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Research Article

Effect of Fermentation on the Physicochemical Properties and Nutritionally Valuable Minerals of Locust Bean (*Parkia biglobosa*)

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Abstract

Objective: The effects of fermentation on the physicochemical properties and nutritionally valuable minerals of locust bean was investigated. The proximate composition, mineral composition, anti-nutrient factors and physicochemical properties of both unfermented and fermented samples were determined. **Methodology:** The proximate analysis, anti-nutrient factors analysis, mineral analysis as well as physicochemical properties were conducted on the unfermented and fermented locust beans. The statistical analysis were carried out with SPSS. **Results:** The result revealed that the proximate compositions (moisture, crude fat, crude protein) of the fermented seeds are higher than the unfermented seeds. However, the unfermented seeds had higher ash, crude fibre and carbohydrate as compared to the fermented seeds. The mineral content of the analyzed samples showed that the fermented seeds were richer in Ca (2750 mg/100 g), Zn (5.5 mg/100 g), Mn (4.8 mg/100 g), Cu (0.7 mg/100 g), Fe (7.8 mg/100 g) and Na (3.6 mg/100 g), while the unfermented seeds recorded higher values for Mg (280 mg/100 g), K (306 mg/100 g) and P (1.1 mg/100 g) than the fermented seeds. For the anti-nutrient factors, the fermented seeds recorded higher tannins (4.72 ± 0.31) and phytates (37.90 ± 4.66) compared to unfermented seeds with low anti-nutrient factors. There was increase in pH from 5.67-6.41 of the fermented seeds with a consequent decrease in their titratable acidity from 17.20-4. 75. **Conclusion:** The results showed that the fermented samples are better in terms of nutritional content than the unfermented seeds.

Key words: Locust bean, anti-nutrients, protein malnutrition, food flavourings, nutritionally valuable minerals

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The role of food for daily sustenance of man cannot be over-emphasized thus food is key to life. The intake of proper nutrients is essential for man's wellbeing or else, there will be body parts dysfunction. Commonly eaten plant parts are the seeds which are either cooked or eaten raw.

Seeds possess nutritive and calorific values which make them important in diets[1]. Among these plant seeds are the seeds of *Parkia biglobosa* popularly known as "African locust bean". *Parkia biglobosa* is a perennial deciduous tree legume and dicotyledonous angiosperm of the *Fabaceae* (*leguminosae*) family belonging to the sub-family *Mimosodeae*. The tree's pods, commonly referred to as locust beans, are pink in the beginning and turn dark brown when fully mature.

In many African countries including Nigeria, protein malnutrition has been a major problem. It has been reported that the diet of most Nigerians is lacking in substantial protein as a result of the high costs of most of the available protein sources such as meat. Therefore food and nutrition security remains Africa's most fundamental challenge for human welfare and economic growth [2]. Importation of food flavorings emphasizes the significance of fermented seed proteins which have great potential as key sources of protein and as basic ingredients for food supplementation in the diet.

In Nigeria indigenous foodstuffs supplies different proportion of nutrients such as protein, carbohydrates, fats, water, minerals and vitamins. Wild seeds and fruits are commonly consumed by both rural and urban dwellers, especially among low income earners. Some of these wild seeds have higher nutritional values compared with levels found in some cultivated foods. However, some of these wild seeds and fruits contain anti-nutritional factors that can affect the availability of nutrients required by body.

The action of enzymes which are produced by microorganisms such as moulds, yeasts and bacteria resulting in the chemical transformation of organic substrate into simpler compounds is referred to as fermentation[3]. Fermented foods as those foods which have been subjected to the action of microorganisms or enzymes so that desirable biochemical changes cause significant modification to the food. Some physical characteristics of legumes are modified by fermentation to increase the level of some nutrients and bioavailability. Fermentation reduces toxicity, improve palatability and impact desirable flavor in foods.

The objective of this research was to compare the compositional, physicochemical and mineral analyses of both fermented and unfermented locust bean in order to elucidate the nutritional content.

MATERIALS AND METHODS

Sources of materials: The locust bean seeds were used procured in the raw and dried form from the Kings Market, Otun-Ekiti, Ekiti state, Nigeria.

Sample preparation: Raw locust bean seeds were cracked, dried for 7 days and ground with Qlink food blender (Model No. QBL-18L40). The flour was kept in an air-tight container prior to analysis.

In the processing of the fermented seeds, raw locust beans were boiled for 5 h, allowed to cool for an hour and the seeds were dehulled by pressing and rubbing between palms. After dehulling, the locust bean seeds were sorted, washed and then cooked for an hour, fermented for 4 days, sun dried for 4 days and ground with Qlink food blender (Model No. QBL-18L40). The flour was kept in an air-tight container prior to analysis.

Sample analysis

Proximate analysis of the fermented and unfermented seed samples: After bringing the samples to uniform size, they were analyzed for moisture, protein, fat, ash and fibre and these were conducted at the Central Research Laboratory, Federal University of Technology, Akure.

The carbohydrate content of each sample was determined by difference i.e., 100-(% moisture content+% protein+% lipid+crude fibre+ash content).

Mineral analysis of the fermented and unfermented seed samples: Mineral contents of locust bean were analyzed from solution obtained by dry ashing. Sample (1.0 g) was weighed into a dried crucible and ashed in muffle furnace at a regulated temperature of 550°C. The crucible plus ash was transferred to a desiccator to cool after which 2% Nitric acid (HNO_3) was added to the ash. It was then filtered through acid washed Whatman number 43 filter paper into 100 mL volumetric flask and diluted to 100 mL with the same dilute solution.

Atomic absorption spectrophotometer (Buck Scientific Model 210VGP) was used for the analysis of the following metals: Ca, Fe, Mg, Zn, Mn, Cu, Pb and Cd while Na and K were determined with flame photometer (JENWAY) and P by Vanado molybedate method.

Physicochemical properties of the fermented and unfermented seed flour: The physicochemical analysis of both the fermented and unfermented seed flour involves the determination of pH, total titratable acidity, bulk density, water absorption capacity, oil absorption capacity, foaming capacity and stability, emulsion capacity and least gelation concentration using standard methods. The statistical analysis were carried out with SPSS Statistical tool version 13 and significant at $p<0.05$.

RESULTS

The results obtained from various analysis carried out on fermented and unfermented locust bean seed flour are presented on Table 1-4.

Table 1: Proximate composition of fermented and unfermented locust bean seed flour

Parameter (%)	Unfermented (Mean±SD)	Fermented (Mean±SD)
Moisture	5.95±0.21	9.47±0.01
Ash	4.00±0.00	2.84±0.08
Crude protein	35.65±0.00	37.87±0.06
Crude fat	27.82±0.33	34.44±0.01
Crude fibre	5.55±0.07	3.25±0.07
Carbohydrate	21.04±0.60	12.14±0.08

Table 2: Mineral composition of fermented and unfermented seed flour

Parameter (mg/100 g)	Unfermented	Fermented
Magnesium	280.00	260.00
Calcium	2450.00	2750.00
Zinc	4.10	5.50
Manganese	2.80	4.80
Copper	0.50	0.70
Cadmium	ND	ND
Iron	6.50	7.80
Sodium	26.00	36.00
Potassium	306.00	146.00
Phosphorus	1.10	1.02
Lead	0.10	ND

ND: Not determined

Table 3: Anti-nutrient factors of fermented and unfermented seed flour

Parameter (mg g^{-1})	Unfermented	Fermented
Saponin	54.73±2.31	39.36±0.39
Tannin	2.08±0.42	4.72±0.31
Oxalate	6.80±0.19	6.03±1.15
Phytate	15.66±1.17	37.90±4.66

Mean±SD

Table 4: Physicochemical properties of fermented and unfermented seed flour

Parameters	Unfermented	Fermented
pH	5.67±0.09	6.41±0.06
Total titratable acidity	17.2±0.57	4.75±0.35
Bulk density (%)	62.18±1.22	54.59±2.37
Water absorption capacity (%)	493.33±15.28	273.33±25.17
Oil absorption capacity (%)	170.00±10.00	163±11.55
Foaming capacity (%)	20.62±0.60	15.66±0.39
Foaming stability (%)	25	50
Least gelation conc. (%)	8	16
Emulsion capacity (%)	73.80±0.62	76.02±0.14

Mean±SD

Proximate composition of fermented and unfermented locust bean seed flour: It was observed from Table 1 that fermentation had significant effect on the proximate composition of the fermented locust bean. The moisture contents of the fermented African locust beans increased significantly from 5.95-9.47%. The percentage fat of African locust beans increased during fermentation from 27.82-34.44%. The percentage of protein of African locust beans as well increased slightly during fermentation from 35.65-37.87%. However, there were significant reduction in percentage content of ash, carbohydrate and crude fibre of the fermented samples. The increase in the moisture content of the fermented samples may be due to the addition of water during cooking and washing of the cotyledon. It may also be due to the activity of the fermenting organisms on the substrate. The higher percentage of protein in the fermented samples may be due to reduction of carbohydrate content of the unfermented samples. The decrease in ash content of the seeds with fermentation may be due to lost in ash because of leaching of the solute inorganic salt into the processing water during the boiling of the samples.

The increase in fat content of the fermented samples to 34.44±0.01, may be attributed to the increase activities of lipolytic enzymes, which hydrolyze fat to glycerol and fatty acid. The reduction in the total carbohydrate content of fermented samples could be as a result of the utilization of some of the sugars by fermenting organisms for growth and metabolic activities. From the results of this study, the seeds of *P. biglobosa* had higher protein and fat.

Mineral composition of the fermented and unfermented locust bean seed flour: The mineral composition of the fermented and unfermented samples shown in Table 2 reveals that there was a significant reduction in the value of magnesium and potassium of fermented samples, while increase in concentration was observed in calcium, zinc, manganese, iron, sodium, the concentration of phosphorus and copper varied considerably. Cadmium and lead concentrations were not detected.

The mineral content of the raw and fermented samples were quite higher, while studying the effect of fermentation on some chemical and nutritive properties of berlandier nettle spurge (*Jatropha cathartica*) and physic nut (*Jatropha curcas*) seeds. The significant higher value of Ca in locust bean seed might be due to the relative abundance of the minerals in rainforest soil. The significant low Fe value might result from abundant moisture which causes the iron to oxidize to form immobile $Fe_2O_3.xH_2O$ and then leached away by rain thereby making it unavailable to the plant. The reduction in the values of potassium and magnesium in the fermented samples may be because of its leaching into the water during boiling or it may be due to its utilization by fermenting organisms. Increase in sodium, calcium, zinc, manganese and iron content of the fermented samples may be due to the contribution from fermentation microorganisms. It was observed that lead was detected in the unfermented sample but no more detected in the fermented sample, which means that fermentation will make this seed safer for consumption.

Anti-nutrient factor of fermented and unfermented seed flour: Table 3 indicated that the value of saponin reduced significantly with fermentation, while phytate increased significantly as presented in Table 3.

It appears, therefore, that heat treatment increased phytate level in the seeds, tannin also increased slightly from 2.08-4.72 mg g^{-1}, while studying the effect of fermentation on some chemical and nutritive properties of berlandier nettle spurge (*Jatropha cathartica*) and physic nut (*Jatropha curcas*) seeds and oxalate varied considerably from 6.80-6.03 mg g^{-1}. Oxalates have a negative effect on mineral availability as they interfere with absorption of divalent minerals, particularly calcium by forming insoluble salts with them. Reduction of these anti-nutrients during the processing of African locust beans is therefore of great importance for the safety of the product. Anti-nutritional factors can cause poor availability and/or utilization of nutrients, producing effects which include reduction in food intake, neurological effects and even death.

Physicochemical properties of fermented and unfermented seed flour: The results of physicochemical properties of both the fermented and unfermented locust bean seed flours are presented in Table 4. The pH of the unfermented African locust beans was lower than the pH of the fermented samples. However, there were corresponding correlations between the pH and total titratable acidity values of the fermented and unfermented samples. Thus, it was observed that the unfermented African locust beans was more acidic than their fermented products.

The increase in pH that led to decrease in acidity of the fermented products can be attributed to the proteolysis and the release of ammonia through deaminase activity. There was a corresponding correlation between the pH and titratable acidity of the samples, that is, an increase in pH led to a decrease in the TTA of the samples. The drop in acidity and increase in pH is an advantage of the fermented seed over the unfermented seed which will help the body acid-base balance become better. The bulk density of the fermented samples were lower than that of the unfermented samples. The fermentation process results in coarse texture of the fermented product that can be attributed for low bulk density and would be an advantage in the formulation of complementary foods. The water and oil absorption capacity of unfermented sample is higher than the water and oil absorption capacity of fermented sample. Protein has both hydrophilic and hydrophobic properties thereby can interact with water and oil in foods. Results for water absorption revealed significant differences between unfermented (493.33$\pm$15.28%) and fermented (273.33$\pm$25.17%) samples, whereas insignificant differences was observed for oil absorption between fermented (163$\pm$11.55%) and unfermented (170.00$\pm$10.00%). Variation in water and oil absorption capacity of protein isolates may be due to different protein concentration, their degree of interaction with water and oil and possibly their conformational characteristics. The foaming capacity of unfermented sample is 20.62% while that of the fermented sample is 15.66%, the value of the foaming capacity falls in line with other varieties of legumes ranging from 7.9-155%. Lower foaming capacity observed in fermented locust bean sample could be due to inadequate electrostatic repulsions, lesser solubility and hence excessive protein-protein interactions. The value of the foaming stability observed in unfermented sample is 25% while that of the fermented sample is 50%, higher value for foaming stability indicates highly hydrated foams and decrease in foaming stability might be due to protein denaturation For the least Gelation properties, the values obtained for *Parkia biglobosa* unfermented sample is 8 and 16% w/v for fermented sample. The value obtained for emulsifying properties of *Parkia biglobosa* unfermented sample is 73.80 and 76.02% w/v for fermented sample.

DISCUSSION

The enormous benefits attached to African locust beans cannot be over-stressed; as proven by this research study. The significant reduction in percentage content of ash, carbohydrates and crude fibre is an indication of the impacts of fermentation on the nutritional quality of African locust beans. This was similar to a report on the effect of fermentation on the nutritional quality of African locust beans[4]. Also, the decrease in ash content of the seeds with fermentation may be due to lost in ash because of leaching of the solute inorganic salt into the processing water during the boiling of the samples. A similar result was reported in Dolichus laboratory on bean seed. The reduction in crude fibre of the seeds with fermentation may be as a result of boiling and dehulling during the processing of the locust bean[5]. Higher levels of crude protein obtained in this study for the seeds (33.5%) were in accordance with Alabi *et al.*[6]. African locust bean has been known to be rich in protein and may thus be used to add protein to a protein-deficient diet.

There was a significant reduction in the value of magnesium, potassium with calcium, zinc, manganese, iron, sodium increasing in content while phosphorus and copper vary in composition. The mineral content of the raw and fermented samples were quite higher than that recorded for raw and fermented *Jatropha* seeds by Oladele and Oshodi[7], while studying the effect of fermentation on some chemical and nutritive properties of berlandier nettle spurge (*Jatropha cathartica*) and physic nut (*Jatropha curcas*) seeds. Calcium is an important mineral required for bone formation and neurological function of the body. Sodium is an important mineral that assist in the regulation of body fluid and in the maintenance of electric potential in the body tissue. Zinc is an essential micronutrient associated with number of enzymes, especially those associated with synthesis of ribonucleic acid. Iron is required for blood formation and it is important for normal functioning of the central nervous system[8]. It also facilitates the oxidation of carbohydrate, protein and fats. Magnesium plays essential role in calcium metabolism in bones and also involve in prevention of circulatory diseases. It helps in regulating blood pressure and insulin releases[9]. Copper is required in the body for enzyme production and biological electron transport.

Antinutrient factors can cause poor availability and/or utilization of nutrients, producing effects which include reduction in food intake, neurological effects and even death. The study showed that there was significant reduction of anti-nutrients during the processing of the locust beans. It appears therefore that heat treatment increased phytate level in the seeds, tannin also increased slightly from 2.08-4.72 mg g^{-1} which corresponds to what was recorded for raw and fermented *Jatropha* seeds by Oladele and Oshodi[7], while studying the effect of fermentation on some chemical and nutritive properties of berlandier nettle spurge (*Jatropha cathartica*) and physic nut (*Jatropha curcas*) seeds and oxalate varied considerably from 6.80-6.03 mg g^{-1}. Oxalates have a negative effect on mineral availability as they interfere with absorption of divalent minerals, particularly calcium by forming insoluble salts with them. Phytates can bind some essential mineral nutrients in the digestive tract and can lead to mineral deficiencies[10].

The correlation established between the pH and titratable acidity of the fermented and unfermented samples clearly shows the disparity between the two samples. Unfermented African locust beans was more acidic than their fermented products. The increase in pH led to a decrease in acidity of the fermented products due to the proteolysis and the release of ammonia through deaminase activity. This is of great importance as it will help the body acid-base balance become better. The bulk density of the fermented samples were lower than that of the unfermented samples. The fermentation process results in coarse texture of the fermented product that can be attributed for low bulk density and would be an advantage in the formulation of complementary foods. The bulk density value of both the fermented and unfermented *Parkia biglobosa* is higher than that of *Prospsis africana*, which recorded a bulk density of 0.5268 g cm^{-3} [11]. The water adsorption capacity for the fermented locust beans was lower than that of *Prosposis africana*; 340.00. The oil absorption capacity of *Cathormion altissimum* is 163%. The value is close to that recorded for *Proposis africana* of 120.0[12]. This is also found to be closer to the value obtained, for varieties of legume seeds ranging from127.8-172.0%[13]. The foaming capacity of unfermented sample is 20.62% while that of the fermented sample is 15.66%, the value of the foaming capacity is higher than that of *Prosposis africana*, 3.9%[12]. The value is however in line with other varieties of legumes ranging from 7.9-155%[13]. Lower foaming capacity observed in fermented locust bean sample could be due to inadequate electrostatic repulsions, lesser solubility and hence excessive protein-protein interactions. The value of the foaming stability observed in unfermented sample is 25% while that of the fermented sample is 50%, higher value for foaming stability indicates highly hydrated foams and decrease in foaming stability might be due to protein denaturation. A report observed decrease in foam volume with the passage of time for protein isolates of different chickpea cultivars[14]. The decrease in foam volume as a function of time was observed for both samples. The value of the fermented sample is the same with that for cowpea flour with 16% least gelation properties[11]. The lower the least gelation concentration the better is the gelling ability of proteins because protein gels are aggregates of denatured molecules. The value obtained for emulsifying properties of *Parkia biglobosa* unfermented sample is 73.80 and 76.02% w/v for fermented sample. There's no significant difference between the two values, however these values are higher than that of *Prosposis africana* 30.0%[12]. Protein, being the surface active agents, can form and stabilize the emulsion by creating electrostatic repulsion on oil droplet surface[15].

CONCLUSION

Traditional fermentation of locust beans (*Parkia biglobosa*) significantly affects the observed properties. However, in some cases fermentation did not improve the nutritional quality of the seeds. The seeds are good sources of fat, protein and minerals.

Results from this study revealed the nutritional adequacy of the African locust bean. It is a good source of potassium, calcium and magnesium. In addition, fermentation reduced the lead content to undetectable level. The flours possess good functional properties which can be incorporated into human diets not only as protein supplements but also as in processed foods such as weaning, baked and soup products. Food processing technologies for exploiting the utilization of locust bean flours should be promoted. Fermentation should always be conducted on locust bean before consumption.

SIGNIFICANCE STATEMENTS

This study elucidated on the protein content of African locust beans among others. The research showed that protein malnutrition can be tackled with the incorporation of fermented African locust beans into foods because of his rich protein content that has proven by the research. Also, the detection of lead in unfermented beans necessitate further works on leguminous plants that undergoes fermentation as part of its processing.

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