Journal homepage: www.fia.usv.ro/fiajournal
Journal of Faculty of Food Engineering,
Ştefan cel Mare University of Suceava, Romania
Volume XXIV, Issue 4 - 2025, pag. 233 - 245

FOOD AND ENVIRONMENT SAFETY

NUTRITIONAL AND PHYSICO-CHEMICAL PROPERTIES OF CASSAVA, MAIZE, AND AFRICAN LOCUST BEAN SEED AS SUBSTRATES FOR FERMENTED FOODS

Damilola Adejoke MAKINDE-OKE[1*] and Olusola Abiola LADOKUN[1]
[1]*Department of Human Nutrition and Dietetics, Lead City University, Ibadan, Oyo State, Nigeria*
***Corresponding author:** darmie42@gmail.com
Received 02 August 2025, accepted 24 December 2025

Abstract: *Fermentation is a cornerstone of Nigeria's culinary heritage, where cassava (Manihot esculenta), maize (Zea mays), and African locust bean (Parkia biglobosa) serve as traditional raw materials. These crops are widely consumed, yet their comparative nutritional and physicochemical properties remain underexplored, particularly in relation to their suitability as substrates for fermented foods. This study evaluated the proximate, mineral, vitamin, and physicochemical profiles of cassava, maize, and African locust bean seeds to provide a scientific basis for their functional use in food processing. Samples were collected from artisanal producers in Abeokuta North, Ogun State, and analysed using standard AOAC methods. Parameters determined included proximate composition (moisture, crude protein, fat, fibre, ash, and carbohydrate), selected minerals (calcium, magnesium, iron, and zinc), vitamins (A, B1, B2, B3, B6, B12, and C), and physicochemical properties (pH, titratable acidity, and total soluble solids). Data were subjected to analysis of variance and mean separation using Duncan's multiple range test. Significant differences (p < 0.05) were observed in the proximate composition of the substrates. Vitamin analysis revealed cassava as the poorest in vitamin A, while African locust bean showed superior B-complex and vitamin C contents. Physicochemical results indicated pH values of 6.13–6.63, titratable acidity of 0.05–0.98%, and soluble solids of 2.8–6.5%, with locust bean showing the highest acidification potential. These findings highlight the complementary roles of cassava, maize, and African locust bean in fermented food systems, suggesting that their combined use can enhance nutritional quality and support food security initiatives in Nigeria.*

Keywords: *cassava, maize, african locust bean, substrates, fermented foods.*

1. Introduction

Fermentation, a time-honoured biotechnological process, is widely employed to enhance the nutritional, sensory, and functional attributes of food substrates, particularly in many African and Asian food systems. In sub-Saharan Africa, staples like cassava (Manihot esculenta), maize (Zea mays), and African locust bean (Parkia biglobosa), commonly known in its fermented form as Iru, serve not only as critical dietary components but also as substrates for the production of a variety of fermented foods with significant cultural, economic, and nutritional value.

Cassava is a starchy root crop that provides a primary energy source for millions, but is limited by its low protein content and the presence of cyanogenic glycosides. Through fermentation, however, the nutritional quality of cassava is significantly improved as anti-nutritional factors are reduced and the bioavailability of micronutrients is enhanced [1, 2].

Maize, another staple cereal, is rich in carbohydrates and dietary fibre and serves as a base for traditional products such as Ogi, Kenkey, and Akamu. Fermentation of maize not only improves protein digestibility and reduces phytate content but also enhances amino acid availability, increases mineral solubility, and supports the growth of beneficial lactic acid bacteria that contribute to gut health and product safety [3]. The African locust bean is valued for its high protein and lipid content and is traditionally fermented to produce Iru or Dawadawa, a widely consumed condiment

DOI: https://doi.org/10.4316/fens.2025.021

in West Africa. Fermentation of Parkia biglobosa seeds improves protein quality, increases essential amino acids, and reduces oligosaccharides and tannins [4, 5]. It also promotes the activity of functional microbial strains, notably Bacillus subtilis, which play a role in enzymatic breakdown and flavour development [6].

The physicochemical and nutritional properties of fermentation substrates, such as moisture content, pH, titratable acidity, crude protein, fat, fibre, ash, and carbohydrate levels are critical factors influencing microbial activity and fermentation outcomes [7, 8]. These factors not only affect microbial succession but also determine product safety, shelf stability, and sensory appeal. Furthermore, fermentation often enhances the concentrations of essential minerals such as calcium, magnesium, and iron [9]. Despite their widespread use, there is limited comparative information on the nutritional and physicochemical properties of cassava, maize, and African locust bean seeds in their raw state as substrates for fermentation. Such knowledge is critical for optimizing their use in product formulation, functional food development, and strategies aimed at combating food insecurity and malnutrition. Therefore, this study aims to investigate the proximate composition, mineral profile, vitamin content, and physicochemical properties of cassava, maize, and African locust bean seeds. The findings are expected to provide baseline data that can inform fermentation processes, improve nutritional outcomes, and guide the utilization of these substrates in developing culturally relevant and nutritionally enhanced foods.

2. Materials and methods

2.1 Sample collection and preparation

Raw cassava tubers (*Manihot esculenta*), maize grains (*Zea mays*), and African locust bean seeds (*Parkia biglobosa*) were obtained in sterile food-grade containers from multiple artisanal producers. Samples were labelled and transported under cold-chain conditions. On arrival, samples were cleaned, oven-dried at 40 °C to reduce surface moisture, milled into fine powder, and stored in sterile polyethylene bags at 18°C until analysis.

2.2 Proximate analysis

Proximate analysis was carried out to determine the moisture content, crude protein, crude fat, total ash, crude fibre, and carbohydrate contents of the samples. The analyses were conducted using standardized procedures as described by the Association of Official Analytical Chemists [10].

2.3 Mineral content analysis

The mineral contents of the samples were determined using the procedures outlined by the Association of Official Analytical Chemists [10]. Calcium, magnesium, iron, and zinc concentrations were determined using Atomic Absorption Spectrophotometry (Thermo Electron Corporation, GE712354, 300 China) after wet digestion of the samples with a perchloric–nitric acid mixture. Precisely 0.5 g of each finely ground sample was weighed into a 125 mL Erlenmeyer flask. Under a fume hood, 4 mL of perchloric acid, 25 mL of concentrated nitric acid (HNO_3), and 2 mL of concentrated sulphuric acid (H_2SO_4) were added. The contents were thoroughly mixed and heated gently on a hot plate within a perchloric acid-compatible fume hood. Heating was continued until dense white fumes were observed, after which strong heating was applied for an additional 30 s. The digestion mixture was then allowed to cool. Subsequently, 50 mL of distilled water was added to the cooled digest, and the mixture was allowed to cool to room temperature. The resulting solution was filtered completely using a wash bottle into a Pyrex volumetric flask and made up to the mark with distilled water. The mineral concentrations were then measured using the Atomic Absorption Spectrophotometer.

2.4 Vitamin content analysis

Determination of vitamin A and B-complex

Vitamin A (Retinol)

Vitamin A was determined by the saponification extraction spectrophotometry method [11]. About 1 g of each powdered sample was saponified with alcoholic KOH, extracted into hexane, evaporated, reconstituted in ethanol, and mixed with ferric chloride and dipyridyl reagents. Absorbance was read at 520 nm against a reagent blank, and results were expressed as mg vitamin A per 100 g of sample.

Vitamin B-Complex (B_1, B_2, and B_3)

Water-soluble vitamins were quantified using reverse-phase high-performance liquid chromatography (HPLC) [10]. One gram of each sample was homogenized in 0.1 N HCl, hydrolysed at 95 °C for 30 min, neutralized, filtered, and injected into the HPLC system (Nexera X2, LC-2030 Japan) equipped with a UV detector set at 270 nm. Quantification was achieved by external calibration with thiamine, riboflavin, and niacin standards.

2.5 Determination of vitamin C

The vitamin C (ascorbic acid) content of the samples was determined using the 2,6-dichlorophenolindophenol (DCPIP) titrimetric method as described by the Association of Official Analytical Chemists [10]. Precisely 5 g of the fresh or properly homogenized sample was weighed and blended with 100 mL of 1% metaphosphoric acid to extract the ascorbic acid. The resulting mixture was filtered through Whatman No. 1 filter paper, and the clear filtrate was collected for analysis. An aliquot of 10 ml of the filtrate was titrated with the standardized dye solution of 2,6-DCPIP until a persistent light pink colour was observed, lasting for at least 15 s. The vitamin C content was calculated based on the volume of dye used and expressed in milligrams of ascorbic acid per 100 grams of sample (mg/100 g).

The standardization of the dye solution was carried out using pure ascorbic acid, and the results were used to determine the vitamin C concentration in the samples.

2.6 Physicochemical properties

pH determination

The pH of the food samples was determined using the method described by AOAC [10]. A 10 g portion of the homogenized sample was weighed and dispersed in 100 mL of distilled water in a beaker. The mixture was stirred thoroughly to get a uniform suspension and allowed to stand for 30 min at room temperature. After equilibration, the pH of the suspension was measured using a calibrated digital pH meter. The pH meter was standardized using buffer solutions of pH 4.0 and pH 7.0 prior to measurement. The electrode was rinsed with distilled water between readings and gently immersed in the sample solution. The stable reading was recorded as the pH of the sample.

Titratable acidity

The titratable acidity was determined using the method described by AOAC [10]. About 25 mL of filtrate was transferred into a 125 mL conical flask. A 25 mL burette was filled with 0.1 N NaOH and adjusted to zero. Two to three drops of phenolphthalein indicator were added to the conical flask containing the filtrate. The filtrate was titrated with 0.1 N NaOH until colour changes occurred, and the volume was recorded. Titratable acidity and the volume were recorded. Titratable acidity was calculated as % citric acid.

3. Results and discussion

3.1 Proximate Composition of Cassava, Corn, and African Locust Bean Seed (Iru)

The proximate composition of cassava tuber, corn grain, and *Iru* seeds is presented in Table 1. The moisture contents of the raw foods varied significantly ($p < 0.05$) from 10.96 to 64.92%, with cassava tuber having the highest value (64.92%), while the least moisture content (10.96%) was observed in corn grain. Moisture content serves as an indicator of storage stability and safety, with ≤15% generally considered ideal for long shelf life [12]. Therefore, the corn grain and *Iru* seed samples may have better storability compared to cassava roots. The high moisture content of cassava is consistent with reported values of 65.91–72.90% in cassava root varieties [13]. Conversely, the lower values in corn and *Iru* corroborate the reports of Sinay and Harijati [14] and Etuk [15], who documented 10.39–14.02% for maize and 18.64% for raw *Iru* seeds. The dry matter contents of the raw foods ranged from 35.09 to 89.05%, with corn grain having the highest value (89.05%), while cassava showed the lowest (35.06%). Significant ($p < 0.05$) differences were observed between the samples. The current results align with previous findings of 70.2–93.4% in corn grain [17], 88.79% in *Iru* seeds [18], and 24.64–37.96% in cassava [19].

The crude fat contents of the samples ranged from 0.24 to 8.45%, with *Iru* seeds having the highest value (8.45%) and cassava the lowest (0.24%). Cassava is known to be very low in fat (1.68–3.06%) [20], supporting the present result. Corn grain showed moderate fat levels, consistent with 3.53–4.47% reported by Mpili et al. [21]. However, the fat content observed in *Iru* seeds was markedly lower than the >20% fat commonly reported in the literature [14, 18]. This discrepancy may be attributed to factors such as variety differences, harvesting maturity, or post-harvest processing (e.g., partial fermentation or lipid oxidation before analysis). Importantly, the relatively low-fat values observed across all samples suggest reduced susceptibility to oxidative rancidity, which supports longer storage stability [12]. The total ash contents of the samples varied from 0.56 to 2.07%, with *Iru* seeds showing the highest value (2.07%) and cassava the lowest (0.56%). Ash provides an estimate of total mineral content [22, 23]. Although *Iru* seeds had higher ash content than cassava and corn in this study, the value was still lower than the ~4.24% reported [18]. This difference may reflect soil nutrient variations, seed maturity, or environmental conditions influencing mineral accumulation**.** Corn ash (1.26%) also fell below the 2.22–2.61% reported by Mpili et al. [21], again suggesting possible varietal or agronomic effects. The crude fibre contents ranged from 1.64 to 9.26%, with corn grain showing the highest value (9.26%) and cassava the lowest (1.64%). Significant differences ($p < 0.05$) were observed among the samples. These values align with literature reports of 2.30–22.8% for corn [17], 3.29% for *Iru* [15], and 1.58–2.96% for cassava [20]. Dietary fibre is essential for digestive health, blood sugar regulation, and reducing the risks of chronic diseases [25]. The crude protein contents ranged from 1.26 to 38.62%, with *Iru* seeds showing the highest (38.62%) and cassava the lowest (1.26%). The protein content of Iru is consistent with values reported [15], while cassava and corn fell within ranges previously documented [14, 20]. The high protein content of *Iru* seeds highlights their importance as a source of plant protein for tissue development, repair, and overall nutritional security [24–26].

The carbohydrate contents varied from 31.40 to 66.17%, with corn grain having the highest value (66.17%) and cassava the lowest (31.40%). These results align with literature values for cassava (23.14–31.28%) [13], *Iru* (41.10%) [18], and corn (69.70–75.74%) [14]. High carbohydrate levels in corn underline its role as a major energy source in human diets [12, 23].

Table 1.
Proximate Composition of Cassava, Maize, and African Locust Bean Seed (*Iru*) as Substrates for Fermented Foods

Raw Foods							
Samples	**Moisture content (%)**	**Dry matter (%)**	**Crude fat (%)**	**Total ash (%)**	**Crude fibre (%)**	**Crude protein (%)**	**Total carbohydrate (%)**
Cassava Tuber	64.92±0.02^{c}	35.09±0.02^{a}	0.24±0.02^{a}	0.56±0.03^{a}	1.64±0.02^{a}	1.26±0.03^{a}	31.40±0.04^{a}
Corn Grain	10.96±0.01^{a}	89.05±0.01^{c}	3.24±0.04^{b}	1.26±0.01^{b}	9.26±0.03^{c}	9.14±0.02^{b}	66.17±0.01^{c}
Iru Seed	12.43±0.03^{b}	87.57±0.03^{b}	8.45±0.04^{c}	2.07±0.02^{c}	6.37±0.03^{b}	38.62±0.03^{c}	32.07±0.15^{b}

Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

Selected Mineral Composition of Cassava, Corn, and African Locust Bean Seed (Iru)

Table 2 depicts the selected mineral composition of raw (cassava, corn, and *Iru* seeds). The calcium contents of the raw foods ranged from 8.26 to 495.82 mg/100 g, with *Iru* seed having the highest calcium content (495.82 mg/100 g), while the least calcium content (8.26 mg/100 g) was observed in the corn grain sample. Significant ($p < 0.05$) differences were observed between the calcium contents of the raw food samples. The calcium contents of the raw food samples are lower than 933.45–1388.15 mg/100 g for some selected legumes (brown cowpea, black-eyed pea, soybean, and groundnut) studied [27] and 414–9747 mg/kg reported for calcium contents of different root and tuber crops (sweet potato, purple yam, cassava, taro, cocoyam, and giant swamp taro) [28]. However, the highest calcium content (495.82 mg/100 g) recorded for the *Iru* seed sample of the current study is expected as literature had shown that African locust bean seeds contain high amount of calcium; [18] reported 222.2 mg/100 g for calcium content of African locust bean seeds while 103.25 mg/kg was also reported for locust bean seed [29]. The calcium content of 18.92 mg/100 g of the cassava sample in the current work is slightly in tandem with 12.80–17.75 mg/100 g reported for calcium contents of different sweet potato varieties [30]. The variations between this study and literature values may be due to unit conversions (mg/100 g vs. mg/kg), varietal differences, or environmental growing conditions. Therefore, the highest calcium content observed in the *Iru* seed of the current study could contribute significantly to bone growth and mineral metabolism. Calcium plays essential roles in skeletal development, the prevention of osteoporosis, and the regulation of muscle and nerve function [31, 32].

The magnesium contents of the raw food samples varied significantly ($p < 0.05$) from 20.69 to 324.17 mg/100 g. *Iru* seed had the highest magnesium content (324.19 mg/100 g), while the lowest magnesium content (20.69 mg/100 g) was observed in the cassava tuber. The highest magnesium content observed in the *Iru* seed is higher than 280.2 mg/100 g reported for the magnesium content of African locust bean [18], 96.34 mg/100 g for the magnesium content of *Parkia biglobosa* seeds [29] and 2.49 mg/100 g for unfermented *Parkia* seeds [33]. On the flip side, the magnesium content of the corn sample 38.64 mg/100 g is lower than 1578.50–2320.50 mg/kg reported for magnesium contents of some legumes (brown cowpea, black-eyed pea, soybean, and groundnut) [27] but higher than 14.15–21.19 ppm reported for magnesium contents of some cereal varieties (Reyna, Attilla, Norman B., Samsorg-41, Samsorg-45, Samsorg-46, Smz-15, Smz-39, and Evdt-2009) available in Kano [34]. The magnesium content of 20.69 mg/100 g of the cassava sample is lower than 313–896 mg/kg reported for magnesium contents of different root and tuber crops (sweet potato, purple yam, cassava, taro, cocoyam, and giant swamp taro) [28].

These differences may reflect reporting on fresh weight vs. dry weight, and variations in analytical method. The value for the iron contents of the raw food samples ranged from 0.26 to 10.37 mg/100 g. The highest iron content (10.37 mg/100 g) was observed in *Iru* seed, while the cassava tuber sample had the lowest iron content (0.26 mg/100 g). The result showed significant variations ($p < 0.05$) between the iron contents of the raw food samples. The findings of the current study for the iron content of the *Iru* seed aligns with 10.31 mg/100 g for iron content of *Parkia biglobosa* seeds [29], slightly in line with 9.30 mg/100 g reported for African locust bean seed [18] but higher than 1.46 mg/100 g reported for iron content of *Parkia biglobosa* [35]. The iron contents of other raw food samples (cassava and corn) are slightly in consonance with 0.04–0.27 mg/100 g reported for iron contents of selected root and tuber crops (sweet potato, purple yam, cassava, taro, cocoyam, and giant swam taro), [28] but lower than 1.68–2.19 mg/100 g reported for iron contents of different potatoes studied [30].

However, the *Iru* seed sample in the study approaches the recommended dietary allowance for adults, especially for males (8 mg/day), while cassava and corn remain poor iron sources. The zinc contents of the raw food samples varied significantly at a 95% confidence level from 0.38 to 1.35 mg/100 g. Iru seed had the best zinc content (1.35 mg/100 g), while the lowest zinc content (0.38 mg/100 g) was observed in the cassava sample. The results are in tandem with 0.49–1.44 ppm reported for zinc content of some cereals available in Kano [34], higher than 0.17 mg/kg for zinc content of African locust bean seed [29] but lower than 3.80 mg/100 g reported for zinc content of African locust bean [18], 7.6–100 mg/kg for zinc contents of different roots and tuber crops (sweet potato, purple yam, cassava, taro, cocoyam and giant swamp taro) [28], and 294.39 mg/100 g reported for zinc content of raw locust bean [36].

The zinc contents of the raw food samples in the current study are below the recommended daily intake for zinc (8–11 mg/day for adults) [37]; hence, they may not suffice as a valuable source of zinc.

Selected vitamin composition of cassava, corn, and African locust bean seed (Iru)

Table 3 highlights the selected vitamin composition of raw food samples (cassava tuber, corn grain, and *Iru* seeds). The vitamin A contents of the raw food samples varied significantly ($p < 0.05$) from 1.86 to 10.86 mg/100 g, with corn grain having the highest vitamin A (10.86 mg/100 g), while the lowest vitamin A content (1.86 mg/100 g) was observed in the cassava sample. The findings of the current study are in line with 1248–2303 µg/100 g reported for vitamin A contents of pigeon pea seeds [38] and 3.36–4051.98 µg/100 g for vitamin A contents of green spinach, red amaranth, barley, corn, and pineapple studied by Zuwariah et al. [39] higher than 0.00002 mg/100 g reported for whole grain of cowpea [40] but lower than 13.69 mg/kg reported for vitamin A content of African locust bean [41] and 15 mg/100 g reported for vitamin A contents of raw and matured cowpea seeds [42]. Conversely, the vitamin A contents of the raw food samples in the current study are higher than the recommended dietary intake level of 600 µg/day for vitamin A [39, 43]. It has been shown that vitamin A helps to promote growth and strengthen the immune system [44]. The mean results for the vitamin B1 (thiamine) contents of the raw

Table 2.

Selected Mineral Composition of Cassava, Maize, and African Locust Bean Seed (*Iru*) as Substrates for Fermented Foods

Raw Foods

Samples	**Calcium (mg/100 g)**	**Magnesium (mg/100 g)**	**Iron (mg/100 g)**	**Zinc (mg/100 g)**
Cassava Tuber	$18.92{\pm}0.00^b$	$20.69{\pm}0.00^a$	$0.26{\pm}0.00^a$	$0.38{\pm}0.00^a$
Corn Grain	$8.26{\pm}0.00^a$	$38.64{\pm}0.00^b$	$0.58{\pm}0.00^b$	$0.47{\pm}0.00^b$
Iru Seed	$495.82{\pm}0.00^c$	$324.17{\pm}0.00^c$	$10.37{\pm}0.01^c$	$1.35{\pm}0.00^c$

Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

food samples ranged from 0.08 to 0.58 mg/100 g. The highest vitamin B_1 content (0.58 mg/100 g) was observed in *Iru* seed, while cassava had the least vitamin B_1 content (0.08 mg/100 g). Significant variations ($p < 0.05$) were observed between the vitamin B_1 contents of the raw food samples. The results are slightly in consonance with 0.08–0.11 mg/100 g reported for vitamin B_1 contents of some roots and tuber crops (potato, sweet potato, taro, cassava, and yam) [45], 0.08–0.19 mg/100 g reported for thiamine (vitamin B_1) contents of selected cereals (guinea corn, maize, rice, and wheat) [44], higher than 0.03 mg/100 g reported for African locust bean seeds [41] but lower than 3.37–9.01 mg/100 g reported for vitamin B_1 contents of purple sweet potato, green spinach, red amaranth, and barley reported [31]. The vitamin B_2 (riboflavin) contents of the raw food sample varied from 0.04 to 0.09 mg/100 g, with the cassava sample having the highest vitamin B_2 content (0.09 mg/100 g), while the least vitamin B_2 content (0.04 mg/100 g) was observed in *Iru* seed. No significant differences ($p > 0.05$) were observed between the vitamin B_2 contents of cassava and *Iru* seed, while the vitamin B_2 content of the corn sample differed significantly ($p < 0.05$) from other raw food samples. It was reported 0.2–0.11 mg/100 g for vitamin B_2 contents of selected whole cereal (wheat, rice, and corn) grains [46], 88.25–672.45 μg/100 g was reported for vitamin B_2 contents of purple sweet potato, green spinach, red amaranth, and barley [39], while 0.16 mg/100 g for vitamin B_2 contents of African locust bean seeds [41] which are higher than the values reported in the current study. The variations in the values can be attributed to differences in the raw materials used and/or the agronomic practices employed.

The mean results for the vitamin B_3 (niacin) contents of the raw food samples ranged from 0.85 to 3.63 mg/100 g. The highest vitamin B_3 content (3.63 mg/100 g) was observed in *Iru* seed, while cassava had the least vitamin B_3 content (0.85 mg/100g). Significant variations ($p < 0.05$) were observed between the vitamin B_3 contents of the raw food samples. The findings of the current study are higher than 0.56 mg/100 g reported for vitamin B_3 contents of African locust bean seeds by [41], 0.00206 mg/100 g for vitamin B3 contents of raw cowpea seeds [40], and 0.05–0.55 mg/100 g for vitamin B_3 contents of selected cereals (guinea corn, rice, and wheat) [44], but slightly in line with 2.075 mg/100 g for niacin contents of raw and matured cowpea seeds [42] and 3.6–4.62 mg/100 g for vitamin B_3 contents of selected cereals (wheat, rice, and corn) reported [46]. The vitamin B_3 contents of the raw food samples are below the recommended daily dose of niacin: 5–6 mg for infants, 9–13 mg for children, 13–20 mg for adults, and 17–20 mg for pregnant and lactating mothers, respectively [47]. The values for the vitamin B_6 (pyridoxine) contents of the raw food samples ranged from 0.06 to 1.37 mg/100 g. The highest vitamin B_6 content (1.37 mg/100 g) was observed in *Iru* seed, while cassava had the lowest vitamin B_6 content (0.06 mg/100g). Significant variations ($p < 0.05$) were observed between the vitamin B_6 contents of the raw food samples. The findings of the current study are within the range 0.24–10.7 mg/100 g reported for vitamin B_6 contents of purple sweet potato, green spinach, red amaranth, and barley [39], 0.119–0.443 mg/100 g for vitamin B_6 contents of raw barley, Eikorn, Kamut, millets, and oats studied [48], and 0.08–0.293 mg/100g reported for vitamin B_6 contents of some root and tuber crops (potato, sweet potato, taro, cassava, and yam) [45]. Except for the cassava sample, other raw food samples (corn and *Iru* seeds) in the current study are in tandem with the recommended dietary allowance of 0.1–2.0 mg for vitamin B_6 [47]. The vitamin B_{12} (cyanocobalamin) contents of the raw food samples varied significantly ($p < 0.05$) from 0.01 to 381.01 µg/100 g. *Iru* seed was observed to have the highest vitamin B_{12} content (381.01 µg/100 g), while the lowest value (0.01 µg/100 g) was observed in the corn sample. Significant differences ($p < 0.05$) were observed between the vitamin B_{12} contents of the raw food samples. It was reported to be 31.25 µg/100 g for the vitamin B_{12} content of purple sweet potato [39], which is in line with the findings of the current study. However, except for the *Iru* seed sample, other raw food samples (corn and cassava) had lower vitamin B_{12} contents compared to 3.39 µg/100 g reported for African locust bean seeds by Enoch et al. [41]. Of all the raw food samples in the current study, only *Iru* seed exceeded the recommended dietary level of 2–5 µg of vitamin B_{12} [49]; hence, the corn and cassava samples may not suffice as rich sources of vitamin B_{12}. Among other disorders, its deficiency has been connected to megaloblastic anemia, sub-acute combined degeneration of the spinal cord, methylmalonic acidemia, and pernicious anaemia [50]. The vitamin C contents of the raw food samples ranged significantly ($p < 0.05$) from 8.13 to 113.81 mg/100 g, with *Iru* seed having the highest vitamin C content (113.81 mg/100 g), while the least vitamin C content (8.13 mg/100 g) was observed in the corn sample. The vitamin C content of the *Iru* seed sample is higher than 25.13–28.21 mg/100 g reported for vitamin C contents of pigeon pea seeds [38], 67.89 mg/100 g for vitamin C contents of African locust bean seeds [41], but lower than 135.76–412.34 mg/100 g for vitamin C contents of purple sweet potato, green spinach, red amaranth and barley [39]. However, the vitamin C contents of other raw food samples (corn and cassava) are higher than 0.25–7.85 mg/100 g reported for vitamin C contents of selected cereals (guinea corn, maize, rice, and wheat) studied [44], 1.5 mg/100 g for vitamin C contents of raw and mature cowpea seeds [42] and 2.40–3.62 mg/100 g for vitamin C contents of sweet potato and taro [45]. However, the vitamin C contents 14.4–7.10 mg/100 g of the potato, cassava, and yam [45] are lower than the current study's value, 21.14 mg/100 g recorded for cassava. Cassava root is recognized as an excellent source of vitamin C, though its concentration varies depending on factors such as species, soil type, plant maturity, and fertilizer application [51, 52]. In addition to being an antioxidant, vitamin C has a role in iron metabolism and the immune system by promoting the activity of white blood cells [49].

Physicochemical properties of cassava, corn, and African locust bean seed (Iru)

The physicochemical properties of the raw

Table 3.
Selected Vitamin Composition of Cassava, Maize and African Locust Bean Seed (*Iru*) as Substrates for Fermented Foods

Raw Foods

Samples	Vitamin A (mg/100 g)	Vitamin B_1 (mg/100 g)	Vitamin B_2 (mg/100 g)	Vitamin B_3 (mg/100 g)	Vitamin B_6 (mg/100 g)	Vitamin B_{12} (mg/100 g)	Vitamin C (mg/100 g)
Cassava	1.86±0.00^a	0.08±0.00^a	0.09±0.00^a	0.85±0.00^a	0.06±0.00^a	0.09±0.00^b	21.14±0.01^b
Corn	10.86±0.00^c	0.16±0.00^b	0.06±0.00^b	3.63±0.00^c	0.61±0.00^b	0.01±0.02^a	8.13±0.00^a
Iru seed	6.18±0.00^b	0.58±0.00^c	0.04±0.00^a	1.03±0.00^b	1.37±0.00^c	381.01±0.00^c	113.81±0.00^c

Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

(cassava, corn and Iru seeds) foods are show in Table 4. The pH of the raw foods varied significantly (p < 0.05) from 6.13 to 6.63, with cassava tuber having the highest pH (6.63), while the lowest pH (6.13) was observed in corn grain. The pH of the Iru seed (6.14) is higher than the 4.50–4.75 reported for the pH of raw and dried locust bean seeds [36]. The pH of the corn grain sample aligns with the reported range of 4.80 to 6.83 for selected cereals such as wheat, maize, sorghum, millet, and fonio [53], as well as the range of 6.45 to 6.95 observed in cereal grains from Mali [54]. Similarly, cassava tubers grown in various locations across Sabah, Malaysia, have been reported to exhibit a relatively high pH range of 6.72 to 6.75 [55]. Differences in pH of the raw food samples could be attributed to variations in intrinsic biological composition (organic acid content, carbohydrate-protein reactions), maturity and harvest time, soil and agro-environmental conditions, enzymatic activities, and genetic variability.

The total titratable acidity (TTA) of the raw food samples ranged from 0.05 to 0.98% with the highest TTA (0.98%) being observed in Iru seed, while cassava tuber had the lowest TTA (0.05%). The lowest TTA of cassava (0.05%) is extremely low compared suggesting either very low organic acid content in the cassava tuber. The findings of the current study for TTA of Iru seed are in consonance with 0.98% for TTA of unfermented Parkia seeds [33] but higher than 0.042 mg lactic acid/g reported for TTA of raw locust bean seeds [36]. Total titratable acidity (TTA) values ranging from 0.99% to 1.02% have been reported for fertilizer-treated cassava roots of different varieties, which are higher than the TTA observed in the present study [56]. Similarly, the TTA of the corn grain sample in the current investigation is lower than the 1.23–6.30% reported for the TTA of whole wheat meal [57]. Variations in TTA of the raw food sample of the current study and those in the cited literature could be attributed to differences in intrinsic (plant variety maturity, genetic composition, moisture content and composition, endogenous enzyme activity) and extrinsic factors (soil type and fertility, agronomic practices, post-harvest handling and storage, and microbial load). The mean value for total soluble solids (TSS) in the raw food samples ranged from 2.83% to 6.53%. Cassava had the highest total soluble solid (6.53%), while the lowest value (2.83%) for total soluble solid was observed in the corn grain. Significant differences (p < 0.05) were observed between the total soluble solids of the raw food samples. Higher total solids, ranging from 12.10% to 17.19% in fresh sweet corn kernels, have been previously reported [58]. The result obtained for the total soluble solids of cassava tuber in the current study is higher than 5.06% reported for total soluble solids of fresh raw cassava root [59], 5.63–5.84% for total soluble solids of different potato varieties [30], and 5.64–6.33% for soluble solids of different cassava varieties researched [60]. However, the total soluble solids of the raw food samples in the current study are higher than 0.10–2.03% reported for total soluble solids of fresh banana [61] but lower than 18.00–24.00% reported for total soluble solids of green asparagus roots [62]. Total soluble solids reflect the concentration of sugars and soluble minerals in food [60]. Variations in the total soluble solids observed between the raw food samples in the present study and those reported in previous literature may be attributed to differences in genetic makeup, environmental conditions, and postharvest handling practices.

Table 4.
Physico-chemical Properties of Cassava, Maize, and African Locust Bean Seed (*Iru*) as Substrates for Fermented Foods

Raw Foods			
Samples	**pH**	**TTA (%)**	**TSS (%)**
Cassava	6.63±0.01[c]	0.05±0.00[a]	6.53±0.04[c]
Corn	6.13±0.02[a]	0.52±0.00[b]	2.83±0.02[a]
Iru seed	6.34±0.02[b]	0.98±0.00[c]	6.14±0.02[b]

Mean values with different superscripts within the same column are significantly different ($p < 0.05$). TTA = total titratable acidity, TSS = total soluble solids.

4. Conclusion

This study demonstrated that African locust bean seed (*Iru*) contained a higher protein (38.62%) content compared to cassava (1.26%), and corn (9.14%). The mineral composition of the substrates (cassava tuber, corn grain, and *Iru* seed) varied significantly, reflecting their nutritional diversity. In addition, cassava, corn, and *Iru* seed were found to contain appreciable levels of vitamin A (10.86 mg/100 g) and vitamin C (113.81 mg/100 g), although these values varied across substrates. Conversely, the total titratable acidity of all three raw materials was generally low (0.05 and 0.98%).

5. Study Limitations

This study was limited to raw substrates obtained from artisanal producers, and results may not fully represent variations due to geographical origin, processing practices, or seasonal differences. Furthermore, only proximate, mineral, and vitamin compositions were assessed, while anti-nutritional factors and bioavailability were not taken into account.

6. Practical Implications

The findings reinforce the value of traditional diets as a foundation for enhancing food formulations and fortification approaches in West Africa. Continued research into fermentation processes, nutrient bioavailability, and associated health outcomes will further support their role in combating nutritional deficiencies.

7. Acknowledgments

The authors gratefully acknowledge the support provided by Tetra An Analytical Laboratory and Kenol Research Laboratory, Abeokuta, Nigeria, for conducting the laboratory analyses associated with this research.

8. Declaration of Interest

No potential conflict of interest was reported by the authors concerning this work.

9. References

[1]. ADESULU-DAHUNSI A. T., SANNI A. I., JEYARAM K., Diversity and Characterization of *Pediococcus Pentosaceus* in Nigerian Fermented Foods, *LWT – Food Science and Technology*, 136: 110352, (2021)

[2]. OLANIRAN C. F., OSEMWEGIE O., TAIWO E. A., Application and Acceptability of Microbiomes in the Production Process of Nigerian Indigenous Foods, *Progress in Nutrition and Food Science*, 28(2): 108–118, (2023)

[3]. BANWO K., SANNI A. T., OGUNREMI G. A., Functional Properties of Fermented Nigerian Foods: A Review, *Journal of Microbiology and Biotechnology Research*, 10(4): 1–9, (2020)

[4]. MARY A., JOHNSON D. O., ADEYEMI T. A., Nutritional Potential and Functional Properties of Fermented Legumes in Africa: A Review, *African Journal of Food Science*, 16(3): 67–78, (2022)

[5]. FAGUNWA O. E., ALAMU E. O., MAZIYA-DIXON B., BELLO F. A., Biotechnological Advances in the Production of Functional African Fermented Foods, *Biotechnology Advances*, 63: 108043, (2023)

[6]. OLANBIWONINU A. A., AKINWANDE B. A., OLOYEDE O. O., Microbial Profile and Nutritional Value of Selected Traditional Fermented Foods in Southwestern Nigeria, *Nigerian Journal of Microbiology*, 36(1): 115–125, (2022)

[7]. OJIMELUKWE P. C., Nutritional and Functional Properties of Indigenous Fermented Foods of Nigeria, *African Journal of Food Science and Technology*, 13(2): 45–56, (2022)

[8]. EDO G. I., JIKAH A. N., NDUDI W., SAMUEL P. O., Traditional Fermented Foods of Nigeria: Microbiological Safety and Health Benefits, *Journal of Food Science and Technology,* (2024.)

[9]. TERMOTE C. T., OUEDRAOGO M., LYKKE A. M., Nutrient Composition of *Parkia Biglobosa* Pulp, Raw and Fermented Seeds: A Systematic Review, *Critical Reviews in Food Science and Nutrition*, 62(1): 119–144, (2022)

[10]. AOAC. Official Methods of Analysis. 18th ed. Gaithersburg, MD: Association of Official Analytical Chemists, (2005)

[11]. ACHIKANU C. C., NWOSU D. O., OGU C. V., Chemical Composition of Some Local Spices Used as Seasoning Agents in Southeastern Nigeria, *International Journal of Nutrition and Food Sciences*, 2(5): 244–252, (2013)

[12]. SOGO-TEMI C. M., IDOWU O. A., LATEEF A. M., Nutritional Quality Assessment of Complementary Food from Plantain, Velvet Bean and Crayfish, *International Journal of Scientific Research and Management*, 1(10): 143–148, (2023)

[13]. PEPRAH B. B., AGYEMANG O., OSEI-AGYEMANG M., Proximate Composition, 22w1`1Cyanide Content, and Carotenoid Retention after Boiling of Provitamin A-Rich Cassava Grown in Ghana, *Foods*, 9(12): 1796, (2020)

[14]. SINAY M., HARIJATI N., Determination of Proximate Composition of Local Corn Cultivar from Kisar Island, Southwest Maluku Regency, *Journal of Biology & Biology Education*, 13(3): 258–266, (2021)

[15]. ETUK E. B., IMOLIKHE C. P., AHIWE E. U., Proximate Composition and Anti-Nutritional Constituents of Different Forms of Raw, Soaked or Cooked African Locust Bean, *International Journal of Agricultural and Rural Development*, 23(2): 5274–5281, (2020)

[16]. EDET I. V., USMAN A. U., IBRAHIM K. O., Comparative Analysis on the Proximate Composition of Processed Cassava Products Obtained from January to March, 2023 in Lafia Town, Nigeria, *Chemical Science International Journal*, 32(4): 50–63, (2023)

[17]. SABARIAH B., NORHAIZAN M. E., HUDA-FAUJAN N., Nutritive Values of Different Types of Corn-Based Animal Feed Based on Samples from 2012 to 2018, *Malaysian Journal of Veterinary Research* 10(2): 39–47, (2019)

[18]. ELEMO G. N., ELEMO B. O., OLADUNMOYE O. O., Comprehensive Investigation into the Nutritional Composition of Dehulled and Defatted African Locust Bean Seed, *International Scholar Journals*, 7(9): 1–5, (2020)

[19]. ALAMU E. O., BELLO F. A., MAZIYA-DIXON B., Correlate the Cyanogenic Potential and Dry Matter Content of Cassava Roots and Leaves Grown in Different Environments, *Scientific Reports*, 13: 11012, (2023)

[20]. BAYATA A., Proximate and Mineral Composition of Cereal-Based Complementary Foods Formulated from Maize, Millet and Sorghum, *African Journal of Food, Agriculture, Nutrition and Development*, 20(2): 15982–15996, (2020)

[21]. MPILI P., VINCENT V., RWEYEMAMU L., Evaluation of the Proximate Composition, Functional, and Pasting Properties of Ichipipi Maize Flour, *Applied Food Research*, 4: 100300, (2024)

[22]. KUMSA F., HAILE W., Minerals Composition and Their Contribution to the Recommended Daily Allowance of Barley Grain Consumed in Ethiopia, *Food Chemistry*, 119(3): 875–881, (2020)

[23]. ADEBAYO T. K., Evaluation of Flour

Blends Made from High Quality Protein Maize and Soursop Seed Flours, *Research Journal of Food Science and Nutrition*, 10(1): 9–22, (2025)
[24]. NASRALLAH K., BELLO F. A., ALAMU E. O., Nutritional, Biochemical and Health Properties of Locust Beans and Its Applications in the Food Industry: A Review, *Journal of Food Science and Technology*, 60(9): 2635–2647, (2023)
[25]. NWAKIFE N. I., EZE V. C., NWANKWO U. C., Comparative Study of Nutrient and Antinutrient Composition of Some Common Nigerian Leafy Vegetables, *International Journal of Biological and Chemical Sciences*, 15(6): 2210–2221, (2021)
[26]. ADEBAYO T. K., AKINWANDE B. A., LAWAL A. A., Wheat-Plantain Flour Blends Enriched with Velvet Bean Flours: Vitamins and Mineral Composition, *Research Journal of Food Science and Nutrition*, 9(2): 67–72, (2024)
[27]. OKONWU K., ADEBANJO R. O., OGBONNA A., Nutritional Composition of Some of the Most Consumed Cereals and Legumes in Nigeria, *European Journal of Nutrition & Food Safety*, 14(2): 53–59, (2022)
[28]. MILLENA C. G., ALIPIO M. M., LLAMES N. G., Nutritional Composition and Mineral Bioavailability of Selected Root and Tuber Crops in the Bicol Region, Philippines, *Food Research*, 8(2): 382–396, (2024)
[29]. ANIMASHAHUN R., OLADUNMOYE O. O., AJAYI O. E., Comparative Study on Proximate, Phytochemicals and Mineral Components of Different Parts of *Parkia Biglobosa*, *Journal of Xi'an Shiyou University*, 20(2): 48–52, (2024)
[30]. ABBASI K. S., MASUD T., ALI S., QAYYUM A., MAHMOOD T., Analysis of Selective Potato Varieties and Their Functional Assessment, *Food Science and Technology*, 39(2): 308–314, (2018)
[31]. SAIDU U., BELLO A., MUSA M., Proximate Analysis and Mineral Compositions of Some Cereals Commonly Sold in Kafin Hausa Market, Jigawa State, Nigeria, *Dutse Journal of Pure and Applied Sciences (DUJOPAS)*, 7(2a): 22–29, (2021)
[32]. VALI PASHA A. R., BANO K., UROOJ A., The Role of Calcium in Bone Growth, *International Journal of Current Research*, 10(4): 63766–63770, (2018)
[33]. OLUWANIYI O. O., BAZAMBO I. O., Nutritional and Amino Acid Analysis of Raw, Partially Fermented and Completely Fermented Locust Bean (*Parkia Biglobosa*) Seeds, *African Journal of Food, Agriculture, Nutrition and Development*, 16(2): 10866–10883, (2016)
[34]. SULAIMAN S. A., BELLO M. O., OKE M. O., Proximate Analysis and Mineral Compositions of Different Cereal Grain Varieties Available in Kano State, Nigeria, *International Journal of Food Science and Nutrition*, 5(2): 108–112, (2020)
[35]. ASUNNI A. O., OLORUNSOLA S. J., FADAHUNSI I. F., OGUNDARE A. O. Amino Acid Profile and Physicochemical Properties of African Locust Bean Seeds as Affected by Combined Irradiation and Cooking, *International Journal of Environment, Agriculture and Biotechnology,* 9(1): 153–164, (2024)
[36]. FAMUWAGUN T. I., TAIWO T. A., Microbiological Safety and Proximate Analysis of Fermented Legume-Based Condiments, *Cogent Food & Agriculture*, 9(1): 1–15, (2023).
[37]. FOOD AND NUTRITION BOARD. Dietary Reference Intake for Energy, Carbohydrate, Fibre, Fat, Fatty Acids, Cholesterol, Protein and Amino Acid (Micronutrients). Washington, DC: National Academies Press, (2011)
[38]. A'YUNI N. R. L., ARIEF R. A., NUGROHO T. T., Physical Characteristics, Nutrients, and Antinutrients Composition of Pigeon Pea Grown in Indonesia, *Food Research*, 6(2): 53–63, (2022)
[39]. ZUWARIAH I., NORAZLINA A., HASHIM H., Screening of Vitamin, Mineral and Antioxidants in Selected Vegetables, Fruit and Grains for the Elderly, *Food Research*, 5(1): 122–131, (2021)
[40]. ABEBE B. K., ALEMAYEHU M. T., A Review of the Nutritional Use of Cowpea for Human and Animal Diets, *Journal of Agriculture and Food Research*, 9: 100306, (2022)
[41]. ENOCH N. O., AYOOLA M. O., EKPO E. J., Assessment of Antioxidant Micronutrient Levels in Traditional Nigerian Condiments, *Scientific Asia*, 2(1): 1–15, (2025)
[42]. GUNEY M., TUNCER A., OZTURK H., The Effect of Cowpea on Human Health, *In Balkan Agriculture Congress*, 325–332, (2021)
[43]. NCCFN (NATIONAL COMMITTEE ON FOOD AND NUTRITION). Dietary Reference Intake Guidelines. Abuja: Federal Ministry of Health, (2017)
[44]. OKONKWO C. J., AGBARANDU A., Proximate and Vitamin Composition of Selected Cereals Commonly Used for Weaning Babies' Food Preparation, *Journal of Biology, Agriculture and Healthcare*, 7(22): 71–75, (2017)
[45]. CHOVATIYA N. C., JANI H. R., SHAH M. P., Roots and Tuber Crops: Nutritional Value and Functional Food Potential – A Comprehensive Review, *Journal of Biochemistry*, 13(2): 1–13, (2025)
[46]. GARG M., SHARMA N., SHARMA S., KAPOOR P., KUMAR A., CHUNDURI V., Biofortified crops generated by breeding, agronomy, and transgenic approaches are improving nutrition security and Reducing Hidden Hunger, *Frontiers*

in Nutrition, 7: 609279, (2021)
[47]. PEECHAKAKARA B. V., GUPTA M. Vitamin B3, In StatPearls, (2024)
[48]. GARUTTI M., ROSSI M., ROSSI F., The Impact of Cereal Grain Composition on the Health and Disease Outcomes, *Frontiers in Nutrition*, 9: 888974, (2022)
[49]. GODSWILL A. C., AMAGWULA V. S., KATE E. C., Health Benefits of Micronutrients (Vitamins and Minerals) and Their Associated Deficiency Diseases: A Systematic Review, *International Journal of Food Sciences*, 3(1): 1–32, (2020)
[50]. OFFICE OF DIETARY SUPPLEMENTS, Vitamin B12: Fact Sheet for Health Professionals, *National Institutes of Health*, (2019)
[51]. CHOWAŃSKI S., ADAMSKI Z., LUBAWY J., Plant-Based Antioxidants in Human Health, *Trends in Food Science & Technology*, 50: 19–33, (2016)
[52]. BANGER S. P., SHARMA R., SINGH A. K., Bioactive Potential of Beetroot, *Food Research International*, 158: 111, (2022)
[53]. JOCELYNE R. E., ADEWALE T. M., GANDONU M. B., Comparative Study of Nutritional Value of Wheat, Maize, Sorghum, Millet, and Fonio, *European Scientific Journal*, 16(21): 118–131, (2020)
[54]. COULIBALY A., TEME B., DIARRA A., Determination of Proximate Compositions and Functional Properties of Selected Cereal Grains from Mali, *American Journal of Food Science and Technology*, 10(5): 207–213, (2022)
[55]. HASMADI M., ZAMRI A. A., RASHID N. A., Physicochemical and Functional Properties of Cassava Flour Grown in Different Locations in Sabah, Malaysia, *Food Research*, 4(4): 991–999, (2020)
[56]. OLAGUNJU A. I., ADEBAYO S. E., OGUNSAKIN O. A., Effect of Fertilizer Treatment on the Titratable Acidity of Cassava Roots, *Journal of Root and Tuber Research*, 9(1): 45–51, (2022)
[57]. MOCKUS E., KAVALIAUSKAS A., ZUKAUSKAITE J., The Potential of Traditional ‘Gaja’ and New Breed Lines of Waxy, Blue and Purple Wheat in Wholemeal Flour Fermentation, *Fermentation*, 8(11): 563, (2022)
[58]. IBRAHIM M. A., ALFAUOMY N. A., Evaluation of Some Sweet Corn Hybrids for Agronomic Traits and Technological Parameters under Different Planting Dates, *Journal of Food Sciences*, 6(1): 49–63, (2019)
[59]. CHIBUZOR I. M., (2022). Influence of Tuber Sections and Chemical Additives on Physicochemical Properties of Pregelatinized Cassava Flour, *Journal of Food Processing and Technology*, 13: 956,
[60]. DE OLIVEIRA L. A., LIMA R. A., PIRES L. V., Effect of the Storage Period on Physicochemical Characteristics and Sensory Acceptance of Frozen Sweet Cassava, *Brazilian Journal of Food Technology*, 24: e2020215, (2021)
[61]. WULANDARI N. P. A. N., ARININGSIH I., SARI N. M., (2022). Effect of Differences in Fruit Maturity Levels of Three Balinese Banana Cultivars on the Quality of Fruit Flesh Flour, *GSC Biological and Pharmaceutical Sciences*, 22(1): 105–113,
[62]. GIANG N. T. N., TRANG H. T., MAI T. T., Effect of Initial Total Soluble Solids and pH on the Quality of Fermented Beverage from Green Asparagus Roots, *Food Research*, 8(3)