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Nutritional, Functional, Anti-Nutritional and Sensory properties of *Kwash* Pap Enriched with Orange-Fleshed Sweet Potato, Soybean, and Groundnut

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ABSTRACT

Vitamin A deficiency remains a significant public health challenge, particularly among children and vulnerable populations in developing countries. This study evaluated the effects of incorporating orange-fleshed sweet potato (OFSP), red maize, soybean, and groundnut on the nutritional, functional, antinutritional, and sensory properties of *Kwash* pap, a traditional cereal-based food. Four formulations were developed: OMSGW (70% maize, 0% OFSP), OMSGX (60% maize, 10% OFSP), OMSGY (50% maize, 20% OFSP), and OMSGZ (40% maize, 30% OFSP), with each containing 20% soybean and 10% groundnut. Vitamin A, proximate composition, antinutritional factors, functional properties, and sensory characteristics were determined using standard analytical procedures. Vitamin A content increased significantly ($p < 0.05$) from 0.1521 mg RE/100 g in OMSGW to 2.6517 mg RE/100 g in OMSGZ, demonstrating the contribution of OFSP to provitamin A enrichment. Protein content increased from 9.58% in OMSGW to 11.11% in OMSGY. OFSP incorporation also influenced functional properties, including water absorption capacity and emulsion stability. Processing significantly ($p < 0.05$) reduced phytate, tannin, oxalate, saponin, and alkaloid contents. Sensory evaluation involving 20 semi-trained panelists using a 9-point hedonic scale revealed that OMSGY achieved the highest scores for taste (7.90), appearance (8.15), and overall acceptability (8.00). Overall, OFSP, soybean, and groundnut incorporation improved the nutritional quality of *Kwash* pap while maintaining sensory acceptability. The 20% OFSP formulation demonstrated favourable sensory characteristics, while the 30% OFSP formulation achieved the highest vitamin A content, highlighting the potential of locally sourced ingredients to improve dietary vitamin A intake and nutritional quality among vulnerable populations

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INTRODUCTION

Vitamin A is an essential micronutrient provided by retinyl esters in animal products and provitamin A carotenoids in plant sources (Carazo, *et al.*, 2021). Globally, vitamin A deficiency (VAD) places 140 to 250 million people at risk for health problems including night blindness, increased child and maternal mortality, and weakened immune function. In sub-Saharan Africa, approximately 32% of children under five years are estimated to be vitamin A deficient, with a 1.5% prevalence of xerophthalmia within the same age group (WHO, 2009). Vitamin A deficiency (VAD) remains a pervasive nutritional disorder on the global scale, with the highest burden concentrated in low- and middle-income countries and other high-risk sub-populations (Qin, *et al.*, 2025). *Kwash* pap, also known as ogi, is a fermented cereal-based porridge widely consumed across West Africa, particularly in Nigeria, Ghana, and Cameroon (Apaliya, *et al.*, 2022). It is typically prepared from maize, sorghum, or millet and serves as a staple food for infants, children, and lactating mothers due to its digestibility and low cost (Kabeer, *et al.*, 2024). Despite its widespread consumption, *Kwash* pap is nutritionally limited in protein, fat, and essential micronutrients, particularly vitamin A, iron, and zinc (Cabal-Herrera, *et al.*, 2025). The low protein content is especially concerning for children during critical growth periods, making *Kwash* pap prone to causing protein-energy malnutrition if consumed as a primary diet without supplementation (Kesharwani, *et al.*, 2024). Orange-fleshed sweet potato (OFSP) is a biofortified crop rich in beta-carotene, a precursor of vitamin A, and has been promoted globally as a cost-effective solution to VAD (Amagloh, *et al.*, 2026). The International Potato Center and partners have bred over 42 OFSP varieties adapted to farmer needs and consumer preferences across sub-Saharan Africa, and multiple efficacy and effectiveness trials have demonstrated that regular consumption of OFSP increases vitamin A intake and serum retinol concentrations in young children. Red maize is another biofortified cereal rich in carotenoids, anthocyanins, and polyphenols that contributes to vitamin A activity (Ahmed, *et al.*, 2026). Soybean and groundnut provide high-quality protein, essential fatty acids, and lipids that enhance the absorption of fat-soluble vitamins, including vitamin A (Guo, *et al.*, 2024).

While supplementation and industrial fortification programs have been implemented to address VAD, they often fail to consistently reach rural populations due to high cost, limited access, and sustainability challenges (Ashraf, 2025). Food-based approaches utilizing locally available, nutrient-dense crops have been recognized by international organizations as more practical and sustainable for improving vitamin A intake (Younge & Amoah, 2026). The enrichment of *Kwash* pap with a combination of OFSP, red maize, soybean, and groundnut therefore represent a sustainable intervention to improve vitamin A intake and reduce micronutrient deficiencies among children and vulnerable populations (Amagloh, *et al.*, 2026)

MATERIALS AND METHODS

Source of Raw Materials

Orange-fleshed sweet potato (OFSP), red maize, soybean, and groundnut were purchased from Muda Lawan Market, Bauchi State, Nigeria. Samples were carefully selected based on freshness and quality. This study aimed to (i) produce flour from OFSP, red maize, soybean, and groundnut; (ii) assess the proximate composition of enriched *Kwash* pap; (iii) determine the vitamin A (provitamin A/carotenoid) content; (iv) evaluate anti-nutritional properties; (v) determine functional properties of composite flours; and (vi) conduct sensory acceptability evaluation of the enriched formulations.

Preparation of Raw Materials

OFSP Flour

Fresh, mature OFSP roots were washed, peeled, sliced into uniform 2 - 5 mm pieces, blanched (2 - 3 min), cabinet-dried at 40 ^{0}C for 12 - 24 h until constant weight, milled using a hammer mill. The flour was sieved to achieve a uniform particle size of approximately 250 µm. Finally, the flour was immediately packaged in airtight containers as sealed polyethylene bags, and stored in a cool, dry place until required for further use in pap formulation.

Red Maize Flour

Grains were sorted to remove extraneous materials, washed with potable water, sun-dried, roasted to inactivate anti-nutritional factors, milled into fine flour, and sieved to uniform particle size. The flour was packaged in airtight containers and stored under cool, dry conditions.

Soybean Flour

Soybeans were soaked for 12 h, roasted, manually dehulled, washed, and boiled for 30 min to inactivate anti-nutritional factors such as trypsin inhibitors. The dried seeds were milled, sieved, and stored.

Groundnut Flour

Groundnuts were roasted at 120 ^{0}C for 20 - 30 min, cooled, manually dehulled, milled using a laboratory grinder, and sieved. The flour was stored in airtight containers under cool, dry conditions.

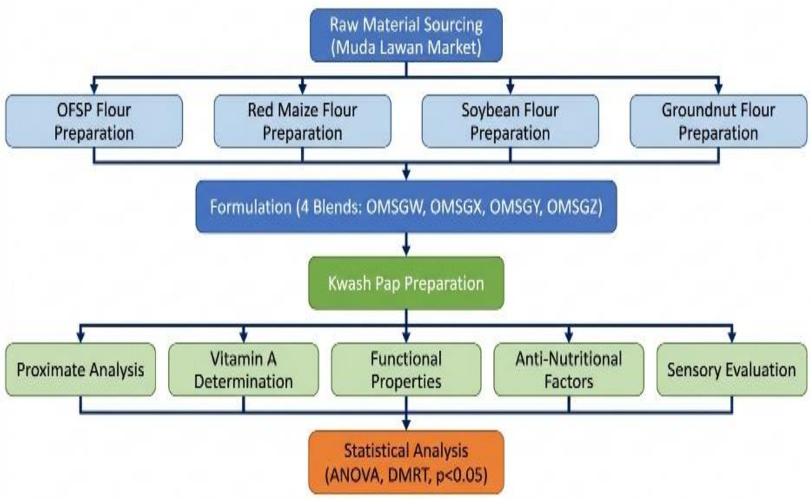

Figure 1: Methodology flowchart for production and analysis of enriched *Kwash* pap formulations

Formulation of Composite Blends

Table 1: Formulation of composite *Kwash* pap production %

Samples	Maize (%)	OFSP (%)	Soybean (%)	Groundnut (%)
OMSGW	70	0	20	10
OMSGX	60	10	20	10
OMSGY	50	20	20	10
OMSGZ	40	30	20	10

Key: OMSGW = Maize 70%: OFSP 0%: Soybean 20%: and Groundnut 10%, OMSGX = Maize 60%: OFSP 10%: Soybean 20%: and Groundnut 10%, OMSGY = Maize 50%: OFSP 20%: Soybean 20%: and Groundnut 10% and OMSGZ = Maize 40g: OFSP 30%: Soybean 20%: and Groundnut 10%

Table 2: Production table of *Kwash* Pap (g for 500g)

Sample	Maize	OFSP	Soybean	Groundnut
OMSGW	350	-	100	50
OMSGX	300	50	100	50
OMSGY	250	100	100	50
OMSGZ	200	150	100	50

Key: OMSGW = Maize 350g: OFSP 0g: Soybean 100g: and Groundnut 50g, OMSGX = Maize 300g: OFSP 50g: Soybean 100g: and Groundnut 50g, OMSGY = Maize 250g: OFSP 100g: Soybean 100g: and Groundnut 50g and OMSGZ = Maize 200g: OFSP 150g: Soybean 100g: and Groundnut 50g

Preparation of *Kwash* Pap
Each composite blend was reconstituted with cold water into a slurry; boiled water was added gradually while stirring continuously until it is cooked for about 5 – 10 minutes, stirring until smooth and properly cooked and *Kwash* pap is produce for analysis.

Determination of Vitamin A Content
The provitamin A carotenoid content of the *Kwash* pap samples was determined using High-Performance Liquid Chromatography (HPLC) following the method as described by (Rodriguez-Amaya and Kimura, 2004). The provitamin A carotenoids, particularly β-carotene, were quantified and expressed as micrograms of retinol equivalents per 100g (µg RE/100g).

Proximate Analysis
Proximate composition of the four *Kwash* pap samples was evaluated following the methods described by the Association of Official Analytical Chemists (AOAC, 2012). Moisture, fat, crude protein, crude fibre, and ash contents were determined. Carbohydrate content was calculated by difference.

Determination of Anti-Nutritional Properties
Phytate Content
Phytate content was determined based on the (AOAC 2005; Haug, & Lantzsch, 1983) colorimetric method. To 1 g of flour, 20 mL HCl was added and the mixture agitated at 25 °C for 2 hours, followed by centrifugation for 15 minutes. A 3 mL aliquot of filtrate was diluted to 18 mL with distilled water and passed through a 200–400 mesh AG1-X8 chloride anion exchange resin. Phytic acid was determined based on the pink colour of Wade reagent. Absorbance was measured at 640 nm using a UV-spectrophotometer (Genesys G10S, Thermo Fisher Scientific). Phytate values were expressed as mg/100 g on dry weight basis.

Tannin Content
Tannin concentration was determined with the vanillin method described by ("AOAC, 2005; Price, *et al.,* 1978"). A 2 g sample was extracted with 50 mL of 99.9% methanol for 20 minutes at room temperature with constant agitation. After centrifugation at 653 × g for 10 minutes, 5 mL of vanillin-HCl (2% vanillin and 1% HCl) reagent was added to 1 mL of aliquots. The colour developed after 20 minutes at room temperature was read at 500 nm. Tannin content was expressed in mg/100 g (dry basis) using catechin as standard.

Saponin Content
Saponin content was determined using a modified colorimetric method involving ethanol extraction and quantification with a diosgenin standard, as described by (Hiai *et al.,* 1976; Obadoni & Ochuko, 2001). A 1 g sample was extracted with 20 mL of 20% ethanol, heated for 4 hours at 55 °C, and filtered. The extract was evaporated to dryness and the residue re-dissolved in 5 mL ethanol. Absorbance was measured at 560 nm. A standard curve using diosgenin was used for calculation.

Oxalate Content
Oxalate content was determined using the permanganate titrimetric method described by Oke (1966), following the principles of quantitative analysis outlined by (Day & Underwood, 1986). Results were expressed as mg/100 g.

Functional Properties
Functional properties were assessed according to the method described by (Sarabandi, *et al.,* 2023).
Bulk Density
Bulk density was determined according to the method of (Oladele & Aina, 2007). Fifty grams (50 g) of the flour sample was gently transferred into a 100 mL graduated measuring cylinder. The cylinder was tapped repeatedly on a laboratory bench until a constant volume was obtained. The final volume occupied by the sample was recorded. Bulk density was calculated as the ratio of the weight of the sample to the volume occupied by the sample and expressed as g/mL
Formula

$$Bulk\ Density\ (\text{g/ml}) = \frac{\text{Weight of sammple (g)}}{\text{Volume occupied by sample (ml)}}$$

Water Absorption Capacity (WAC)
Water absorption capacity (WAC) was determined according to the method described by (Sosulski *et al.,* 1976). Water absorption capacity (WAC) was determined by weighing 1.0 g of sample was weighed into a pre-weighed centrifuge tube, and 10 mL of distilled water was added. The mixture was thoroughly mixed and allowed to stand at room temperature for 30 min with intermittent stirring. The suspension was centrifuged at about 3,000 × g for 15–20 min. The supernatant was carefully decanted, and the tube containing the sediment was weighed. Water absorption capacity was expressed as grams of water absorbed per gram of sample (g/g).
WAC was calculated as:

$$WAC = \frac{\text{Weight of water absorbed}}{\text{Weight of dry sample}} \times 100$$

Oil Absorption Capacity (OAC)
Oil absorption capacity (OAC) were determined according to the method described by (Sosulski *et al.,* 1976). Oil absorption capacity (OAC)was determined similarly using refined vegetable oil instead of water. One gram of sample was mixed with 10 mL of refined vegetable oil in a centrifuge tube. The mixture was stirred thoroughly, allowed to stand for 30 min at room temperature, and centrifuged at approximately 3,000 × g for 15–20 min. The unabsorbed oil was decanted, and the retained oil was determined gravimetrically. Oil absorption capacity was expressed as grams of oil retained per gram of sample (g/g).

Emulsion Capacity
Emulsion capacity (EC) was determined according to the method of Yasumatsu *et al.* (1972), with slight modifications. Briefly, 1 g of flour sample was dispersed in 10 mL of distilled water, followed by the addition of 10 mL of vegetable oil. The mixture was homogenized thoroughly to form an emulsion and transferred into a graduated centrifuge tube. The emulsion was centrifuged at 3,000 × g for 5 min. The height of the emulsified layer and the total height of the mixture were recorded. Emulsion capacity was calculated as the ratio of the height of the emulsified layer to the total height of the mixture, expressed as a percentage.
The calculation is:
Emulsion capacity

$$EC = \frac{\text{Height of emulsified layer}}{\text{Total height of mixture}} \times 100$$

Sensory Evaluation

Sensory evaluation was performed using the method described by Condurso *et al.,* (2025), with slight modification using a semi-trained consumer panel consisting of 20 panelists selected from the Department of Food Science and Technology and Department of Nutrition and Dietetics, both from Federal Polytechnic Bauchi, Nigeria. The panelists evaluated the four formulations coded as OMSGW the control (Maize 70%: OFSP 0%: Soybean 20%: and Groundnut 10%), OMSGX (Maize 60%: OFSP 10%: Soybean 20%: and Groundnut 10%), OMSGY (Maize 50%: OFSP 20%: Soybean 20%: and Groundnut 10%) and OMSGZ (Maize 40g: OFSP 30%: Soybean 20%: and Groundnut 10%): Sensory evaluation was conducted using a 9-point hedonic scale to assess color, taste, aroma, texture, and overall acceptability.

Statistical Analysis

Data were subjected to Analysis of Variance (ANOVA) using SPSS version 25.0, and means were separated using Duncan's Multiple Range Test (DMRT) at a significance level of $p < 0.05$.

RESULTS AND DISCUSSION

Vitamin A Content

The Vitamin A content of the pap samples differed significantly ($p < 0.05$), with values ranging from 0.1521 µg RE/100 g to 2.6517 µg RE/100 g representing the control and the highest incorporation of OFSP respectively. In contrast, OMSGZ showed the highest Vitamin A content (2.6517 µg RE/100 g), followed closely by OMSGY (2.4450 µg RE/100 g), while OMSGX recorded 2.3400 µg RE/100 g. The higher values observed in OMSGZ, OMSGY, and OMSGX demonstrate the positive contribution of orange-fleshed sweet potato enrichment to provitamin A content with incremental level of OFSP. The increased vitamin A content observed in the enriched samples demonstrated the positive contribution of OFSP to provitamin A enrichment. The high β-carotene content of OFSP likely accounted for the improved vitamin A values observed in the formulations described by (Tumwegamire, *et al.,* 2004).

Table 3: Vitamin A Content (µg RE/100g) of the samples

Sample	OMSGW	OMSGX	OMSGY	OMSGZ
Vitamin A (µg RE/100g)	0.1521^{a}	2.3400^{b}	2.4450^{b}	2.6517^{c}

Values represent mean ± standard deviation of vitamin A. There was a significant ($p < 0.05$) increase in vitamin A levels across enriched samples compared with the control. OMSGW Maize 70%: OFSP 0%: Soybean 20%: and Groundnut 10%, OMSGX Maize 60%: OFSP 10%: Soybean 20%: and Groundnut 10%, OMSGY Maize 50%: OFSP 20%: Soybean 20%: and Groundnut 10% and OMSGZ Maize 40%: OFSP 30%: Soybean 20%: and Groundnut 10%

Proximate Composition

The proximate composition of the four *Kwash* pap formulations is presented in Table 4 and Figure 2. Significant differences ($p < 0.05$) were observed in protein, ash, and fiber contents among the samples, demonstrating the nutritional enhancement effects of the enrichment materials.

Table 4: Proximate Composition of *Kwash* Pap

Parameter	OMSGW	OMSGX	OMSGY	OMSGZ
Moisture (%)	5.68 ± 0.11^{a}	6.43 ± 0.11^{a}	7.18 ± 0.11^{b}	5.83 ± 0.11^{a}
Ash (%)	2.63 ± 0.04^{a}	3.18 ± 0.04^{b}	3.18 ± 0.04^{b}	3.80 ± 0.07^{c}
Fiber (%)	2.13 ± 0.04^{a}	2.78 ± 0.04^{c}	3.48 ± 0.04^{b}	2.43 ± 0.04^{b}
Fat (%)	16.28 ± 0.11^{c}	15.08 ± 0.11^{b}	13.83 ± 0.11^{a}	15.93 ± 0.11^{b}
Protein (%)	9.58 ± 0.05^{a}	10.35 ± 0.05^{b}	11.11 ± 0.04^{c}	10.19 ± 0.04^{b}
Carbohydrate (%)	63.73 ± 0.23^{c}	62.21 ± 0.23^{b}	60.62 ± 0.28^{a}	62.76 ± 0.24^{b}

Significant ($p < 0.05$) differences were observed in protein, ash, and fiber contents among the samples, demonstrating the nutritional enhancement effects of enrichment materials. Key: OMSGW= Maize 70%: OFSP 0%: Soybean 20%: and Groundnut 10%, OMSGX = Maize 60%: OFSP 10%: Soybean 20%: and Groundnut 10%, OMSGY = Maize 50%: OFSP 20%: Soybean 20%: and Groundnut 10% and OMSGZ = Maize 40%: OFSP 30%: Soybean 20%: and Groundnut 10%

The proximate composition of the formulated *Kwash* pap varied significantly ($p < 0.05$) with increasing substitution of maize by orange-fleshed sweet potato (OFSP), while soybean and groundnut remained constant at 20% and 10%, respectively. This demonstrates that ingredient proportion can influence the nutritional quality of cereal, legume and OFSP complementary foods, consistent with previous reports (Alomatu, *et al.,* 2025). Moisture content ranged from 5.68% (OMSGW) to 7.18% (OMSGY). OMSGY had significantly higher moisture, although all values were relatively low and therefore favourable for storage stability by limiting microbial growth. Comparable moisture levels have been reported for OFSP-based complementary foods (Alomatu, *et al.,* 2025). Ash content increased from 2.63% in OMSGW to 3.80% in OMSGZ. The higher ash content of OMSGZ, which contained 30% OFSP, suggests a potentially greater mineral contribution. Similar variations in ash content have been reported in complementary foods containing OFSP, soybean and groundnut (Obinna-Echem *et al.,* 2021). Fibre content ranged from 2.13% to 3.48%, with OMSGY recording the highest value. The increased fibre may be associated with the incorporation of OFSP and changes in the composite flour composition. The values are comparable with those reported for other OFSP-based complementary foods (Jenfa, *et al.,* 2024).

Fat content decreased from 16.28% in OMSGW to 13.83% in OMSGY. This reduction may reflect the increasing replacement of maize with OFSP, which contains less fat than the oil-rich soybean and groundnut. The relatively high fat content remains nutritionally valuable because fat provides energy and facilitates absorption of fat-soluble nutrients, including provitamin A carotenoids. Protein increased from 9.58% in OMSGW to 11.11% in OMSGY, indicating an improvement in protein concentration. Soybean and groundnut, maintained at 20% and 10%, respectively, are important contributors to the protein quality of the formulations. Similar improvements have been reported in cereal-based complementary foods enriched with legumes (Okwunodulu, *et al.,* 2024). Carbohydrate decreased from 63.73% to 60.62%, reflecting the progressive replacement of maize with OFSP. Overall, OMSGY (50% maize, 20% OFSP, 20% soybean and 10% groundnut) showed the most favourable proximate profile, with the highest protein and fibre and lower carbohydrate and fat contents.

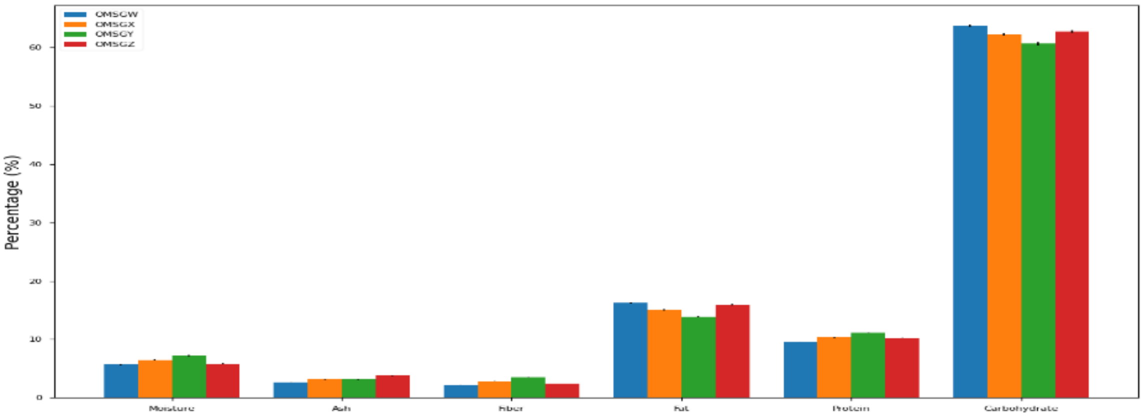

Figure 2: Proximate composition of enriched *Kwash* pap formulations.

Anti-Nutritional Factors

Table 5: Anti-Nutritional Factors of Composite Flour Samples

Anti-Nutritional Factor	OMSGW	OMSGX	OMSGY	OMSGZ
Phytate (mg/100g)	464.29 ± 50.51[a]	339.29 ± 5.05[b]	321.43 ± 50.51[b]	292.86± 10.10[c]
Tannin (mg/100g)	40.00 ± 0.00[a]	30.00 ± 0.00[b]	29.00 ± 0.00[c]	26.00 ± 0.00[d]
Oxalate (mg/100g)	30.21 ± 1.47[a]	21.90 ± 1.46[b]	21.88 ± 1.47[b]	18.75 ± 2.94[c]
Saponin (g/100g)	1.53 ± 0.002[a]	1.13 ± 0.009[b]	1.12 ± 0.002[b]	0.92 ± 0.002[b]
Alkaloid (mg/100g)	132.50 ± 10.61[a]	7.25 ± 1.06[b]	6.25 ± 1.77[c]	0.25 ± 0.07[d]

Significant ($p < 0.05$) differences were recorded across all anti-nutritional parameters, showing the positive effect of processing and enrichment on the nutritional safety of the product. Key: OMSGW= Maize 70%: OFSP 0%: Soybean 20%: and Groundnut 10%, OMSGX = Maize 60%: OFSP 10%: Soybean 20%: and Groundnut 10%, OMSGY = Maize 50%: OFSP 20%: Soybean 20%: and Groundnut 10% and OMSGZ = Maize 40%: OFSP 30%: Soybean 20%: and Groundnut 10%

The anti-nutritional factor contents of the *Kwash* pap composite flour are presented in Table 5. Significant differences ($p < 0.05$) were observed among the formulations for phytate, tannin, oxalate, saponin and alkaloid. The general reduction in anti-nutritional factors can be attributed mainly to the soaking and roasting treatments, together with the progressive replacement of maize with orange-fleshed sweet potato (OFSP). Soaking promotes the leaching of water-soluble anti-nutrients into the soaking water, whereas roasting can cause thermal degradation of heat-sensitive compounds. Similar effects of processing on plant-based anti-nutrients have been reported by (Abebe, *et al.,* 2024). Phytate decreased from 464.29 mg/100 g in OMSGW to 292.86 mg/100 g in OMSGZ. This reduction is nutritionally beneficial because phytate can bind minerals such as calcium, iron and zinc, thereby reducing their bioavailability. The decline may be associated with leaching during soaking and degradation during roasting. Similar reductions in phytate following processing of cereals and legumes have been reported by (Abera, *et al*., 2023). Tannin content declined from 40.00 to 26.00 mg/100 g, with the lowest value observed in OMSGZ. Tannins can interact with proteins and digestive enzymes and consequently reduce nutrient utilization. Their reduction following soaking and roasting may therefore improve the nutritional quality of the composite flour. Oxalate decreased from 30.21 mg/100 g in OMSGW to 18.75 mg/100 g in OMSGZ. Soaking may remove soluble oxalates through diffusion into the soaking water, while roasting may further reduce heat-sensitive compounds. The lower oxalate content is desirable because oxalates can form complexes with minerals and reduce their absorption.

Saponin declined from 1.53 to 0.92 g/100 g, while alkaloid showed the greatest reduction, from 132.50 to 0.25 mg/100 g. These changes indicate the effectiveness of soaking and roasting in reducing undesirable compounds. Overall, soaking followed by roasting effectively reduced the anti-nutritional factors of the *Kwash* pap flour. OMSGZ recorded the lowest phytate, tannin, oxalate and alkaloid contents, suggesting improved nutritional quality and potentially better mineral bioavailability. Thus, combining OFSP enrichment with appropriate bioprocessing provides a promising approach for improving the nutritional quality of *Kwash* pap.

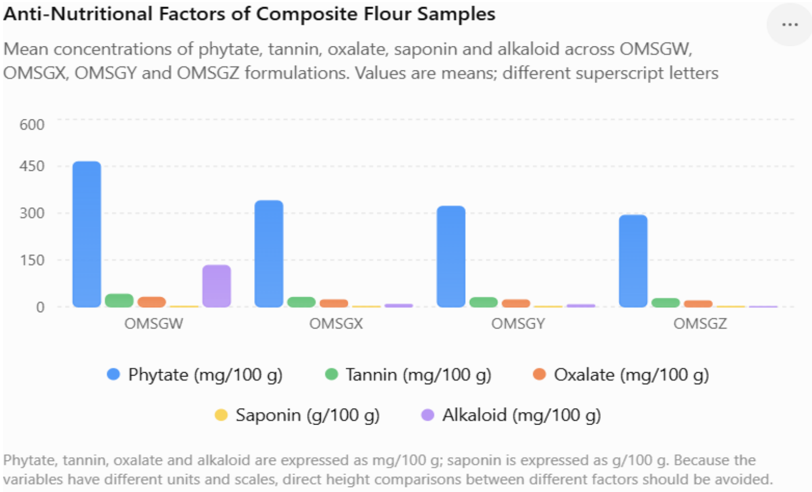

Figure 3: Anti-nutritional factors of Composite flour samples

Functional Properties

Table 6: Functional Properties of Flour

Parameter	OMSGW	OMSGX	OMSGY	OMSGZ
Bulk density (g/mL)	0.619[a]	0.590[b]	0.580[b]	0.560[c]
WAC (g/g)	1.89[b]	2.10[a]	2.18[a]	2.28[a]
OAC (g/g)	1.93[b]	1.22[a]	1.28[a]	0.95[a]
Emulsion capacity (%)	60.0[a]	70.0[b]	72.0[b]	73.5[b]

There were significant ($p < 0.05$) differences among samples, particularly in WAC and emulsion capacity, indicating that enrichment materials improved hydration and emulsifying functionality compared to the control. Key: OMSGW= Maize 70%: OFSP 0%: Soybean 20%: and Groundnut 10%, OMSGX = Maize 60%: OFSP 10%: Soybean 20%: and Groundnut 10%, OMSGY = Maize 50%: OFSP 20%: Soybean 20%: and Groundnut 10% and OMSGZ = Maize 40%: OFSP 30%: Soybean 20%: and Groundnut 10%

The functional properties of the *Kwash* pap composite flours are presented in Table 6. Increasing OFSP incorporation from 0 to 30%, while maintaining soybean and groundnut at 20% and 10%, respectively, influenced the hydration, oil-binding and emulsifying characteristics of the flour. Similar effects of incorporating OFSP and legumes into composite flours have been reported by (Obinna-Echem et al. 2021). Bulk density decreased slightly from 0.619 g/mL in OMSGW to 0.560 g/mL in OMSGZ, although the differences were not significant ($p > 0.05$). The reduction may be associated with differences in particle composition and structure resulting from increasing OFSP substitution. Lower bulk density can be advantageous in complementary foods because it may permit the preparation of more nutrient-dense meals with less flour volume (Eke-Ejiofor, *et al.,* 2021). Water absorption capacity (WAC) increased from 1.89 g/g in OMSGW to 2.28 g/g in OMSGZ. Although the differences were not statistically significant according to the superscript letters, the progressive numerical increase suggests improved hydration with increasing OFSP inclusion. This may be related to hydrophilic components such as dietary fibre and starch, which can bind and retain water. Vicente, *et al.,* (2025) reported that variations in flour composition, particularly protein, starch and fibre, can influence water absorption properties. Oil absorption capacity (OAC) decreased from 1.93 g/g to 0.95 g/g, with OMSGW significantly higher than the other formulations. This reduction may reflect changes in the relative proportions of protein and fibre components following OFSP substitution. OAC is important because it contributes to flavour retention, mouthfeel and palatability of food products (Oresanya, *et al.,* 2026). Emulsion stability increased significantly from 60.0% in OMSGW to 73.5% in OMSGZ. The improved stability may be associated with the emulsifying activity of soybean proteins, which can facilitate the formation and stabilization of oil–water interfaces reported by (Oresanya, *et al.,* 2026). Overall, OFSP enrichment improved the functional characteristics of the flour, particularly water absorption and emulsion stability, supporting its suitability for *Kwash* pap preparation.

Sensory Evaluation

Table 7: Sensory evaluation of *Kwash* pap

Sample	Taste	Odor	Appearance	Texture	General acceptability
OMSGW	7.15± 0.87[a]	6.95 ±0.68[a]	6.90 ±0.78[a]	6.95 ± 0.75[a]	6.95 ±0.88[a]
OMSGX	7.15± 0.67[a]	6.85± 0.81[a]	6.95 ± 0.82[a]	6.80 ±0.95[a]	7.15 ±0.58[a]
OMSGY	7.90± 0.64[c]	7.85± 0.87[c]	8.15 ± 0.93[c]	7.45 ± 1.05[c]	8.00 ± 0.79[c]
OMSGZ	7.40± 0.99[b]	7.30± 1.03[b]	7.55 ± 1.05[b]	7.20 ±1.00[b]	7.75 ± 0.91[b]

Table 7. Sensory evaluation of enriched *Kwash* pap formulations on a 9-point hedonic scale (Mean ± SD). There was slight but significant ($p < 0.05$) differences in sensory attributes, with Sample OMSGY most preferred. Key: OMSGW= Maize 70%: OFSP 0%: Soybean 20%: and Groundnut 10%, OMSGX = Maize 60%: OFSP 10%: Soybean 20%: and Groundnut 10%, OMSGY = Maize 50%: OFSP 20%: Soybean 20%: and Groundnut 10% and OMSGZ = Maize 40%: OFSP 30%: Soybean 20%: and Groundnut 10%.

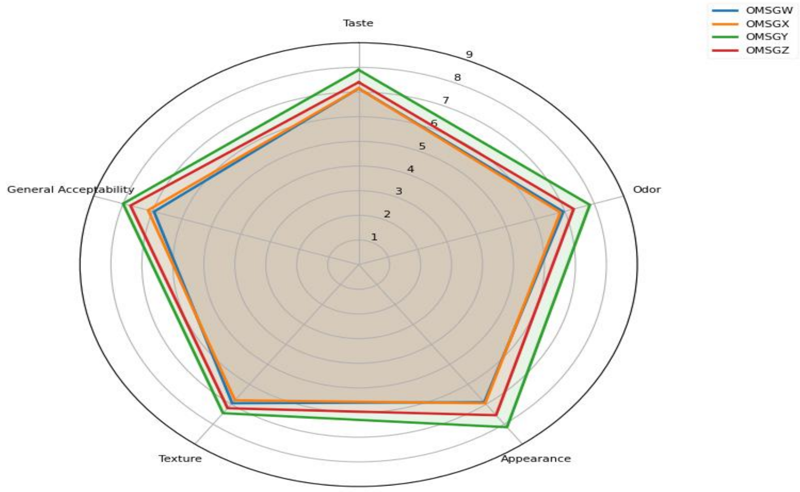

Figure 4: Sensory evaluation of enriched *Kwash* pap

Significant differences were observed in appearance and general acceptability, with OMSGZ and OMSGY rated higher than the control (OMSGW). The improved sensory appeal of enriched formulations, particularly the 20% OFSP inclusion, may be attributed to the vibrant color and natural sweetness contributed by OFSP carotenoids.

Sensory evaluation demonstrated that OFSP-enriched formulations, particularly OMSGY, were preferred over the control. The enhanced appearance scores reflect the vibrant yellow-orange color contributed by OFSP carotenoids. OMSGY's highest general acceptability score (8.00) indicates that 20% OFSP inclusion represents an optimal balance between nutritional enhancement and sensory quality. This finding is supported by Aloka, *et al.*, (2026), who reported that roasted maize-soy meals containing 25% OFSP flour achieved the highest consumer acceptability (87%) among the nutty flavor of groundnut and creamy texture from soybean further enhance sensory acceptability, creating a balanced and appealing product suitable for infant and young child feeding.

CONCLUSION

This study demonstrates that varying the proportions of maize, orange-fleshed sweet potato (OFSP), soybean, and groundnut in *Kwash* pap formulations significantly influences the nutritional, functional, and sensory properties of the product. The enrichment with OFSP resulted in a 17-fold increase in vitamin A content (0.1521 to 2.6517 mg RE/100 g), highlighting the substantial fortification potential of this biofortified crop for addressing vitamin A deficiency. OMSGY (Maize 50%, OFSP 20%, Soybean 20%, Groundnut 10%) emerged as the most balanced formulation, exhibiting superior protein (11.11%), fiber (3.48%), and sensory properties (general acceptability: 8.00), while OMSGZ demonstrated the highest ash (3.80%) and emulsion stability (73.5%). The significant reduction in anti-nutritional factors across enriched formulations confirms that processing techniques including soaking, boiling, roasting, and fermentation effectively improve the nutritional safety of the product. These findings support the incorporation of OFSP, soybean, and groundnut into traditional *Kwash* pap as a viable, affordable, and culturally acceptable food-based strategy for improving dietary vitamin A intake among children and other vulnerable groups in developing countries. The findings support the use of locally available, nutrient-dense crops in the development of affordable complementary foods with enhanced vitamin A content. Future research should focus on optimizing processing conditions to maximize carotenoid retention, particularly at higher OFSP substitution levels, and on conducting community-based intervention trials to assess the impact of enriched *Kwash* pap consumption on vitamin A status among target populations. Additionally, investigating shelf stability and long-term nutrient retention during storage would strengthen the evidence base for scaling this intervention.

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