yam bean flour

The African yam beans were transformed into flour following the procedure outlined in [20], with a minor adjustment. First, the beans were carefully examined to remove any damaged portions and then soaked in clean water for a full day. Afterward, they were manually dehulled by vigorous rubbing between the palms. Subsequently, the de-hulled beans were subjected to drying in a hot air oven (Model 10-D1390) at 72 °C for a duration of 4 hours. These dried, de-hulled beans were then finely ground using a hammer mill machine (Tigerextruda 6.5 hp, UK) to achieve a particle size of approximately 250 microns. Finally, the resulting flour was placed in a polyvinyl chloride bag and stored at room temperature until it was ready for use.

2.3 Preparation of Tiger nut residue Flour

Tiger nut tubers were selected, thoroughly cleaned, crushed, blended and sieved to extract milk, leaving the residue, which was then dried in a cabinet dryer at 60° C for 24 h. The residue was then milled into flour, sieved using a 212 m sieve size to obtain flour of uniform particle size and stored in a plastic air-tight container with a lid at room temperature for later use.

2.3 Research Design

The design is completely randomized design; three different flours were mixed at various ratios to give 100g composite

Table 1: Ratios of blends of wheat, African yam beans and tiger nut residue in Cookies production

No	Wheat flour(g)	African Yam Bean flour (g)	Tigernut Residue flour (g)
1	70	15	15
2	70	20	10
3	70	10	20
4	80	10	10
5	90	05	05
6	100	00	00

2.4 Production of cookies

The cookies were made using the previously discussed technique [22]. The ingredients were as follows; milk powder (30g), baking powder (2g), fat (40g), sugar (20g), whisked egg (30ml), and flour (100g). With the aid of a weighing balance (Mettler, PC 400, Switzerland), the ingredients were accurately weighed. Then the butter, sugar and egg were creamed and the flour, baking powder, salt, and milk powder were added. The creamy mixture was then

combined for 30 minutes with a Kenwood electric mixer to create a uniform mass. Next, using a rolling pin and a biscuit cutter, the dough was flattened out to a thickness of 3 inches and a diameter of 1 inch. The sliced dough was placed on a baking sheet and baked for 10-15 minutes at 175 °C. The cookies were then removed from the oven, allowed to cool to room temperature, and then sealed in a plastic bag for analyses to follow.

2.5 Chemical Analysis

The moisture, crude protein, fat, ash and crude fiber levels in the cookies were evaluated in triplicate using established analytical procedures [23]. Carbohydrate content was calculated as the difference from 100% after accounting for moisture, protein, fat, and ash [24]. The potassium and iron concentrations in the cookies were measured following ashing, utilizing a flame photometer (Model 405, Corning, UK) in accordance with the approach described by Ndie et al [25]. To determine the calcium and magnesium content of the samples, atomic absorption spectrophotometry was employed (Perkin-Elmer, Model 1033, Norwalk, CT, USA), following the method outlined in [23]. The assessment of phosphorus was carried out using the colorimetric method established by Giami [26].

2.6 Sensory Evaluation

A group of 50 panelists, consisting of both male and female individuals who were staff and students of the Department of Food Science and Technology at Nnamdi Azikiwe University in Awka, participated in the study. These panelists received training in the specific descriptive terms of the sensory scales and were asked to assess the different cookie samples for taste, appearance, texture, aroma, and overall acceptability using a 7-point hedonic scale. In this scale, a rating of 7 indicated a strong liking, while a rating of 1 indicated a strong disliking. The presentation of coded samples was conducted randomly, and participants were provided with portable water to rinse their mouths between the evaluations [27].

2.7 Statistical Analysis

The mean of all parameters were evaluated for significance ($P < 0.05$) by analysis of variance (ANOVA) and the mean separation and the significant effect tested by Duncan's multiple range of test using SPSS version 23.0 (IBM, USA)

3. RESULTS AND DISCUSSION

3.1 Proximate composition (%) of cookies produced from composite flours

The proximate composition of the cookie samples was displayed in Table 2, revealing that the composition of the cookies changed in response to the varying proportions of the three flours used in the formulated mixtures. These fluctuations can be ascribed to variances in the chemical makeup of the individual flours employed in creating the composite flour blend. Notably, the inclusion of African yam bean and tiger nut residue in the cookie samples led to an increase in their moisture, ash, fiber, fat, and protein content, while diminishing the carbohydrate content.

The moisture content ranged from 5.43% to 6.91%, with the control sample (100% wheat flour) having the lowest moisture content and the sample 1 (WH-70: AYB-15: TNR-15) exhibiting the highest moisture content. The impact of incorporating African yam bean and tiger nut residue on the moisture content of the cookie samples was evident, as all the

composite samples displayed higher moisture levels compared to the control sample. In contrast, smaller moisture values, ranging from 3.70% to 4.60%, were reported for cookies produced from maize and tiger nut flour blends [28]. However, another study [29] documented higher moisture content, ranging from 7.10% to 10.89%, for biscuits produced from composite flours of wheat, sorghum, and defatted coconut flour. The variability in moisture content can be attributed to disparities in the raw materials employed, as well as environmental and experimental factors [30]. The low moisture content observed in this study is considered advantageous for inhibiting microbial activity and prolonging the shelf-life of the cookies, provided that they are shielded from moisture absorption through appropriate packaging.

The ash content of a food material can serve as an indicator of its mineral composition, as ash remains after heating the material in the presence of an oxidizing agent, removing water and organic matter [31]. In our study, the composite cookies showed higher ash content compared to the control cookies. Sample 2 (WH-70: AYB-20: TNR-10) had the highest ash content at 2.10%, while sample 6 (100% wheat flour) had the lowest at 1.33%. This increase in ash content was primarily due to the incorporation of African yam bean, known for its high ash content [32;33].

The analysis in Table 2 demonstrated a significant ($p < 0.05$) increase in fiber content in the cookies, from 3.85% in sample 6 (100% wheat flour) to 7.65% in sample 3 (70% wheat flour, 10% African yam bean flour, and 20% Tiger nut residue). This aligns with previous studies [34] and [11], which also reported increased fiber content in cookies made from wheat-tiger nut residue composite flour (1.06 – 3.13%) and wheat-African yam bean composite flour (3.84 - 4.22%), respectively. [35] similarly reported an increase in fiber content (0.48 to 1.03%) in wheat cookies fortified with pineapple peel flour, although their values were lower than those in our study. Crude fiber composition is a measure of indigestible cellulose, pentose, lignin, and other components like these in food [36]. Although it lacks significant nutritional value, crude fiber aids in nitrogen utilization, absorption of micronutrients, and provides bulk for intestinal peristalsis [37].

All samples exhibited significant differences ($p < 0.05$) in fat content, with fortified cookies showing substantially higher fat content compared to the control sample. Fat content ranged from 6.70% in control sample 6 (100% wheat flour) to 12.20% in sample 3 (70% wheat flour, 10% African yam bean flour, and 20% Tiger nut residue). The fat content falls within the range of 9.95-20.45% reported by [38] for cookies made from wheat, defatted peanut, and avocado flour blends but is higher than the 3.84-4.63% reported by [11] for wheat-African yam bean composite cookies. These variations could be attributed to differences in raw materials used and the type of butter used in cookie formulation [37]. High-fat content in baked goods can pose challenges related to rancidity during storage, but it also facilitates the absorption of fat-soluble vitamins and contributes to flavor and sensory qualities [39].

The protein content of the control sample 6 (100% wheat flour) was the lowest at 11.20%, while samples with African yam bean flour and tiger nut residue substitutions had higher protein content. The addition of African yam bean flour and tiger nut residue resulted in an increase in protein content, with sample 2 (WH-70: AYB-20: TNR-10) reaching the highest level at 15.08%. This observation is consistent with reports that African yam bean is a good protein source [40; 41; 42]. Similar increases in protein content have been reported in bakery products using pigeon pea flour as a substitute [12].

The carbohydrate content of the cookies ranged from 57.33% to 71.48%. Significant differences ($p < 0.05$) were observed between sample 6 (100% wheat flour) and other blended samples, while samples 1 (WH-70: AYB-15: TNR-15), 2 (WH-70: AYB-20: TNR-10), and 3 (WH-70: AYB-10: TNR-20) did not show significant differences ($p > 0.05$) among them. Cookies containing African yam bean and tiger nut residue had lower carbohydrate content than the control sample, primarily due to the substitutions made, resulting in reduced or altered carbohydrate content in the blended samples. Similar decreases in carbohydrate

content have been reported in cookies made from blends of wheat and African yam bean and wheat and bambara groundnut [43;11]. According to [44], carbohydrate content contributes to the energy value of food formulations, making these cookies suitable for individuals of all age groups, especially infants who require energy for rapid growth.

Table 2: Proximate composition (%) of cookies produced from composite flour

NO	WH:AYB:TR	Moisture	Ash	Fibre	Fat	Protein	Carbohydrate
1	70 : 15 : 15	6.86 ^a ±0.53	1.80 ^b ±0.13	6.90 ^b ±0.05	12.10 ^b ±0.05	14.30 ^{ab} ±0.61	57.70 ^d ±0.70
2	70 : 20 : 10	6.60 ^{ab} ±0.91	2.10 ^a ±0.19	5.73 ^c ±0.03	11.06 ^c ±0.06	15.08 ^a ±0.88	58.46 ^d ±1.40
3	70 : 10 : 20	6.91 ^a ±0.82	1.77 ^{bc} ±0.12	7.65 ^a ±0.05	12.20 ^a ±0.00	14.14 ^{ab} ±0.93	57.33 ^d ±0.90
4	80 : 10 : 10	6.39 ^{ab} ±0.64	1.58 ^{cd} ±0.08	5.70 ^c ±0.05	10.46 ^d ±0.05	13.01 ^{bc} ±0.01	62.86 ^c ±0.12
5	90 : 05 : 05	5.81 ^{ab} ±0.45	1.41 ^{de} ±0.00	5.50 ^d ±0.00	7.50 ^e ±0.05	11.80 ^{cd} ±1.00	67.97 ^b ±0.52
6	100: 00: 00	5.43 ^b ±0.45	1.33 ^e ±0.00	3.85 ^e ±0.05	6.70 ^f ±0.05	11.20 ^d ±1.00	71.48 ^a ±0.48

Means ± standard deviation of triplicate determinations. Means in the same column with different superscripts are significantly different ($p \leq 0.05$).

The key: WH – Wheat flour, AYB – African yam bean flour, TNR – Tiger nut residue

3.2 Mineral composition (mg/100g) of cookies produced from the composite flours

The mineral composition of cookies made from a blend of wheat, African yam bean and tiger nut residue flours is detailed in Table 3. The magnesium levels varied, ranging from 67.33 to 79.50 mg per 100 grams. Sample 6 (100% wheat flour) had the lowest magnesium content, while sample 2 (WH-70: AYB-20: TNR-10) had the highest. It was observed that incorporating African yam bean and tiger nut residue flour into the cookie formulation generally enhanced the magnesium content in all composite samples. Notably, the magnesium values obtained in this study were lower than the range of values (78.55 – 98.88 mg/100 g) reported for wheat-defatted peanut avocado biscuits [38]. These differences in results may be attributed to variations in the choice of raw materials. As noted by [45], magnesium serves as an activator for numerous enzyme systems and plays a role in maintaining nerve electrical potential. Additionally, magnesium collaborates with calcium to facilitate muscle contraction, blood clotting, and the regulation of blood pressure and lung function [45].

The analysis of calcium content in the cookie samples revealed a range from 29.00 mg/100g in sample 6 (100% wheat flour) to 43.03 mg/100g in sample 2 (WH-70: AYB-20: TNR-20). Notably, the inclusion of African yam bean and tiger nut residue flour led to an augmentation in calcium levels, aligning with findings reported in [42], which also documented an increase in calcium content in wheat-African yam bean cookies. Calcium holds paramount importance in maintaining overall bodily health, as it plays a pivotal role not only in fortifying bones and teeth but also in ensuring the proper operation of muscles and nerves [16]. Furthermore, it contributes significantly to the regulation of heart tone and contractility, while serving as a counteractive agent to the depressant effects of potassium [46].

In addition, an increase in the iron content of the cookies was observed when compared to the control sample, with values ranging from 2.30 mg/100g to 3.26 mg/100g in the substituted samples. This observation concurs with the findings of [11], who reported a similar increase in iron content in cookies made from a blend of wheat and African yam bean flours. Iron content assumes a critical role in bolstering the overall daily intake of essential elements, particularly micronutrients [47].

The phosphorus content in the cookie samples exhibited a range, spanning from 117 to 139.00 mg/100 g. The highest recorded value was in sample 2 (WH-70: AYB-20: TNR-10), whereas the lowest was observed in sample 6 (comprising 100% wheat flour). Notably, these results were lower than the phosphorus levels (ranging from 176.37 to 221.36 mg/100 g) documented in biscuits produced from a blend of wheat, defatted peanut, and avocado composite flour, as reported in [38]. The variations in outcomes could be ascribed to differences in the selection of raw materials. Phosphorus plays a pivotal role in maintaining the osmotic balance of body fluids, regulating body pH, controlling muscle function and nerve excitability, managing glucose absorption, and promoting normal protein retention during growth [48]. Additionally, it serves as a crucial component of both cell and bodily fluids, aiding in the regulation of heart rate and blood pressure, thereby countering the adverse effects of sodium [48].

Significant differences ($p < 0.05$) were observed in the sodium content across all the samples, with levels ranging from 25.26 to 33.26 mg/100 g. However, these values did not align with the recommended sodium intake level established by the United States Department of Agriculture (USDA), which stands at 1500 mg/g [49]. Instead, they exceeded the sodium content range of 14.11 – 16.08 mg/100 g, as reported in [31] for cookies produced using flour blends of wheat, walnut, and carrots. The disparities in raw material composition are likely responsible for these varying results. Sodium plays a crucial role in maintaining water balance, facilitating nerve impulse transmission, and aiding in the absorption and transportation of certain nutrients. However, it is advisable to limit sodium intake to a reduced level (2.0 g per day) [50], as excessive sodium consumption may contribute to elevated blood pressure, especially in individuals sensitive to salt [51].

Table 3: Mineral composition (mg/100g) of cookies produced from the composite flours

NO	WH:AYB:TR	Magnesium	Calcium	Iron	Phosphorus	Sodium
1	70 : 15 : 15	78.50 ^b ±0.10	39.01 ^b ±0.02	3.10 ^a ±0.10	135.33 ^b ±1.52	29.80 ^b ±0.10
2	70 : 20 : 10	79.50 ^a ±0.10	43.03 ^a ±0.50	3.26 ^a ±0.05	139.66 ^a ±1.52	33.26 ^a ±0.15
3	70 : 10 : 20	74.56 ^c ±0.05	36.31 ^c ±0.54	2.86 ^b ±0.05	129.66 ^c ±1.52	28.56 ^c ±0.20
4	80 : 10 : 10	73.30 ^d ±0.05	36.00 ^c ±1.00	2.80 ^b ±0.10	123.00 ^d ±1.00	28.53 ^d ±0.14
5	90 : 05 : 05	70.43 ^e ±0.51	32.00 ^d ±1.00	2.56 ^c ±0.15	120.00 ^e ±1.00	28.14 ^e ±0.22
6	100 :00 :00	67.33 ^f ±0.57	29.00 ^e ±1.00	2.30 ^d ±0.10	117.00 ^e ±1.00	25.26 ^f ±0.15

Values are mean ± standard deviation of triplicate determinations. Means in the same column with different superscripts are significantly different ($p \leq 0.05$).

The key: WH – Wheat flour, AYB – African yam bean flour, TNR – Tiger nut residue

3.3 Sensory properties of the cookies

The sensory evaluation results for cookies made from a blend of wheat, African yam bean, and tiger nut residue flours are presented in Table 4. Cookies received mean scores ranging from 5.00 to 6.00. Sample 1 (WH-70: AYB-15: TNR-15) received the highest scores, while sample 3 (WH-70: AYB-10: TNR-20) received the lowest scores. Importantly, all the samples scored above the average level for color, indicating that the inclusion of African yam bean and tiger nut residue flour did not have a detrimental impact on this aspect. Panelists expressed a preference for the brown color of the cookies, which may have resulted from Maillard reactions due to the presence of reducing sugars, proteins, and amino acids, as well as caramelization caused by intense heating during processing [38].

Taste is a crucial aspect of sensory perception in food products, involving the sensation of flavor experienced in the mouth and throat upon contact with a substance [52]. It ranks among the most important attributes to consider. Taste can be influenced by the types and quality of ingredients and may also depend on the formulation of the food material [53]. The mean taste scores for the cookie samples ranged from 4.40 to 6.33. Sample 6 (100% wheat flour) received the highest score, while sample 2 (WH-70: AYB-20: TNR-10) received the lowest score. Notably, all the samples scored above the average level for taste, indicating that the incorporation of African yam bean and tiger nut residue flour did not have an adverse impact on this attribute. This finding aligns with the results reported in [11], which indicated that cookies fortified with African yam bean were well-received by consumers.

Mouthfeel refers to how our mouth's sensory organs perceive attributes such as roughness, smoothness, chewiness, and stickiness of food [44]. In terms of mouthfeel, the control sample 6 (100% wheat flour) received the highest mean score of 5.93, while sample 3 (WH-70: AYB-10: TNR-20) had the lowest score of 4.60. Importantly, all the samples scored above the average level for mouthfeel, suggesting that the inclusion of African yam bean and tiger nut residue flour did not have an adverse effect on this aspect.

Crispiness is a textural characteristic that indicates how soft or hard a cookie is and how easily it can be crunched [54]. The results presented in Table 4 indicated significant differences ($p < 0.05$) in the crispiness of the cookie samples, with the lowest score of 4.86 observed in Sample 3 (WH-70: AYB-10: TNR-20) and the highest score of 6.06 in sample 6 (100% wheat flour).

The mean scores for the overall acceptability of the cookies were consistently above the average, indicating a high level of acceptability among the samples. There was no significant difference ($p > 0.05$) between sample 6 (100% wheat flour), which received the highest score of 6.20, and sample 1 (70% wheat flour, 15% African yam bean flour, and 15% Tiger nut residue). However, these two samples did differ significantly ($p < 0.05$) from the other samples. As noted in [38], factors such as baking conditions (including temperature and time variables), the state of cookie constituents (e.g., fiber, starch, and gluten) whether damaged or undamaged, and the amount of absorbed water during dough mixing all contribute to the final overall acceptability of the cookies.

Table 4: Sensory properties of the cookies

NO	WH:AYB:TR	Colour	Taste	Mouth feel	Aroma	Crispiness	Overall Acceptability
1	70 : 15 : 15	6.00 ^a ±0.75	5.60 ^{ab} ±1.35	5.66 ^{ab} ±0.81	5.26 ^a ±1.22	6.06 ^a ±0.88	6.13 ^a ±0.91
2	70 : 20 : 10	5.66 ^{ab} ±0.81	4.40 ^c ±1.35	5.00 ^{bc} ±1.30	4.20 ^b ±1.82	4.93 ^c ±1.16	5.06 ^b ±0.96
3	70 : 10 : 20	5.00 ^b ±1.36	4.73 ^{bc} ±1.03	4.60 ^c ±0.91	4.40 ^b ±0.88	4.86 ^c ±0.83	4.93 ^b ±0.96
4	80 : 10 : 10	5.66 ^{ab} ±0.89	5.46 ^{ab} ±1.40	5.80 ^a ±1.01	5.26 ^a ±0.89	5.60 ^{abc} ±1.18	5.40 ^b ±1.21
5	90 : 05 : 05	5.80 ^a ±0.86	5.00 ^{bc} ±1.13	5.26 ^{ab} ±1.09	5.13 ^a ±0.89	5.66 ^a ±1.20	5.53 ^b ±1.17
6	100:00: 00	5.86 ^a ±0.74	5.93 ^a ±0.79	5.93 ^a ±0.79	5.66 ^a ±0.89	6.00 ^{ab} ±1.06	6.20 ^a ±0.67

Mean ± standard deviation of triplicate determinations. Means in the same column with different superscripts are significantly different ($p \leq 0.05$).

The key: WH – Wheat flour, AYB – African yam bean flour, TNR – Tigernut residue

4. CONCLUSION

Cookies were produced by partially replacing wheat with African yam bean and tiger nut residue flour. The samples containing these substitutions exhibited higher levels of protein, fat, ash, and dietary fiber compared to the control sample, which consisted of 100% wheat flour. Among these samples, sample 2 (cookies with 20% African yam bean and 10% tiger nut residue flour substitution) recorded the highest content of magnesium, calcium, iron, phosphorus, and sodium. Interestingly, the control sample received the highest overall acceptability ratings. However, among the blended samples, sample 1 (cookies with 15% African yam bean and 15% tiger nut residue flour substitution) was the most favored in terms of overall acceptability. This suggests that it is feasible to produce well-accepted cookies with enhanced nutritional value and a higher dietary fiber content by incorporating blends of wheat, African yam bean, and tiger nut residue flour.

REFERENCES

1. Okaka JC. Handling, storage and processing of plant foods. Academy Publishers Enugu, Nigeria. 2009.
2. Olaoye OA, Onilude AA, Idowu OA. Quality characteristics of bread produced from composite flour of wheat, Plantain and Soybean. African. J.Biotechnol. 2007;5:1102-1106
3. Ani EC, Okoye JI. Nutrient Composition, Physical and Sensory Properties of Cookies Produced from Millet, African Walnut and Unripe Plantain Composite Flours. Journal of Food Sci Nutr. 2021;7:108.
4. Ajibola FC, Oyerinde OV, Adeniyani SO. Physicochemical and antioxidant properties of whole wheat biscuits incorporated with Moringaoleifera leaves and cocoa powder. Journal of scientific research and report. 2015;7(3)195 – 206
5. Hanan MA, Al-Sayed. Quality characteristics of cuntaloope seed on and cookies substituted with ground foll fat and defatted seeds. Journal of Applied Science Research. 2013;9(1): 435-443.
6. Chima CE, Gernah DI. Physico-chemical and sensory properperities of cookies produced from blends of cassava, soybean and mango composite flour, Journal of food technology. 2007;2:256-260
7. Okpala LC, Okoli EC, Udensi C. physico-chemical and sensory properties of cookies made from the blends of germinated pigeon pea, femementedsorgurm and cocoyam flours, food. Food science and Nutrition. 2013;1(1):8-14.

8. Kumar P, Yadava R.K, Gollen B, Kumar S, Verma RK, Yadav S. Nutritional Contents and Medicinal Properties of Wheat, L. Sci. M. Res. 2011;22: 1-7.
9. Onwuka C, Ikewuchi CC, Ikewuchi, CJ, Ayalogu, OE. Investigation on the effect of germination on the proximate composition of African yam bean (*Sphenostylis stenocarpa*) and fluted pumpkin (*Telferia occidentalis*). Journal of Applied Sciences and Environmental Management. 2009;13(12): 59 – 61.
10. Wokoma EC, Aziagba, GC. Sensory evaluation of dawadawa produced by the traditional fermentation of African yam bean (*Sphenostylis stenocarpa*) seeds. J. Appli. Sci. Environ. Manage.2001;5(1): 85 – 91.
11. Okoye JI, Obi CD. Chemical Composition and Sensory Properties of WheatAfrican Yam Bean Composite Flour Cookies. Discourse Journal of Agriculture and Food Sciences. 2017;5(2): 21-27.
12. Eneche HE. Production and evaluation of cakes from African yam bean and wheat flour blends. Proceedings of the Nigerian Institute of Food Science and Technology pp. 2006;46 – 47.
13. Adejuyitan JA. Tigernut processing: its food uses and health benefits. American Journal of Food Technology. 2011; 6:197-201.
14. Ayo-Omogie HN, Odekunle OY. Substituting wheat flour with banana flour: effects on the quality attributes of doughnut and cookies. Applied Tropical Agriculture. 2016;1: 134-137.
15. Shaker MA, Ahmed MG, Amany MB, Shereen LN. Chufa Tubers (*Cyperus esculentus* L): as a new source of food. World Applied Sciences Journal. 2009;7(2): 151-156.
16. Oladele AK, Aina JO. Chemical composition and functional properties of flour produced from two varieties of tigernut (*Cyperus esculentus*). African Journal of Biotechnology. 2007;6(21): 2473-2476.
17. McWatters KH, Ouedraogo JB, Resurreccion AVA, Hung Y, Phillips RD. Physical and sensory characteristics of sugar cookies containing mixtures of wheat, fonio (*Digitariaexilis*) and cowpea (*Vignaunguiculata*) flours. International Journal of Food Science and Technology. 2003;38: 403-410.
18. Adebayo SF, Okoli EC. Production and evaluation of biscuits from lima bean (*Phaseoluslunatus*), sorghum and wheat flours. IOSR-Journal of Environmental Science, Toxicology and Food Technology. 2017;2(7): 44-48.
19. Arukwe DC. Proximate composition, physical properties and sensory evaluation of wheatcocoyam-pigeon pea biscuits. IOSR-Journal of Environmental Science, Toxicology and Food Technology. 2020;14(7): 47-51.
20. Abiodun AO, Adepeju AB. Effect of processing on the chemical, pasting and anti-nutritional composition of bambara nut (*Vigna subterranea* L. Verdc) flour. Advance Journal of Food Science and Technology. 2011; 3: 224-227.
21. Senya EK, Kwaatema F, Sitsofe KR. Production and acceptability of tit-bits made from wheat and tiger nut flour blends. International Journal of Academic and Applied Research. 2021;5(1): 142-147.

22. Makanjuola OM, Adebawale OJ. Vitamins, functional and sensory attributes of biscuit produced from wheat-cocoyam composite flour. *Journal of Scientific and Innovative Research*. 2020;9(2): 77-82.
23. AOAC. Official Method of Analysis. 18thEdn., Association of Official Analytical Chemists International, Washington, D.C. USA. 2010;777-784.
24. Onwuka GI. Food and Instrumentation Analysis: Theory and Practice. Naphthali Publishers Ltd, Lagos, Nigeria. 2005;46 – 52
25. Ndie EC, Nnamani CV, Oselebe HO. Some physicochemical characteristics of defatted flours derive from African walnut (*Tetracarpidiumconoforum*): an underutilized legume. *Pak J. Nutri*. 2010;9(9): 909 – 911.
26. Giami SY. Compositional and nutritional properties of selected newly developed lines of cowpea (*Vigna unguiculata* (L) warp) flour. *J. Food Compos*. 2005;18:665 – 673.
27. Iwe MO. Handbook of sensory methods and analysis. Re-joint Communications Services Ltd. 2010; 75-78. Ref.: <https://goo.gl/nvGYrL>
28. Obinna-EchemPC, Robinson ES. Proximate composition, physical and sensory properties of biscuits produced from blends of maize (*Zea mays*) and tigernut (*Cyperus esculentus*) flour. *Sky Journal of Food Science*. 2019;7(2): 30-36.
29. Alebiosu MO, Akinbode BA, Oni IS, Oladele JO. Quality evaluation of cookies produced from wheat, sorghum and defatted coconut flour blends. *Asian Food Science Journal*. 2020; 17(3): 11-21.
30. Obasi NE, Uchekwuku N, Eke-Obia E. Production and evaluation of biscuits from African yam bean (*Sphenostylisstenocarpa*) and wheat (*Triticum aestivum*) flours. *Food Science and Quality Management*. 2012;7: 5-12.
31. Kiin-Kabari DB, Mbanefo CU, Akusu OM. Production, nutritional evaluation and acceptability of cookies made from a blend of wheat, african walnut, and carrot flours. *Asian Food Science Journal*. 2021;20(6): 60-76.
32. Ojukwu M, Olawuni IA, Ibeabuchi C, Amandikwa C. Physical, proximate and functional properties of “Nsamu” a local variety of African yam bean (*Sphenostylisstenocarpa*) grown in Southern States in Nigeria. *African Journal of Food Science and Technology*;2012;3(10): 266 – 267.
33. Adegunwa MO, Bakare HA, Akinola OF. Enrichment of Noodles with soy flour and carrot powder. *Journal of Food Science*. 2012;30(1): 74- 81.
34. Eke-Ejiofor J, Deedam JN. Effect of tiger nut residue flour inclusion on the baking quality of confectionaries. *Journal of Food Research*. 2015;4(5): 172-180.
35. Adeoye, BK, Alao AI, Famurewa JA. Quality evaluation biscuits produced from wheat and pineapple peel flour. *Applied Tropical Agriculture*. 2017;22(2): 210-217.
36. Akajiaku LO, Kabuo NO, Alagbaoso SO, Orji IG, Nwogu AS. Proximate, mineral and sensory properties of cookies made from tiger-nut flour. *Journal of Nutritional Diet Practice*. 2018;2(1): 1-5.

37. Obinna-Echem PC, Robinson ES. Proximate composition, physical and sensory properties of biscuits produced from blends of maize (*Zea mays*) and tigernut (*Cyperus esculentus*) flour. *Sky Journal of Food Science*. 2019; 7(2): 30-36.
38. Nwatum IA, Ukeyima MT, Eke MO. Production and quality evaluation of cookies from wheat defatted peanut and avocado composite flour. *Asian Food Science Journal*. 2020;15(4): 1-12.
39. Musa A, Lawal T. Proximate composition of ten types of biscuits and their susceptibility to *Tribolium castaneum* herbivory (Tenebrionidae: Bostrichidae) in Nigeria. *Food Science and Quality Management*. 2013;14: 33-40.
40. Uguru MI, Madukaife SO. Studies on the variability in agronomic and nutritive characteristics of African yam bean (*Sphenostylis stenocarpa*). *Journal of Plant Products and Resources*. 2001;6:10 – 16
41. Adeparusi EO. Effect of processing on some minerals, anti-nutrients and nutritional composition of African yam bean: Sustainability of environment. 2001;3: 101-108.
42. Okoye JI, Alugwu SU, Obi CD. Effect of processing methods on the proximate composition and functional properties of African yam bean (*Sphenostylis stenocarpa*) seed flours. *Journal of Science, Agriculture, Food Technology and Environment*. 2015;14:1 – 6.
43. Elochukwu CU, Onyekwelu CN. Nutrition composition and sensory properties of Biscuits produced from blends of Bambara Groundnut (*Vigna subterranea*) and Cassava (*Manihot esculenta*) flours. *Bioglobia Journal*. 2015;2 (2):39-41.
44. Okache TA, Agomuo JK, Kaida IZ. Production and evaluation of breakfast cereal produced from finger millet, wheat, soybean, and peanut flour blend. *Research Journal of Food Science and Quality Control* 2020;6(2): 9-19.
45. Swaminathan R. Magnesium metabolism and its disorders. *Clinical Biochemist Reviews* 2013;24(2): 47–66.
46. Pravina P, Sayaji D, Avinash M. Calcium and its role in human body. *International Journal of Research in Pharmaceutical and Biomedical Sciences*. 2013;4(2):659-668.
47. Singh K, Sandhu T, Kaur G. Breadfruit flour in biscuit making. *African Journal of Food Science*. 2015; 2:20-23.
48. Giwa R, Ikuje-Ikolu A. Chemical composition and functional properties of flour produced from two varieties of tigernut (*Cyperus esculentus*). *African Journal of Biotechnology*. 2018; 6 (21), 2473-2476.
49. USDA. World soybean production 2007 Soy stats. American soybean association. 2010 Annual report. 2 pages. 2009.
50. World Health Organization. Guideline: Sodium Intake for Adults and Children; World Health Organization: Geneva, Switzerland. 2012.
51. Whitney B, Rolfes E. Processing effects on susceptibility of starch to digestion in some dietary starch sources. *International Journal of Food Science and Nutrition*. 2011;54, 97-109.

52. Olurin TO, Abbo ES, Oladiboye OF. Production and evaluation of breakfast meal using blends of sorghum, bambara nut and date palm fruit flour. *Journal of Tropical Agriculture, Food, Environment and Extension*. 2021;20(3): 30-36.

53. Small D, Prescott J. Odor/taste integration and the perception of flavor. *Experimental Brain Research* 2005;166(3-4): 345-357.

54. Porcel MVO, Rinaldoni AN, Rodríguez Furlan LT, Campderrós ME. Influence of the Particle Size and Level of Substitution of Okara Flour in the Development of Gluten-Free Cookies. *International Journal of Research in Advent Technology*. 2016;4(8):82-92.

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