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Quality evaluation of *chin-chin* produced from aerial yam (*Dioscorea bulbifera*) and wheat flour blends

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Abstract

The objective of this study was to investigate the quality of *chin-chin* produced from aerial yam and wheat flour blends with the aim to improve the utilisation of aerial yam flour and reduce over-dependence on wheat flour. A portion of aerial yam tubers was sun-dried and the other was dried in a dehydrator. They were made into flour and substituted with wheat flour at varying proportions (85:15, 67.5:32.5, and 50:50). 100% wheat flour was used as the control. The flour blends were analyzed for proximate, functional, and phytochemical properties. The *chin-chin* produced were evaluated for their sensory properties. Wheat-aerial yam flour blends were nutritionally superior (with respect to protein, fat, fibre, and carbohydrates), and had better functional and phytochemical properties when compared to plain wheat flour used as the control. Sensory evaluation revealed that the most appealing sample among the flour blends was $W_{85}AYD_{15}$ (with 85% wheat flour and 15% dehydrated aerial yam flour) even though samples $W_{50}AYS_{50}$ (with 50% wheat flour and 50% sun-dried aerial yam flour) and $W_{50}AYD_{50}$ (with 50% wheat flour and 50% dehydrated aerial yam flour) were more nutritious. Since the findings of this study showed that highly nutritious and functional flours can be produced by including aerial yam flour in flour blends, the industrial production of aerial yam flour will increase its economic value by improving utilisation and providing cheaper alternatives to wheat flour.

Keywords Aerial yam, Chin-chin, Composite flours, *Dioscorea bulbifera*, Flour blends, Wheat flour

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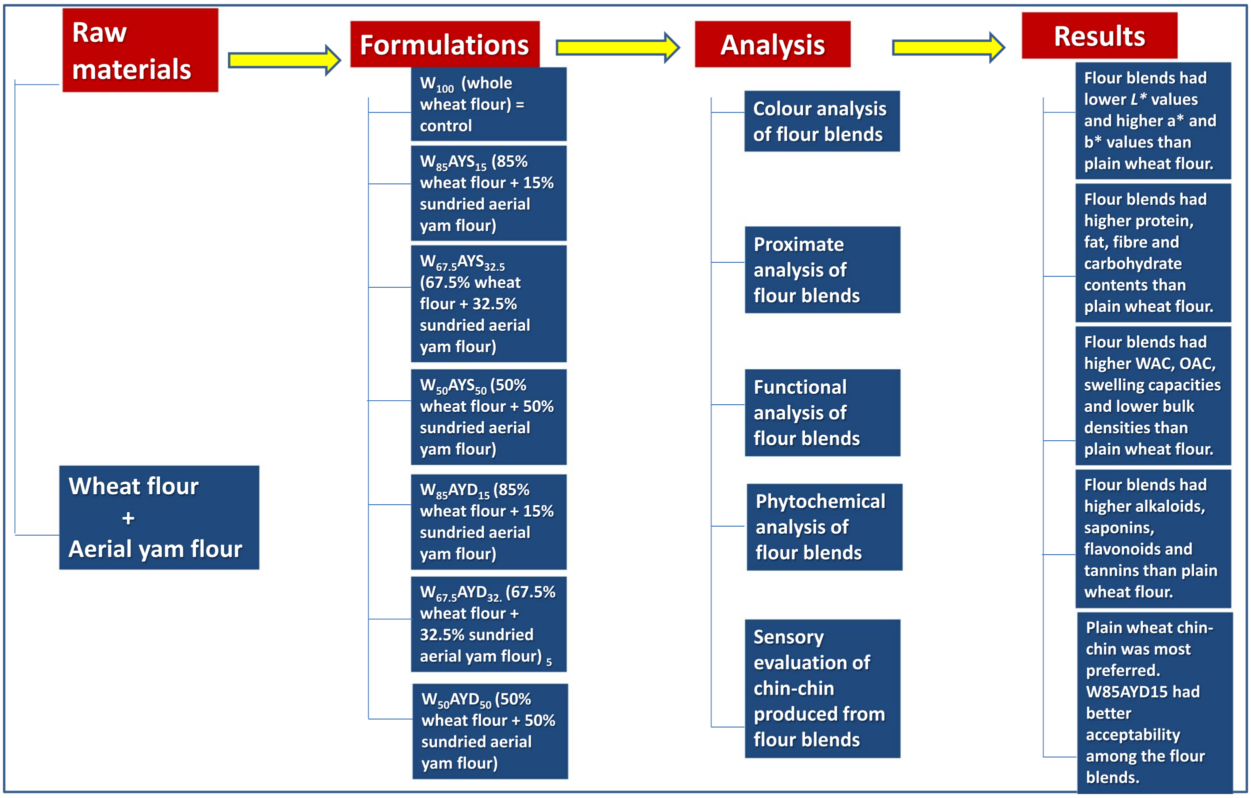
Graphical Abstract



Introduction

In Nigeria, the baking industry majorly relies on wheat flour as the major ingredient for baked goods. This has become problematic as wheat cannot be cultivated in Nigeria due to its agronomic requirements, hence, wheat must be imported. This in turn, negatively affects the Nigerian economy. This has made food processors and researchers tasked with the responsibility of finding cheaper and readily available alternatives (Olanipekun et al. 2018). To reduce the over-dependence on wheat flour, food processors are beginning to use flour blends i.e. the mixture of several flours (including wheat flour) which could be obtained from other cereals, legumes, roots, or tubers. These flour blends have the potential of being more nutritionally and economically advantageous (Bolarinwa et al. 2015).

The aerial yam (*Dioscorea bulbifera*) is a rare edible yam species that, in contrast to the ordinary yam, produces aerial bulbil that resembles potatoes, hence the name aerial yam (Igyor et al. 2004). The consumption of this yam species is limited to a small population for a variety of reasons, and these have led to its underutilisation. This variety, in comparison to other varieties, has an unpleasant bitter aftertaste (Sanful & Engmann 2016). It's also unknown to the general public, and little research has been done on it to suggest potential uses. Aerial yam is reported to be rich in protein, fibre, and minerals. It also has appreciable amounts of phytochemicals which make it useful in the treatment of gastro-intestinal disorders, diabetes, and inflammations (Celestine & David 2015; Uchenna & Omolayo 2017).

Chin-chin is a typical Nigerian snack that is formed from a stiff paste made from wheat flour, butter, milk, and eggs. The dough is deep-fried or baked until a golden brown and crispy product is obtained. It is extremely popular and enjoyed by people of all age groups throughout Nigeria and the whole of Western Africa (Adegunwa et al. 2014).

The inclusion of aerial yam in flours for baking is to improve the nutritional quality of the flour blend and to reduce the over-dependence on wheat flour by providing a suitable alternative. In furtherance of the above, this study investigated the possibility of preparation of *chin-chin* from uncooked aerial yam and wheat flour blends with good acceptability, which will invariably stimulate increased aerial yam production and utilisation as a raw material in the processing industry.

Materials and methods

Sources of materials

Aerial yam was bought from farmers' market in Aduratedo-Ape, Kabba/Bunu LGA, Kogi State, Nigeria, and Wheat flour was bought from Oja-Oba market in Ilorin, Kwara State, Nigeria. Other ingredients were purchased at Folax Store, Tanke, Ilorin, Kwara State.

Preparation of aerial yam flour

The standard method described by Kayode et al. (2017) was modified and used for the processing of aerial yam into flour. Disease-free and whole tubers were picked and cleaned in running tap water. They were peeled underwater to limit enzymatic browning and cut into thin slices (2 – 3 cm thickness) to ensure efficient heat circulation during drying. The yam slices were divided into two portions. One portion was dried in a dehydrator at 65 ℃ for 4 h while the other portion was sun-dried for 48 h. The dried yam slices were milled into flour in a hammer mill and screened through a 40-mesh sieve. The yam flour obtained was then stored in an air-tight container.

Flour blend formulation

Response surface methodology on Design expert software (version 7.0) was used to obtain the various blend formulations (Table 1).

Table 1 Flour blend formulation

Sample codes	Wheat flour (%)	Aerial yam flour (%)
$W_{100}A_0$	100	0
$W_{85}AS_{15}$	85	15
$W_{67.5}AS_{32.5}$	67.5	32.5
$W_{50}AS_{50}$	50	50
$W_{85}AD_{15}$	85	15
$W_{67.5}AD_{32.5}$	67.5	32.5
$W_{50}AD_{50}$	50	50

W100A0 = 100% wheat flour (control sample); W70AD30 = 70% wheat flour + 30% dehydrated aerial yam flour; W60AD40 = 60% wheat flour + 40% dehydrated aerial yam flour; W50AD50 = 50% wheat flour + 50% aerial yam flour; W70AS30 = 70% wheat flour + 30% sun−dried aerial yam flour; W60AS40 = 60% wheat flour + 40% sun−dried aerial yam flour; W50AS50 = 50% wheat flour + 50% sun−dried aerial yam flour

Production of *Chin-chin*

The method adopted by Abioye et al. (2020) was modified for the production of *chin-chin* from aerial yam and wheat flour blends. One hundred gramme of flour was mixed with 1 g of baking powder, 1 g of salt, 10 g of powdered milk, and 30 g of margarine. One large egg and 20 g of sugar were beaten manually for 2 minutes and the mixture was added in. All the ingredients were mixed to form dough which was kneaded manually on a flat board, the dough was rolled using a rolling pin and cut into strips. The strips were cut into squares of 2 by 2 cm using a cutter, and then the cubes were deep-fried in vegetable oil at 180 ℃ until they turned golden brown. The *chin-chin* was placed on absorbent paper to drain and cool, after which they were packed in air-tight containers and stored at room temperature.

Determination of the colour properties of wheat-aerial yam flour blends

Colour was determined based on the CIE Lab method, where L^* represents the whiteness/brightness, a^* represents the redness/greenness, and b^* represents the yellowness/blueness using a colorimeter with the model number WR-10 (Cotovanu & Mironeasa 2021).

Proximate analysis of wheat-aerial yam flour blends

The proximate composition of the flour blends was analysed using the methods specified by the Association of Official Analytical Chemists (AOAC 2019).

Moisture content determination

One gramme of flour was dried in a hot air oven at 105 ℃ until a constant weight was obtained. Samples were cooled in a desiccator and moisture content was calculated using the equation below.

$$\%\ Moisture = \frac{weight\ of\ the\ sample\ after\ drying}{weight\ of\ the\ sample\ before\ drying} \times 100$$

Protein content determination

The nitrogen content of the samples was determined using the Kjeldahl method. To 2 g of sample, 5 g of sodium sulphate, and 1 g of copper sulphate were added and 25 ml of concentrated sulphuric acid were added, then the mixture was gently heated in a fume cupboard until digestion was complete. The digest was allowed to cool, and then it was transferred into a 250 ml volumetric flask and made up to the mark using distilled water. This was followed by distillation in a Markham distillation apparatus. Five millilitres of the digest and 5 ml of 60% sodium hydroxide solution were added to the distillation apparatus and steam distillation was allowed to take place for 10 min. The distillate was collected in a 50 ml conical flask containing 5 ml of boric acid indicator and titrated against 0.01N hydrochloric acid and the endpoint was recorded. The nitrogen content was calculated using the equation below.

$$\%\ Nitrogen = \frac{titre\ value \times molecular\ mass\ of\ N \times normality\ of\ HCl \times vol.flask\ containing\ digest \times 100}{weight\ of\ sample\ digested \times vol.\ of\ the\ digest\ for\ steam\ distillation}$$

Molecular mass of nitrogen = 0.014.
Molarity of HCl = 0.01.
Protein content was further calculated using the formula

$$\%\ protein = \%\ nitrogen \times conversion\ factor$$

Conversion factor = 6.25.

Fat content determination

The solvent extraction method in a Soxhlet apparatus was used for the determination of fat content. Two gramme of sample was placed in a labelled thimble which was inserted in the Soxhlet apparatus and extraction was done under reflux with petroleum ether (bp. 40 – 60 ℃) for 6 h. After extraction, the thimble was removed and dried in a hot air oven at 105 ℃ for 1 h to evaporate the solvent. The thimble was cooled in a desiccator and weighed. Fat content was calculated as

$$\%\ Fat = \frac{weight\ of\ fat}{weight\ of\ sample} \times 100$$

Fibre content determination

The defatted sample was used for the determination of fibre content using the gravimetric method. Two hundred millilitres of a solution containing 1.25 g of H_2SO_4 per 100 ml solution was added to 2 g of the defatted sample. The mixture was heated under reflux for 30 min, and then it was filtered through a linen cloth. The filtrate was discarded and the residue was returned to a beaker and boiled with 200 ml of 0.313N NaOH for another 30 min. The mixture was filtered and 100 ml of acetone was added to the residue to dissolve any organic component. The residue was further washed with boiling water and then dried in a hot air oven at 105 ℃. The dried residue was incinerated in a muffle furnace at 550 ℃ for 4 h, after which it was cooled and weighed. Fibre content was calculated using the equation below.

$$\%\ Fibre = \frac{weight\ of\ residue - weight\ of\ ash}{original\ weight\ of\ sample} \times 100$$

Ash content determination

One gramme of sample was incinerated in a muffle furnace at 550 ℃ for 12 h to obtain ash. The ash was allowed to cool in a desiccator and then weighed. The total ash was calculated as a percentage of the original sample weight using the formula below.

$$\%\ Ash = \frac{weight\ of\ ash}{weight\ of\ sample} \times 100$$

Carbohydrate content determination

Carbohydrate content was determined by difference using the formula below % Carbohydrate = 100 - (% moisture + % protein + % fat + % fibre + % ash.

Phytochemical analysis

The phytochemical composition of the flour blends was determined for their alkaloid, saponin, tannin, and flavonoid contents.

Alkaloid content determination

Two hundred millilitres of 10% acetic acid in ethanol was added to 5 g of the flour samples, covered, and allowed to stand for 4 h. The mixture was filtered using Whatman No. 1 filter paper and the filtrate was concentrated to one-quarter of its original volume using a water bath at 100 ℃. Next, drops of concentrated ammonium hydroxide were added and precipitates were formed. These were filtered, washed with dilute ammonium hydroxide, dried in an oven, and weighed. Alkaloid content was expressed as milligramme per kilogramme dry weight of flour (Bukuni et al. 2022).

$$Alkaloid\ content\left(\frac{mg}{kg}\right) = \frac{weight\ of\ alkaloids}{weight\ of\ sample} \times 1000$$

Saponin content determination

Twenty gramme of the flour sample was extracted using 200 ml of 20% ethanol and the mixture was heated in a water bath at 100 ℃ for 4 h. The mixture was filtered and the residue was re-extracted using another 200 ml of the solvent. The filtrates were combined and concentrated to about 40 ml over a water bath. The concentrate was poured into a 250 ml separating funnel and 20 ml of diethyl ether was added followed by vigorous shaking. The aqueous layer was collected and purified again with another 20 ml of diethyl ether. Then 60 ml of n-butanol was added and the extract was washed with 10 ml of 5% sodium chloride. The solution was evaporated and subsequently dried in an oven at 105 ℃ until a constant weight was obtained. Saponin was expressed as milligramme per kilogramme dry weight of flour sample (Bukuni et al. 2022).

$$Saponin\ content\left(\frac{mg}{kg}\right) = \frac{weight\ of\ saponin}{weight\ of\ sample} \times 1000$$

Flavonoid content determination

An extract was made by adding 100 ml of 80% aqueous methanol to 10 g of flour and allowing the mixture for 24 h at room temperature. The mixture was filtered and the extract obtained was evaporated to dryness, cooled, and weighed. Flavonoid content was expressed as milligramme per kilogramme dry weight of flour (Joshua et al. 2023).

$$Flavonoid\ content\left(\frac{mg}{kg}\right) = \frac{weight\ of\ flavonoids}{weight\ of\ sample} \times 1000$$

Tannin content determination

Tannins were extracted by placing 250 mg of flour in 40 ml of boiling distilled water for 30 min. This was followed with centrifugation at 2000 rpm for 20 min after which the supernatant was collected in a 100 ml flask and made up to mark with distilled water. One millilitre of Folin-Denis reagent and 2 ml of sodium carbonate were added to 0.5 ml of the extract and left to stand for colour development. The absorbance of the mixture was read using a UV–Vis spectrophotometer operating at 700 nm. Tannic acid was used as standard and tannin content was expressed as mg per kilogramme dry weight of flour (Haleshappa et al. 2022).

$$Tannin\ content\left(\frac{mg}{kg}\right) = \frac{C \times vol.\ extract}{aliquot\ vol. \times\ weight\ of\ sample} \times 1000$$

C = concentration of tannic acid from the graph.

Functional properties of wheat-aerial yam flour blends.

Bulk density, water absorption capacity, and oil absorption capacity of the flour blends were determined following the methods of Abioye et al. (2020).

Bulk density

Briefly, loose bulk density was determined by filling a 100 ml measuring cylinder to the mark with the flour samples and measuring the weight. The same steps were followed for packed bulk density and the measuring cylinder was tapped 50 times before weighing. Bulk density was calculated as the ratio of the weight of the samples and the volume of the samples.

$$Bulk\ density = \frac{weight\ of\ sample}{volume\ of\ cylinder\ occupied\ by\ the\ sample}$$

Water and oil absorption capacity

For water absorption capacity, 10 ml of distilled water was added to 1 g of flour and left to stand for 30 min at room temperature. The mixture was spun in a centrifuge at 2000 g for 30 min and the water absorption capacity was expressed as Percent water bound per gram of flour. The density of water was taken as 1 g/ml. A similar procedure was followed to determine oil absorption capacity using refined soybean oil with a specific gravity of 0.9092.

$$Water\ absorption\ capacity = \frac{density\ of\ water \times volume\ absorbed}{weight\ of\ sample} \times 100$$

$$Oil\ absorption\ capacity = \frac{density\ of\ oil \times volume\ absorbed}{weight\ of\ sample} \times 100$$

Swelling capacity

Swelling capacity was determined according to the methods of Lagnika et al. (2019). 0.3 g of flour in 10 ml of distilled water was allowed to stand in a water bath at 60 ℃ for 30 min after which it was allowed to cool and then centrifuged at 3000 rpm for 20 min. The supernatant was discarded and the residue was weighed. Swelling capacity was determined with the formula below.

$$Swelling\ capacity = \frac{weight\ of\ residue}{weight\ of\ flour}$$

Sensory evaluation of *chin-chin* produced from wheat-aerial yam flour blends.

The *chin-chin* samples were evaluated following the modified method of Abioye et al. (2020), for their appearance, crunchiness, taste, texture, and overall acceptability by a panel of 30 evaluators recruited from the staff and students of the department of Home Economics and Food Science, University of Ilorin. The evaluators were recruited based on their willingness to participate and familiarity with *chin-chin.* They were provided with water to rinse their mouths after assessing each sample. The samples were ranked on the 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely.

Statistical analysis

Analyses were performed in triplicates and data are presented as mean ± standard deviation. Data were analyzed using analysis of variance (ANOVA) on statistical package for social sciences (SPSS) software, version 20 (SPSS Inc., Chicago, IL, USA). Means were separated using multiple range test to detect significant differences (p<0.05) among the samples.

Results and discussion

Colour attributes of wheat-aerial yam flour blends

The colour of flour is an important physical attribute that influences its acceptability and potential use (Beena et al. 2022). Colour determination (Table 2) showed that the L^* (lightness) values varied from 77.32 ± 3.56 to 80.59 ± 0.16 with samples $W_{85}AS_{15}$ and W_{100} having the lowest and highest values, respectively. A^* (-ve = green, +ve = red) values ranged between 3.78 ± 0.01 and 5.13 ± 0.03 with samples W_{100} and $W_{50}AS_{50}$ having the lowest and the highest values, respectively. The values were positive, indicating that a^* values tended towards the red axis. The b^* (-ve = blue, +ve = yellow) values ranged from 12.27 ± 0.05 to 14.61 ± 0.04 with samples W_{100} and $W_{50}AS_{50}$ having the lowest and the highest values, respectively. The positive values indicate that b^* tended towards the yellow axis. The a^* and b^* values of the flour blends were statistically (p < 0.05) different from those of the plain wheat flour used as control (W_{100}) and they were observed to increase as levels of aerial yam increased in the formulation blends. Cotovanu and Mironeasa (2021) reported similar trends in wheat-amaranth composite flours. In addition, they reported that the lightness (L^*) of the composite flours was statistically (p < 0.05) lower than that of plain wheat flour. However, the L^* values recorded in this study for wheat-aerial yam flour blends showed no statistical (p > 0.05) difference.

Table 2 Colour of wheat-aerial yam flour blends

Samples	L*	a*	b*
W_{100}	80.59 ± 0.16 ^{a}	3.78 ± 0.01 ^{e}	12.27 ± 0.05 ^{e}
$W_{85}AYS_{15}$	77.32 ± 3.56 ^{a}	4.23 ± 0.00 ^{d}	13.09 ± 0.04 ^{d}
$W_{67.5}AYS_{32.5}$	78.50 ± 0.39 ^{a}	4.67 ± 0.01 ^{b}	13.88 ± 0.04 ^{c}
$W_{50}AYS_{50}$	78.46 ± 0.05 ^{a}	5.13 ± 0.03 ^{a}	14.61 ± 0.04 ^{a}
$W_{85}AYD_{15}$	80.07 ± 0.08 ^{a}	4.19 ± 0.00 ^{d}	13.27 ± 0.07 ^{d}
$W_{67.5}AYD_{32.5}$	79.43 ± 0.08 ^{a}	4.42 ± 0.08 ^{c}	14.21 ± 0.01 ^{b}
$W_{50}AYD_{50}$	79.07 ± 0.01 ^{a}	4.75 ± 0.03 ^{b}	14.36 ± 0.20 ^{b}

*Values are mean± standard deviation. Values in a column with the same superscript are not significantly (p > 0.05) different from each other. W100A0 = 100% wheat flour (control sample); W70AD30 = 70% wheat flour + 30% dehydrated aerial yam flour; W60AD40 = 60% wheat flour + 40% dehydrated aerial yam flour; W50AD50 = 50% wheat flour + 50% aerial yam flour; W70AS30 = 70% wheat flour + 30% sun−dried aerial yam flour; W60AS40 = 60% wheat flour + 40% sun−dried aerial yam flour; W50AS50 = 50% wheat flour + 50% sun−dried aerial yam flour

Proximate composition of wheat-aerial yam flour blends.

The proximate composition of the flour blends (Table 3) showed that the moisture content of the flour samples was between 4.42 ± 0.94 and 8.03 ± 1.61%. The moisture content of the flour blends was significantly (p < 0.05) lower than that of the control flour. Cotovanu and Mironeasa (2021) similarly reported that wheat-amaranth composite flours presented lower moisture contents as compared to plain wheat flour. The flour blends including the control sample generally presented moisture contents below the 14% standard specified for long-term storage of flours (Abioye et al. 2020; Amankwah et al. 2022). The protein content significantly (p < 0.05) varied among the samples with values ranging between 5.59 ±0.02 and 7.11 ± 0.01%. The protein content was found to increase with increasing levels of aerial yam flour in the blend formulation, which is why the flour blends had higher protein content than the control flour. This could be attributed to the high protein levels (6.82 – 9.38%) reported in aerial yam (Ojinnaka et al. 2016; Princewill-Ogbonna & Ibeji 2015). Similarly, Abioye et al. (2020) and Cotovanu and Mironeasa (2021) reported that protein contents increased in wheat-finger millet and wheat-amaranth composite flours, respectively. The

Table 3 Proximate composition of wheat-aerial yam flour blends

Samples	Moisture Content (%)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrate (%)
W_{100}	8.03 ± 1.61 ^{a}	5.59 ± 0.02 ^{e}	1.16 ± 0.01 ^{d}	0.26 ± 0.01 ^{e}	5.85 ± 3.45 ^{a}	79.12 ± 1.79 ^{a}
$W_{85}AYS_{15}$	4.73 ± 1.81 ^{b}	5.86 ± 0.01 ^{d}	3.46 ± 0.01 ^{c}	0.54 ± 0.01 ^{d}	1.97 ± 0.55 ^{a}	83.45 ± 2.39 ^{a}
$W_{67.5}AYS_{32.5}$	4.57 ± 1.48 ^{b}	6.90 ± 0.04 ^{c}	3.52 ± 0.01 ^{b}	0.56 ± 0.01 ^{c}	1.97 ± 0.70 ^{a}	82.50 ± 2.17 ^{a}
$W_{50}AYS_{50}$	4.42 ± 0.94 ^{b}	7.08 ± 0.01 ^{a}	3.59 ± 0.02 ^{a}	0.58 ± 0.01 ^{b}	1.24 ± 0.35 ^{a}	83.11 ± 0.56 ^{a}
$W_{85}AYD_{15}$	8.02 ± 0.15 ^{a}	5.88 ± 0.00 ^{d}	3.46 ± 0.01 ^{c}	0.54 ± 0.00 ^{cd}	3.68 ± 3.81 ^{a}	78.44 ± 3.66 ^{a}
$W_{67.5}AYD_{32.5}$	5.29 ± 0.55 ^{ab}	6.98 ± 0.01 ^{b}	3.54 ± 0.01 ^{b}	0.55 ± 0.01 ^{cd}	1.22 ± 1.03 ^{a}	82.43 ± 1.61 ^{a}
$W_{50}AYD_{50}$	4.50 ± 0.39 ^{b}	7.11 ± 0.01 ^{a}	3.58 ± 0.01 ^{a}	0.61 ± 0.00 ^{a}	1.22 ± 0.34 ^{a}	83.00 ± 0.06 ^{a}

*Values are mean ± standard deviation. Values in a column with the same superscript are not significantly (p > 0.05) different from each other. W100A0 = 100% wheat flour (control sample); W70AD30 = 70% wheat flour + 30% dehydrated aerial yam flour; W60AD40 = 60% wheat flour + 40% dehydrated aerial yam flour; W50AD50 = 50% wheat flour + 50% aerial yam flour; W70AS30 = 70% wheat flour + 30% sun-dried aerial yam flour; W60AS40 = 60% wheat flour + 40% sun-dried aerial yam flour; W50AS50 = 50% wheat flour + 50% sun-dried aerial yam flour increased protein levels in wheat-aerial yam flour blends indicate their potential in addressing protein-energy malnutrition (Adeloye et al. 2020). The fat content of the flour blends (3.46 ± 0.01 – 3.58 ± 0.01%) presented significantly higher values than that of the control flour (1.16 ± 0.01%). Similar findings were reported by Bolarinwa et al. (2015), Abioye et al. (2020) and Cotovanu and Mironeasa (2021) for the fat content of composite flours substituted with malted sorghum, finger millet, and amaranth, respectively. Fats are necessary for flavour retention and for the absorption of fat-soluble vitamins (Adeloye et al. 2020). Crude fibre showed significant ($p < 0.05$) variation among the samples, with values ranging from 0.26 ± 0.01 – 0.61%. The flour blends had higher amounts of fibre than the control flour as values were observed to increase with increasing amounts of aerial yam flour in the blend formulation. This could be attributed to the high fibre content (1.63 – 2.45%) in aerial yam as reported by Princewill-Ogbonna and Ibeji (2015). This is in agreement with the works of Bolarinwa et al. (2015) and Abioye et al. (2020) who reported similar trends in sorghum-soybean and wheat-finger millet composite flours, respectively. Dietary fibre has been reported to reduce the risks of gastrointestinal disorders like constipation, duodenal ulcer, and haemorrhoids (Bukuni et al. 2022). The ash content of the samples ranged from 1.22 ± 0.34 – 5.85 ± 3.45%. No significant variation was observed among the flour blends and the control flour. This is in contrast with previous research. Bolarinwa et al. (2015), Abioye et al. (2020) and Cotovanu and Mironeasa (2021) reported an increase in the ash content of composite flours substituted with malted sorghum, finger millet, and amaranth, respectively. The ash content of food represents the total amount of minerals in that food (Bongjo et al. 2022). The carbohydrate content of the samples varied from 78.44 ± 3.66 – 83.45 ± 2.39% with samples W_{100} and $W_{85}AYS_{15}$ having the lowest and highest values, respectively. Although the control sample (W_{100}) had a quantitatively lower value, the substitution of wheat with aerial yam in the flour blends had no significant ($p > 0.05$) effect on the carbohydrate content of the samples. Abioye et al. (2020) reported that wheat-finger millet composite flour had higher amounts of carbohydrates in comparison to plain wheat flour. However, Cotovanu and Mironeasa (2021) reported that the carbohydrate content of wheat-amaranth composite flour was lower than that of plain wheat. Carbohydrates are the major source of energy in foods. Generally, protein, fat, and fibre contents increased with the inclusion of aerial yam flour. This could have been influenced by the higher levels of these constituents in aerial yam flour (Supplementary Table 1).

Phytochemical composition of wheat-aerial yam flour blends

The phytochemical composition (Table 4) of the samples showed varying amounts of alkaloids, saponins, flavonoids, and tannins in the samples. The alkaloid content of the samples ranged from 0.27 ± 0.01 – 7.33 ± 0.01 mg/kg with samples W_{100} and $W_{50}AYS_{50}$ having the lowest and highest values, respectively. Alkaloids have been reported to demonstrate analgesic, anticancer, antibiotic, and sedative properties (Akubor & Nwawi 2019). The saponin content of the samples was between 0.03 ± 0.01 and 5.56 ± 0.01 mg/kg with samples W_{100} and $W_{50}AYS_{50}$ having the lowest and highest values, respectively. Saponins have been reported to help with lowering blood cholesterol, scavenging free radicals, and stimulating the immune system (Akubor & Nwawi 2019). Flavonoids ranged from 0.06 ± 0.01 – 12.06 ± 0.01 mg/kg with samples W_{100} and $W_{50}AYD_{50}$ presenting the lowest and highest values, respectively. Flavonoids have been known to exhibit anti-inflammatory, antitumor, and antioxidant properties (Akubor & Nwawi 2019). Tannins were not detected in the control flour. However, values ranged between 0.04 and

Table 4 Phytochemical composition of wheat-aerial yam flour blends

Samples	Alkaloid (mg/Kg)	Saponin (mg/Kg)	Flavonoid (mg/Kg)	Tannin (mg/Kg)
W_{100}	0.27 ± 0.01 ^{e}	0.03 ± 0.01 ^{f}	0.06 ± 0.01 g	ND
$W_{85}AYS_{15}$	3.62 ± 0.01 ^{c}	2.84 ± 0.00 ^{e}	6.13 ± 0.00 ^{e}	0.04 ± 0.00 ^{e}
$W_{67.5}AYS_{32.5}$	6.00 ± 0.01 ^{b}	4.82 ± 0.04 ^{c}	10.62 ± 0.00 ^{d}	0.05 ± 0.00 ^{b}
$W_{50}AYS_{50}$	7.33 ± 0.01 ^{a}	5.56 ± 0.01 ^{a}	11.95 ± 0.01 ^{b}	0.06 ± 0.00 ^{a}
$W_{85}AYD_{15}$	3.56 ± 0.03 ^{d}	2.85 ± 0.01 ^{e}	5.89 ± 0.00 ^{f}	0.03 ± 0.00 ^{f}
$W_{67.5}AYD_{32.5}$	6.02 ± 0.01 ^{b}	4.70 ± 0.00 ^{d}	11.01 ± 0.01 ^{c}	0.04 ± 0.00 ^{d}
$W_{50}AYD_{50}$	7.32 ± 0.00 ^{a}	5.49 ± 0.01 ^{b}	12.06 ± 0.01 ^{a}	0.05 ± 0.00 ^{c}

*Values are mean ± standard deviation. Values in a column with the same superscript are not significantly (p > 0.05) different from each other. ND = not detected. W100A0 = 100% wheat flour (control sample); W70AD30 = 70% wheat flour + 30% dehydrated aerial yam flour; W60AD40 = 60% wheat flour + 40% dehydrated aerial yam flour; W50AD50 = 50% wheat flour + 50% aerial yam flour; W70AS30 = 70% wheat flour + 30% sun−dried aerial yam flour; W60AS40 = 60% wheat flour + 40% sun−dried aerial yam flour; W50AS50 = 50% wheat flour + 50% sun−dried aerial yam flour

0.06 mg/kg in the flour blends. Tannins protect against cancer and degenerative diseases. On the other hand, tannins make foods unpleasant by imparting a bitter taste (Akubor & Nwawi 2019). The flour blends had significantly (p < 0.05) higher amounts of these phytochemicals as compared to the control flour and values were seen to increase as the quantity of aerial yam flour increased in the blend formulation. This may be attributed to the high amounts of these phytochemicals in aerial yam flour (Supplementary Table 2). This is similar to the findings of Adesina and Ifesan (2022) who reported that phytochemical levels were significantly (p < 0.05) increased in wheat-milkweed composite flours.

Functional properties of wheat-aerial yam flour blends

The functional properties (Table 5) showed variations among the samples. Loose and packed bulk densities of the samples ranged from 0.43 – 0.53 ± 0.01 g/ml and 0.67 ± 0.01 – 0.75 g/ml, respectively. The bulk density of foods is essential as it is an indication of packaging requirements. The findings of this study show that the flour blends had significantly (p < 0.05) lower densities in comparison to the control flour (W_{100}). This implies that they would require fewer packaging materials and would save packaging costs. More so, the bulk densities of the samples decreased with increasing levels of aerial yam flour in the blend formulation. Similar findings were reported by Bolarinwa et al. (2015) for bulk densities of sorghum-soybean composite flour. The water absorption capacity (WAC) of the samples ranged between 88.5 ± 0.71 and 122.5 ± 2.12% with samples W_{100} and $W_{50}AYS_{50}$ having the lowest and highest values, respectively. WAC shows the ability of the flours to absorb and retain water by virtue of hydrophilic constituents e.g. protein and fibre, thus, improving viscosity (Cotovanu & Mironeasa 2021). This means that flours with good WAC show potential for use in products (soups and gravies) where viscosity is required. The flour blends generally presented significantly (p < 0.05) higher values of WAC than the control flour, and this can be related to their higher protein and fibre contents. Similarly, Abioye et al. (2020) reported that WAC increased when wheat was substituted with finger millet in composite flours. On the contrary, Bolarinwa et al. (2015) reported that WAC decreased when sorghum was substituted with soybean in composite flours. Oil absorption capacity (OAC) is a factor to consider when flavour, mouth-feel, and texture are paramount to a product as it influences these properties (Abioye et al. 2020). OAC of the samples ranged from 102 – 119 ± 1.41%, and significant (p < 0.05) variations were observed between the flour blends and the control flour. However, only the blends containing sun-dried aerial yam flour had higher OAC than the control flour. For swelling capacity, the flour blends generally presented significantly (p < 0.05) higher values (2.65 ± 0.04 – 2.96 ± 0.01 g/g) than the control flour (2.64 ± 0.03 g/g). Values were found to increase with increasing levels of aerial yam flour in the blend formulation. Swelling capacity is influenced by the WAC of the flours, which is why the values recorded were found to correlate with the WAC values. This is in agreement with the findings of Abioye et al. (2020) for wheat-finger millet composite flour.

Sensory properties of *chin-chin* produced from wheat-aerial yam flour blends

The sensory properties (Table 6) of the samples showed variations in the parameters tested. The control flour was most preferred in all parameters. This could be because the evaluators were more familiar with it than with the *chin-chin* produced from the flour blends. *Chin-chin* from the flour blends particularly scored low for taste. This could be attributed to their tannin content. Similarly, Abioye et al. (2020) reported that *chin-chin* made

Table 5 Functional properties of wheat-aerial yam flour blends

Samples	Loose BD (g/ml)	Packed BD (g/ml)	WAC (%)	OAC (%)	SC (g/g)
W_{100}	0.53 ± 0.01 ^{a}	0.75 ± 0.00 ^{a}	88.50 ± 0.71 ^{c}	108.00 ± 1.41 ^{c}	2.64 ± 0.03 ^{e}
$W_{85}AYS_{15}$	0.43 ± 0.00 ^{d}	0.67 ± 0.01 ^{d}	103.00 ± 1.41 ^{b}	119.00 ± 1.41 ^{a}	2.76 ± 0.01 ^{d}
$W_{67.5}AYS_{32.5}$	0.44 ± 0.01 ^{d}	0.68 ± 0.01 ^{d}	116.50 ± 0.71 ^{a}	115.00 ± 1.41 ^{b}	2.77 ± 0.01 ^{cd}
$W_{50}AYS_{50}$	0.48 ± 0.00 ^{c}	0.72 ± 0.00 ^{c}	122.50 ± 2.12 ^{a}	113.00 ± 1.41 ^{b}	2.90 ± 0.01 ^{b}
$W_{85}AYD_{15}$	0.52 ± 0.01 ^{b}	0.74 ± 0.00 ^{b}	98.00 ± 1.41 ^{b}	102.00 ± 0.00 ^{e}	2.65 ± 0.04 ^{e}
$W_{67.5}AYD_{32.5}$	0.52 ± 0.00 ^{ab}	0.74 ± 0.00 ^{ab}	122.00 ± 5.66 ^{a}	103.50 ± 0.71 ^{de}	2.81 ± 0.00 ^{c}
$W_{50}AYD_{50}$	0.51 ± 0.01 ^{b}	0.68 ± 0.01 ^{d}	121.00 ± 1.41 ^{a}	105.00 ± 0.99 ^{d}	2.96 ± 0.01 ^{a}

*Values are mean ± standard deviation. Values in a column with the same superscript are not significantly (p > 0.05) different from each other. W100A0 = 100% wheat flour (control sample); W70AD30 = 70% wheat flour + 30% dehydrated aerial yam flour; W60AD40 = 60% wheat flour + 40% dehydrated aerial yam flour; W50AD50 = 50% wheat flour + 50% aerial yam flour; W70AS30 = 70% wheat flour + 30% sun−dried aerial yam flour; W60AS40 = 60% wheat flour + 40% sun−dried aerial yam flour; W50AS50 = 50% wheat flour + 50% sun−dried aerial yam flour

Table 6 Sensory attributes of *chin-chin* produced from wheat-aerial yam flour blends

Samples	Colour	Crunchiness	Taste	Texture	Overall Acceptability
W_{100}	8.35 ± 1.04 [a]	8.00 ± 1.03 [a]	8.00 ± 1.12 [a]	7.85 ± 1.42 [a]	8.20 ± 1.11 [a]
$W_{85}AYS_{15}$	6.60 ± 1.00 [b]	6.30 ± 1.66 [b]	6.63 ± 1.42 [b]	6.20 ± 1.74 [bc]	6.70 ± 1.08 [b]
$W_{67.5}AYS_{32.5}$	5.80 ± 1.44 [b]	6.25 ± 1.77 [b]	6.32 ± 2.24 [b]	6.15 ± 1.87 [bc]	6.40 ± 1.23 [bc]
$W_{50}AYS_{50}$	4.25 ± 1.48 [c]	3.35 ± 1.60 [c]	4.45 ± 2.00 [c]	3.70 ± 1.56 [d]	4.25 ± 1.37 [d]
$W_{85}AYD_{15}$	5.95 ± 1.47 [b]	7.00 ± 1.41 [b]	7.40 ± 0.75 [ab]	6.90 ± 1.17 [ab]	7.15 ± 0.93 [b]
$W_{67.5}AYD_{32.5}$	6.40 ± 1.50 [b]	6.80 ± 1.36 [b]	6.50 ± 1.47 [b]	6.74 ± 1.52 [b]	6.70 ± 1.69 [b]
$W_{50}AYD_{50}$	7.55 ± 0.95 [a]	4.30 ± 1.72 [c]	5.10 ± 1.86 [c]	5.58 ± 1.68 [c]	5.70 ± 1.46 [c]

*Values are mean ± standard deviation. Values in a column with the same superscript are not significantly ($p > 0.05$) different from each other. ND = not detected. W100A0 = 100% wheat flour (control sample); W70AD30 = 70% wheat flour + 30% dehydrated aerial yam flour; W60AD40 = 60% wheat flour + 40% dehydrated aerial yam flour; W50AD50 = 50% wheat flour + 50% aerial yam flour; W70AS30 = 70% wheat flour + 30% sun−dried aerial yam flour; W60AS40 = 60% wheat flour + 40% sun−dried aerial yam flour; W50AS50 = 50% wheat flour + 50% sun−dried aerial yam flour

from plain wheat flour had better acceptability than those produced from wheat-finger millet composite flours. Otunola et al. (2013) also reported that cookies produced from plain wheat flour had higher acceptability than those produced from wheat-moringa flour blends. In this study, the blend formulation that had acceptability close to that of the control flour was sample $W_{85}AYD_{15}$. This means that organoleptically appealing *chin-chin* can be made from a flour blend containing 85% of wheat flour and 15% of aerial yam flour.

Conclusion

From the foregoing findings of this study, it is evident that wheat-aerial yam flour blends were nutritionally superior (with respect to protein, fat, fibre, and carbohydrates) to plain wheat flour used as the control. Results also indicated that the flour blends are more suitable for long-term storage by virtue of their low moisture content in comparison to plain wheat flour. Furthermore, the wheat-aerial flour blends have the potentials to promote health and well-being as they contained higher amounts of alkaloids, saponins, flavonoids, and tannins than plain wheat flour. With respect to functional properties, wheat-aerial yam flour blends presented lesser bulk densities, higher WAC, and swelling capacities than plain wheat flour. Results obtained from sensory evaluation revealed that the most appealing sample among the flour blends was $W_{85}AYD_{15}$ (with 85% wheat flour and 15% dehydrated aerial yam flour) even though samples $W_{50}AYS_{50}$ (with 50% wheat flour and 50% sun-dried aerial yam flour) and $W_{50}AYD_{50}$ (with 50% wheat flour and 50% dehydrated aerial yam flour) were more nutritious. Since the findings of this study have shown that highly nutritious and functional flours can be produced by including aerial yam flour in flour blends, the industrial production of aerial yam flour will increase its economic value by improving utilisation and providing cheaper alternatives to wheat flour.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43014-023-00159-8.

Additional file 1: Table 1. Proximate composition of aerial yam flour. **Table 2.** Phytochemical composition of aerial yam flour.

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Authors' contributions
RMOK conceptualized the study, managed project administration and supervision. CNC provided resources, carried out investigation and data analysis regarding the colour attributes and proximate composition of the flour blends. BIK provided resources, carried out investigations and data analysis on the functional properties of the flour blends. APO provided resources, investigated and analyzed data regarding the sensory properties of the *chin-chin* produced from the flour blends. VAJ provided resources, investigated the phytochemical composition of the flour blends and wrote the original draft for the manuscript. All authors read and approved the final manuscript.

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Declarations

Ethics approval and consent to participate
The sensory evaluators were recruited based on their willingness to participate.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no financial and non-financial competing interests that could influence the work described in this study.

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