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Research Article

Quality Attributes of Wheat and Aerial Yam Composite Flours and Evaluation of Biscuits from the Flours

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Abstract: Wheat flour is the basic flour for flour confectionaries; however, its strict agronomic requirements limit its cultivation in many regions of the world. Hence, it has to be imported, raising the cost of production. Researchers are on the lookout for cheaper alternatives from locally available materials, and this has led to the use of composite flours. This study aimed to evaluate the quality attributes of wheat and aerial yam composite flours and the properties of biscuits produced from the composite flours. The composite flours were analyzed for their functional, proximate, mineral and phytochemical properties. While the biscuits were evaluated for their physical, microbial and sensory properties. Results showed a significant increase in the protein, fibre and fat contents of the composite flour in comparison to the control with values ranging from 5.77-7.18%, 0.4-0.62%, and 3.4-3.62%, respectively. Calcium (1.16-1.69 mg/100 g), iron (0.38-0.67 mg/100 g), magnesium (24.00-35.38 mg/100 g), potassium (2.87-5.06 mg/100 g), sodium (0.20-0.28 mg/100 g) and phytochemicals were also observed to increase in the composite flours. The composite flours also had lesser bulk densities (0.70-0.75 g/ml) and higher water absorption capacities (113.50-134.00 g/ml) than 100% wheat flour (0.77 g/ml and 102.50 g/ml, respectively). The physical and sensory properties of the biscuits produced from the composite flours compared favourably with those produced from the control flour as there was no significant difference in the diameter, taste, crispness and overall acceptability of the biscuits. The findings showed the suitability of aerial yam flour as an alternative to wheat flour.

***Keywords*:** composite flour, aerial yam, biscuits, flour blends, wheat flour, Dioscorea bulbifera

1. Introduction

Biscuits are the commonest snack food among flour confectionaries. They are small, flat cakes made from flour. They are convenient, ready-to-eat and widely consumed by people of all ages and statuses. Biscuits are the most popular bakery goods, as they have been identified as a rich source of carbohydrates and fat. The basic ingredients include flour (usually obtained from wheat), shortenings, sugar, salt, eggs and milk [1-2]. Wheat flour, which is the basic ingredient in biscuits, suffers some shortfalls as it is relatively expensive and has strict agronomic requirements, limiting cultivation in many regions of the world. In Nigeria, the climatic conditions do not particularly favour wheat cultivation, resulting

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in low production. The confectionery industry survives by importing wheat, and this invariably increases the cost of baked goods. This has made it necessary for researchers to look for cheaper and readily available alternatives, of which one is the use of flour blends, i.e. the mixture of two or more flours obtained from cereals, tubers or roots [3-4].

Aerial yam (*Dioscorea bulbifera*), commonly known as air potato or bulbil yam, is a member of the Dioscorea family, often producing large numbers of potato-like growths from the leaf axil. Aerial yam is a good source of nutrients like protein, fibre, iron, calcium and phosphorus. It is also rich in phytochemicals, which accounts for its use in traditional medicine for the treatment of diarrhoea, dysentery, diabetes, inflammations, gastro-intestinal disorders and other diseases. Despite its nutritional content, aerial yam is unpopular; less studied and has received little to no interest from food processors/researchers in Nigeria. This may be attributed to the fact that it is often perceived as food for low-income households. Aerial yam is grossly underutilized, resulting in post-harvest losses and waste [2, 5].

The inclusion of aerial yam flours in snack making is hoped to provide more nutritious snacks and foster the utilization of aerial yam, thereby reducing over-dependence on wheat flour. However, the successful formulation and production of high-quality biscuits necessitates an understanding of various factors influencing biscuit performance and quality. Flour composition and the quality of ingredients play pivotal roles in the overall quality of biscuits. The unique blends of proteins, fibre, fats, sugars and starch influence dough consistency, biscuit spread, texture and flavour. Furthermore, processing techniques also influence the quality of biscuits. Mixing time and speed influence dough development and gluten formation, thereby affecting biscuit texture and spread. Baking temperature and duration also affect colour development, flavour generation and moisture content. In addition, the moisture content of biscuits affects dough texture, baking properties and shelf life. Optimal moisture content ensures proper dough formation, uniform baking, desirable texture properties and biscuits with good shelf life. Deviations can lead to excessively dry or soft biscuits [6-8]. Therefore, this study aimed to evaluate the quality of biscuits produced from wheat and aerial yam composite flours.

2. Materials and methods

2.1 *Sources of raw materials*

Aerial yam tubers were purchased from a local market in Aduratedo-Ape, Kabba-Bunu LGA, Kogi State, Nigeria. While wheat flour was sourced from the Oja-Oba market in Ilorin, Kwara State, Nigeria. Other baking ingredients including baking powder, milk, sugar, salt and margarine were purchased at Folax Store in Tanke, Ilorin, Kwara State. Samples derived were packed and transported in clean polythene bags into the laboratory.

2.2 *Preparation of aerial yam flour*

Aerial yam tubers were sorted and washed thoroughly under running tap water to remove filth. The yams were then peeled using a kitchen knife and sliced under water to limit enzymatic browning. The slices were pre-cooked in boiling water for 5 minutes. A portion of the pre-cooked sample was sun-dried, while the other was dried in a dehydrator at 50 °C. The dried yam slices were milled to fine flour using a hammer mill and the flour was passed through a 40-mesh sieve [9].

2.3 *Formulation of composite flours*

Design software expert version 7.0 (D-optimal) was used to determine the mixing ratio of wheat and aerial yam flours for the production of the flour blends. The formulations included $W_{100}A_0$: 100% wheat flour; $W_{70}AD_{30}$: 70% wheat flour and 30% dehydrated aerial yam flour; $W_{60}AD_{40}$: 60% wheat flour and 40% dehydrated aerial yam flour; $W_{50}AD_{50}$: 50% wheat flour and 50% dehydrated aerial yam flour; $W_{70}AS_{30}$: 70% wheat flour and sundried aerial yam flour; $W_{60}AS_{40}$: 60% wheat flour and 40% sundried aerial yam flour; and $W_{50}AS_{50}$: 50% wheat flour and 50% sundried aerial yam flour.

2.4 *Preparation of biscuits*

The creaming method was used for the preparation of the biscuits (Figures 1-3). Sugar (20 g) and margarine (50 g) were mixed in an electric mixer at 550 rpm for five minutes to obtain a fluffy and smooth cream. Baking powder (3 g), salt (2 g) and milk powder (30 g) were added to the cream and thoroughly mixed in the mixer, then flour (150 g) was added intermittently until a smooth dough was obtained. The dough was kneaded manually on a flat board, rolled using a rolling pin and cut into round shapes using a round biscuit cutter. The dough was allowed to rest on a greased pan for 30 minutes at room temperature to allow proper leavening, and baked in an electric oven at 200 °C for 15 minutes. Biscuits were allowed to cool and packed in polythene bags for further analysis [9].

Figure 1. 100% wheat biscuits

Figure 2. Biscuits produced from wheat and sundried aerial yam composite flour

Figure 3. Biscuits produced from wheat and dehydrated aerial yam composite flour

2.5 *Analysis on the composite flours*

2.5.1 *Functional properties*

2.5.1.1 *Water/oil absorption capacities*

Water absorption capacity was determined by adding 10 ml of distilled water to 1 g of composite flour. The same was done to determine oil absorption capacity by using refined soybean oil with a specific gravity of 0.9092. The mixtures were allowed to stand for 30 minutes at room temperature, and then they were centrifuged at 5,000 rpm for 10 minutes. The residues were weighed after the supernatants were discarded. Results were expressed as the percentage of water/oil absorbed per gramme of flour [10].

2.5.1.2 *Bulk density*

For loose bulk density, 10 g of composite flour was placed in a measuring cylinder and the volume was recorded. The measuring cylinder was tapped continuously until there was no further reduction in volume; the final volume was recorded for the determination of packed bulk density. Results were expressed as the ratio of the weight of the flour to the volume of the flour [10].

2.5.1.3 *Swelling capacity*

A mixture was made using 10 ml of distilled water and 0.3 g of composite flour and allowed to stand in a water bath at 60 °C for 30 minutes. The mixture was left to cool, and then it was centrifuged at 3,000 rpm for 20 minutes. The supernatant was collected and the residue was weighed for the calculation of swelling capacity. The results were expressed as the ratio of the weight of residue to the weight of flour [11].

2.5.2 *Colour determination*

L^* a^* b^* colour parameters were determined using a Chroma meter (A60-1014-593, Hunter Associates, USA.). L^* was taken to represent lightness/brightness, a^* represented redness/greenness (+ve a^* = red, -ve a^* = green) and b^* represented yellowness/blueness (+ve b^* = yellow, -ve b^* = blue) [12].

2.5.3 Proximate analysis

2.5.3.1 *Moisture content*

Composite flour samples were weighed (2 g) and dried in a hot air oven operating at 100 ± 3 °C. Drying continued until a constant weight was achieved at intervals of 15 minutes. Samples were left to cool in a desiccator and then they were weighed. Results were expressed as a percentage of the ratio of the weight of dried flour to the weight of the original sample [13].

2.5.3.2 *Ash content*

Two grammes (2 g) of composite flour were placed in a weighed crucible and then incinerated in a muffle furnace operating at 550 °C for 12 hours. The resulting ash was allowed to cool in a desiccator and then weighed. The results were expressed as a percentage of the ratio of the weight of ash to the weight of the flour sample used [13].

2.5.3.3 *Protein content*

Two grammes (2 g) of composite flour were digested using 5 g of sodium sulphate, 1 g of copper sulphate and 25 ml of concentrated sulphuric acid. The mixture was placed on heat and allowed to digest until a clear solution was obtained. The digest was allowed to cool, and then it was diluted to 250 ml with distilled water. Five millilitres (5 ml) of the digest and 5 ml of 60% sodium hydroxide solution were placed in the distillation apparatus and distillation was allowed for 10 minutes. The resulting distillate was collected in 5 ml of boric acid indicator and then titrated against 0.01 N hydrochloric acid until a colour change was observed. Nitrogen content was obtained using the formula below.

$$\text{Nitrogen }(\%) = \frac{\text{titre value} \times \text{molecular mass of N} \times \text{normality of HCl} \times \text{vol. of flask containing digest}}{\text{weight of sample digested} \times \text{vol. of digest distilled}} \times 100$$

Protein content was calculated by multiplying nitrogen content by a factor of 6.25 [13].

2.5.3.4 *Fat content*

Fat was extracted from 2 g of composite flour samples using petroleum ether in a Soxhlet apparatus. The extraction was done under reflux for 6 hours and the samples were dried in a hot air oven at 105 °C for 1 hour so that the petroleum ether evaporated. The samples were cooled in a desiccator and then weighed. Results were expressed as a percentage of the ratio of the weight of extracted fat to the weight of flour used [13].

2.5.3.5 *Fibre content*

A mixture of 2 g of defatted composite flour and 200 ml of sulphuric acid (0.127 M) was made and then it was heated to boiling point and allowed to boil for 30 minutes. The mixture was filtered through a linen cloth and the residue was washed with distilled water, followed by 1% hydrochloric acid. The residue was further washed using ethanol and diethyl ether. The washed residue was then dried in a hot air oven at 105 °C and then incinerated in a muffle furnace at 550 °C. The samples were cooled and weighed. Results were expressed as a percentage of the ratio of the weight of fibre to the weight of flour [13].

2.5.3.6 *Carbohydrate content*

The carbohydrate content of the composite flours was calculated by difference i.e. subtracting the total sum of other components from 100% [13].

2.5.4 *Mineral content*

An atomic absorption spectrophotometer (BUCK Scientific ACCUSYS 211) was used to determine the concentrations of mineral elements in the composite flours. First, 20 ml of freshly prepared Aqua-Regia solution (1:3 of 65% nitric acid and 37% hydrochloric acid) was added to 2 g of flour and heated continuously until a clear digest was obtained. The digest was diluted to 100 ml using deionized water, allowed to cool and then filtered through Whatman No. 1 filter paper. The samples were analyzed for calcium, zinc, phosphorus, magnesium, iron, potassium, sodium and copper. Quantification was done by using stock solutions of the elements (Sigma-Aldrich, Switzerland) to prepare reference standards. Results were expressed as milligramme per 100 grammes (mg/100 g) dry weight of flour [14].

2.5.5 *Phytochemical analysis*

2.5.5.1 *Alkaloids*

A mixture of 200 ml of 10% acetic acid in ethanol and 5 g of composite flour was covered and allowed to react for 4 hours. The mixture was filtered through Whatman No. 1 filter paper and the filtrate obtained was concentrated to one-fourth its volume. Concentrated ammonium hydroxide was added drop by drop until the formation of precipitates was observed. The precipitates were collected and washed with dilute ammonium hydroxide and then dried in an oven, cooled and weighed. Results were expressed as a percentage of the ratio of the weight of alkaloids to the weight of flour used [13].

2.5.5.2 *Saponins*

Saponins were extracted from 2 g of flour by allowing the flour to react with 200 ml of pure acetone in a reflux condenser for 2 hours. Re-extraction was done using 200 ml of ethanol in a Soxhlet apparatus for 2 hours. The extract obtained was evaporated and then dried to a constant weight in a hot air oven at 105 °C. Results were expressed as a percentage of the ratio of the weight of saponins to the weight of flour used [13].

2.5.5.3 *Flavonoids*

Ten grammes (10 g) of composite flour were treated with 100 ml of 80% aqueous methanol and the mixture was left to stand at room temperature for 24 hours. Next, the mixture was filtered and the filtrate obtained was evaporated to dryness, allowed to cool and then weighed. Results were expressed as a percentage of the ratio of the weight of flavonoids to the weight of flour used [14].

2.5.5.4 *Tannins*

The Folin-Denis method was used to quantify tannins in the composite flours. Forty millilitres (40 ml) of boiling distilled water were added to 250 mg of composite flour and left to stand for 30 minutes. The mixture was spun in a centrifuge at 2,000 rpm for 20 minutes and then the supernatant was collected and diluted to 100 ml using distilled water. To 0.5 ml of the extract, 1 ml of Folin-Denis reagent and 2 ml of sodium carbonate were added and allowed to react until colour development was observed. Absorbance was read using a UV-Vis spectrophotometer at 700 nm. Using tannic acid as a reference standard, tannin content was expressed as milligramme per 100 gramme dry weight of flour [14].

2.6 *Analysis on the biscuits*

2.6.1 *Physical analysis*

A Vernier calliper was used to measure the diameter and thickness of the biscuits. Measurements were taken on three biscuits per sample at two different points on each biscuit and the mean was recorded. The diameter/thickness of the biscuits is the average of the two readings divided by three. The spread ratio of the biscuits was calculated by dividing the diameter by the thickness of the biscuits [10].

2.6.2 *Microbial analysis*

One gramme (1 g) of sample was placed in 9 ml of sterile distilled water and from this, two ten-fold serial dilutions were made. The media used were prepared and sterilized according to the instructions of the manufacturers. The samples were plated in sterile petri dishes using the pour plate method and bacteria were enumerated on nutrient agar at 37 °C for 24 hours, while fungi were enumerated on potato dextrose agar (to which streptomycin has been added at a concentration of 30 µg/ml) at 28 °C for 72 hours. Serial dilutions and sample plating were done in a laminar flow cabinet to avoid cross-contamination of samples. The total counts were expressed as coliform forming units per gramme of biscuit [14].

2.6.3 *Sensory analysis*

Thirty (30) semi-trained panellists were recruited from among students and staff of the Department of Home Economics and Food Science, University of Ilorin, Ilorin, Nigeria. The panel consisted of 11 males and 19 females with ages ranging between 19 and 42 years. The panellists were recruited based on their willingness to participate and their familiarity with biscuits. The biscuit samples were coded and presented to the panellists at the same time. The panellists were directed to rinse their mouths with the warm water provided after assessing each sample. The biscuits were assessed for appearance, taste, crispness and overall acceptability on a 9-point hedonic scale, where 1 represented ‘dislike extremely’, 5 represented ‘neither like nor dislike’ and 9 represented ‘like extremely’. This was done following the modified method described by [10].

2.7 *Statistical analysis*

Analyses were performed in triplicate and the data are presented as mean ± standard deviation. Data were analyzed using analysis of variance (ANOVA) and a significant difference between means was determined using the Duncan post-hoc test and $P \leq 0.05$ was taken as statistically significant. Data analysis was done on the statistical package for social sciences (SPSS) software, version 20 (SPSS Inc., Chicago, IL, USA).

3. Results and discussion

3.1 *Colour parameters of wheat and aerial yam composite flours*

The colour parameters of wheat and aerial yam composite flours (Table 1) show that the L^* values for lightness ranged from 76.85-80.54, with samples $W_{50}AD_{50}$ and W_{100} having the lowest and highest values, respectively. The control flour presented lighter values than the composite flours. Furthermore, significant ($p < 0.05$) variation was observed among the composite flours as samples containing sundried aerial yam flour presented lower L^* values. a^* values for red/green were positive, showing that values tended towards the red axis. Values ranged between 3.80 and 5.55, with samples W_{100} and $W_{50}AS_{50}$ presenting the lowest and highest values, respectively. The composite flours presented higher values than the control flour. Similarly, significant ($p < 0.05$) variation was observed among the composite flours. Samples containing sundried aerial yam flour presented higher a^* values. b^* values for blue/yellow were positive, indicating that values tended towards the yellow axis. Values ranged from 12.31-18.66, with samples W_{100} and $W_{50}AS_{50}$ presenting the lowest and highest values, respectively. There was no significant variation among the samples. Previous researchers like Cotovanu et al. have reported findings similar to this study with respect to the lightness and redness of wheat-quinoa composite flours. However, they reported that the yellowness of the composite flours decreased, contrary to the findings reported in this study [15]. The colour of flours is pertinent to their acceptability and potential use [16].

3.2 *Functional properties of aerial yam and wheat composite flours*

Table 1. Colour and functional properties of wheat and aerial yam composite flours

Samples	$W_{100}A_0$	$W_{70}AS_{30}$	$W_{60}AS_{40}$	$W_{50}AS_{50}$	$W_{70}AD_{30}$	$W_{60}AD_{40}$	$W_{50}AD_{50}$
Loose bulk density (kg/m^3)	0.55 ± 0.00^a	0.54 ± 0.02^b	0.54 ± 0.01^b	0.53 ± 0.18^c	0.50 ± 0.20^f	0.51 ± 0.01^e	0.52 ± 0.17^d
Packed bulk density (g/mL)	0.77 ± 0.03^a	0.75 ± 0.21^b	0.75 ± 0.07^b	0.74 ± 0.01^c	0.70 ± 0.05^e	0.71 ± 0.11^d	0.73 ± 0.13^c
Water absorption (g/mL)	102.50 ± 0.09^f	115.50 ± 0.07^e	123.00 ± 0.01^d	131.50 ± 0.03^b	113.50 ± 0.24^d	127.00 ± 0.09^c	134.00 ± 0.22^a
Oil absorption (g/mL)	108.00 ± 0.03^a	105.50 ± 0.03^a	108.50 ± 0.17^a	109.50 ± 0.01^a	104.00 ± 0.05^a	105.50 ± 0.00^a	109.50 ± 0.07^a
Swelling capacity (sec)	2.64 ± 0.25^b	2.53 ± 0.03^d	2.58 ± 0.18^c	2.64 ± 0.01^b	2.58 ± 0.09^c	2.67 ± 0.99^b	2.75 ± 0.06^a
L^*	80.54 ± 0.01^a	78.71 ± 0.04^c	77.32 ± 0.01^d	76.88 ± 0.10^d	79.32 ± 0.011^b	78.33 ± 0.01^c	76.85 ± 0.03^d
a^*	3.80 ± 0.15^f	4.58 ± 0.14^d	5.14 ± 0.07^c	5.55 ± 0.00^a	4.41 ± 0.00^e	5.13 ± 0.01^c	5.36 ± 0.05^b
b^*	12.31 ± 0.00^a	13.77 ± 0.21^a	14.54 ± 0.05^a	18.66 ± 0.19^a	13.63 ± 0.06^a	15.23 ± 0.01^a	15.75 ± 0.08^a

Values are mean ± S.D. $W_{100}A_0$ = 100% wheat flour (control sample); $W_{70}AD_{30}$ = 70% wheat flour + 30% dehydrated aerial yam flour; $W_{60}AD_{40}$ = 60% wheat flour + 40% dehydrated aerial yam flour; $W_{50}AD_{50}$ = 50% wheat flour + 50% dehydrated aerial yam flour; $W_{70}AS_{30}$ = 70% wheat flour + 30% sundried aerial yam flour; $W_{60}AS_{40}$ = 60% wheat flour + 40% sundried aerial yam flour; $W_{50}AS_{50}$ = 50% wheat flour + 50% sundried aerial yam flour.

The bulk densities of the samples (Table 1) ranged from 0.50-0.55 kg/m^3 for loose bulk density and 0.70-0.77 kg/m^3 for packed bulk density. The results indicate that the composite flours containing sundried aerial yam flour were denser than the control flour. On the other hand, composite flours containing dehydrated aerial yam flour presented lower densities than the control flour. Previous research reported decreased densities in banana pseudostem-wheat flour as compared to whole wheat flour [10]. The bulk densities of flours are usually used to judge the volume of packaging material required [17]. For water absorption capacity, the composite flours generally presented a higher value (113.5-134 g/ml) than the control flour. Among the composite flours, samples containing dehydrated aerial yam flour presented higher values than those containing sundried aerial yam flour. Oil absorption capacity ranged between 104 and 109 g/ml. No significant ($p > 0.05$) difference was observed between the samples. Similarly, Aljahani [18] reported that substituting wheat with yellow pumpkin flour increased the water holding capacity and oil holding capacity of the composite flours. Water absorption capacity shows the ability of the flours to absorb water well, and oil absorption capacity is important for flavour retention and mouth-feel [17].

3.3 *Proximate composition of wheat and aerial yam composite flours*

Table 2. Proximate composition of wheat and aerial yam composite flours

Samples	Moisture (%)	Ash (%)	Protein (%)	Fibre (%)	Fat (%)	Carbohydrates (%)
$W_{100}A_0$	7.02 ± 0.00^a	3.95 ± 0.00^a	5.59 ± 0.00^e	0.26 ± 0.00^d	1.16 ± 0.00^d	82.03 ± 0.00^a
$W_{70}AS_{30}$	6.29 ± 0.00^a	2.21 ± 0.00^b	5.77 ± 0.00^d	0.48 ± 0.0°C	3.48 ± 0.0°C	81.79 ± 0.00^a
$W_{60}AS_{40}$	6.21 ± 0.00^a	2.43 ± 0.00^b	6.86 ± 0.0°C	0.53 ± 0.00^b	3.54 ± 0.00^b	80.44 ± 0.00^{ab}
$W_{50}AS_{50}$	6.19 ± 0.00^a	3.69 ± 0.00^a	7.16 ± 0.00^a	0.62 ± 0.00^a	3.61 ± 0.00^a	78.75 ± 0.00^b
$W_{70}AD_{30}$	7.18 ± 0.00^a	2.44 ± 0.00^b	5.77 ± 0.00^d	0.47 ± 0.0°C	3.47 ± 0.0°C	80.68 ± 0.00^{ab}
$W_{60}AD_{40}$	7.18 ± 0.00^a	2.73 ± 0.00^b	6.90 ± 0.00^b	0.54 ± 0.00^b	3.56 ± 0.00^b	79.11 ± 0.00^b
$W_{50}AD_{50}$	5.99 ± 0.00^a	4.25 ± 0.00^a	7.18 ± 0.00^a	0.62 ± 0.00^a	3.62 ± 0.0°C	78.36 ± 0.00^b

Values are mean ± S.D. $W_{100}A_0$ = 100% wheat flour (control sample); $W_{70}AD_{30}$ = 70% wheat flour + 30% dehydrated aerial yam flour; $W_{60}AD_{40}$ = 60% wheat flour + 40% dehydrated aerial yam flour; $W_{50}AD_{50}$ = 50% wheat flour + 50% dehydrated aerial yam flour; $W_{70}AS_{30}$ = 70% wheat flour + 30% sundried aerial yam flour; $W_{60}AS_{40}$ = 60% wheat flour + 40% sundried aerial yam flour; $W_{50}AS_{50}$ = 50% wheat flour + 50% sundried aerial yam flour.

The moisture content of foods is a quality index used to determine the stability of foods during storage [19]. The moisture content of the samples (Table 2) ranged from 5.99-7.18%. No significant ($p < 0.05$) variation was observed between the samples. This disagrees with previous literature, which reported a significant decrease in the moisture content of composite flours made from wheat-quinoa flour fractions and amaranth-wheat flour, respectively [15, 20]. The low moisture content presented by all samples meets the standard specification of 10% for long-term storage of flours [17]. Total ash content ranged from 2.21-4.25%. Only composite flours containing 50:50 aerial yam and wheat flours presented high values similar to that of the control flour. This contrasts with the findings of Cotovanu et al. as they reported a significant increase in the ash content of wheat-quinoa formulated flours [15]. Ash content indicates the total amount of minerals present in the flours. Crude protein was seen to vary significantly among the samples with values ranging from 5.59-7.18%. As the amount of aerial yam flour in the sample formulation increased, the composite flours' crude protein content increased relative to the control flour; no variation was observed among the composite flour formulations. This implies that the composite flours will be useful in addressing protein deficiencies. For crude fat, values ranged between 1.16 and 3.62%, and the control flour presented a significantly ($p < 0.05$) lower amount than those observed in the composite flour samples. No variation was observed among the composite flour samples. Fats are required for the absorption of fat-soluble vitamins [21]. Similarly, increases in the protein and fat contents of composite flours from amaranth & wheat and wheat & quinoa flour fractions, respectively, as compared to whole wheat flour have been reported from previous studies [15, 20]. Crude fibre ranged from 0.26-0.62%, and the composite flours presented significantly ($p < 0.05$) higher levels as compared to the control flour; no variation was observed among the composite flour formulations. Nasir et al. stated that the fibre content of amaranth-wheat flour increased with increasing levels of amaranth in the formulations [20]. Fibre is beneficial in the regulation of bowel movement and weight [22]. The carbohydrate content of the samples ranged from 78.36-82.03%. Only samples $W_{50}AS_{50}$, $W_{60}AD_{40}$ and $W_{50}AD_{50}$ were significantly ($p < 0.05$) lower than the control flour. All other samples had values similar to the control flour. Cotovanu et al. and El-Sohaimy et al. reported a significant ($p < 0.05$) decrease in the carbohydrate content of wheat-quinoa flour formulations. Carbohydrates are the chief energy source in foods [15, 23].

3.4 *Mineral composition of wheat and aerial yam composite flours*

The mineral analysis (Table 3) of the samples revealed that calcium (1.17-1.69 mg/100 g), zinc (0.24-0.44 mg/100 g), phosphorus (66.09-87.21 mg/100 g), potassium (2.87-5.06 mg/100 g), copper (0.02-0.04 mg/100 g), iron (0.38-0.67 mg/100 g), magnesium (19.38-35.38 mg/100 g) and sodium (0.19-0.28 mg/100 g) were present. Generally, calcium, magnesium, iron, potassium and sodium were significantly ($p < 0.05$) higher in the composite flours than in the control flour. On the other hand, zinc levels were significantly ($p < 0.05$) lower in the composite flours as compared to the control flour. For phosphorus, only samples $W_{60}AS_{40}$ and $W_{60}AD_{40}$ presented higher levels than that recorded for the control flour; all other formulations had lower values than the control flour. In agreement, Hassan reported similar trends for the calcium, potassium and iron contents of wheat-baobab pulp composite flour. However, they reported no variation in magnesium and phosphorus levels, reduced sodium levels and increased zinc levels in wheat-baobab pulp flour as compared to whole wheat [24]. Minerals are essential inorganic elements required for proper functioning. Calcium is necessary for the development of bones and teeth; zinc is a cofactor of most metabolic enzymes; potassium is needed for smooth muscle contraction and control; copper aids the absorption of iron; iron helps with oxygen transport and haemoglobin formation; sodium regulates the osmotic pressure of body fluids and magnesium is needed for the metabolism of macromolecules [14].

Table 3. Mineral composition of wheat and aerial yam composite flours

Samples	Calcium (mg/100 g)	Zinc (mg/100 g)	Phosphorus (mg/100 g)	Magnesium (mg/100 g)	Iron (mg/100 g)	Potassium (mg/100 g)	Sodium (mg/100 g)	Copper (mg/100 g)
$W_{100}A_0$	1.17 ± 0.00^a	0.44 ± 0.01^f	77.7 ± 0.00^d	19.38 ± 0.13^a	0.39 ± 0.01^{ab}	4.27 ± 0.01^b	0.19 ± 0.01^a	0.02 ± 0.00^{ab}
$W_{70}AS_{30}$	1.45 ± 0.00^b	0.37 ± 0.00^d	73.86 ± 0.06^c	24.00 ± 0.00^b	0.44 ± 0.01^{cd}	4.99 ± 0.10^d	0.25 ± 0.02^b	0.03 ± 0.01^{abc}
$W_{60}AS_{40}$	1.61 ± 0.01^c	0.24 ± 0.01^a	86.51 ± 0.51^e	35.05 ± 0.15^f	0.38 ± 0.03^a	4.84 ± 0.01^{cd}	0.27 ± 0.00^b	0.04 ± 0.01^c
$W_{50}AS_{50}$	1.16 ± 0.01^a	0.29 ± 0.01^c	66.09 ± 0.11^a	28.63 ± 0.13^e	0.43 ± 0.01^{bcd}	2.87 ± 0.00^a	0.20 ± 0.01^a	0.02 ± 0.01^a
$W_{70}AD_{30}$	1.51 ± 0.01^b	0.39 ± 0.01^e	73.98 ± 0.01^c	24.75 ± 0.25^c	0.46 ± 0.02^d	5.06 ± 0.14^d	0.27 ± 0.01^b	0.02 ± 0.00^{ab}
$W_{60}AD_{40}$	1.69 ± 0.03^d	0.24 ± 0.00^a	87.21 ± 0.11^e	35.38 ± 0.13^f	0.39 ± 0.01^{abc}	$4.85 \pm 0.0°C^d$	0.28 ± 0.01^b	0.03 ± 0.00^{bc}
$W_{50}AD_{50}$	1.51 ± 0.02^b	0.27 ± 0.00^b	70.70 ± 0.30^b	27.63 ± 0.13^d	0.67 ± 0.00^e	$4.69 \pm 0.0°C$	0.27 ± 0.02^b	0.03 ± 0.01^{abc}

Values are mean ± S.D (n = 3). $W_{100}A_0$ = 100% wheat flour (control sample); $W_{70}AD_{30}$ = 70% wheat flour + 30% dehydrated aerial yam flour; $W_{60}AD_{40}$ = 60% wheat flour + 40% dehydrated aerial yam flour; $W_{50}AD_{50}$ = 50% wheat flour + 50% dehydrated aerial yam flour; $W_{70}AS_{30}$ = 70% wheat flour + 30% sundried aerial yam flour; $W_{60}AS_{40}$ = 60% wheat flour + 40% sundried aerial yam flour; $W_{50}AS_{50}$ = 50% wheat flour + 50% sundried aerial yam flour.

3.5 *Phytochemical composition of wheat and aerial yam composite flours*

The phytochemical composition of the flour samples (Table 4) showed that flavonoids were the most abundant phytochemicals, with values ranging from 0.05-12.43%, with samples $W_{100}A_0$ and $W_{50}AS_{50}$ presenting the lowest and highest values, respectively. The composite flours presented significantly ($p < 0.05$) higher values than the control flour ($W_{100}A_0$) and the values were observed to increase with increasing amounts of aerial yam in the formulation. Alkaloids ranged between 0.27-7.38%; the control flour presented the lowest value and sample $W_{50}AS_{50}$ presented the highest value. A significant ($p < 0.05$) variation was observed among the composite flours, as the formulations containing sundried aerial yam flour presented higher alkaloid contents than those with dehydrated aerial yam flour. Saponins ranged between 0.03 and 5.47%, with samples $W_{100}A_0$ and $W_{50}AS_{50}$ having the lowest and highest values, respectively. The composite flour samples had higher contents than the control flour. Furthermore, no variation was observed among the composite flours. Tannins were undetected in the control flour, however, values ranged from 0.03-0.07% in the composite flours. Variations were observed among the composite flours as samples containing sundried aerial yam flour had a higher content than those containing dehydrated aerial yam flour in their formulations. The findings of this study are similar to those of Adesina and Ifesan, who reported significantly ($p < 0.05$) higher levels of alkaloids, flavonoids, saponins and tannins in wheat composite flours containing milkweed flour as compared to whole wheat flour [12]. Phytochemicals are known to perform various physiological functions. Flavonoids are reported to have antioxidant, anti-inflammatory and anti-cancer properties. Alkaloids have been shown to have analgesic, antioxidant, antitumor and antimutagenic properties. Saponins lower cholesterol absorption and tannins inhibit cancer, tumours, mutagenic and inflammatory agents [14].

Table 4. Phytochemical composition of wheat and aerial yam composite flours

Samples	Alkaloids (%)	Saponins (%)	Flavonoids (%)	Tannins (%)
$W_{100}A_0$	0.27 ± 0.00^g	0.03 ± 0.00^d	0.05 ± 0.00^e	ND
$W_{70}AS_{30}$	3.59 ± 0.00^e	2.82 ± 0.0°C	6.37 ± 0.0°C	0.04 ± 0.00^e
$W_{60}AS_{40}$	6.11 ± 0.0°C	4.75 ± 0.00^b	10.97 ± 0.00^a	0.06 ± 0.0°C
$W_{50}AS_{50}$	7.38 ± 0.00^a	5.47 ± 0.00^a	12.43 ± 0.00^a	0.07 ± 0.00^a
$W_{70}AD_{30}$	3.53 ± 0.00^f	2.86 ± 0.0°C	5.87 ± 0.00^d	0.03 ± 0.00^f
$W_{60}AD_{40}$	6.04 ± 0.00^d	4.75 ± 0.00^b	10.96 ± 0.00^b	0.05 ± 0.00^d
$W_{50}AD_{50}$	7.31 ± 0.00^b	5.46 ± 0.00^a	12.17 ± 0.00^a	0.06 ± 0.00^b

Values are mean ± S.D. $W_{100}A_0$ = 100% wheat flour (control sample); $W_{70}AD_{30}$ = 70% wheat flour + 30% dehydrated aerial yam flour; $W_{60}AD_{40}$ = 60% wheat flour + 40% dehydrated aerial yam flour; $W_{50}AD_{50}$ = 50% wheat flour + 50% dehydrated aerial yam flour; $W_{70}AS_{30}$ = 70% wheat flour + 30% sundried aerial yam flour; $W_{60}AS_{40}$ = 60% wheat flour + 40% sundried aerial yam flour; $W_{50}AS_{50}$ = 50% wheat flour + 50% sundried aerial yam flour.

3.6 *Physical properties of biscuits produced from wheat and aerial yam composite flours*

The diameter (Table 5) of the biscuits varied from 43.60-46.75 mm. No significant ($p < 0.05$) difference was observed between biscuits produced from the composite flours and those produced from the control flour. Thickness varied from 48.02-79.97 mm, with samples $W_{70}AS_{30}$ and $W_{60}AD_{40}$ having the lowest and highest values, respectively. Biscuits produced from composite flours containing sundried aerial yam flours were observed to have higher values for thickness than the control flour and the other composite flours. The spread ratio of the samples varied between 0.58 and 1.39, with samples $W_{70}AS_{30}$ and $W_{60}AD_{40}$ having the lowest and highest values, respectively. Biscuits from the composite flours had lower spread ratios than those from the control flour, except for samples $W_{70}AD_{30}$ and $W_{50}AD_{50}$. Similarly, Chakraborty et al. reported that there was no variation in the diameter of biscuits made from banana pseudostem-wheat flour as compared to whole wheat flour. On the other hand, they reported that the thickness of the composite biscuits decreased while the spread ratio increased in comparison to the control sample [10]. The physical characteristics of baked goods are a factor of their gluten content, since it is the gluten that enables them to trap the gas produced, resulting in higher yields and weights [2].

Table 5. Physical properties of biscuits produced from wheat and aerial yam composite flours

Samples	Diameter (mm)	Thickness (mm)	Spread ratio
$W_{100}A_0$	46.75 ± 0.00^a	63.51 ± 0.08^d	0.74 ± 0.05^a
$W_{70}AS_{30}$	45.95 ± 0.00^a	79.97 ± 0.05^a	0.57 ± 0.05^e
$W_{60}AS_{40}$	43.60 ± 0.00^b	75.03 ± 0.01^b	0.58 ± 0.02^d
$W_{50}AS_{50}$	45.90 ± 0.00^a	75.30 ± 0.02^b	0.61 ± 0.01^{bc}
$W_{70}AD_{30}$	45.80 ± 0.00^a	79.02 ± 0.02^a	0.58 ± 0.02^d
$W_{60}AD_{40}$	46.75 ± 0.00^a	74.02 ± 0.04^{bc}	0.63 ± 0.04^b
$W_{50}AD_{50}$	46.10 ± 0.00^a	76.86 ± 0.09^{ab}	0.60 ± 0.03^c

Values are mean ± S.D. $W_{100}A_0$ = 100% wheat flour (control sample); $W_{70}AD_{30}$ = 70% wheat flour + 30% dehydrated aerial yam flour; $W_{60}AD_{40}$ = 60% wheat flour + 40% dehydrated aerial yam flour; $W_{50}AD_{50}$ = 50% wheat flour + 50% dehydrated aerial yam flour; $W_{70}AS_{30}$ = 70% wheat flour + 30% sundried aerial yam flour; $W_{60}AS_{40}$ = 60% wheat flour + 40% sundried aerial yam flour; $W_{50}AS_{50}$ = 50% wheat flour + 50% sundried aerial yam flour.

3.7 *Microbial quality of biscuits produced from wheat and aerial yam composite flours*

Table 6. Microbiological quality of biscuits produced from wheat and aerial yam composite flours

Samples	TBC ($\times 10^4$ cfu/g)	TFC ($\times 10^3$ cfu/g)
$W_{100}A_0$	17.5 ± 0.02^c	17.5 ± 0.05^c
$W_{70}AS_{30}$	32.0 ± 0.14^a	32.0 ± 0.32^b
$W_{60}AS_{40}$	25.0 ± 0.01^b	41.0 ± 0.07^a
$W_{50}AS_{50}$	28.0 ± 0.00^b	29.0 ± 0.06^b
$W_{70}AD_{30}$	10.3 ± 0.05^c	16.5 ± 0.41^c
$W_{60}AD_{40}$	11.5 ± 0.11^c	14.5 ± 0.01^c
$W_{50}AD_{50}$	15.0 ± 0.07^c	8.0 ± 0.072^d

Values are mean ± S.D. $W_{100}A_0$ = 100% wheat flour (control sample); $W_{70}AD_{30}$ = 70% wheat flour + 30% dehydrated aerial yam flour; $W_{60}AD_{40}$ = 60% wheat flour + 40% dehydrated aerial yam flour; $W_{50}AD_{50}$ = 50% wheat flour + 50% dehydrated aerial yam flour; $W_{70}AS_{30}$ = 70% wheat flour + 30% sundried aerial yam flour; $W_{60}AS_{40}$ = 60% wheat flour + 40% sundried aerial yam flour; $W_{50}AS_{50}$ = 50% wheat flour + 50% sundried aerial yam flour.

The microbial quality of the biscuits was assessed to determine whether or not the samples were safe for human consumption. Results (Table 6) show that the total bacterial count ranged from 10.3 – 32.0 × 10^4 cfu/g and the total fungal count ranged between 8.0 and 41.0 × 10^3 cfu/g. Samples containing dehydrated aerial yam flour had lower total bacterial and total fungal counts as compared to the samples containing sundried aerial yam flour. This could be a result of contamination of the sundried aerial yams as they were exposed during the drying process. No significant variation was observed between the samples from the control flour and those containing dehydrated aerial yam flour. However, all counts were within the acceptable microbial limits of 10^4-<10^6 for ready-to-eat food products [25-26]. This indicates that the samples were safe for consumption.

3.8 *Sensory properties of biscuits produced from wheat and aerial yam composite flours*

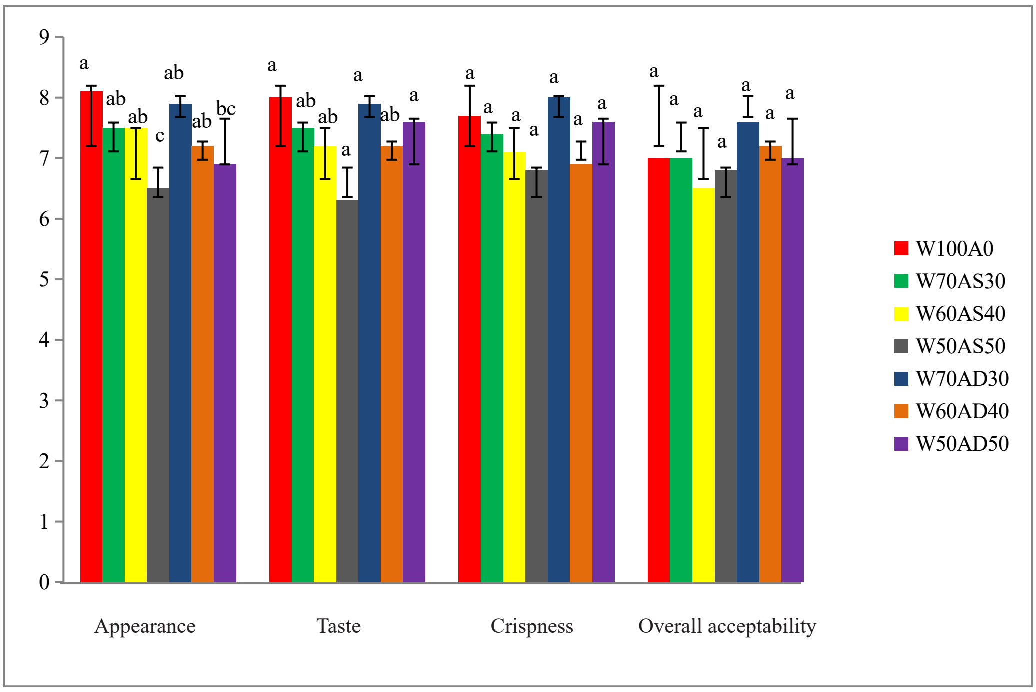

Figure 4. Sensory properties of biscuits produced from wheat and aerial yam composite flours

Values are scored on a 9-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely). Values are mean ± S.D. $W_{100}A_0$ = 100% wheat flour (control sample); $W_{70}AD_{30}$ = 70% wheat flour + 30% dehydrated aerial yam flour; $W_{60}AD_{40}$ = 60% wheat flour + 40% dehydrated aerial yam flour; $W_{50}AD_{50}$ = 50% wheat flour + 50% dehydrated aerial yam flour; $W_{70}AS_{30}$ = 70% wheat flour + 30% sundried aerial yam flour; $W_{60}AS_{40}$ = 60% wheat flour + 40% sundried aerial yam flour; $W_{50}AS_{50}$ = 50% wheat flour + 50% sundried aerial yam flour.

The biscuit samples were assessed for appearance, crispiness, taste and overall acceptability, and results (Figure 4) showed that the appearance varied between 6.5 and 8.1, with samples $W_{50}AS_{50}$ and W_{100} presenting the lowest and highest ratings, respectively. The samples from the composite flours competed favourably with samples from the control flour, except for samples $W_{50}AS_{50}$ and $W_{50}AD_{50}$. For crispness, values ranged from 6.8-7.7, with samples $W_{50}AS_{50}$ and $W_{60}AS_{40}$ presenting the lowest and highest ratings, respectively. No significant ($p < 0.05$) variation was observed among the composite biscuit samples and the control flour biscuits; all other samples had scores similar to that of the control sample. The taste scores ranged between 6.3 and 8.0, with samples $W_{50}AS_{50}$ and W_{100} presenting the lowest and highest ratings, respectively. However, no significant ($p < 0.05$) differences were observed among the samples. Scores for overall acceptability ranged from 6.5-7.6, with samples $W_{60}AS_{40}$ and $W_{70}AD_{30}$ presenting the lowest and highest ratings, respectively. No significant variations were recorded among the samples; however, the samples differed quantitatively, and sample $W_{70}AD_{30}$ was found to be the most appealing to the evaluators. Uchenna and Omolayo noted that biscuits made from 100% wheat flour had significantly ($p < 0.05$) higher scores for appearance, taste and overall acceptability as compared to those made from composite flours of wheat, Bambara nut and aerial yam. Similar to the findings of this study, they reported that there was no significant ($p > 0.05$) difference in the crispness of the samples [2].

4. Conclusion

This study was carried out to reduce the over-reliance on wheat flour and to provide suitable, readily-available and nutritive alternatives. The findings revealed that the substitution of wheat flour with aerial yam flour significantly increased the nutritive value, particularly the protein, fibre and fat contents. The mineral (calcium, magnesium, iron, potassium and sodium) and phytochemical (alkaloids, saponins, flavonoids and tannins) compositions of the flour blends were also improved. The substitution was also found to have reduced bulk densities and increased water holding capacity and swelling capacity (at ≥ 40% level of substitution) of the flour. The composite flour biscuits had similar diameter as the plain wheat biscuits. Furthermore, they presented higher thickness and lower spread ratios than the plain wheat biscuits. Sensory evaluation showed that the composite flour biscuits had similar properties for taste, crispness and overall acceptability as the plain wheat biscuits. Generally, this study suggests that aerial yam flour has great potential for use in the baking industry for the production of nutritive and appealing products. More so, it encourages the utilization of aerial yam flour and reduces overdependence on wheat flour.

Compliance with ethics requirements

The sensory evaluators were recruited based on their willingness to participate.

Conflict of interest

The authors declare no competing financial interest.

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