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STUDIES ON THE PHYTOCHEMICAL COMPOSITION AND FERMENTATION OF THE SEEDS OF AFRICAN OIL BEAN TREE (*PENTACLETHRA MACROPHYLLA* BENTH)

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ABSTRACT

Phytochemical composition, proximate, vitamins and mineral contents of the African oil bean seed (*Pentaclethra macrophylla Benth)* which is well known food and medicinal plant in Nigeria was assessed with a view to establishing and understanding the nutritional values of raw boiled and fermented seeds. Phytochemical studies revealed the presence of bioactive compounds comprising alkaloids (1.88 -8.96 mg $100g^{-1}$), saponins (0.22 – 4.96 mg $100g^{-1}$), flavonoids (0.28 – 0.90 mg $100g^{-1}$), phenols (0.02 – 0.75 mg $100g^{-1}$) and tannins (3.0×10^{-3} – 0.49 $mg100g^{-1}$). The protein, lipids, carbohydrates and fiber content were 24.06 - 28.25%; 44.20 – 52.50%, 17.31 – 21.93% and 2.66 – 3.76%, respectively. The food energy content ranged from 598.52 to 640.50 cal g^{-1}. The seeds are rich in B- vitamins such as riboflavin (0.09 – 0.18 mg $100g^{-1}$), niacin (0.62 – 2.10 mg $100g^{1}$), and thiamine (0.14 – 0.25 mg $100g^{-1}$) while ascorbic acid content ranges from 2.64 – 10.56 mg $100g^{-1}$. The mineral contents include calcium (1.0 – 1.21 mg $100g^{-1}$), potassium (0.38 – 0.65 mg $100g^{-1}$), phosphorus (1.51 – 2.56 mg $100g^{-1}$), magnesium (0.30 – 0.55 mg $100g^{-1}$), sodium (0.18 – 0.23 $mg100g^{-1}$), iron (4.23 – 7.30 mg $100g^{-1}$), zinc (1.14 – 1.31 mg $100g^{-1}$), and copper (0.67 – 0.98 mg $100g^{-1}$). Fermentation increases the food value of oil bean seeds for human consumption. The seeds can be considered as source of quality raw material for food and pharmaceutical industries.

Key words: Oil bean seeds, Fermentation, Chemical composition, Nutraceutical, Phytochemical.

INTRODUCTION

The African oil bean tree (*Pentaclethra macrophylla* Benth) is a tropical tree crop found mostly in the Southern rain forest zone of West Africa where it grows wild[1-4.] It belongs to the leguminosae family and the sub-family minosoideae[5]. The plant is recently cultivated by peasant farmers in rural communities in Southern and middle belt regions of Nigeria[6]. Seeds of the African oil bean are edible especially in the eastern states of Nigeria

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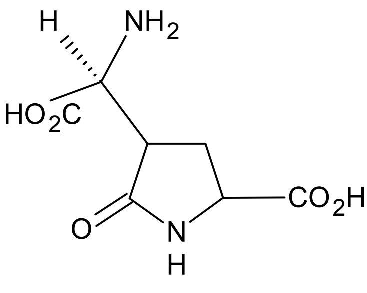
where it is eaten alone or with other ingredients like stock fish, garden egg and sliced tapioca or as a mixed vegetable salad [2-3]. This is extremely popular "African salad" a favorite snack at masquerade and other festivals[3]. The edible seed require tedious but careful processing and fermentation before they can be eaten as food supplement[4].

The fermentation seed product is traditionally prepared by boiling the oil bean seeds overnight for easy removal of the seed coats, slicing of the cotyledons, cooking until the sliced cotyledons become soft with reduced bitterness, washing in five or more changes of water and fermenting the sliced cotyledons for a period of 3 days[7, 8]. The seed when cooked, processed and fermented is used for the preparation of many delicious African delicacies including African salad, soups and sausages for eating with different staples[4,7] It is rich in phytochemicals, vitamins and minerals for both local consumption and for export. It is a low acid food, which could be prepared for flour and explored in food fortification and confectionaries[4].

The tree grows to about 21 meters in height and to about 6 m in girth[5]. The leaves posses a stout angular petiole. The compound leaves are usually about 20-45 cm long and covered with rusty hairs. The flowers are creamy–yellow or pinkish – white and sweet swelling. The main flowering season is between March – April with smaller flushes in June and November. Fruits are available at most periods of the year because the large woody pods, which are persistent. The pods, are 40- 50 cm long and 5-10 cm wide. The pods contain between 6-10 flat flossy brown seeds. The seeds are up to 7 cm long. The trunk provides timber used for structural work.



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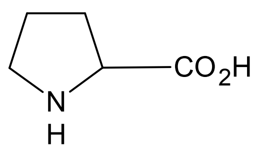

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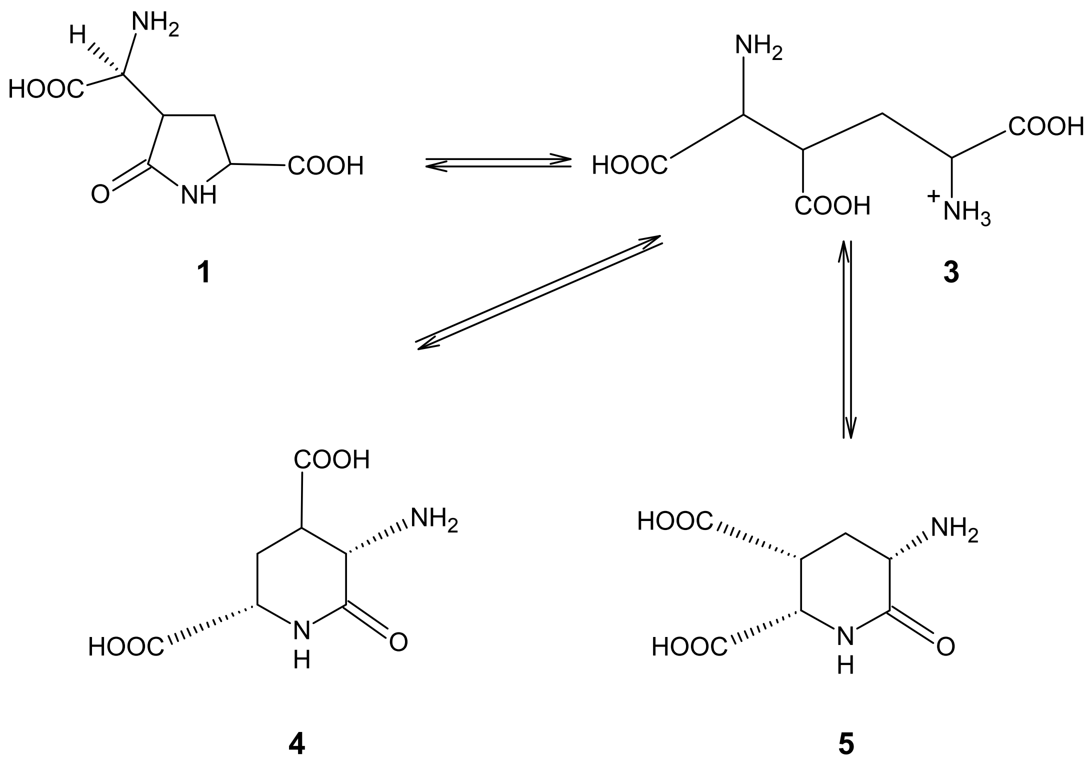
The tree yields forest products for wooden household utensils[4]. The flat glossy brown edible seed (of about 6-10 in number) are contained in a brownish flattened pod[4, 7] (Fig. 1) which explodes at maturity and disperse the seed (Fig. 2). The mature dispersed seeds are harvested by gathering or picking them manually from around the tree. The kernel (a dicotyledon) which is gray in colour is embedded in a glossy brownish seed coat. The seeds are irregular or oval in shape and lie flat in its natural position.

Fig. 1

Fig. 2

Permacric acid **1** was isolated from the raw seeds of *P. macrophylla*. The seeds also contain proline **2** and pipecolic acids **4** and **5**. A number of chemical studies were carried out on penmaric acid by the Belgian workers, who originally reported the isolation of compound **1** from raw oil bean seed[9]. The lactans of penmaric acid is hydrolyzed under a variety of acidic conditions to afford the substituted adipic acid **3,** which re-closes in dilute acid solution to give either of the two possible substituted pipecolic acids **4** and **5** **(Scheme 1).** It also contains the twenty (20) essential amino acids and essential fatty acids that constitutes over 10% of the fatty acid in the oil[7,8]. Despite detailed chemical studies, nothing is known about the biological origin or role of penmacric acid[9]. However, oil bean extracts from leaves, seeds, kernel, roots, bark and stem bark of oil bean for medicinal purposes in Nigeria, Ghana and Cameroon have been extensively reported [10-12].



Scheme 1: Hydrolysis of panmacric acid and closure of adipic acids

The ethnomedical utilization of the oil beans stem bark aqueous extract in Ghana has been documented widely[10] and it has been extensively used in infertility, convulsion, abortion, diarrhea, itching, lactogenicity and wound treatment. Recently, the fermented form of the African oil bean seed is used as food supplement and has greatly reduced the risk of cancer and some tobacco related diseases[13]. Cancer patients, who had regular fermented oil bean seed as food supplement have shown marked improvement in regaining their health quickly[1, 3].

In spite of the various uses of P. *macrophylla* as food and drugs in Nigeria, there is a paucity of literature regarding the phytochemical profile. The phytoconstituents of the crop have not been fully documented. The present study was undertaken to evaluate the secondary metabolite constituents and consequently assess the nutritional quality of *P. macrophylla* seed.

EXPERIMENTAL

Materials and method

The experiment was carried out in the Department of Chemistry, Michael Okpara University of Agriculture Umudike Nigeria. Fresh leaves and seeds of African oil bean were collected from Ekwelu village, Ariam, Usaka Ikwuano Local Government, Abia State Nigeria. The plant was botanically identified by Dr. Nmeregini of the Taxonomy unit, Forestry Department of Michael Okpara University of Agriculture, Umudike.

The seeds were boiled for 12 hours at 105°C. The seed coats were removed. The embryo was sliced into smaller pieces with sharp knife and boiled again for further 2 hours. The sliced seeds were washed thoroughly in water with four changes of water. The washed sliced seeds were wrapped with banana leaves and packed together in baskets and left to ferment for 3 days at room temperature (29-32°C). The fermented sliced seeds, boiled sliced seeds and raw seeds were weighed 500 g, respectively and separately ground into uniform flour using a Thomas Wiley machine (Model: ED.5 USA). The flour were then dried and stored in airtight bottles for chemical analysis. The yields were as follows; fermented seeds 462 g; raw seed 460 g and boiled seed 420 g.

Chemical analysis

Total nitrogen (N) content was determined by the use of an apparatus (Micro-Kjeldahl MD 55, Singapore). The protein content was calculated as N x 6.25. Crude fat (ether extract), crude fiber and ash content were determined according to the methods of Association of Analytical Chemists (AOAC)[14]. Total carbohydrates were estimated as the remainder after accounting for ash, crude fiber, protein and fats[15]. The gross food energy was estimated according to the method of Osborne and Voogt[16] using the equation.

$$FE = (\% \text{ CP} \times 4) + (\% \text{ CHO} \times 4) + (\% \text{ Fat} \times 9)$$

Where:

FE = Food energy (in g calories)

CP = Crude protein

CHO = Carbohydrates.

The mineral, calcium, sodium, potassium, magnesium and trace elements (iron, zinc and copper) all of which were determined according to the method of Shahidi et al[17]. Phosphorus content of the digest was determined calorimetrically according to the method described by Nahapetain and Bassiri [18]. Alkaloids and phenols were determined according to the methods of Harbone[19] while tannin was determined using the method of Van-Burden and Robinson[20]. Saponins content was determined using the method of Obadoni and Ochuko[21]. Flavonoids were determined according to the method of Boham and Kocipai[22]. The B- complex vitamins (thiamine, riboflavin and niacin) were determined according to the method of SKALAR Analysers[23] while ascorbic acid (Vitamin C) was determined using the method of Baraket et al.[24.]

Statistical analysis

All measurements were replicated three times and standard deviation determined. The student's t-test at $P < 0.05$ was applied to assess the difference between the means[25].

RESULTS AND DISCUSSION

The phytochemical content of *P. macrophylla* seeds is shown in Table 1. The alkaloids content was very high in raw *P. macrophylla* seed at 8.96mg $100g^{-1}$, boiled unfermented seed contained 4.22 mg $100g^{-1}$ and the processed fermented seed contained 1.88 mg $100g^{-1}$ of alkaloids. The high alkaloid content of *P. macrophylla* seed explains the reason for the prolonged tedious but careful cooking and fermentation before they can be eaten as food supplement by the natives [4]. An alkaloid is a plant derived compound that is toxic or physiologically active and contains nitrogen in heterocyclic ring. It is basic and has a complex structure and is of limited distribution in the plant kingdom[26.] Penmaric acid and pipecolic acids isolated from the oil bean seed are alkaloids. Processing and fermentation drastically reduced the alkaloids content and the toxicity of the seeds.

Table 1: Phytochemical composition of raw, cooked and cooked fermented *P. macrophylla* seeds

Phytochemicals	*P. macrophylla* raw seeds	*P. macrophylla* boiled seeds	*P. macrophylla* boiled fermented seeds
Alkaloids	8.96 $\pm$ 0.10^b	4.22 $\pm$ 0.22^b	1.88 $\pm$ 0.10^a
Saponins	4.96 $\pm$ 0.30^b	0.36 $\pm$ 0.10^a	0.22 $\pm$ 0.20^a
Flavonoids	0.90 $\pm$ 0.22^b	0.56 $\pm$ 0.11^b	0.28 $\pm$ 0.10^a
Phenols	0.75 $\pm$ 0.10^b	0.05 $\pm$ 0.20^a	0.02 $\pm$ 0.1^a
Tannins	0.49 $\pm$ 0.22^b	0.10 $\pm$ 0.11^a	0.003 $\pm$ 0.11

Data are means $\pm$ standard deviation of triplicate determinations on dry weight basis, values with superscript that are the same are not significantly different at $P < 0.05$.

However, pure isolated plant alkaloids and their synthetic derivatives are used as basic medicinal agents for their analgesics, antispasmodic and bacterial effects[26- 27,] They exhibit marked physiological activity when administered to animals like cattle, goats and sheep. Again the high alkaloid content in African oil bean explains their therapeutic and medicinal properties and the use of this plant in herbal medicine in Nigeria, Ghana and Cameroon. Most plant parts that are used in the curing of diseases contain alkaloids. For example *Azadirachta indica* (the neem tree) used in the cure of malaria also contain alkaloids[28]. Quinine, isolated from *Cinchona* bark is the oldest known effective anti-malarial agent[29]. The presence of alkaloids and saponin in the African oil bean seed may be the reason for the bitter principle and astringent taste of the seeds.

Saponins were found to be available at 4.96 mg $100g^{-1}$ in raw seeds; boiled seeds contained 0.36 mg $100g^{-1}$ of saponin and fermented seeds contained 0.2296 mg $100g^{-1}$ of saponins. The high saponin content in the raw seeds justifies the use of the extracts from this plant in treating wounds. Some of the general characteristic of saponins includes formation of foams in aqueous solutions, hemolytic activity and cholesterol binding properties[26]. Saponins natural tendency to ward off microbes makes them good candidates for treating fungal and yeast infections. These compounds served as natural antibiotics, helping the body to fight infections and microbial invasion [26,30]. Plant saponins help human to fight fungal infections, combat microbes and viruses, boost the effectiveness of certain vaccine and knock out some kinds of tumour cells particularly lung and blood cancers[30, 31.]

African oil been seeds can be used as food supplement in the control of cancer and tobacco related diseases. This may be due to their saponin content. Saponin lower blood cholesterol and hence, reducing heart disease. The most outstanding and exciting prospects for saponins is how they inhibit or kill cancer cells. They may also be able to do it without killing normal cells on the process as is the mode of some cancer fighting drugs. Cancer cells have more cholesterol-type compounds on their membranes than normal cells. Saponins therefore bind cholesterol and thus, interfere with cell growth and replication [30]. Research has identified a host of active substances that provides the protection against cancer. These phytochemicals include saponins and alkaloids in legumes. These beneficial chemicals block various hormone actions and metabolic pathways that are associated with the development of cancer[32,33].

The flavonoids content was high in the raw seeds at 0.90 mg $100g^{-1}$, boiled seed contained 0.56 mg $100g^{-1}$ while fermented seeds contained 0.28 mg $100g^{-1}$ of flavonoids. Flavonoids are widely distributed groups of polyphenolic compounds characterized by a common benzopyrone ring structure that has been reported to act as antioxidants in many biological systems. The family encompasses flavonoids, flavones, flavanones, chalcones, catchins, anthocyanidins and isoflavonoids[34.] They have remarkable biological functions, including inhibiting effects on large members of enzymes, modulatory effects on some cell types, antiviral, antioxidant and anticancer properties[30, 34]. In addition to their free radical scavenging activity, flavonoids have multiple biological activities including vasodilatory, anti-carcinogenic, anti-allergic, antiviral, estrogenic effects as well as being inhibitor of phospholpase A_2, cyclooxygenase, lypo-oxygenase, glutathione reductase and xanthine oxidase[27.] These supported the lactogenicity properties and the use of *P. macrphylla* seed in cancer therapy[4,13]

The phenolic contents ranges from 0.75 mg $100g^{-1}$ obtained by raw seeds to 0.05 mg $100g^{-1}$ found in boiled seeds. Phenolic content was drastically reduced to 0.02 mg $100g^{-1}$. Recently, there is growing interest in polyphenolic compounds as therapeutic agents against many diseases such as cardic and cerebral ischemic, arteriosclerosis and rhematic or pulmonary diseases [35, 36]. The activated phagocytic cells are known to produce potentially destructive oxygen species like superoxide anions (O_2^-), hydrogen peroxide (H_2O_2) and hypochlorus acid (HOCl) during chronic inflammatory disorder [35-37.] Many polyphenolics are known to exhibit antioxidative properties [38] They are oxygen free radical scavengers[35,38]. Phenolic flavonoids are also excellent hydroxyl radical scavengers[39]. The antioxidant content and other health benefits such as prevention of cancer and infertility prompted the utilization of African oil bean seeds as nutraceutical and functional foods. Functional foods are those that resemble traditional foods but render benefits beyond their nutrition and energy value in promoting health and preventing certain chronic diseases especially cancer, cardiovascular disease, diabetes, arthritics and arrhythmia[40,41].

Tannin content was 0.49 mg $100g^{-1}$ in boiled seed and 0.003 mg 100^{-1} in fermented seeds. The presence of tannins and alkaloids on the seeds behave as nutritional inhibitor because they combine with proteins and this makes them indigestible and unavailable to the body. Adequate processing (cooking and fermentation), therefore, reduces alkaloids and tannins to trace amounts.

P. macrophylla seeds have high content of proteins and lipids (Table 2). The highest protein content was obtained from the fermented seeds (28.25%), followed by boiled seed, which contained 25.59% of protein while the raw seed contained 24.06% of protein. The increase in crude protein value observed in fermented oil bean seeds could be due to the action of extracellular enzymes produced by the fermenting micro-organisms[7]. Fermentation led to an increase in protein content and a decrease in total lipid (Table 2).

Table 2. Proximate composition of raw, cooked and cooked fermented *P. macrophylla* seeds.

Constituents	*P. macrophylla* raw seeds	*P. macrophylla* boiled seeds	*P. macrophylla* boiled fermented seeds
Crude Protein (N x 6.25)	24.06 ± 0.22^{b}	25.59 ± 0.11^{b}	28.25 ± 0.20^{a}
Crude fiber	2.80 ± 0.11^{b}	2.66 ± 0.10^{b}	3.76 ± 0.22^{a}
Lipids	52.50 ± 0.20^{b}	51.40 ± 0.30^{b}	44.20 ± 0.10^{a}
Ash	2.70 ± 0.20^{b}	3.04 ± 0.22^{b}	1.86 ± 0.30^{a}
Carbohydrates	17.94 ± 0.10^{b}	17.31 ± 0.11^{b}	21.93 ± 0.22^{a}
Calorific value (Cal g^{-1})	640.50^{b}	634.20^{b}	598.52^{a}

Data are means $\pm$ standard deviation of triplicate determinations on dry weight basis.
Values with superscript that are the same not significantly different at $p < 0.05$.

In estimating the protein content of the fermented oil bean, the micro-organisms which brought about fermentation were not isolated but digested together with the oil bean seeds. The observed high level of protein in fermented oil bean seeds may be attributed to the contribution of microbial protein together with that of the oil bean seed. Such an increase in protein content of oil bean seeds on fermentation have been reported[42]. The researchers attribute this increase to predigestion of protein during fermentation. Many amino acids can be deaminated by micro-organisms and in general are excellent sources of nitrogen for their growth[43]. Moreover, the activities of micro-organisms may lead to breakdown of some amino acids, with the liberation of ammonia. Fermentation of oil bean seeds leads to the reduction in the levels of some amino acids[42]. Such reduction may be attributed to the degradation of these amino acids by the fermentative micro-organisms and/or their utilization for synthesis of proteins particularly enzymes[43]. The predominant micro-organisms isolated from the fermented oil bean seeds were identified as *Lactobacillus plantasum, Leuconsostoc mesenterods, Streptococcus lactis* and *Bacillus subtilis* and were implicated in oil bean seeds fermentation[43].

Fermented oil bean seed have the highest carbohydrate content (21.93%), followed by raw seed, which contains 17.94% and the unfermented boiled seed contained 17.31% of carbohydrate. The increase in carbohydrate content in the fermented seed could be attributed to the hydrolysis of complex oligosaccharides in the seeds[42].

Similarly, the value of crude fiber was high in fermented seeds containing 3.76% fiber content; the raw seeds contained 2.90% of fiber while the unfermented boiled seeds contained 2.66% of fiber. Oil bean seeds provide dietary fiber, soften stool and enhance waste elimination including bile acids, sterols and fats [3]. Fiber acts as authentic broom in the intestine absorbing toxins and carrying our harmful substances such as baillery acids, the precursor of cholesterol [30]. Fiber has a physiological effect on the gastrointestinal function by promoting the reduction of traclonic pressure which is beneficial in diverticular disease such as cancer of the colon and hemorrhoids[44]. The utilization of the fermented oil bean seed as food supplement has greatly reduced cancer incindeince[13]. The raw seeds have high lipid content (52.50%), followed by the boiled seeds which contained 51.40% while fermented oil bean seeds contained 44.20% of lipids. The fatty acid profile comprises linoleic, oleic, stearic, palmitic, myristic, lauric and capric acids[7]. Research on the raw African oil bean seed have shown that linoleic acid is the major fatty acid followed by oleic acid[7]

The energy values ranged from 598.52 cal g^{-1} in fermented seed to 634.20 cal g^{-1} in boiled seeds while raw seeds contained 640.50 cal g^{-1}. The high energy value might be due to high lipids content from the seeds. Fermented African oil bean seeds contained 1.86% ash; the raw seed contained 2.70% of ash while boiled unfermented seeds contained 3.40% ash content. These values give an indication of the level of macro and micro elements in the seeds. The raw *P. macrophylla* seed contained 10.56 mg $100g^{-1}$ ascorbic acids; boiled unfermented seed contained 5.28 mg $100g^{-1}$ while fermented seed contained 2.64 mg $100g^{-}$

[1] ascorbic acid. The seeds also contained mostly B- vitamins such as niacin, riboflavin and thiamine. Processing and fermentation reduced the value of ascorbic acids (Table 3).

Table 3: Vitamin composition of raw, cooked, and cooked fermented of *P. macrophylla* seeds.

Vitamins	*P. macrophylla* raw seeds	*P. macrophylla* boiled seeds	*P. macrophylla* boiled fermented seeds
Ascorbic acid	10.56 ± 0.20^{b}	5.28 ± 0.11^{a}	2.64 ± 0.10^{c}
Riboflavin	$0.8 \pm .010^{b}$	0.09 ± 0.20^{c}	0.12 ± 0.11^{a}
Thiamine	0.14 ± 0.22^{a}	0.23 ± 0.10^{b}	0.25 ± 0.22^{b}
Niacin	2.10 ± 0.11^{b}	0.62 ± 0.22^{a}	0.74 ± 0.22^{a}

Data are means ± standard deviation o f triplicate determinations on dry weight basis values with superscript that are the same are not significantly different of $P < 0.05$.

Table 4 shows the macro elements present in African oil bean seeds. The seeds contained appropriate amount of macro elements comprising calcium, phosphorus, potassium, magnesium and sodium. The micro elements include zinc, iron and copper. Fermented oil bean seeds contained 1.21 mg $100g^{-1}$ of calcium, while boiled unfermented seed contained 1.0 mg $100g^{-1}$ of calcium. The magnesium content in the fermented seed was 0.56 mg $100g^{-1}$, boiled seed contained 0.50 mg $100g^{-1}$ while the raw seeds contained 0.30 mg $100g^{-1}$ of magnesium. Normal extracellular calcium concentrations are very important for blood coagulation[45].

Lack of calcium or phosphorous in the diet causes a disease known as rickets[46] and osteoporosis[47] disease normally results due to lack of calcium. In osteoporosis condition, the bone mass is so decreased that adequate mechanical support can no longer be provided and sustained; spontaneous fractures often results[44]. The iron level is high in the fermented seeds 7.30 mg $100g^{-1}$. The boiled seed contained 4.68 mg $100g^{-1}$ while raw seed contained 4.23 mg $100g^{-1}$ of iron. This element is known to be important in human body because it is a component of haemoglobin. It helps oxygen transport. Iron, together with haemoglobin and ferrodixin plays a vital role in man's metabolism[48].

Table 4: Mineral composition of raw, cooked and cooked fermented *P. macrophylla* seeds

Mineral	*P. macrophylla* raw seeds	*P. macrophylla* boiled seeds	*P. macrophylla* boiled fermented seeds
Macro element			
Calcium	1.10 ± 0.10^a	1.00 ± 0.02^b	1.21 ± 0.20^a
Potassium	0.65 ± 0.22^a	0.60 ± 0.10^a	0.38 ± 0.22^b
Magnesium	0.30 ± 0.11^b	0.50 ± 0.22^b	0.55 ± 0.10a
Phosphorus	1.51 ± 0.10^a	2.56 ± 0.20^b	1.77 ± 0.11^a
Sodium	0.18 ± 0.22^a	0.23 ± 0.10^b	0.23 ± 0.10^b
Micro element			
Iron	4.23 ± 0.10^a	4.68 ± 0.22	7.30 ± 0.10
Zinc	1.31 ± 0.11^b	1.14 ± 0.20^a	1.22 ± 0.22^a
Copper	0.98 ± 0.20^b	0.67 ± 0.10^a	$0. 89 \pm 0.11^a$

Data are means ± standard deviation of triplicates determinations on dry weight basis, values with superscript that are the same are not significantly different at $P < 0.05$.

The raw seed contained 1.31 mg $100g^{-1}$ of zinc; fermented seeds contained 1.22 mg $100g^{-1}$ of zinc while boiled seed contained 1.14 mg $100g^{-1}$ of zinc. The zinc content could mean that the seeds can play a valuable role in the management of diabetes, which results from insulin malfunctioning. Zinc is essential for production of insulin, a hormone and carbonic anhydrase, an enzyme in the body[45,48]. This implies that Ca, Zn, Fe, Mg and other mineral elements are essential components for human health. Mineral deficiencies such as Ca, Zn and Fe are the major health problems in developing countries particularly for infants[41]. Zn or Fe deficiency causes poor growth, impaired immune function and consequently delayed mental development. The African oil bean seeds can therefore act as mineral supplements. The fermented oil bean seeds contained linoleic acids, phytochemicals, proteins, minerals and vitamins. The seeds can be incorporated into infant formulae and weaning foods in developing countries where infant mortality rates are very high due to protein energy mal-nutrition (PEM), scurvy, kwashiorkor and pellagra[3]. The crop provides great benefits as nutritional food crop requiring low levels of inputs for production. The high protein content, vitamin and mineral composition can be useful for the poor who cannot afford protein–rich foods. The crop provides numerous medicinal benefits and the presence of phytochemicals (natural flavonoids) enable it to function not only as antioxidants but also as anti-inflammatory and anticarcinogenic agents. The nutritional and health benefits place this crop in an excellent position for utilization as nutraceuticals.

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