

Assessment of Proximate and Mineral Composition of Fermented Castor Bean, Melon, and African Locust Bean Seeds for Local Condiment Production

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Abstract

Fermented castor bean, melon, and African locust bean seeds serve as a protein source in the diet of many Nigerians. Proximate and mineral composition changes during fermentation remain underexplored, particularly in comparative contexts. This study aimed to evaluate and compare these seeds' proximate and mineral compositions during controlled fermentation. Raw seeds were sourced from local markets and subjected to traditional fermentation processes for seven days in the laboratory. Proximate analysis was conducted using standard methods, while mineral contents were quantified using flame photometry after ashing. Analysis of Variance was used to determine a significant difference. Comparatively, at the end of the fermentation, the highest protein ($39.96 \pm 0.76\%$), fibre ($8.03 \pm 0.26\%$), ash ($4.20 \pm 0.00\%$), carbohydrate ($13.10 \pm 1.25\%$) and moisture ($16.55 \pm 0.79\%$) were recorded in fermented African locust bean seeds. The highest fat content was recorded in castor bean seeds ($45.80 \pm 0.62\%$). Comparative mineral composition at the end of fermentation showed that the highest zinc (3.31 ± 0.29 mg/ 100 g), magnesium (282.56 ± 2.03 mg/ 100 g), and calcium (220.00 ± 1.20 mg/ 100 g) were recorded in fermented African locust bean seeds. The highest potassium ($1307.85 \pm 5.87\%$) and sodium (55.93 ± 0.96 mg/ 100 g) contents were recorded in melon and castor bean seeds, respectively. This study suggests that fermentation enhances traditional condiments' nutritional and mineral value in West African cuisine. These findings support process optimisation, especially for African locust bean seed to inform dietary recommendations.

Keywords:

Analysis, Condiment, Fermentation, Mineral, Proximate

Introduction

For generations, Nigerian ethnic groups have enjoyed their culinary heritage by using local condiments made from various protein seeds (Ndukwe & Solomon, 2017). Despite their socioeconomic importance, the biochemical mechanisms driving nutrient modulation during fermentation to food condiments remain inadequately characterised for key indigenous seeds, including *Ricinus communis* (castor bean), *Citrullus lanatus* (melon), and *Parkia biglobosa* (African locust bean). According to Eze et al. (2014), food condiments are prepared using traditional, uncontrolled solid substrate fermentation methods. This results in the extensive breakdown of protein seeds' anti-nutritional and nutritional components. Knez et al. (2023) reported that fermentation has resulted in a significant increase in free fatty acids, minerals, vitamins, carbohydrates, and protein, which is linked to an enhancement in the dietary and nutritional characteristics.

Studies on the changes that occur in the nutritional components of foods linked to traditional protein condiments show that microorganisms can boost the nutritional value by enhancing their taste and texture and introducing metabolic substances, minerals, and vitamins that are necessary for a healthy lifestyle (Achi, 2015; Rusu et al., 2023).

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It has also been suggested that fermentation by these species increases antioxidant qualities and improves seed digestibility while enhancing metabolism and decreasing the amounts and concentrations of anti-nutritive substances (Olagunju et al., 2018). Existing research on castor bean fermentation reveals progressive increases in crude protein, carbohydrates, and zinc content over four days, coupled with a 44% rise in bioavailable lysine critical for protein quality (Ishiwu et al., 2015). Melon seeds exhibit inherent nutritional richness pre-fermentation, while African locust beans demonstrate remarkable iron enrichment (Aborisade et al., 2021).

Lack of comparative studies across these nutritious seeds limits understanding of how fermentation duration and environmental conditions differentially impact nutrient profiles. Furthermore, mineral bioavailability studies remain scarce despite evidence that fermentation reduces phytates in legumes, potentially enhancing iron and zinc absorption (Aborisade et al., 2021). This investigation intends to address these gaps by analysing proximate and mineral composition changes across the three seeds during standardised laboratory fermentation, providing critical insights for process optimisation and improved nutritional security.

Materials and Methods

Collection of samples

Unprocessed castor bean seeds (*R. communis*) were purchased at Ubulu-uku primary market in Delta state, Nigeria, while African locust beans (*P. biglobosa*) and melon seeds (*C. colocynthis* L.) were purchased from Auchi in Edo state, Nigeria.

Preparation of condiments

Fermentation of melon seeds

Melon seeds were dehulled, prepared by cooking for three hours and drained. After draining and mashing the cotyledon, it was securely wrapped in blanched banana leaves and cooked again for two (2) hours and placed in sterile containers to ferment for seven (7) days at ambient temperature (Omodara & Olowomofe, 2015).

Fermentation of castor bean seeds

Raw castor bean seeds were first dehulled, sorted, and washed to remove debris. This was then cooked for six (6) hours, drained, and fresh water. This was then cooked for another two (2) hours, drained, cooled, mashed, and wrapped in blanched banana leaves and

placed in sterile containers to ferment for seven (7) days at ambient temperature (Liman et al., 2010).

Fermentation of African locust bean seeds

The seeds were sorted, washed to remove debris, and soaked in water for 15 minutes to eliminate the adhering pulp. They were cooked for six (6) hours to loosen the testa, washed to separate it from the endosperm, and cooked for 30 minutes. The beans were drained, wrapped in blanched banana leaves, and placed in sterile containers to ferment at ambient temperature for seven (7) days (Liman et al., 2010).

Evaluation of proximate composition

Standard methods of the Association of Official Analytical Chemists (AOAC, 2000) were used to determine the moisture, crude protein, crude fat, ash and fibre contents of the raw, freshly cooked, and fermented samples. This was carried out in triplicate for raw, freshly cooked (FC), day 1, day 3, day 5, and day 7.

Determination of mineral composition

Ten (10) grams of each sample was ashed for 18 hours at 550 °C in a furnace, and the ash was dissolved in 10 mL of 0.1M HCl, filtered into a 100 mL volumetric flask, and brought up to mark with distilled H₂O. Using standard procedure, the flame photometer was then used to determine the concentrations of sodium, potassium, calcium, magnesium, and zinc (Omodara & Olowomofe, 2015). This was also carried out in triplicate for raw, freshly cooked (FC), day 1, day 3, day 5, and day 7.

Statistical analysis

The mean ± standard error of triplicates was used to express the data. The difference in means was tested using one-way analysis of variance (ANOVA) using SPSS (v20 incorporation, Chicago, Illinois, USA).

Results and Discussion

Proximate compositions of the fermented seeds

The percentage proximate composition of melon, castor, and African locust bean seeds following a 7-day fermentation period is presented in Tables 1, 2, and 3, respectively. Fermentation significantly increased ($p < 0.05$) the protein content across all three seed types, with the protein content of the fermented samples ranging from 21.03% to 39.96%, and fermented African locust bean seeds having the highest protein percentage. The protein content of melon seeds increased from $21.44 \pm 1.21\%$ in the raw (R) sample to

28.10 ± 1.03% on day 7 ($p < 0.05$). Similarly, castor bean seeds significantly increased protein content from 16.98 ± 1.07% in the raw (R) sample to 21.03 ± 1.15% on day 7. African locust bean seeds showed the highest increase, with protein content increasing significantly from 31.53 ± 0.76% (R) to 39.96 ± 0.76% on day 7 ($p < 0.05$). These findings align with studies reporting increased crude protein content in fermented legume seeds (Omodara & Olowomofe, 2015; Iheke et al., 2017). Furthermore, Oboh (2006) earlier reported similar protein content in locust beans (35.2 ± 3.4%), soybeans (44.6 ± 2.5%), melon (23.6 ± 3.0%), and pigeon pea (17.8 ± 2.7%). Increased protein content during fermentation is primarily attributed to the metabolic activities of fermenting microorganisms, which utilise microbial biomass rich in protein and break down complex proteins into more readily available peptides and amino acids (Achi, 2015). The high percentage of protein content recorded in these fermented condiments potentially makes them an affordable source of dietary protein, especially in regions where animal proteins may be economically inaccessible. Also, the protein content of these fermented seeds (ranging from 21.03% to 39.96%) comfortably satisfies the Recommended Daily Allowance (RDA) for protein, which typically falls within 15 – 25% for healthy adults (Zeece, 2010), and even for those on specialised diets (Richter et al., 2019). The enhanced protein bioavailability and quantity contribute to the body's energy production, tissue repair, and the solubilisation of essential nutrients such as vitamins, omega-3, and omega-6 fatty acids, and linoleic acids, which are crucial for physiological functions (Achi, 2015).

Fermentation similarly resulted in a significant increase in fat content for melon and castor bean seeds, and a slight increase for locust bean seeds. An increase from 38.91 ± 0.79% (R) to 41.24 ± 0.68% on day 7 ($p < 0.05$) was recorded in fermented melon seeds. African locust bean seeds also increased, from 16.86 ± 1.30% (R) to 18.16 ± 0.93% on day 7. A significant increase from 41.86 ± 0.73% (R) to 45.80 ± 0.62% on day 7 ($p < 0.05$) was recorded in fermented castor bean seeds, implying that it had the highest fat content after fermentation compared to melon and African locust bean seeds. The recorded increase in crude fat content during fermentation is consistent with the report of Achi (2015) on fermented protein seeds and is usually attributed to the hydrolysis of complex lipids by lipolytic enzymes secreted by the fermenting microbial species, such as *Bacillus subtilis*, as well as species of *Pseudomonas*, *Proteus*, *Serratia*, and *Micrococcus*

(Isiekwene et al., 2023). This enzymatic breakdown can lead to the release of free fatty acids or changes in lipid composition that are quantifiable as increased crude fat. The fat content contributes to the caloric value of the condiments and aids in absorbing fat-soluble vitamins and essential fatty acids.

A significant reduction in carbohydrate content was observed across all fermented seed samples. For melon seeds, carbohydrate content decreased significantly from 21.15 ± 1.51% (R) to 8.45 ± 0.25% on day 7 ($p < 0.05$). Castor bean seeds experienced a decrease from 23.04 ± 1.02% (R) to 10.02 ± 0.03% on day 7 ($p < 0.05$), while in locust bean seeds, carbohydrate content declined from 29.47 ± 1.30% (R) to 13.10 ± 1.25% on day 7 ($p < 0.05$). However, initial African locust bean seeds had the highest carbohydrate levels. The decrease in carbohydrate content is a typical outcome of microbial fermentation, as fermenting microorganisms utilise carbohydrates as their primary energy source for growth and metabolic activities (Achi, 2015). The reduced carbohydrate content (ranging from 8.45 to 13.10%) in the fermented condiments is considered adequate for their customary use in soups, contributing beneficially to their caloric profile without excessive carbohydrate load (Omogbai & Ojeaburu, 2010). Moisture content generally increased in all seed samples after cooking. This was then followed by a progressive decline during fermentation till the end of the study. The increase in moisture content before fermentation is typical, as the process often involves soaking or boiling the seeds, allowing for water absorption. More so, a decrease in moisture content during fermentation is supported by the work of Maji & Adegoke (2019), who reported that fermentation processes generate heat through metabolic activity, which increases the rate of water evaporation from the seed surface. All fermented seed samples observed a significant reduction in crude fibre content. Melon seeds showed a significant decrease from 6.90 ± 0.63% (R) to 5.15 ± 0.08% on day 7 ($p < 0.05$). Castor bean seeds experienced a significant reduction from 6.71 ± 0.24% (R) to 5.03 ± 0.13% on day 7 ($p < 0.05$). African locust bean seeds also exhibited a significant reduction in fibre content from 10.94 ± 0.68% (R) to 8.03 ± 0.26% on day 7 ($p < 0.05$). The decrease in crude fibre content during fermentation is primarily due to microbial enzymes' enzymatic breakdown of complex carbohydrates like cellulose and hemicellulose (Achi, 2015). This reduction indicates that fermentation improves the digestibility and nutrient availability of the seeds by degrading anti-nutritional factors and complex

indigestible components. The reduced fibre content (ranging from 5.03 to 8.03%) is considered appropriate for condiments commonly used in soups, contributing to their beneficial caloric contribution and mouth feel (Omogbai & Ojeaburu, 2010).

Ash content decreased in castor and African locust bean seeds following fermentation. For castor bean seeds, ash content decreased from $4.80 \pm 0.00\%$ (R) to $2.80 \pm 0.23\%$ on day 7. African locust bean seeds also showed a decline in ash content from $5.80 \pm 0.00\%$ (R) to $4.20 \pm 0.00\%$ on day 7. Ash content data for melon seeds were not recorded in this study. The observed

decrease in ash content aligns with findings from other studies on fermented food products (Iheke et al., 2017). This reduction can be attributed to the leaching of some inorganic salts from the raw seeds into the processing water during the initial boiling or soaking stages of fermentation, or due to microbial utilisation of certain minerals during their metabolic processes (Iheke et al., 2017). The resulting ash content (2.80 to 4.20%) remained within an adequate range for condiments used in soups, ensuring a beneficial caloric contribution (Omogbai & Ojeaburu, 2010).

Table 1: Proximate composition (%) of fermented melon seed

Days	Moisture	Carbohydrate	Ash	Fibre	Fat	Protein
R	6.73±0.21 ^a	21.15±1.51 ^c	4.20±0.01 ^c	6.90±0.63 ^b	38.91±0.79 ^b	21.44±1.21 ^b
FC	30.37±1.47 ^d	13.08±1.05 ^b	3.80±0.12 ^b	6.72±0.12 ^b	26.25±1.12 ^a	19.61±0.98 ^a
1	27.65±1.41 ^d	10.15±0.11 ^a	3.40±0.00 ^a	6.51±0.26 ^b	28.71±1.96 ^b	24.42±0.73 ^c
3	19.42±1.20 ^c	9.02±0.27 ^a	3.40±0.00 ^a	5.39±0.22 ^a	36.04±1.21 ^b	26.73±1.22 ^c
5	15.09±0.35 ^b	8.55±0.21 ^a	3.20±0.12 ^a	5.22±0.07 ^a	40.78±1.27 ^c	27.15±0.90 ^c
7	13.86±0.71 ^b	8.45±0.25 ^a	3.20±0.00 ^a	5.15±0.08 ^a	41.24±0.68 ^c	28.10±1.03 ^d

Values are mean ± SEM (n = 3); R represents Raw Sample; FC represents freshly cooked sample; Superscripts a, b, c and d show significant difference along the column.

Table 2: Proximate composition (%) of fermented castor bean seed

Days	Moisture	Carbohydrate	Ash	Fibre	Fat	Protein
R	6.62±0.36 ^a	23.04±1.02 ^d	4.80±0.00 ^e	6.71±0.24 ^b	41.86±0.73 ^d	16.98±1.07 ^a
FC	38.49±0.98 ^e	14.12±0.45 ^c	4.47±0.18 ^d	5.64±0.28 ^a	22.40±1.53 ^a	14.86±0.68 ^a
1	31.00±0.74 ^e	13.15±1.23 ^c	4.20±0.00 ^d	5.35±0.41 ^a	30.39±2.29 ^b	15.91±0.22 ^a
3	24.77±0.81 ^d	12.21±0.02 ^b	3.80±0.00 ^c	5.13±0.25 ^a	36.51±0.52 ^c	18.05±0.77 ^b
5	20.40±1.57 ^c	10.05±0.00 ^a	3.20±0.00 ^b	5.05±0.02 ^a	41.84±0.74 ^d	19.46±0.78 ^c
7	15.32±0.60 ^b	10.02±0.03 ^a	2.80±0.23 ^a	5.03±0.13 ^a	45.80±0.62 ^d	21.03±1.15 ^d

Values are mean ± SEM (n = 3); R represents Raw Sample; FC represents freshly cooked sample; Superscripts a, b, c and d show significant difference along the column.

Table 3: Proximate composition (%) of fermented African locust bean

Days	Moisture	Carbohydrate	Ash	Fibre	Fat	Protein
R	5.40±0.52 ^a	29.47±1.30 ^c	5.80±0.00 ^d	10.94±0.68 ^d	16.86±1.30 ^b	31.53±0.76 ^c
FC	34.20±2.11 ^e	18.74±1.27 ^b	6.00±0.12 ^d	10.21±0.00 ^c	10.45±0.48 ^a	20.45±1.13 ^a
1	29.88±1.13 ^d	16.32±0.83 ^a	5.80±0.00 ^d	10.05±0.00 ^c	13.98±0.92 ^b	26.21±2.78 ^b
3	24.15±0.51 ^c	14.83±0.31 ^a	5.20±0.00 ^c	9.65±0.09 ^b	16.18±1.10 ^b	29.99±0.86 ^b
5	20.79±1.36 ^b	14.11±0.26 ^a	4.60±0.00 ^a	8.71±0.33 ^a	17.67±1.06 ^c	34.23±1.01 ^c
7	16.55±0.79 ^b	13.10±1.25 ^a	4.20±0.00 ^a	8.03±0.26 ^a	18.16±0.93 ^c	39.96±0.76 ^d

Values are mean ± SEM (n = 3); R represents Raw Sample; FC represents freshly cooked sample; Superscripts a, b, c and d show significant difference along the column.

Mineral compositions of the fermented seeds

Fermentation significantly impacts the mineral composition of seeds (Nkhata et al., 2018). As shown in Table 4, the highest potassium content in melon seeds (1316.73 ± 2.67 mg/ 100 g) was recorded in the raw sample, which declined significantly to 1243.86 ± 3.72 mg/ 100 g (FC). A progressive increase was observed during fermentation, reaching 1307.85 ± 5.87 mg/ 100 g by Day 7, though it remained significantly lower than the raw sample. Also, the raw sample recorded the highest potassium content in castor bean seeds (1218.50 ± 3.53 mg/ 100 g), which declined significantly to 1150.22 ± 4.18 mg/ 100 g (FC). A significant increase in potassium content in castor bean seeds was also recorded during fermentation, reaching 1195.69 ± 2.16 mg/ 100 g by Day 7. Similarly, as shown in Table 6, the highest potassium content in African locust bean seeds (1213.84 ± 2.45 mg/ 100 g) was recorded in the raw sample, which declined significantly to 1106.23 ± 2.08 mg/ 100 g (FC). Subsequent analysis showed a progressive increase over the fermentation period, reaching 1181.34 ± 2.33 mg/ 100 g by Day 7. Okpo et al. (2022) reported low potassium content in fermented pumpkin seed (2.44 and 0.49 mg/100 g) and African locust bean condiments (9.36 and 35.3 mg/100 g). Oboh & Ekperigin (2004) also found a similar trend in some Nigerian wild seeds, attributing the reduction to mineral solubilisation and loss in processing water. As observed in this study, fermented African locust bean seeds had the highest initial mineral concentrations but experienced the most significant losses, which could be attributed to substrate-dependent fermentation dynamics. This inverse relationship between initial mineral content and retention rates supports substrate competition theories in fermentation science (Gernah et al., 2007).

As shown in Table 4, the highest zinc content in melon seeds (1.96 ± 0.00 mg/ 100 g) was recorded in the raw sample, which declined significantly to 1.46 ± 0.01 mg/ 100 g (FC). Gradual increase over the fermentation period was then recorded till 1.87 ± 0.06 mg/ 100 g at Day 7. Similarly, in Table 5, the highest zinc content (1.77 ± 0.26 mg/ 100 g) was recorded in the raw castor bean seed sample, then declined to 1.53 ± 0.04 mg/ 100 g (FC), and then showed a gradual increase during fermentation till the end of the study (1.95 ± 0.04 mg/ 100 g). In Table 6, the highest zinc content in African locust bean seed (3.69 ± 0.12 mg/ 100 g) was recorded in the raw sample, which also declined significantly to 2.35 ± 0.08 mg/ 100 g (FC), then increased to 3.31 ± 0.29 mg/ 100 g at the end of

fermentation. The breakdown of anti-nutritional factors, which might improve minerals such as zinc, could cause the increase shown in this study. Oluwole et al. (2019) reported that both direct and indirect effects of human activity and natural soil profiles may also be responsible for these variations in mineral composition. Similarly, as earlier noted in this study, an increase in zinc content may have resulted from enzymatic liberation from bound complexes or concentration effects due to dry matter reduction during fermentation (Olagunju et al., 2018). Additionally, Falade & Akinrinde (2021) reported similar findings in their study on fermented soybean cultivars and dehulled *P. biglobosa* seeds using selected *Bacillus* spp.

As shown in Table 4, the highest magnesium content in melon seeds (105.68 ± 3.06 mg/100 g) was recorded in the raw sample, which declined significantly to 96.30 ± 3.56 mg/100 g (FC), then remained stable through Day 7. Similarly, in Table 5, the highest magnesium content (123.25 ± 1.99 mg/100 g) was recorded in the raw castor bean seed sample, which declined significantly to 110.16 ± 1.77 mg/100 g (FC), followed by a progressive increase during fermentation, reaching 120.70 ± 2.68 mg/100 g by Day 7, not significantly different from the raw sample. In Table 6, the highest magnesium content in African locust bean seed (283.65 ± 1.77 mg/100 g) was recorded in the raw sample, which declined significantly to approximately 270 mg/100 g. FC remained stable through Day 5, then increased significantly to 282.56 ± 2.03 mg/100 g by Day 7. The composition of magnesium ranged from 96.48 ± 1.87 mg/100 g in fermented melon seed to 282.56 ± 2.03 mg/100 g in fermented African locust bean seed. According to Rizwan et al. (2023), consuming these condiments can lead to the release of proteins, contraction of muscles, transmission of nerve impulses, fluid balance, development of the immune system, sexual development, synthesis of RNA and DNA, regulation of blood pressure, and levels following the delivery of sodium into the body system. As shown in Table 4, the highest calcium content (131.85 ± 2.16 mg/ 100 g) was recorded in the raw sample, and there were no significant changes throughout the fermentation period. As shown in Table 5, calcium content was highest in the raw sample (85.88 ± 0.76 mg/ 100 g) and showed a decreasing trend to 79.11 ± 3.10 mg/ 100 g (FC), but this decline was not statistically significant ($p > 0.05$). Calcium content slightly increased over the fermentation days, reaching 83.88 ± 2.77 mg/ 100 g by Day 7, with no

significant difference ($p < 0.05$) recorded. As shown in Table 6, the highest calcium content (220.84 ± 1.12 mg/ 100 g) was recorded in the raw sample, which declined significantly to 215.10 ± 1.31 mg/ 100 g (FC). Subsequent analysis showed a gradual increase over the fermentation period, reaching 220.00 ± 1.20 mg/ 100 g by Day 7, with Day 7 values not significantly different from raw.

As shown in Table 4, the highest sodium content (41.04 ± 1.24 mg/ 100 g) was recorded in the raw sample, which declined significantly to 32.53 ± 0.82 mg/ 100 g (FC). Sodium levels gradually increased through fermentation, reaching 39.86 ± 2.05 mg/ 100 g by Day 7, remaining significantly lower than the raw sample. As shown in Table 5, the highest sodium content (57.52 ± 3.01 mg/ 100 g) was recorded in the raw sample, which declined to 51.36 ± 1.76 mg/ 100 g (FC), but this change was not statistically significant ($p < 0.05$). Sodium levels remained relatively stable (FC) to Day 7, with no significant differences detected ($p < 0.05$). As shown in Table 6, the highest sodium content

(38.23 ± 1.15 mg/ 100 g) was recorded in the raw sample, which declined significantly to 35.11 ± 0.79 mg/ 100 g (FC). Subsequent analysis showed relatively stable levels between FC and 7, with no significant differences among these days. Values obtained in this study were similar to those reported by Omafuvbe et al. (2004) from fermented African locust beans, which had sodium content ranging between 30 and 45 mg/100 g. Although lower sodium values were reported in the study carried out by Termote et al. (2022), higher values similar to that obtained in this present study were recorded in African locust bean seed dehulled by cracking and dried at 60°C for 6 hours before milling, and seed boiled at 100°C for 8 hours, dehulled, and dried at 60°C for 10 hours before milling. This was attributed to the preparation method used to process the seeds. The metabolic activities of fermenting bacteria, which break down complex macromolecules, lower anti-nutritional factors, improve amino acid profiles, and increase nutrient absorption and digestibility, are primarily responsible for these alterations.

Table 4: Mineral composition of fermented melon seed (mg/ 100 g)

Days	Zinc	Magnesium	Calcium	Potassium	Sodium
R	1.96 ± 0.00^d	105.68 ± 3.06^b	131.85 ± 2.16^a	1316.73 ± 2.67^c	41.04 ± 1.24^c
FC	1.46 ± 0.01^a	96.30 ± 3.56^a	127.32 ± 1.09^a	1243.86 ± 3.72^a	32.53 ± 0.82^a
1	1.57 ± 0.05^{ab}	96.48 ± 1.87^a	127.89 ± 1.76^a	1255.61 ± 2.23^a	32.81 ± 1.48^a
3	1.60 ± 0.00^{bc}	96.85 ± 1.18^a	128.42 ± 0.64^a	1287.10 ± 3.48^b	35.08 ± 1.06^{ab}
5	1.73 ± 0.06^c	97.13 ± 0.69^a	129.60 ± 0.51^a	1292.41 ± 5.28^{bc}	38.59 ± 1.09^{bc}
7	1.87 ± 0.06^d	97.23 ± 1.37^a	129.78 ± 2.38^a	1307.85 ± 5.87^{cd}	39.86 ± 2.05^c

Values are mean \pm SEM ($n = 3$); R represents Raw Sample; FC represents freshly cooked sample; Superscripts a, b, c and d show significant difference along the column.

Table 5: Mineral composition of fermented Castor bean seed (mg/ 100 g)

Days	Zinc	Magnesium	Calcium	Potassium	Sodium
R	1.77 ± 0.26^{ab}	123.25 ± 1.99^d	85.88 ± 0.76^a	1218.50 ± 3.53^d	57.52 ± 3.01^a
FC	1.53 ± 0.04^a	110.16 ± 1.77^a	79.11 ± 3.10^a	1150.22 ± 4.18^a	51.36 ± 1.76^a
1	1.56 ± 0.05^a	113.21 ± 1.56^{ab}	81.61 ± 1.20^a	1157.00 ± 1.03^b	52.19 ± 1.92^a
3	1.63 ± 0.03^{ab}	114.85 ± 1.32^{abc}	83.13 ± 1.78^a	1175.55 ± 8.97^b	54.11 ± 1.51^a
5	1.73 ± 0.02^{ab}	118.90 ± 1.62^{bcd}	83.85 ± 1.50^a	1180.68 ± 3.80^c	55.83 ± 1.49^a
7	1.95 ± 0.04^b	120.70 ± 2.68^{cd}	83.88 ± 2.77^a	1195.69 ± 2.16^c	55.93 ± 0.96^a

Values are mean \pm SEM ($n = 3$); R represents Raw Sample; FC represents freshly cooked sample; Superscripts a, b, c and d show significant difference along the column.

Table 6: Mineral composition of fermented African locust bean (mg/ 100 g)

Days	Zinc	Magnesium	Calcium	Potassium	Sodium
R	3.69±0.12 ^c	283.65±1.77 ^b	220.84±1.12 ^c	1213.84±2.45 ^e	38.23±1.15 ^a
FC	2.35±0.08 ^a	270.11±1.94 ^a	215.10±1.31 ^a	1106.23±2.08 ^a	35.11±0.79 ^a
1	2.88±0.12 ^b	271.60±4.84 ^a	215.55±1.19 ^{ab}	1119.14±4.84 ^b	35.91±1.43 ^a
3	2.91±0.01 ^b	273.42±0.16 ^a	218.61±1.43 ^{abc}	1125.26±1.84 ^b	36.34±1.06 ^a
5	3.12±0.02 ^b	275.29±1.03 ^a	219.03±0.09 ^{bc}	1158.75±6.33 ^c	36.56±1.93 ^a
7	3.31±0.29 ^{bc}	282.56±2.03 ^b	220.00±1.20 ^c	1181.34±2.33 ^d	36.62±1.11 ^a

Values are mean ± SEM (n = 3); R represents Raw Sample; FC represents freshly cooked sample; Superscripts a, b, c and d show significant difference along the column.

Conclusion

This study demonstrated that traditional fermentation processes significantly enhanced the nutritional and mineral quality of the local condiments produced from *C. lanatus*, *R. communis*, and *P. biglobosa* seeds. The increased fat and protein content increase and the decline in ash, fibre, and carbohydrate concentrations highlight biochemical changes during fermentation. Furthermore, the higher protein content of fermented African locust bean seeds and the elevated fat content in castor bean seeds indicate the potential of these condiments to address protein-energy malnutrition and enhance dietary abundance in West African food culture. Findings of this study thus support the promotion of these traditional condiments as affordable, nutrient-dense food sources. Future studies should examine the bioavailability of micronutrients after fermentation and refining fermentation conditions to further reduce mineral loss and maximise nutrient retention.

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