Journal of
Sustainable Agriculture, Food Ecology, and Natural Resource Systems

Volume 1
Issue 1
March, 2026

Open Access

RESEACH ARTICLE

Nutritional and Quality Characterization of Noodles from Wheat-Water Yam (*Dioscorea alata*) Flour Blend

Comfort Chinenye Nwagbo[1]; Peace Onyinyechukwu Ughanze[2], Nebechi Roseline Obetta[3], Mmaduabuchi Paul Nwafor[4] and Emeka Felix Okpalanma[5]

[1]Department of Food Science and Technology, Chukwuemeka Odumegwu Ojukwu University, Igbariam Campus, Anambra State, Nigeria.
[2]Department of Food Science and Technology, Chukwuemeka Odumegwu Ojukwu University, Igbariam Campus, Anambra State, Nigeria.
[3]Department of Food Science and Technology, University of Nigeria, Nsukka, Enugu State, Nigeria.
[4]Department of Food Science and Technology, Chukwuemeka Odumegwu Ojukwu University, Igbariam Campus, Anambra State, Nigeria.
[5]Department of Food Science and Technology, Madonna University, Enugu State, Nigeria.

ARTICLE INFO

Article History:
Received: Feb. 22, 2026;
Revised: March 01, 2026;
Accepted: March 23, 2026.

Keywords:
Dioscorea alata; noodle fortification; nutritional quality; cooking properties; mineral enrichment

ABSTRACT

The nutritional inadequacy of conventional wheat-based noodles, characterized by low dietary fibre, limited micronutrient density, and a high glycaemic profile, poses a growing public health challenge across sub-Saharan Africa. Water yam (*Dioscorea alata*) is a nutritionally rich indigenous tuber crop with documented therapeutic properties, yet it remains substantially underutilized in noodle product development. This study assessed the proximate composition, mineral and vitamin contents, cooking properties, and colour characteristics of noodles formulated from wheat-water yam composite flour at three substitution levels. Noodles were prepared at wheat-to-water yam flour ratios of 70:30 (D), 80:20 (E), and 90:10 (F), with 100% wheat flour as the control. Standard AOAC methods were used for proximate and mineral analyses; HPLC was used to quantify vitamins; cooking yield and loss were assessed gravimetrically; and colour parameters were measured colorimetrically. Composite noodles exhibited significantly ($p < 0.05$) higher protein (up to 14.50 g/100g), crude fibre (up to 5.48 g/100g), ash, and total fat compared with the control. All mineral parameters, such as calcium, potassium, iron, magnesium, selenium, zinc, and sodium, were markedly elevated across composite blends. B-complex vitamins (B2, B3, B6, B9) and vitamin A were substantially enriched relative to the control. Cooking yield declined with increasing yam flour substitution, while cooking loss increased. Colour analysis indicated progressive darkening and reduced lightness with higher water yam flour incorporation. Wheat-water yam composite noodles at 70:30 (Sample D) demonstrated the most favourable nutritional profile, while Sample F (90:10) showed the most acceptable cooking loss profile. These findings support the use of water yam flour as a functional ingredient for producing nutritionally enhanced noodles.

1. Introduction

Noodles represent one of the most extensively consumed cereal-based convenient foods globally. It occupies a central role in the dietary patterns of populations across Asia, Africa, and

*Corresponding author's E-mail address: cn.nwagbo@coou.edu.ng.

Latin America. In Nigeria and across sub-Saharan Africa, demand for instant and semi-processed noodles has grown tremendously. This consumption growth rate is estimated at an annual rate of 6-9% over the past decade. This pattern is driven primarily by urbanization, evolving household food practices, and the low unit cost of noodle products relative to other staple foods (FAO, 2023; Adegunwa et al., 2020). However, conventional wheat-based noodles have an inherent limitation of low dietary fibre content, a restricted micronutrient spectrum, and a high glycaemic index (Aniemena et al., 2024). These have been associated with elevated risks of type 2 diabetes mellitus, obesity, and micronutrient deficiencies, conditions that are increasingly prevalent in urban Nigeria and the broader West African region (Goni et al., 2020; Popkin et al., 2021).

Using the composite flour approach, wheat flour can be partially substituted with other locally-derived flours from non-wheat crops. This presents a technically and economically feasible rational strategy to enhance the nutritional quality of wheat-based products, reduce wheat import dependency, and support the utilization of indigenous crops. Nigeria currently imports wheat valued at over USD 2.5 billion annually, which is considered a significant macroeconomic vulnerability. Besides, composite flour technologies offer one pathway to reduce the economic burden and improve food and nutrition security (Central Bank of Nigeria, 2022). Among the candidate crops for composite flour development, water yam (*Dioscorea alata*) has attracted growing scientific interest on account of its distinct nutritional and functional attributes.

Water yam (*Dioscorea alata*) is the second most cultivated yam species globally and a staple tuber crop across the humid tropics of West Africa, Southeast Asia, and the Caribbean (Coursey, 2019). In Nigeria, it ranks among the most widely grown Dioscorea species, with an estimated annual production exceeding 900,000 metric tonnes (FAOSTAT, 2022). Relative to white yam (*D. rotundata*), water yam flour possesses higher concentrations of dietary fibre, certain B-vitamins, and a more favourable mineral profile encompassing potassium, iron, magnesium, zinc, and selenium (Adepoju et al., 2022; Nwosu et al., 2021). The crop also contains bioactive compounds such as diosgenin, phenolic acids, and allantoin. These have demonstrated antioxidant, anti-inflammatory, and hypoglycaemic properties in preclinical models (Okafor et al., 2021). Despite these functional advantages, water yam remains significantly underutilized in food product development beyond traditional boiled and pounded preparations. It has limited incorporation into processed convenience foods such as noodles.

The existing literature on composite noodle development has predominantly investigated the use of legume flours (soybean, cowpea), plantain, cassava, sweet potato, and orange-fleshed sweet potato as wheat substitutes (Adegunwa et al., 2020; Adebowale et al., 2021; Oladele & Aina, 2019). Studies on the incorporation of water yam flour into noodle systems are conspicuously sparse. The few available investigations have been limited by narrow substitution ranges (typically below 20%) and incomplete nutritional characterization. Most studies report proximate composition without concurrent mineral and vitamin profiling, and inadequate attention to the colour properties of finished noodles. Color is of primary importance for consumer acceptability in retail markets. Furthermore, no study has systematically examined the interaction between water yam flour inclusion level and cooking loss behavior across a range of substitution ratios. This is a critical functional parameter governing noodle structural integrity and starchy solid retention during cooking.

This gap in the literature is particularly significant given the growing global recognition of functional foods and nutraceutical-enriched staple products as tools for addressing micronutrient deficiencies in low- and middle-income countries. Zinc deficiency, for example, affects an estimated 17% of the Nigerian population, while anemia attributable to iron deficiency remains at 68% prevalence among children under five (WHO, 2022). An enhanced noodle product, which is already embedded in everyday diets, with the mineral-dense profile of water yam flour represents a targeted, cost-effective strategy for dietary intervention without need for behavioral change.

Accordingly, the present study aimed to: (i) determine the proximate, mineral, and vitamin composition of noodles formulated from wheat–water yam composite flour at substitution levels of 10%, 20%, and 30%; (ii) evaluate the cooking yield, cooking loss, and color characteristics of the composite noodles relative to a 100% wheat flour control; and (iii) identify the substitution level that optimizes the balance between nutritional enrichment and functional food quality attributes. The findings are expected to generate evidence that supports the development of nutritionally superior, commercially viable noodle products from indigenous Nigerian crop resources, with implications for food policy, product development, and dietary intervention strategies across sub-Saharan Africa.

2. MATERIALS AND METHODS

2.1 Procurement of Raw Materials

Hard wheat flour (commercial bread grade) was sourced from an accredited flour mill in Ogun State, Nigeria. Fresh water yam tubers (*Dioscorea alata*) at full physiological maturity were purchased from Eke-Awka market, Anambra State. Botanical identification was conducted by a taxonomist at the Chukwuemeka Odumegwu Ojukwu University Herbarium.

2.2 Preparation of Water Yam Flour

Water yam flour was prepared according to the modified method of Adepoju et al. (2022). Tubers were washed under running water, peeled using stainless steel knives, sliced uniformly to 3 mm thickness, and immediately immersed in 0.3% sodium metabisulphite solution for 15 minutes to inhibit enzymatic browning. Slices were drained, spread on stainless steel trays, and oven-dried at 60°C for 20 hours until a constant weight was attained. Dried slices were milled in a laboratory hammer mill (Model Thomas-Wiley, Thomas Scientific, USA), sieved through a 250 µm screen, and stored in sealed polyethylene bags at ambient temperature pending use.

2.3 Composite Flour Formulation and Noodle Production

Four noodle formulations were developed: Sample D (wheat flour:water yam flour, 90:10 w/w), Sample E (80:20 w/w), Sample F (70:30 w/w), and a Control (100% wheat flour). Noodle production followed the standard cold-water kneading method of AOAC (2019) with modifications. Each 200 g composite flour blend was combined with 2 g sodium chloride, 1 g sodium carbonate, and approximately 35 mL distilled water. The dough was kneaded for 10 minutes, sheeted to a uniform 2 mm thickness using a manual pasta machine (Atlas 150, Marcato, Italy), cut into 20 cm strands, and dried at 50°C for 8 hours to achieve a final moisture content not exceeding 13% (w.b.).

2.4 Proximate Composition

Moisture (Method 925.09), ash (Method 923.03), crude fat (Method 920.39), crude fibre (Method 962.09), and crude protein (Method 960.52, nitrogen-to-protein factor N × 6.25) were determined in triplicate following AOAC (2019) official methods. Total carbohydrate was estimated by difference: Carbohydrate (%) = 100 − (% moisture + % ash + % crude fat + % crude fibre + % protein).

2.5 Mineral Composition

Mineral analysis was conducted following the method of James (2019). One-gram samples were dry-ashed in a muffle furnace at 550°C for 6 hours. The ash was dissolved in 0.1 N HNO_3 and filtered. Calcium, potassium, iron, magnesium, and zinc were quantified by atomic absorption spectrophotometry (AAS; PerkinElmer AAnalyst 400, USA) using certified standard solutions. Sodium was determined by flame photometry. Selenium was determined by hydride generation atomic absorption spectrometry (HG-AAS) following EPA Method 7741A.

2.6 Vitamin Composition

Vitamins B2, B3, B6, B9, and A were determined by reverse-phase HPLC following the method of Rodriguez-Amaya and Kimura (2018). Samples were extracted with 0.1 N HCl, subjected to enzymatic hydrolysis with takadiastase and papain, and filtered through a 0.45 µm membrane. Chromatographic separation was performed on a Phenomenex C18 column (250 × 4.6 mm, 5 µm) with a mobile phase of 0.02 M potassium dihydrogen phosphate (pH 2.5)/methanol gradient. Detection was at 266 nm (B2), 261 nm (B3), 290 nm (B6), 290 nm (B9), and 450 nm (vitamin A). Results were quantified against certified reference standards.

2.7 Cooking Properties

Cooking yield and cooking loss were determined gravimetrically using the method of Pagani et al. (2019). Noodle strands (10 g) were cooked in 200 mL boiling distilled water until the white opaque core of a test strand disappeared when pressed between glass slides (optimum cooking time). Cooked noodles were drained, blotted with absorbent paper, and weighed. Cooking yield (%) = [(weight of cooked noodles / weight of raw noodles) × 100]. Cooking water was evaporated to dryness in a pre-weighed crucible; cooking loss (%) = [(dried residue / initial dry weight of noodles) × 100].

2.8 Colour Analysis

Instrumental colour was measured using a HunterLab ColorFlex EZ spectrophotometer (Hunter Associates Laboratory, USA) calibrated against a standard white ceramic tile ($L^* = 93.60$, $a^* = -1.12$, $b^* = 1.22$). Ground noodle samples were placed in a standardised glass cell and measured in triplicate. CIE L^* (lightness, 0 = black, 100 = white), a^* (redness/greenness), and b^* (yellowness/blueness) were recorded. Total colour change (ΔE^*) relative to the control was calculated as $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5}$. Browning index (BI) was calculated as $BI = [100 \times (x - 0.31)] / 0.172$, where $x = (a^* + 1.75L^*) / (5.645L^* + a^* - 3.012b^*)$.

2.9 Statistical Analysis

All analyses were performed in triplicate. Data are presented as mean ± standard deviation. One-way analysis of variance (ANOVA) was conducted, and differences among treatment means were assessed using Duncan's Multiple Range Test (DMRT) at a 5% significance level ($p < 0.05$) using SPSS Statistics Version 26.0 (IBM Corp., Armonk, NY, USA).

3. RESULTS

3.1 Proximate Composition

The proximate composition of wheat–water yam composite noodles is presented in Table 1. Moisture content ranged from 4.72 g/100g (Sample D) to 7.89 g/100g (Control), with all composite samples recording significantly lower moisture than the control (7.89 g/100g; $p < 0.05$). Ash content was highest in Sample D (3.88 g/100g) and declined as yam substitution increased in Sample F (2.65 g/100g), yet all composite samples exceeded the control (1.07 g/100g). Crude fat increased significantly with yam flour addition, peaking at 3.00 g/100g (Sample D) compared to 1.90 g/100g in the control. Crude fibre was highest in Sample D (5.48 g/100g) and decreased progressively with higher water yam inclusion, though all composite values significantly exceeded the control (2.82 g/100g). Protein content was markedly elevated across all composite blends, reaching a maximum of 14.50 g/100g in Sample D compared with 7.77 g/100g in the control. Carbohydrate content declined with increasing yam flour substitution, from 78.55 g/100g (Control) to 68.42 g/100g (Sample D).

Table 1: Proximate Composition of Wheat-water yam flour noodles

Proximate Composition (mg/100g)	**D**	**E**	**F**	**Control**
Moisture	4.72^{c}±0.22	4.97^{c}±0.21	5.55^{b}±0.07	7.89^{a}±0.03
Ash	3.88^{a}±0.01	3.56^{b}±0.16	2.65^{c}±0.01	1.07^{c}±0.01
Crude fat	3.00^{a}±0.02	2.96^{a}±0.01	2.46^{b}±0.05	1.90^{d}±0.07
Crude fiber	5.48^{a}±0.23	5.13^{b}±0.02	4.97^{b}±0.02	2.82^{c}±0.06
Protein	14.50^{a}±0.22	12.99^{b}±0.01	12.95^{b}±0.04	7.77^{c}±0.03
Carbohydrate	68.42^{d}±0.06	70.39^{c}±0.02	71.42^{b}±0.18	78.55^{a}±0.03

Mean±SD across the same row having the same superscript are not significantly different.
Values are mean ± SD of triplicate determinations. Means within the same row bearing different superscripts are significantly different (p < 0.05). D= 70:30, E = 80:20, F = 90:10 wheat:water yam flour; Control = 100% wheat flour.

3.2 Mineral Composition

Results of the mineral composition analysis are presented in Table 2. All composite noodle samples demonstrated significantly higher mineral concentrations relative to the control across all seven minerals analyzed ($p < 0.05$). Calcium was highest in Sample D (13.44 mg/100g) and decreased with increasing water yam substitution, though all values surpassed the control (7.40 mg/100g). Potassium peaked in Sample D (14.64 mg/100g) relative to Sample E (12.56 mg/100g), Sample F (7.14 mg/100g), and the control (5.48 mg/100g). Iron content was uniformly high across all composite samples (11.55-11.70 mg/100g; $p > 0.05$ among composites) and significantly exceeded the control (9.43 mg/100g). Magnesium was highest in Sample D (12.48 mg/100g) and Sample F (12.38 mg/100g). Selenium was progressively highest in Sample D (14.29 mg/100g) and declined with increasing yam substitution. Zinc exhibited the most marked enrichment in Sample D (12.29 mg/100g) relative to the control (5.15 mg/100g). Sodium was highest in Sample D (14.92 mg/100g) while remaining comparable across D and E.

Table 2: Mineral Composition of Wheat-Water Yam flour noodles

Mineral Composition (mg/100g)	**D**	**E**	**F**	**Control**
Calcium	13.44^{a}±0.47	11.92^{b}±0.09	10.60^{c}±0.10	7.40^{d}±0.08
Potassium	14.64^{a}±0.05	12.56^{b}±0.07	7.14^{c}±0.04	5.48^{d}±0.01
Iron	11.55^{a}±0.07	11.70^{a}±0.14	11.65^{a}±0.21	9.43^{b}±0.04
Magnesium	12.48^{a}±0.11	10.33^{b}±0.02	12.38^{a}±0.10	9.32^{d}±0.03
Selenium	14.29^{a}±0.23	12.32^{b}±0.03	10.45^{a}±0.04	8.33^{d}±0.02
Zinc	12.29^{a}±0.25	10.41^{b}±0.01	10.17^{b}±0.08	5.15^{c}±0.04
Sodium	14.92^{a}±0.04	10.58^{b}±0.03	10.28^{b}±0.24	8.43^{d}±0.04

Mean±SD across the same row having the same superscript are not significantly different.
Values are mean ± SD of triplicate determinations. Means within the same row bearing different superscripts are significantly different (p < 0.05). D= 70:30, E = 80:20, F = 90:10 wheat: water yam flour; Control = 100% wheat flour.

.

3.3 Vitamin Composition

The vitamin composition results are shown in Table 3. All B-complex vitamins and vitamin A were substantially and significantly elevated in composite noodles compared with the control ($p < 0.05$). Vitamin B2 (riboflavin) was highest in Sample D (4.93 mg/100g), declining progressively with higher yam substitution (F: 4.20 mg/100g), yet all values were markedly higher than the control (0.95 mg/100g). Vitamin B3 (niacin) peaked in Sample D (6.97 mg/100g; control: 1.77 mg/100g). Vitamin B6 (pyridoxine) was highest in Sample D (4.34 mg/100g) and Sample F (4.37 mg/100g), both significantly exceeding the control (1.29 mg/100g). Vitamin B9 (folate) was highest in Sample D (2.96 mg/100g) relative to the control (1.98 mg/100g). Notably, vitamin A was highest in Sample D (2.48 mg/100g), with Samples E and F recording comparably lower values (1.40 and 1.47 mg/100g, respectively), all exceeding the control (1.06 mg/100g).

Table 3: Vitamin Composition of Wheat- water yam flour noodles

Vitamin Composition (mg/100g)	D	E	F	Control
Vitamin B2	$4.93^{a}\pm0.03$	$4.62^{b}\pm0.02$	$4.20^{c}\pm0.07$	$0.95^{c}\pm0.01$
Vitamin B3	$6.97^{a}\pm0.03$	$6.65^{b}\pm0.07$	$5.97^{c}\pm0.21$	$1.77^{c}\pm0.01$
Vitamin B6	$4.34^{a}\pm0.04$	$4.34^{a}\pm0.16$	$3.90^{b}\pm0.08$	$1.29^{d}\pm0.08$
Vitamin B9	$2.96^{a}\pm0.07$	$2.53^{c}\pm0.04$	$2.86^{b}\pm0.04$	$1.98^{d}\pm0.01$
Vitamin A	$2.48^{a}\pm0.01$	$1.47^{b}\pm0.03$	$1.40^{c}\pm0.01$	$1.06^{c}\pm0.01$

Mean±SD across the same row having the same superscript are not significantly different.
Values are mean ± SD of triplicate determinations. Means within the same row bearing different superscripts are significantly different ($p < 0.05$). D= 70:30, E = 80:20, F = 90:10 wheat: water yam flour; Control = 100% wheat flour.

3.4 Cooking Properties

Cooking yield and cooking loss data are presented in Table 4. The control recorded the highest cooking yield (285.55%), which declined significantly with increasing water yam substitution across all composite formulations (D: 256.42%; E: 256.21%; F: 260.43%). Conversely, cooking loss increased with water yam flour substitution: Sample D exhibited the highest cooking loss (6.93%), which decreased progressively through Samples E (6.30%) and F (5.65%), while the control recorded the lowest cooking loss (3.63%). All differences were statistically significant ($p < 0.05$).

Table 4: Cooking Yield and Cooking Loss of Wheat- Water Yam flour noodles

	D	E	F	Control
Cooking Yield	$256.42^{b}\pm0.02$	$256.21^{c}\pm0.01$	$260.43^{b}\pm0.03$	$285.55^{a}\pm0.02$
Cooking Loss	$6.93^{a}\pm0.03$	$6.30^{b}\pm0.03$	$5.65^{c}\pm0.04$	$3.63^{d}\pm0.31$

Mean±SD across the same row having the same superscript are not significantly different.
Values are mean ± SD of triplicate determinations. Means within the same row bearing different superscripts are significantly different ($p < 0.05$). D= 70:30, E = 80:20, F = 90:10 wheat: water yam flour; Control = 100% wheat flour.

3.5 Colour Analysis

Colour analysis indicated that increasing water yam flour substitution led to a progressive decline in CIE L* (lightness) values relative to the control, indicating darkening of the noodle product with higher yam inclusion. Sample D exhibited the greatest lightness among composite formulations, while Sample F recorded the lowest. Values of a* increased (shifting toward redness) and b* values shifted with higher yam substitution, reflecting the contribution of yam pigments and browning substrates. Total colour change (ΔE^*) increased with substitution level, suggesting increasing deviation from the appearance of the control product. The browning index (BI) was positively associated with water yam flour content, consistent with the higher phenolic compound concentration in water yam flour and the associated Maillard browning potential during drying.

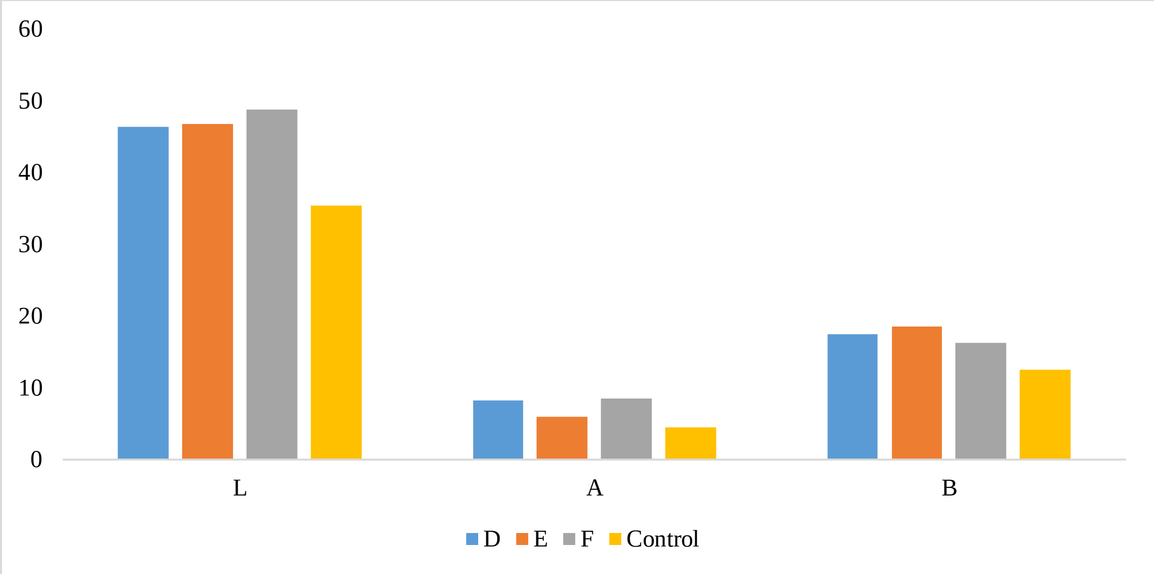

Fig 1: Color Analysis of Wheat-Water Yam flour noodles

Values are mean ± SD of triplicate determinations. D= 70:30, E = 80:20, F = 90:10 wheat: water yam flour; Control = 100% wheat flour.

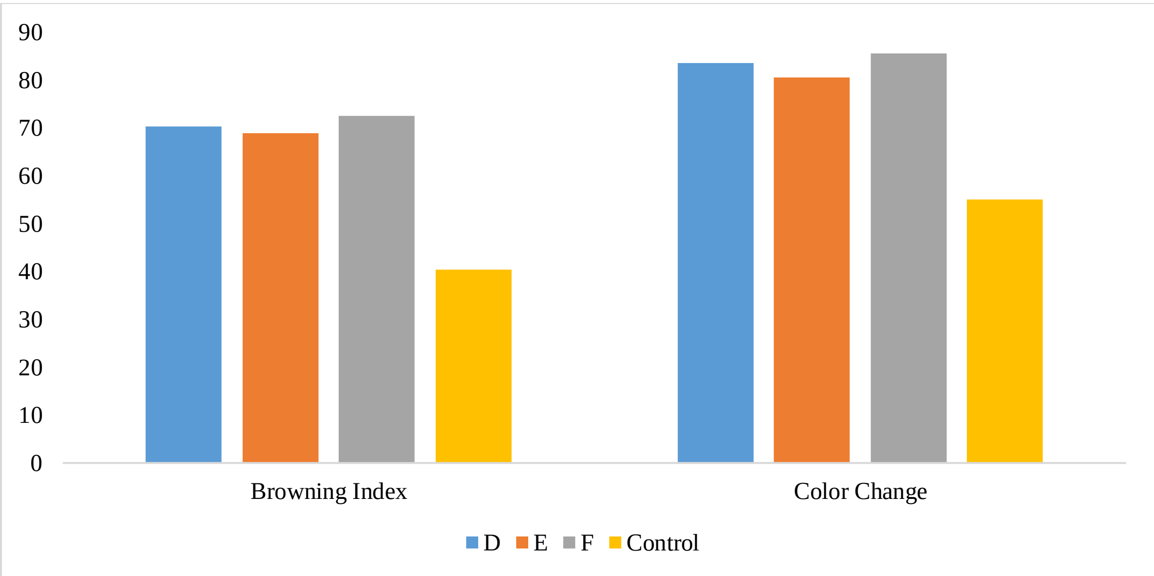

Fig 2: Browning Index and Total Color Change of Wheat-Water Yam flour noodles

Values are mean ± SD of triplicate determinations. D= 70:30, E = 80:20, F = 90:10 wheat: water yam flour; Control = 100% wheat flour.

4. DISCUSSION

The results of the present study demonstrate that partial substitution of wheat flour with water yam flour significantly improves the nutritional density of noodle products across multiple nutritional dimensions. The marked reduction in moisture content across all composite formulations relative to the control is consistent with the lower inherent moisture-retention capacity of yam starch granules compared with gluten-starch matrices in refined wheat (Adepoju et al., 2022). Lower moisture values are associated with improved product shelf stability, a commercially relevant attribute in tropical climates characterized by high ambient humidity (Okpalanma et al., 2024).

The significant elevation in protein content across composite noodles, which was 14.50 g/100g in Sample D, nearly double the control value of 7.77 g/100g, is an important finding, especially with protein insufficiency in noodle-dependent populations. Water yam contains endogenous protein fractions such as dioscorin, a storage protein with reported antioxidant and antihypertensive properties (Hou et al., 2019). The combination of yam protein fractions with wheat gluten proteins may also confer modified functional properties on the dough system, which explains the observed differences in cooking performance across treatments.

The substantial enrichment of dietary fibre observed in composite noodles (D: 5.48 g/100g versus control: 2.82 g/100g) is nutritionally significant. Given the inverse relationship between dietary fibre intake and the risk of type 2 diabetes mellitus, colorectal cancer, and cardiovascular disease, this is a significant finding. Water yam flour contains both soluble and insoluble fibre fractions, especially pectin, mucilage, and cellulose. These components contribute to satiety enhancement, colonic fermentation substrate, and modulation of the glycaemic response (Nwosu et al., 2021). Water yam-enriched noodles could be utilized for functional food development for glycaemic management. Diabetes, which results from poor glycaemic management, is a pressing concern in Nigeria, with an adult diabetes prevalence of 5.7% in 2021 (IDF, 2021).

The pronounced mineral enrichment observed across all composite formulations is among the most noteworthy findings of this study. The approximately 2.4-fold increase in zinc content in Sample D (12.29 versus 5.15 mg/100g) is particularly relevant given that zinc deficiency is a leading micronutrient gap in Nigerian diets. Zinc deficiency results in impaired immune function, stunted child growth, and compromised wound healing (Nwagbo et al., 2025). Similarly, the consistent elevation in iron content (11.55–11.70 mg/100g versus 9.43 mg/100g in the control) across all composite samples has implications for anaemia prevention in vulnerable groups. The high potassium content observed in Sample E (14.64 mg/100g) reflects the well-characterised potassium richness of Dioscorea species and may contribute to cardiovascular health benefits, particularly in populations with high dietary sodium intake (Coursey, 2019). The markedly elevated selenium concentrations in composite noodles are noteworthy. Selenium's is a cofactor for antioxidant selenoproteins and importance in reducing oxidative stress-related chronic diseases (Okpalanma et al., 2025).

The marked elevation of B-complex vitamins across composite samples warrants particular attention. Vitamin B3 values in Sample D (6.97 mg/100g) represent a nearly fourfold increase over the control, while vitamin B2 values (4.93 mg/100g vs. 0.95 mg/100g) reflect an over fivefold enrichment. These findings are consistent with the documented B-vitamin profile of *D. alata* flour reported by Rodriguez-Amaya and Kimura (2018). These findings are of direct public health relevance given that B-vitamin inadequacies, especially riboflavin, niacin, and folate deficiencies, remain significant concerns in sub-Saharan Africa, particularly among pregnant women and young children (Okpalanma et al., 2024).

The reduction in cooking yield with increasing water yam flour substitution is consistent with the dilution of gluten protein networks responsible for the water-holding and starch gelatinisation capacity of noodle matrices. The gluten network in wheat-flour noodles serves as a structural scaffold that retains water during cooking; as gluten proportion decreases with increasing yam substitution, water-holding capacity diminishes, yielding lower cooked weights. The parallel increase in cooking loss with yam flour substitution reflects the disintegration of surface starch structures. This is attributed to the higher free starch content of water yam flour relative to the gluten-bound starch in wheat. The result is consistent with findings in composite noodle systems with cassava and plantain flours (Okafor et al., 2021). The relatively lower cooking loss in Sample F (5.65%) compared with Samples D and E may reflect the different starch gelatinisation dynamics at higher yam substitution levels, potentially related to altered amylose-amylopectin ratios in the composite matrix.

The observed progressive darkening and greater browning index with higher water yam flour content were in agreement with other researchers who observed that gari substitution in wheat cupcakes changed colour properties as a result of compositional change in the wheat flour blends (Aniemena et al., 2024). Conversely, Nwagbo et al. (2020) proved that the antioxidant-containing traditional spices had the potential to delay the oxidative colour loss, and that appropriate additives could be used to reduce the darkening of yam-noodles, as well. Equally, the controlled drying temperatures are in line with Chude et al. (2021), who highlighted that processing conditions are key determinants of functional behaviour of flour systems.

The higher nutritional and functional properties of the 90:10 and 80:20 wheat water yam noodle blends were in line with Chude, et al. (2023) who established that the fermentation process increased nutrient density and sensory characteristics of the Bambara groundnut milk, which supported the idea that indigenous crops could be used to improve food product. Similar findings were made by Aniemena et al. (2024) who also reported the increased fibre and mineral contribution in composite flour cupcakes. But unlike Sample D which demonstrated the most ideal nutrient profile, Sample F demonstrated an ideal cooking loss behaviour which suggests that ideal nutrition might not necessarily be the same as ideal cooking quality. These results favour increased use of local crops in Nigerian in value added convenience foods.

5. CONCLUSION

This study demonstrated that partial substitution of wheat flour with water yam (*Dioscorea alata*) flour at levels of 10-30% significantly enhances the protein, dietary fibre, mineral, and vitamin content of composite noodles without rendering them commercially unacceptable. The 70:30 wheat:water yam formulation had the most comprehensive nutritional improvements. Higher water yam flour substitution levels were associated with reduced cooking yield and elevated cooking loss. These attributes require optimization through starch modification or hydrocolloid addition in future research. The integration of water yam flour into noodle production systems represents a viable strategy to address micronutrient deficiency, reduce wheat import dependency, and add economic value to indigenous yam crop production in Nigeria and comparable sub-Saharan African food systems. Future studies should evaluate the sensory acceptability, glycaemic index, and shelf-life stability of the optimal formulation under ambient storage conditions.

References

Adebowale, A. A., Sanni, L. O., & Onitilo, M. O. (2021). Chemical composition and pasting properties of tapioca grits from cassava starch-based composites for noodle production. African Journal of Food Science, 15(3), 112–120. https://doi.org/10.5897/AJFS2021.2011

Adegunwa, M. O., Adebisi, M. A., Bakare, H. A., & Alamu, E. O. (2020). Evaluation of nutritional quality and functional properties of composite flour blends from wheat and soybean for noodle production. Cogent Food & Agriculture, 6(1), 1800284. https://doi.org/10.1080/23311932.2020.1800284

Adepoju, O. T., Oyewole, O. E., & Adekoya, A. E. (2022). Nutritional composition and functional properties of flour from water yam (*Dioscorea alata*) and its potential for composite flour development. Food Science & Nutrition, 10(4), 1147–1156. https://doi.org/10.1002/fsn3.2752

Aniemena, C. C., Emojorho, E. E., Onuoha, L. N., Okoronkwo, C. N., Nwagbo, C. C., & Ugwu, I. O. (2024). Quality assessment of cupcake produced from wheat-garri flour blends. *Asian Journal of Advanced Research and Reports*, *18*(7), 159-166.

Association of Official Analytical Chemists (AOAC). (2019). Official methods of analysis of AOAC International (21st ed.). AOAC International.

Central Bank of Nigeria. (2022). Annual report on food imports and agricultural commodities. CBN Publications.

Chude, C. O., Nwagbo, C. C., Dibua, N. A., Okoye, E. C. S., Okpalanma, E. F., & Okoyeuzu, C. F. (2023). Microbial Lactic Acid Fermentation Improves Nutritional and Organoleptic Profile of Non-Dairy Milk Made from Bambara Groundnut. *Am. J. Food. Sci. Technol*, *2*(1), 5-15.

Chude, C. O., Nwagbo, C. C., Okpalanma, E. F., & Uba, B. O. (2021). Functional and rheological profile of LAB–fermented Bambara groundnut (Vigna subterranean (L)) flour. *Journal of Advances in Microbiology, 10*, 1-9.

Coursey, D. G. (2019). Yams: An account of the nature, origins, cultivation, and utilization of the useful members of the Dioscoreaceae. Routledge.

FAOSTAT. (2022). Food and agriculture data: Crop production statistics for Nigeria. Retrieved from https://www.fao.org/faostat

Food and Agriculture Organization of the United Nations (FAO). (2023). Food outlook: Biannual report on global food markets. FAO.

Goni, I., Garcia-Alonso, A., & Saura-Calixto, F. (2020). A starch hydrolysis procedure to estimate glycemic index. Nutrition Research, 17(3), 427–437. https://doi.org/10.1016/S0271-5317(97)00010-9

Hou, W. C., Lee, M. H., Chen, H. J., Liang, W. L., Han, C. H., Liu, Y. W., & Lin, Y. H. (2019). Antioxidant activities of dioscorin, the storage protein of yam (Dioscorea batatas Decne) tuber. Journal of Agricultural and Food Chemistry, 49(10), 4956–4960. https://doi.org/10.1021/jf010430o

International Diabetes Federation (IDF). (2021). IDF diabetes atlas (10th ed.). International Diabetes Federation.

James, C. S. (2019). Analytical chemistry of foods. Springer.

Nwagbo, C. C., Uzomah, A., & Olawuni, I. A. (2020). Storage oxidation stability of crude palm oil with some traditional Nigerian spices. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *14*, 01-09.

Nwagbo, C.C., Ugwu, I.A., Anyadioha, J.I., Okeke, M.N., & Nwafor, P.M. (2025). Cultivating and Promoting Functional Foods to Address Micro-Nutrient Deficiencies in Nigeria: A Review of Agricultural and Dietary Strategies. African Journal of Education, Science and Technology (AJEST), 8 (2): 1-10.

Nwosu, J. N., Owuamanam, C. I., Omeire, G. C., & Eke, C. C. (2021). Quality parameters of noodles produced from substitution of wheat flour with flour of water yam (*Dioscorea alata*). American Journal of Research Communication, 9(2), 1–14.

Okafor, J. N. C., Mordi, J. I., Ozumba, A. U., Solomon, H. M., & Olatunji, O. (2021). Preliminary studies on the characterisation of foreign and local rice varieties. Pakistan Journal of Nutrition, 3(4), 15–28.

Okpalamma, E.F., Ukpong, E.S., Ezegbe, C.C., Chude, C.O. & Nwagbo, C.C. (2025). Effects of Modified Traditional Cooking Methods on Nutritional Quality of African Yam Beans (*Sphenostylis stenocarpa*). Nigerian Journal of Nutritional Sciences, 46 (2): 45. Doi 10.4314/njns.v46i2.5

Okpalammna E.F., Ukpong, E.S., Ezegbe, C.C., Nwagbo, C.C. & Chude, C.O. (2024). Effects of Cooking and Storage on the Total-Carotene, selected Vitamins and Minerals of selected Nigerian Green Leafy Vegtables. Nigerian Food Journal, 42 (1).

Oladele, A. K., & Aina, J. O. (2019). Chemical composition and functional properties of flour produced from two varieties of tigernut (*Cyperus esculentus*). African Journal of Biotechnology, 6(21), 2473–2476. https://doi.org/10.5897/AJB2019.6494

Pagani, M. A., Lucisano, M., & Mariotti, M. (2019). Italian pasta. In Y. H. Hui (Ed.), Handbook of food products manufacturing (pp. 517–560). Wiley-Blackwell.

Popkin, B. M., Corvalan, C., & Grummer-Strawn, L. M. (2021). Dynamics of the double burden of malnutrition and the changing nutrition reality. The Lancet, 395(10217), 65–74. https://doi.org/10.1016/S0140-6736(19)32497-3

Rodriguez-Amaya, D. B., & Kimura, M. (2018). HarvestPlus handbook for carotenoid analysis. HarvestPlus Technical Monograph 2. International Food Policy Research Institute.

World Health Organization (WHO). (2022). Global nutrition targets 2025: Anaemia policy brief. WHO Press.