POSTHARVEST PROCESSING, PACKAGING AND STORAGE OF AFRICAN OIL BEAN SEED

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Abstract: The underutilization of African oil bean seed necessitated the study of its post-harvest operations. This work reviews the status of research on postharvest processes of African Oil Bean (AOB) seed. Information was sought through a search query with African oil bean post-harvest processing, packaging and storage as keywords on Google Scholar, internet, publishers’ website, textbooks and oral interview with local processors. The results showed that researchers have focused on the fermentation, proximate, phytochemical, mineral and vitamins composition of AOB seeds. This study also revealed the dearth of research on characterization, improved variety, packaging, storage, value addition and oil extraction from AOB seeds. Research on postharvest handling, storage, packaging and processing of AOB seed is imperative for optimal utilization of the seed, and to prevent the prevalent post-harvest losses.

Key words: African oil bean seed, packaging, processing, storage, value addition

INTRODUCTION

The African oil bean (\textit{Pentaclethra macrophylla} Benth.) is a tropical tree crop treasured for the multipurpose usefulness of its seed, pod, timber, bark, root and leaf.
The crop is native to Africa, with the distribution cutting across the Cameroon, Cote d’Ivoire, Democratic Republic of Congo, Ghana, Niger, Nigeria and Togo rain forest zones [1].

The AOB is known in Nigeria as ugba or ukpaka, apara and ukana among the Igbo, Yoruba and Efik tribes, respectively. The crop belongs to the family of Leguminosae (Mimosoideae) with no recognized varietal characterization [1-3]. The crop flowers and produce green dicotyledon pods that changes to brown on maturity. Each pod contains up to 10 seeds that are glossy brown, and at maturity, the pod splits open explosively scattering its seeds up to a distance of 20 m from the tree [2]. After the explosion, the pods usually curl up. The seeds of African oil bean are flat in shape, hard, but smooth in texture and have an average length of 56.18 mm and width of 37.89 mm [4-5]. The seed is a good source of minerals, vitamins (Table 2), protein, carbohydrate, crude fibre, oil (Table 3), and contain many phytochemicals (Table 4). These researchers [6] found that AOB seeds protein content is greater than those of high animal protein sources like beef, oyster, pork and fishes.

In other to maximize the protein constituent, a texturized vegetable protein from AOB seed that will serve as a meat analogue at optimal parameters of 92.45°C barrel temperature, 101.48 rpm screw speed, 59.63 % feed moisture, and 1% AOB seed protein concentrations was developed [7].
A work by [8] posits that the seed is a good source of lipase. AOB seed improves metabolism and possess anti-atherogenic property [9]. Some researchers [10] recommended the use of the seed in the treatment of diabetes because of the hypolipidemic activities it exhibited.

According to [11], AOB seed could help to improve kidney functionality. The seed, also, contains anti-inflammatory and analgesic properties and is used to treat gonorrhoea and convulsions in Cameroon [12]. Besides, it is an excellent raw material for the manufacturing of cosmetics, oil paints, varnishes, edible oil for cooking, and margarine production [13]. The oil of AOB seed is relatively high in viscosity compared to other under-exploited seeds in Africa like Baobab, African pear, African nutmeg and fluted pumpkin seed [14]. Investigation by [15] suggests that the oil of AOB seed is a good raw material for pharmaceutical industries because the extract from the seeds can inhibit the growth of micro-organisms such as B. cereus, B. licheniformis, L. species, E. coli and C. albican.

The stem, bark, root, hull and pod of AOB are equally important to man (Table 1).

Table 2. The nutritional contents of African oil bean seed

| Minerals       | Compositions | ppm  | (mg 100g⁻¹) | (mg 100g⁻¹) | (µg g⁻¹) | (mg 100g⁻¹) |
|----------------|--------------|------|-------------|-------------|----------|-------------|
| Calcium        |              | 104.5| 1.10        | -           | 8.16     | 2.89        |
| Copper         |              | -    | 0.98        | -           | 0.05     | -           |
| Iron           |              | 34.8 | 4.23        | -           | 1.60     | 0.13        |
| Lead           |              | -    | -           | -           | 3.94     | -           |
| Magnesium      |              | -    | 0.30        | -           | 4.86     | 11.10       |
| Manganese      |              | -    | -           | -           | 0.72     | -           |
| Phosphorous    |              | 101.6| 1.51        | -           | 0.06     | -           |
| Potassium      |              | 181.3| 0.65        | -           | -        | 4.95        |
| Sodium         |              | 236.2| 0.18        | -           | -        | 5.28        |
| Zinc           |              | -    | 1.31        | -           | -        | 3.31        |

Vitamins

| Ascorbic acid  |              | -    | 10.56       | -           | -        | -           |
| Niacin         |              | -    | 2.10        | 2.00        | -        | -           |
| Riboflavin     |              | -    | 0.18        | 0.11        | -        | -           |
| Thiamine       |              | -    | 0.25        | 1.10        | -        | -           |

References

[13] [16] [17] [18] [19]

In their work, [19] found that AOB seed contains high levels of some anti-nutritional and toxic factors which are eliminated during cooking and fermentation. The fermented AOB seed sliced or shreds are commonly known as ugba. The ugba is prevalent in Eastern Nigeria, and is usually consumed as a snack or a condiment for preparing African salad, soup, porridge yam, cocoyam, meat (nkwoi), among others delicacies.

Fermentation improves the amino acids and nutritional contents of ugba [20, 21]. Also, fermentation increases the proximate composition and reduces the phytochemical content of the seed [16, 19, 22]. The kinetics of AOB fermentation is influenced by boiling time and slice thickness [23].
The bacteria responsible for fermenting of AOB, according to [24], are *Bacillus pumilus* and *Bacillus sphaericus*, apart from *Bacillus licheniformis* and *Bacillus subtilis*. In their study, [25] discovered that the starter culture fermented ugba is rated higher by the consumers in terms of consistency, aroma and taste than those obtained from the markets. It has been found that African oil bean seeds fermented with oil palm inflorescence ash have better chemical and microbial composition than the one processed without the oil palm ash [26]. The fermentation of AOB seed enhances its oil extraction [27]. Though fermentation is necessary for processing AOB seed into ugba, [28] found a high prevalence and co-contamination of different potentially toxigenic fungi on ugba and other fermented foods in Nigeria. Extract from the seed, as suggested by [29] could be used for bio-preservation of condiments against pathogens that spoil food.

| Constituents          | Raw          | Boiled       | Fermented    |
|-----------------------|--------------|--------------|--------------|
| Crude Protein (N x 6.25) | 24.06 ± 0.22b | 25.59 ± 0.11b | 28.25 ± 0.20a |
| Crude fiber           | 2.80 ± 0.11b | 2.66 ± 0.10b | 3.76 ± 0.22a |
| Lipids                | 52.50 ± 0.20b| 51.40 ± 0.30b| 44.20 ± 0.10b|
| Ash                   | 2.70 ± 0.20b | 3.04 ± 0.22b | 1.86 ± 0.30a |
| Carbohydrates         | 17.94 ± 0.10b| 17.31 ± 0.11b| 21.93 ± 0.22a|
| Calorific value (Cal g⁻¹) | 640.50b    | 634.20b      | 598.52a      |

Values with superscript that are the same not significantly different at p < 0.05.

Table 4. Phytochemical compositions of African oil bean seed

| Components (mg 100g⁻¹) | [16] | [31] |
|-------------------------|------|------|
| Alkaloid                | 1.88-8.96 | 11.24+0.01 |
| Flavonoid               | 0.28-0.90 | - |
| Oxalate                 | -    | 1.39+0.01 |
| Phenol                  | 0.02-0.75 | - |
| Phylate                 | -    | 1.17+0.01 |
| Saponin                 | 0.22-4.96 | 3.20+0.01 |
| Tannin                  | 3.0x10⁻²-0.49 | 0.95+0.01 |

Hence, this study is aimed at reviewing the importance of African oil bean seed, the status of postharvest research on the seeds’ processing, handling, storage, value addition, and to highlight the research needs of the crop.
PRODUCTION AND PROPERTIES

Production of African oil bean seed

The African oil bean trees grow in the wild until recently when the domestication has started. However, the wild still makes up a higher percentage of total production. Currently, there is neither any empirical data on the quantity produced annually nor any known commercial plantation. It was showed by [12] that the seeds and stem cuttings are used in propagating the crop. The seeds are dispersed naturally (during the splitting of the pods) or manually after harvest. It can also be propagated by air-layering or budding. The budded trees start fruiting after 3 years whereas the stem-cuttings may produce seeds after four years [32].

Engineering properties of African oil bean seeds

Engineering properties of biomaterials are essential in designing their postharvest processing machines, storage facilities and handling equipment [33, 34]. The average major, intermediate and minor diameters of African oil bean seed at 14.5%, moisture content were 65.332 mm, 60.269 mm and 59.584 mm, respectively [35]. At the moisture content of 8.73% dry basis, [5] obtained values for these properties the major, intermediate and minor diameters of the seeds averaged 56.18mm, 37.89mm, 12.01m with standard deviations 8.46, 3.82 and 1.66 mm respectively. They, also, got the equivalent diameter, sphericity and porosity as 32.51 mm, 0.523 mm and 51.56 mm, respectively. The seed dimensions are relatively larger than many oil seeds. The gravimetric properties show that the seed is heavier than water [5, 35]. In addition, [36] found the angle of repose and friction coefficient to be 17.20° and 0.31, respectively. In their own work, [3] investigated the mechanical properties of the seed at moisture content range of 15.76 to 34.43% wet basis and loading rate of 25 mm/min., and they found the values of rupture force, toughness, rupture stress, yield force and modulus of stiffness of the seeds to decreased linearly from 362.04 to 168.82 N, 1.783 to 0.623 J, 7.4 to 3.15 N/mm², 213.42 to 89.68 N and 39.74 to 24.77 N with moisture increase in transverse axis. Whereas for longitudinal loading, the values decreased from 276.64 to 195.26 N, 1.355 to 0.641 J, 16.12 to 6.23 N/mm², 211.58 to 124.72 N and 38.74 to 24.77 N with an increase in moisture content. The seeds’ physical and mechanical properties were affected by moisture content [3, 35]. However, it was observed that adequate work had not been done on the thermal properties of the seeds despite the fact that heat treatment is essential for its processing.

POSTHARVEST AND STORAGE

Processing of African oil bean seed

It has been stated [37] that Ugba contains some anti-nutritional factors like undigestible oligosaccharides and phytate in its natural state, and this make processing inevitable. The processing of the seed into Ugba involves boiling or roasting, dehulling, shredding / slicing, soaking, washing, packaging, and fermenting (Table 5).
However, the processing method affects the nutrients and phytochemical properties of AOB seeds *Ugba* [10, 38, 39, 40, 41]. This revelation makes optimization of the processing method imperative to get the optimal variables for *Ugba* processing. A study [42] is of the opinion that *Ugba* should be handled properly during processing in order to take care of the *Micrococcus spp* and to inhibit the enzyme production responsible for spoilage. Processors can save up to 2 days by using a rapid technique for *Ugba* processing proposed by [43]. The apparent simple process achieved the same quality of *Ugba* after fermentation as the much more cumbersome, fuel-wasting and time-consuming.

**Fermentation of African oil bean seed shreds/slices (ugba)**

Some foods are probiotics and must have to undergo fermentation before they are ready to be consumed. Examples of such foods to include wine, yogurt, cheese, alcohol, vinegar and bread [22]. The shreds and slices of cooked African oil bean is fermented before they are consumed.

![Flowchart of Ugba processing](image-url)

Unfermented shreds/slices are bitter and not tasty. The first stage in the processing is cleaning to remove damaged seeds. After cleaning, the traditional processing operations follows (Figure 2).

However, [44] recommended 2-3 days of fermentation and reported that fermentation for 4 days increased cholesterol levels which could pose a problem for patients of cardiovascular disease-related to cholesterol.

Different processors adopt varying sequence of the processing methods (Table 5), however, there are two main methods of processing African oil bean seeds into *Ugba* (Figure 2) prevalent within the Southeastern part of Nigeria as reported by local processors.
Packaging of the shreds/slices of African oil bean seeds

African oil bean seed shreds and slices are traditionally packaged by wrapping a handful with different kinds of leaves (Figure 1). The wrapping of the seeds with leaves is believed to aid the fermentation process. The leaves wrapping and the poor measures during handling contaminates the product [45]. Also, leaves-wrapping creates openings for microbes to enter the product resulting to rapid deterioration. The leaves-wrapped product has a low shelf life of not more than 5 days under tropical ambient conditions of 31-32°C.

Fig. 1a. AOB shreds  
Fig. 1b. AOB slices  
Fig. 1c. Wrapped AOB shreds/slices

The type and the number of leaves varies from one processor to another, and they are determined by the processor’s discretion and experience. The effect of the type and number of leaves on the quality of wrapping African oil bean shreds was evaluated by [46]. Their study showed that the leaves of plantain (Musa paradisiaca), cocoyam (Xanthosoma sagittifolium) and Okpopia (Alchornea laxifora Benth) did not affect the proximate composition of the product so also the number of leaves used. However, they recommended five leaves of Okpopia (Alchornea laxiflora Benth) for wrapping African oil bean seed slices and shreds because of the high storage quality observed.

Other researchers have studied alternative ways to package and extend the shelf life of African bean seed shreds/slices. The use of canning method of packaging was studied by [47]. They used brine, groundnut and tomato sauce as various media to extend the shelf of African oil bean slices. They observed that canning with media led to softening and colour darkening of the samples over prolonged storage time. Apart from these problems detected, another challenge would be the acceptability of those media with African oil bean slices in dish preparations. This is because the foods prepared with African oil bean does not go with any of those media as an ingredient. In their work, [48] evaluated bottle/cup packaging with locally adapted pasteurization technique as an alternative storage method.

They used starter culture of washed cells of Bacillus subtilis and Bacillus megaterium to ferment the sliced and sterilized slices of African oil bean seeds for 48 hours at room temperature (30±2°C). Although they observed no microbial growth on the product at the end of 6 weeks of storage, they did not indicate whether or not the intrinsic properties of the product were affected.

Some other researchers [49] studied the possibility of using polyethylene bags and foil wraps with the aid of preservatives to package and extend the storage duration of African oil bean seeds. Their method was able to keep the product for only eight days after which the product quality was found to degrade.
Besides, some preservatives can alter the organoleptic properties of food, and carrying out tests such as Hedonic, could have been useful in evaluating the effects of the preservatives and storage methods on the organoleptic characteristics of the product.

Notably, the various methods evaluated, when compared to leaves wrapping, have the advantage of reducing or preventing the entrance of microbes that leads to product spoilage. Nonetheless, none of the methods is satisfactory in solving the packaging and storage problems of African oil bean shreds/slices.

| S/N | Processing method                                                                 | Reference |
|-----|------------------------------------------------------------------------------------|-----------|
| 1   | Boil the seeds for 4 hours, dehull, slice, boil for another two hours, drain and soak in water for two hours, wash and package in leaves for fermentation | [22]      |
| 2   | Boil at 121°C for 1 hour, dehull, wash kernel, drain, rewash kernel several times in cold water, slice, mix with salt, wrap with leaves and place in a basket to ferment for 3-5 days. | [50]      |
| 3   | Boil for 3 hours, dehull, slice, wash and boil for 2 hours, cool and soak for 10 hours, wash, drain water and keep in a basket lined with banana leaves to ferment | [51]      |
| 4   | Boil for 12 hours, slice, boil for 24 hours, wash, drain and allow to ferment       | [52]      |
| 5   | Boil for 12 hours, dehull, slice, boil for 2 hours, wash, wrap in banana leaves and packaged in the basket for fermentation | [16]      |
| 6   | Toast in hot (100°C) sand and hold for a further 30 min at 100°C, slice to 1 mm, boil for 30 mins and soak for 2 hours. | [43]      |
| 7   | Boil for 12 hours, dehull, slice, boil for 30 mins, drain, cool, wash and ferment at room temperature in wraps of heat-blanchedd banana leaves | [53]      |

Seed storage

The information obtained from local processors and farmers showed that the seeds of African oil bean are stored in their pods until they are taken to the market or processed.

Farmers do harvest the pods early because of their susceptibility to explode under the intense heat of the sun. The maturity index of the pod is taken as a change in their colour, from green to brown. Some farmers see the maturity index as when any of the pods start to explode.
Harvested pods are kept in shade or room where sunlight does not touch them. Another way to store the seeds is to remove them from the pods and store in a jute bag or multilayer black polyethylene bags. The seeds are removed from matured pods by breaking the pods through their longitudinal axis using a machete or by smashing it on a hard object. Otherwise, the seeds are collected from the farm where they are dispersed after splitting of the pod while still on the tree.

![Fig. 3(a). Deteriorated AOB seeds](image)

![Fig. 3(b). AOB seeds](image)

The information obtained from local processors showed that the shelf life of the seeds stored in their pods could be up to 6 months, depending on the prevalent ambient conditions, whereas, the jute bag or multilayer black polyethylene bag storage shelf life is within three months. However, none of these methods proved to be effective in storing AOB seeds, since some of the products were spoilt over time as shown in Figure 3.

**OIL PROSPECTS OF AFRICAN OIL BEAN SEEDS**

The African oil bean seed is rich in oil content (53.98%) and oleic acid (29.0%) [54, 55]. The AOB seed oil yield is greater than that of castor bean (42.2%) and locust bean (20.68%) [56]. This high oil content of the seed indicates that processing of the seeds for oil would be economically viable [18]. However, there is no grocery shelve where oil from African oil bean seed is displayed. Such neglect has limited the potential of the crop to date.

The influence of moisture content and seed dimension on the mechanical expression of oil from African oil bean seeds has been evaluated [57]. The research showed an oil yield of 47.7% and oil expression efficiency of 78.96% using mechanical oil expression. Also found was that the higher the moisture content and seed dimensions, the lower the quantity of oil expressed by the machine from the seeds.

Mechanical expression of oil seeds does leave some fractions of the oil in the cake, which will require the use of solvent, like food grade n-Hexane, to extract. It implies that solvent extraction will give oil yield higher than 47.7% obtained by [57].
POSTHARVEST CHALLENGES

Postharvest losses

Postharvest losses, which refer to losses in quality and quantity, are usually preceded by physical or physiological damage of agricultural produce. Physical damage occurs during harvest, transportation, handling, packaging and in storage for most agricultural products, while physiological damage results from physiological changes that take place after harvest. The African oil bean seeds are hard and are not susceptible to physical damage during postharvest handling. Many post-harvest losses of the seeds are mostly due to physiological damage, pests attack and diseases. The physiological changes are made possible because of high the moisture contents of the seeds at harvest. It was stated by [58] that the two significant factors affecting physiological deterioration of products are pre-harvest factors (temperature, moisture status, mineral nutrition and cultural practices) and postharvest factors (temperature, chilling injury, light, gases such as carbohydrate, oxygen, ethylene). Ugba has a very low shelf life, and whenever the product is not marketed within days of processing, the product will be lost to spoilage.

Dearth of research

There is a decline in the production of African oil bean seeds because of afforestation, urbanization and lack of planting new trees [59]. Majority of the tree still grows in wild and there is no known plantation for the crop. The seed has only a mono bye-product (ugba) in Nigeria despite its potential for other products. Researchers have focused their attention of the proximate, organoleptic, chemical, nutritional, functional properties, fermentation, phytochemical and health benefits of African oil bean seed [16, 18, 31, 54, 55, 60-70]. The problem of lack of research input from agronomy and engineering disciplines has led to the absence of improved variety and many postharvest challenges, respectively. As a result, the crop could be termed an orphan and endangered species.

RESEARCH NEEDS OF AFRICAN OIL BEAN SEED

In order to maximize the potential of African oil bean research, there is an urgent need for researchers to look into the following research areas for the crop:

- Development of improved varieties of African oil bean seed
- Optimization of the oil yield of African oil seed
- Characterization of the oil from African oil bean seed
- Evaluation of the drying kinetic of African oil bean shreds/slices for improved shelf life
- Effects of drying on the proximate, phytochemical, mineral and vitamins contents of the African oil bean seed
- Technological development of a proper packaging method for African oil bean seed
- Process optimization of Ugba preparation
CONCLUSIONS

The growing population of developing nations has put enormous pressure on the staple food availability of the people, and imported foods are relatively expensive and unaffordable to the majority of the populace due to poverty. To ensure food security in these regions, research on nutritious but neglected crops that grow and flourish with little or no special care, like AOB, should be encouraged. Considering the nutrient attribute, the phytochemical, proximate, mineral and vitamin constituents of African oil bean; the crop could be regarded as a great complementary food for household nourishment and an essential raw material for food and pharmaceutical industries. AOB seed has great prospect of improving the economy of households and the nation through value addition. The exploration of the oil potentials of AOB seed could see the crop compete in world oil-seed trade. Moreover, it brings a high return to investors. Improving the postharvest operations of AOB seed through research could help to tackle food insecurity. Furthermore, there is need to get improved varieties for increased production, and improved research on the postharvest challenges of the crop. So, any value addition on the AOB seed could possibly create wealth and jobs for the teeming youth population of these regions.

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OBRADA POSLE ŽETVE, PAKOVANJE I SKLADIŠTENJE AFRIČKOG SEMENA (ZRNA) ZA ULJE

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Sažetak: Nedovoljna upotreba Afričkog zrna (semena) (*Pentaclethra macrophilla* Benth.) za ulje, zahteva proučavanje operacija posležetvenih postupaka. Ovaj rad daje pregled stanja i situacije istraživanja procesa žetve Afričkog semena (zrna) za ulje (AUS). Informacije su dobijene putem upita za pretragu, obradu, pakovanje i skladištenje afričkog zrna (semena) posle berbe, kao ključne reči na Google Scholar info sistemu, internetu, veb lokaciji izdavača, udžbenicima i usmenim intervjuima sa lokalnim proizvođačima ove kulture. Rezultati su pokazali da su straživači fokusirani na fermentacioni, fitohemijski, mineralni i vitaminski sastav afričkog zrna – semena za ulje (AUS). Ova studija je takođe otkrila nedostatak istraživanja o karakterizaciji, poboljšanoj sorti, pakovanju, skladištenju, dodavanju vrednosti i ekstrakciji ulja iz zrna (semena).

Istraživanje rukovanja, skladištenja, pakovanja i prerade AUS semena (zrna) nakon berbe neophodno je za optimalno korišćenje semena i za sprečavanje raširenih gubitaka posle berbe.

Ključne reči: Afričko seme (zrno) za ulje, pakovanje, prerada, skladištenje, dodate vrednosti.

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