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Compositional Changes in African Oil Bean (*Pentaclethra macrophylla* Benth) Seeds During Thermal Processing

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Abstract: The effect of thermal processing as a preservation technique on the nutritional, anti-nutritional and functional characteristics of African oil bean seeds (*Pentaclethra macrophylla* Benth) was investigated. Samples were drawn from the different stages during the processing (namely; cooked, fermented and canned) along with the raw seeds, and examined for proximate chemical composition, elemental concentrations, anti-nutritional content and functional properties. The results show that processing reduced the protein content from 22.32% dry wt. in the raw seeds to 19.00% dry wt. in the canned product; while oil content increased from 53.98% to 60.11% respectively. Also, fermentation and canning significantly ($P<0.05$) reduced the phosphorus and iron contents of the seeds while processing generally raised the calcium and magnesium contents. Each processing step brought about a decrease in levels of anti-nutritional factors analyzed. Oxalates, tannins and phytic acid were reduced from 2.79mg/g, 0.38g/100g and 2.11g/100g in the raw seeds to 0.81mg/g, 0.22g/100g and 1.16g/100g in the canned product, respectively. Water and oil absorption capacities were not significantly ($P>0.05$) affected by the processing operations. However, the capacity to gel and foam reduced with successive processing steps. Overall, thermal processing of the African oil bean seeds raised nutrient bioavailability, digestibility and functionality.

Key words: African oil bean seeds, thermal processing, nutrients and anti-nutrients, functional properties

Introduction

The problem of widespread prevalence of protein energy malnutrition (PEM) has resulted in high morbidity and mortality rates, especially among infants and children in low-income groupings in the third world, including Nigeria. The reliance on starchy roots and tubers and protein-deficient cereals as main staples results in consumption of stodgy monotonous non-nutritious diets. The insufficient availability of animal protein sources, and costliness of the few available plant protein sources, has prompted an intense research within the last two decades into harnessing of the nutrient potentials of lesser known underutilized legumes and oil seeds. One of such seeds is the African oil bean seed (*Pentaclethra macrophylla* Benth), a highly nutritious leguminous crop seed abundant in the rainforest areas of West and Central Africa.

The traditionally fermented product of African oil bean seed is called ugba, a popular condiment and meat analogue among consuming populations (Kingsley, 1995). The fermentation of the African oil bean seed effects better nutrient availability and digestibility with significant softening of the cotyledons (Enujiugha and Akanbi, 2002). With successive processing steps during the fermentation, there is progressive softening of the cotyledons; reduced astringency and increased palatability; and enhanced meaty flavour. However, the fermented product ugba has a high rate of deterioration and susceptibility to microbial spoilage within 2 weeks of production. The major concern has been to seek ways of lengthening the shelf life without lowering the nutritional quality, freshness and consumer acceptance of ugba.

Recent studies have shown that apart from fermentation, roasting could serve either as an alternative processing technique (Enujiugha and Olagundoye, 2001) or as a supplementary treatment to elongate the shelf life and diversibility of the fermented product (Enujiugha, 2000). Roasting as an alternative processing technique yielded a nutritionally better product, while roasting as a supplementary processing step did not significantly ($P>0.05$) affect the nutrient composition of the fermented product. However, both approaches tend to alter the use of the seed product as a cherished condiment by bringing about undesirable changes in the essential quality attributes. Although the keeping quality (or shelf life) of ugba has been a major parameter in seeking alternative and supplementary processing methods, the maintenance of quality and freshness of the fermented product should be the most critical variables, as consumers are used to particular quality attributes.

Thermal processing is viewed as an achievable technique for the maintenance of the preferred form and quality of ugba while at the same time ensuring the elongation of its shelf life (Enujiugha and Akanbi, 2002). Ugba is a low-acid food, a product of alkaline fermentation, and it is expected that the application of heat to maintain commercial sterility could bring about changes in the nutritional and anti-nutritional status of the product as well as its functional characteristics.

Therefore, it is necessary to examine the chemical composition and functional properties of the processed ugba to ensure preservation of its nutrient potentials. The objective of this study was to evaluate these attributes as affected by the processing steps involved in canned ugba production.

Materials and Methods

Preparation of the different samples: Mature African oil bean seeds were obtained from local farmers at Nri in Eastern Nigeria. Upon receipt, the oil bean seeds were visually inspected and defective seeds were discarded. The seeds were then stored at 7°C and 60% relative humidity until used. The fermentation process of the seeds followed a previously outlined procedure (Enujiugha and Olagundoye, 2001) with slight modifications. Parboiling of whole seeds was done for 4 h while cooking of sliced cotyledons was done for 6-8 h. The cooked seedslices were soaked overnight, washed in several changes of water, and spread out for 4-h natural inoculation, before being fermented at 30°C for 4 days. The raw seed sample was obtained by mechanically dehulling fresh seeds, drying the cotyledons at 40°C for 8 h and milling into flour to pass through 60-mesh screen using laboratory hammer mill. The cooked sample was obtained by drying soaked and washed seedslices at 40°C overnight and milling into flour as above. The fermented sample was obtained by drying the fermented product, ugba, at 40°C overnight and milling as for raw seed sample. The canned sample was obtained by subjecting the fermented product to conventional canning procedures (Lu *et al.*, 1984), and drying and milling the canned seedslices as described above.

Determination of proximate chemical composition: Quantitative composition was determined on each of the samples using the following analytical methods: Moisture content according to method 964.22 (AOAC, 1990); crude protein according to method 955.04 (AOAC, 1990); crude fat extracted overnight in a Soxhlet extractor with hexane and quantified gravimetrically; ash according to method 923.03 (AOAC, 1990); crude fibre determined after digesting a known weight of fat-free sample in refluxing 1.25% sulphuric acid and 1.25% sodium hydroxide; and carbohydrates determined by the difference method (subtracting the percent crude protein, crude fibre, crude fat, and ash from 100% dry matter). All analyses were carried out in triplicates.

Mineral analysis: Analysis of sodium and potassium contents of the samples was carried out using flame photometry, while phosphorus was determined by the phosphovanado-molybdate (yellow) method (AOAC, 1990). The other elemental concentrations were determined, after wet digestion of sample ash with a mixture of nitric and perchloric acids (1:1 v/v), using Atomic Absorption Spectrophotometer (AAS, Buck Model 20A, Buck Scientific, East Norwalk, CT06855, USA). All the determinations were carried out in triplicates.

Determination of anti-nutritional factors: Phytic acid was extracted from each 3 g flour sample with 3% trichloroacetic acid by shaking at room temperature followed by high-speed centrifugation. The phytic acid in the supernatant was precipitated as ferric phytate, and iron in the sample was estimated. Phytate-phosphorus (phytate-P) was calculated from the iron results assuming a 4:6 iron: phosphorous molecular ratio according to method 970.39 (AOAC, 1990). The phytic acid was estimated by multiplying the amount of phytate-phosphorous by the factor 3.55 based on the empirical formula $C_6P_6O_{24}H_{18}$. Tannin contents were determined by the modified vanillin-HCL method of Burns (1971). Determination of oxalate was by the AOAC (1990) method. All procedures were carried out in triplicates.

Analysis of functional properties: The determination of water and oil absorption capacities followed a modification of the method of Prinyawiwatkul *et al.* (1997). Each flour sample (5.0g) was thoroughly mixed, without pH adjustment with 25ml of deionized water or oil in 50-ml centrifuge tubes. Suspensions were stirred intermittently over a 30-mins period at room temperature (ca.25°C) and then centrifuged at 12,000g for 30 min at 25°C. The volume of decanted supernate was measured, and the water and oil absorption capacities were calculated. Triplicate samples were analyzed for each flour sample category.

For the least gelation concentration, triplicate suspensions of 1-20% seed flour sample (dry w/v, at 1% increment) were prepared in 10ml of deionized water and mixed thoroughly without pH adjustment. The slurries were heated in 125 x 20 mm screw-capped test tubes in a water bath with in-biult magnetic stirrer (Julabo Model SW22, Julabo Labortechnik GMBH, Seelbach, Germany) at 95± 2°C. After 1hr of heating, tubes were immediately cooled in tap water for 30s and then in ice water for 5 min to accelerate gel formation. All tubes were then held at 4°C for 3hr. Least gelation concentration (percent) was determined as the concentration above which the sample remained in the bottom of the inverted tube.

The foaming properties of the samples were determined using the procedures of Coffmann and Garcia (1977), while emulsifying properties were determined as described by Ige *et al.* (1984). The results were expressed in percentages (g/g basis).

Results and Discussion

The effects of processing steps on the proximate chemical composition of African oil Bean seed during

Table 1: Effect of processing on the proximate chemical composition (mean ± s.d.)

Sample	Components (% dry wt)				
	Crude Protein	Oil	Crude Fibre	Ash	Carbohydrate
Raw	22.32±0.37	53.98±0.99	2.13±0.55	2.40±0.11	19.16±0.76
Cooked	19.15±0.13	58.95±0.46	3.26±0.04	1.43±0.13	17.49±0.46
Fermented	17.13±0.21	61.35±1.21	2.93±0.11	1.11±0.04	17.48±1.07
Canned	19.00±0.19	60.11±0.86	3.27±0.12	2.37±0.17	15.26±1.04

Table 2: Changes in mineral Contents of the Seeds during processing (mg\kg dry wt)

	Raw	Cooked	Fermented	Canned
P	351.89±2.58	317.92±2.24	291.02±0.53	176.06±12.69
K	127.19±7.99	175.80±12.46	110.39±6.18	156.67±11.49
Na	184.98±12.31	113.49±2.17	172.06±9.42	168.57±7.30
Ca	314.30±11.32	329.29±11.35	208.92±14.37	404.54±13.34
Mg	292.05±9.86	479.37±5.61	334.98±11.07	397.03±2.02
Zn	9.78±0.61	13.47±0.28	9.23±0.78	15.41±1.98
Fe	56.28±5.42	56.80±1.39	42.46±1.02	42.48±3.19
Mn	23.99±3.06	27.71±1.69	26.87±0.36	15.60±2.75

the production of canned ugba are presented in Table 1. Fermentation as a processing step lowered the protein content and enhanced oil extraction. This trend has been observed in an earlier work (Enujiugha and Olagundoye, 2001). The additional thermal processing step did not significantly (P> 0.05) affect the protein and oil contents. *Pentaclethra macrophylla* is known for its high oil content with high proportion of unsaturated fatty acids (Enujiugha, 2003a). It is therefore expected that post-processing quality deterioration could affect the shelf-life and acceptability of its products. However, hermetic sealing and thermal processing are enough to elongate shelf-life and ensure acceptability. Cooking and fermentation significantly (P<0.05) reduced the ash content of the oil bean seeds, reflecting in the reduced concentrations of some major minerals like phosphorus and sodium (Table 2).

The oil bean seeds are high in phosphorus, calcium and magnesium, the minerals which are necessary for teeth and bone development in children. Canning of the oil bean seeds brought about a significant (P<0.05) decrease in phosphorus from 351.89 mg/kg in the raw seeds to 176.06 mg/kg in the canned product. However, the same process raised the concentrations of calcium, magnesium and zinc in the seed samples. A previous study also observed an increase of calcium with processing of the seeds (Enujiugha and Olagundoye, 2001). The low iron content of the processed seed product could be compensated for by other dietary sources that can generate enough iron needed in the body. Copper and lead were not detected in the samples. The absence of lead is a great nutritional advantage.

Table 3 shows the levels of some anti-nutritional factors in the raw and processed seed flour samples. The anti-nutritional factors are generally reported to have the capacity of retarding growth and lowering digestibility and absorption of important dietary nutrients. Each successive processing step lowered the concentrations of phytates, oxalates and tannins in the *Pentaclethra* seeds. At the end of the canning process, phytic acid was reduced by >45%; oxalates were reduced by >70%; and tannins were reduced by >42%. Phytates are known to chelate some divalent metals, notably Ca, Mg, Zn and Mn, making them metabolically unavailable. The reduction in phytate level could be interpreted as the main reason behind the observed increases in the concentrations of these minerals in the canned sample (Table 2). Tannins, and to some extent, oxalates, bind to proteins thereby making them unavailable in the body. The results of the present study point to thermal processing as bringing about improved bioavailability of *Pentaclethra* seed proteins. This confirms an earlier suggestion that the traditional methods employed in processing the seeds, namely hydrothermal treatment, soaking and fermentation, would considerably reduce the levels of the anti-nutritional factors (Enujiugha and Ayodele-Oni, 2003).

The effects of cooking, fermentation and canning on the functional properties of African oil bean seeds are presented in Table 4. Cooking and fermentation progressively increased the gel forming abilities of the full-fat African oil bean seeds, as lower sample concentrations are needed to form a gel. A further canning process did not change the least gelation concentration of the fermented product. The gel forming ability is reported to be influenced by the nature of the protein, starch and gums in the sample as well as their interaction during heat treatment (Enujiugha and Ayodele, 2003). The results of the present study show that the processed seed flour samples are better binders, especially if they are to be used as functional

Table 3: Levels of some antinutritional factors (mean ± s.d)

	Phytic acid (g/100g)	Phytate-P (g/100g)	Oxalates (mg/g)	Tannins (g/100g)
Raw seeds	2.11±0.02	0.59±0.06	2.79±0.05	0.38±0.02
Cooked seeds	1.80±0.05	0.51±0.01	1.35±0.06	0.30±0.01
Fermented seeds	1.37±0.02	0.39±0.07	0.90±0.01	0.28±0.01
Canned seeds	1.16±0.09	0.33±0.01	0.81±0.03	0.22±0.02

Table 4: Effect of processing on the functional properties of canned ugba

	Raw seed	Cooked seed	Fermented seed	Canned seed
Gelation (%)	12	11	10	10
Water absorption (ml / g)	1.74 ± 0.08	1.56 ± 0.01	1.82 ± 0.23	1.75 ± 0.02
Oil absorption (ml / g)	1.60 ± 0.01	1.40 ± 0.01	1.25 ± 0.06	1.69 ± 0.13
Foaming capacity (%)	9.80 ± 0.20	5.23 ± 0.10	2.95 ± 0.15	2.66 ± 0.10
Emulsion capacity (%)	15	20	20	20

ingredients. Cooking lowered the water absorption capacity of the oil bean seeds; while subsequent fermentation significantly (P<0.05) demonstrated a higher water absorption capacity; a further thermal processing lowered the water retention ability of the fermented product. The results imply that hydrothermal treatment tended to block the tissue pores, thereby hindering water shippage and retention, while the demand for water by the seed macromolecules during hydrolysis raised the water retention during fermentation. Cooking has also been shown to reduce water absorption capacity in conophor nut (Enujiugha, 2003b).

Fermenting the African oil bean seeds lowered oil absorption capacity, while canning the fermented product raised oil retention. Oil absorption is attributed to physical entrapment of oil and is important for flavour retention and mouth feel of foods. Canning ugba could therefore be said to effect better flavour retention. Foaming capacity is dependent on the protein, and the raw seed flour with higher protein content demonstrated higher foaming capacity. Each successive processing operation brought about a reduction in the foaming capacity. A previous work also demonstrated reduction in foaming capacity of conophor nut with processing (Enujiugha, 2003b). The foams from processed seed flours showed no stability at 30 min, while the raw seed flour gave a foam that was stable at 2 h, indicating that the native protein gives higher stability than denatured protein. Emulsion capacity increased with processing possibly due to increased oil extraction. The results of the present study generally imply that canning ugba raises its functionality as a meat analogue and soup or porridge ingredient, but does not promote its aerating properties.

Conclusion: The fermented product of African oil bean seeds, ugba, has been canned with slight nutrient changes and significant (P<0.05) reductions in major anti-nutritional factors. The functional properties of the oil bean seeds are found to improve with processing with the exception of foaming properties. Thermal processing is therefore recommended as a preservation technique for ugba. More work is needed to establish optimum conditions for the heat penetration steps, and also to establish the best storage conditions for canned ugba.

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