Assessment of trace metal accumulation potentials and Health risk of three selected edible mushroom species from Ehime Mbano Imo state, Nigeria.

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Research Article

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Abstract

The effects of processing on the chemical properties (proximate, mineral, vitamins, as well as anti-nutritional factors and oil characterization) of Mucuna flagellipes seeds and seed oil were assessed. Mucuna flagellipes seeds were purchased from a local market in Isiagu, Ebonyi State, Nigeria and divided into three equal portions, which were further processed by frying, boiled, and roasted. Samples were analyzed by official methods of analysis as results generated were subjected to one-way analysis of variance (ANOVA). The proximate compositions showed a significant difference at ($P < 0.05$) in some nutrients evaluated. In terms of moisture content, all the fried samples were lower (5.00%) than the boiled (14.53%) and roasted (11.87%) samples. The protein content of the processed samples was low, and no significant difference ($P < 0.05$) was observed. The seed oil was extracted with (40–60°C) n-hexane and the oil was separated from the solvent using a rotary evaporator. The saponification value, peroxide value, and iodine value showed significant differences ($P < 0.05$). The fat content showed lower values of 5.13%, 3.87%, and 4.87% for fried, boiled, and roasted Mucuna flagellipes seed oil. The seed samples contained no less than 0.60 mg/100 g of oxalate, 0.70 mg/kg of phytate in addition to high alkaloid, terpenoid, cyanide, and flavonoid values. The predominant mineral was sodium in all the processed samples with the values ranging from (119.48mg/kg) to (102.20mg/kg) followed by magnesium 8.53mg/100ml, 7.12mg/100ml, and 7.03mg/100ml for fried, boiled, and roasted Mucuna flagellipes, while all the processed samples were significantly low in potassium (0.37 to 0.30mg/kg). There was a significant difference ($P < 0.05$) observed in some of the vitamin content. These research results may offer a scientific basis for the use of the processed Mucuna flagellipes seeds as food for humans and its oil extracts for the manufacture of industrial products.

Introduction

Edible fruits from wild plants are often taken as food or added to food as a condiment to supplement important vitamins and minerals in human diets in many communities in South-East Nigeria. However, many of the edible legumes, whose fruit seeds could serve as sources of protein, are under-utilized (Nwajagu et al 2021). Consideration has therefore been focused on under-utilized local seeds for possible development and use. There are several of these underexploited plant seeds in Nigeria, one of which includes *Mucuna flagellipes* popularly called “Ukpo” by the Igbos, “Kararra” by the Hausas, and “Yerepe” by the Yorubas (Akubugwo et al, 2012). Global food needs for future populations require urgent and un-relented efforts in exploiting the underutilized agricultural products of high magnitude of protein, minerals, and vitamins by both food scientists and agriculturists. To be economically sustainable, however, both oil and meal from these fruit seeds must be utilized. *Mucuna flagellipes* is a family fabaceae, found worldwide in the woodlands of tropical areas. The leaves are 3-palmate, alternate, or spiral and the lowers are pea-like but larger with distractive curved petals and occur in racemes (Bressani, 2012). At maturity, each pod produces several hard, marble-like seeds, which are used as soup thickeners and for vegetable oil, beverages, and food items (Eze et al., 2021).

Nutritionally, 'Ukpo' are important and economic sources of protein, carbohydrates, calories as well as certain vitamins and minerals. These nutrients are essential to human nutrition but the composition of these nutrients in them differs. The protein of these foods is rich in lysine but deficient in sulfur-containing amino acids, particularly cysteine and methionine. *Mucuna flagellipes* (Ukpo) contains between 6–19% crude protein; 39.8- 61.49% carbohydrate; 1.84–5.9% fat and 11.24–17.10% vitamins. (Ene-bong, 2014).

The difficulty encountered in processing *Mucuna flagellipes* is also an area of concern. In West Africa, seeds require cracking, extensive boiling, and soaking to eliminate toxic and inhibitory constituents. The toxicity from the preparation and consumption of *Mucuna flagellipes* seeds results in dizziness, diarrhea, and pathological changes in organs, growth depression, and death (Obiakor-Okeke and Anozie, 2014). Therefore, this study aims to assess the effects of different processing (cooking, roasting, and frying) on the nutritive and anti-nutritive properties of *Mucuna flagellipes* seeds.

Experimental Procedure

Sample collection

Fresh Ukpo seeds used for this study were purchased from the open market in Isiagu, Ebonyi State Nigeria. The seed which belong to the fabaceae family is round in shape as shown in Fig. 1 and was identified by the head of the Department of Plant Science and Biotechnology, Abia State University, Uturu, Nigeria, the seeds were screened to remove the bad ones.

Preparation of Samples

The method described by Omokpariola *et al*, (2021) was used for the processing of the seeds into flour. The seeds were sorted and divided into three. Boiled for 45 mins in distilled water at 100°C, roasted on a hot iron pan at a temperature of 45–55°C, and fried on a hot iron Pan with sand at a temperature of 45–55°C. The seeds were cooled in desiccators and after all processing treatments were completed all processed seed samples were sun-dried to reduce moisture content and then grounded using a mechanical grinder, put in an air-tight container at room temperature, and stored for further analysis. The chemicals used were of analytical grade.

Chemical Characterization

The percentage free fatty acid, iodine value, saponification number, peroxide, and acid values of the seed oil were determined by the Official method of analysis of the Association of Official Analytical Chemists, AOAC (2016).

Proximate analysis

Standard methods were employed for the proximate analysis. Crude fat was extracted by the soxhlet extraction method with n-hexane at 40–60°C for 8 hours as described by AOAC, 2016. Crude protein content was determined by the micro Kjeldahl method. Available carbohydrate, crude fiber, ash, and moisture contents were estimated as described by AOAC, 2015.

Anti-nutrient analysis

Tannin, flavonoid, and cyanide were quantified according to Trease and Evan, (1996) method. Alkaloid and saponin content were determined using the methods described by AOAC (2016) while oxalate was determined using the method reported by Ceiwyn (1988).

Mineral composition analysis

5g of each oven-dried powdered sample were weighed into dry crucibles in triplicates and ignited in a muffle furnace at 600°C until greyish white ash was obtained. The ash was cooled in a desiccator and $5cm^3$ of 1 $moldm^{-3}$ HNO_3 was added and evaporated to dryness on a steam bath. The treated sample was heated in a muffle furnace until grayish ash was obtained. The sample was again removed, cooled in a desiccator, and retreated by the addition of 10 cm^3 of 1.0 $moldm^{-3}$ HCl before filtering into 100 cm^3 volumetric flasks. Sodium and potassium ions were determined using the standard flame emission photometer while concentrations of the other minerals were determined using Atomic Absorption Spectrophotometer (AAS Model SP9) operating with standard air-acetylene flame as described by AOAC, 2015. The concentration of phosphorus was determined using Jenway 6100 spectrophotometer at 470 nm (Ihekoronye *et al.*, 2015).

Vitamin content analysis

Determination of vitamins such as vitamin A, B_1, B_2, C, D, E, and K was carried out by the procedure and method of AOAC (2015).

Statistical analysis

Results were expressed as mean ± SD (standard deviation) of triplicate determinations. The software package used for the statistical analysis was version 20.0 of the SPSS. The data were evaluated for significance differences ($p < 0.05$) in their means using Analysis of Variance (ANOVA). Differences between means were separated using Duncan’s Multiple Range Test (DMRT). A p-value of < 0.05 was considered statistically significant.

Results And Discussion

Chemical properties

Table 1 shows the effect of the different processing methods on the chemical properties of oil extracted from *Mucuna flagellipes* seed. The result showed that the percentage oil yield revealed that both the three processed samples were not oil seeds yielding with the values $5.13 \pm 0.42\%, 3.87 \pm 0.12\%,$ and $4.87 \pm 0.31\%$ for fried, boiled, and roasted *Mucuna flagellipes* seeds respectively. A significant difference ($p < 0.05$) was observed in peroxide value, iodine value, and saponification value.

Table 1
Chemical properties of *Mucuna flagellipes* seed oil as affected by frying, boiling, and roasting

Parameters	Fried	Boiled	Roasted
% Oil Yield	5.13 ± 0.42[a]	3.87 ± 0.12[a]	4.87 ± 0.31[a]
Acid value (mgKOH/g)	1.22 ± 0.02[a]	1.21 ± 0.01[a]	1.22 ± 0.01[a]
Free Fatty Acid (%)	0.62 ± 0.02[a]	0.54 ± 0.06[a]	0.61 ± 0.01[a]
Wij's Iodine value (g/100g)	196.25 ± 0.06[a]	244.95 ± 1.48[b]	222.18 ± 1.39[c]
Peroxide value (meq/g)	0.00 ± 0.00[a]	129.11 ± 0.53[b]	124.35 ± 0.12[b]
Saponification value (mgKOH/g)	665.22 ± 0.95[a]	683.34 ± 0.66[a]	630.41 ± 0.55[b]

*Values are Means ± standard deviations of triplicate determinations. Values in the same row having the same superscript letters are not significantly different ($p < 0.05$).

The percentage yield of the oil was very low, implying that to obtain a very high percentage oil yield, a very large quantity of the seed will be required. The iodine value of oil is a measure of its unsaturation and is a useful criterion for purity and identification which is the most important analytical characteristic of oil. The Wij's iodine values were 196.25 ± 0.06g/100g, 224.95 ± 0.53g/100g, and 222.18 ± 1.39g/100g for fried, boiled and roasted *Mucuna flagellipes* seed oil respectively, with the boiled processed sample having the highest value. Significant differences were observed. The Wij's iodine value of the processed samples was higher than the prescribed 75–94g/100g Wij's iodine value for vegetable oils (Gordon *et al* 1993). The result of high iodine values indicates that *Mucuna flagellipes* seed oil was composed primarily of unsaturated long chain fatty acids and this can be deduced from the nature and change in constitution of the oil when left at room temperature after a long time. A decrease in this parameter is generally attributed to the destruction of some of the double bonds of polyunsaturated fatty acids by free radicals (Tynek et al., 2001). The value for processed *Mucuna flagellipes seed oil* samples indicates that the oil was semi-drying with iodine numbers between 100 and 130 (Kochhar, 2015). Semi-drying oils contain some unsaturated long chain fatty acids. Saponification values of *Mucuna flagellipes* seed oil of the different processed samples were all high ranging from 630.41 ± 0.55 mg/g in roasted, 665.22 ± 0.95mg/g in fried to 683.34 ± 0.66 mg/g in boiled processed samples, when compared to conventional oils such as palm oil (200.05mg/g) (Echendu., 2014) and groundnut oil (185-195mg/g) (Anderson-Foster et al., 2012). Significant differences ($P < 0.05$) were observed between the processed seed samples. The saponification value is an indication of the average molecular weight of fatty acids present in the oil. The high saponification value is an indication that the oil may be suitable for soap making, oil-based ice cream, and shampoos. It has been reported by Pearson, 2014 that oils with high saponification values contain a high proportion of lower fatty acids. The acid value indicates the quality of fatty acids in the oil. From Table 1, the acid values range from $1.22 \pm 0.02 \mathrm{mgKOH/g}$, $1.21 \pm 0.01 \mathrm{mgKOH/g}$, to 1.22

$\pm 0.01 \mathrm{mgKOH/g}$ in boiled, fried and roasted *Mucuna flagellipes* seed oil respectively. The acid values of all the processed samples were generally low and no significant difference (P< 0.05) was observed. These values however accounted for the presence of free fatty acids in the oils as an indicator of the presence and extent of hydrolysis by lipolytic enzymes and oxidation (Igwenyi and Akubugwo, 2014). Therefore, the higher the free fatty acid content, the higher the acid value, the lower the free fatty acid content, the more appealing the oil is (Igwenyi et al, 2015). Low acid value in oil in *Mucuna flagellipes* indicated that the oil will be stable over a long period of time and protect against rancidity and peroxidation. This could be attributed to the presence of natural antioxidants in the seeds such as vitamins C and A as well as other possible anti-nutrient like flavonoids. The acid value is used as an indicator for the edibility of an oil and suitability for use in the paint and soap industries (Akintayo et al., 2012). High acid value in oil shows that the oil may not be suitable for use in cooking (edibility), but be useful for the production of paints, liquid soap, and shampoos. Peroxide value is generally used to determine the degree of primary oxidation products (mainly peroxides) in oils (Shaide and Wanasundara, 2008). It helps us know whether an oil has aged or the extent of spoilage in the oil. The fried sample has zero peroxide value indicating that it has no rancidity while the boiled and roasted samples have significant peroxide values showing that they have some degree of rancidity. There was a significant difference (p<0.05) in the frying, boiling, and roasting of these seeds. From Fig. 2, the abundant chemical parameters for the oil were saponification values(77.05%,64.52% and 64.41%) and iodine values(22.73%,23.13% and 22.70%) while the acid values(0.14%,0.11% and 0.12%), peroxide values(0%,12.19% and 12.70%) and free fatty acid (0.07%,0.05% and 0.06%) were present in small quantities.

Proximate composition

The results of the proximate compositions of *Mucuna flagellipes seed flours* are shown in Table 2, the result of the proximate composition showed no significant difference (P < 0.05) between the different processing methods except moisture content.

Table 2

Proximate analysis (%) of *Mucuna flagellipes* seed flour as affected by frying, boiling, and roasting.

Parameters	Fried	Boiled	Roasted
Moisture content (%)	5.00 ± 0.92^{a}	14.53 ± 0.42^{b}	11.87 ± 0.23^{b}
Crude fat (%)	5.13 ± 0.42^{a}	3.87 ± 0.12^{a}	4.87 ± 0.31^{a}
Crude fiber (%)	8.67 ± 0.31^{a}	7.27 ± 0.31^{a}	8.67 ± 0.12^{a}
Ash (%)	3.07 ± 0.12^{a}	2.87 ± 0.12^{a}	3.07 ± 0.12^{a}
Protein (%)	2.48 ± 0.93^{a}	2.55 ± 1.05^{a}	2.49 ± 0.72^{a}
Carbohydrate (%)	75.65 ± 0.47^{a}	68.91 ± 1.76^{a}	69.04 ± 1.03^{a}

*Values are Means ± standard deviations of triplicate determinations. Values in the same row having the same superscript letters are not significantly different (p < 0.05).

The percentage crude protein content of the processed samples were 2.48 $\pm 0.93\%, 2.55 \pm 1.05\%, \text{and} 2.49 \pm 0.72\%$ for fried, boiled and roasted *Mucuna flagellipes* seed flour respectively. The crude protein content of the processed flour samples was low and showed no significant difference (P < 0.05). These values were observed to be lower than the report of Nwajagu et al., 2021 on boiled, roasted, and autoclaved *Mucuna flagellipes* seeds but in line with the result of Ihekoronye and Ngoddy, 2015) on cooked *Mucuna flagellipes* who observed that excessive heat of processing causes severe protein damage which leads to the destruction of amino acids by complete decomposition or by racemization and the formation of cross-linkages forming poly-amino acids. The decrease could be a result of the processing method in the preparation of the seed samples and other environmental factors. It should be noted that proteins functionally promote growth, tissue repair, and maintenance (Igwenyi, 2015). The percentage compositions of lipids in the samples were low as revealed in Table 2 ranging from 3.87±0.12% in a boiled processed sample, 4.87± 0.31% roasted processed sample to 5.13±0.42% in a fried processed sample. No significant difference was observed. These values were lower than the result of Igwenyi and Azoro, 2014 on cooked ukpo, Achi, Akparata, and ofo. This variation in the oil contents may be attributed to differences in climatic conditions, soil properties, and storage conditions/time of the seeds. The oil content was however lower than 59.46% as reported for *Cucumis melo* var. *agrees* scrab seeds in Nigeria (Adekunle and Olumo, 2014). The analysis of lipid contents however showed that the seed samples were not oil seeds or oil crops and cannot serve as commercial sources of vegetable oils. However, lipids are the principal form of stored energy (fat and oils) in most organisms and major constituents of cellular membranes (Nelson and Cox, 2015). The percentage crude fiber content of the processed *Mucuna flagellipes* seed flour samples were 5.13 $\pm 0.31\%$, 7.27$\pm 0.31\%,$ and 8.67$\pm 0.12\%$ for fried, boiled, and roasted respectively. No significant difference exists between the processed samples. These values are comparable to the values for *Detarium macrocarpum* (2.90%) and *Xylopia aethiopica* (8.66%) reported by Igwenyi and Azoro, 2014 and Okaka et al., 2016 respectively. Crude fiber is the inorganic residue left after the defatted food materials have been treated with dilute hydrochloric acid, diluted sulphuric acid, and ether. Fiber supplements normal dietary agents by modulating the digestive and absorptive processes (Okaka et al., 2016). The processing methods brought about a low value in crude fiber as reported by Adebayo *et al*., 2013 who also observed a decrease in crude fiber during his work on the upgrading of local technology of ogiri production. The ash contents revealed that the values were low with 3.07$\pm$ 0.12 %, 2.87$\pm$0.12%, and 3.07$\pm$0.12% for fried, boiled, and roasted *ucuna flagellipes* respectively. No significant differences were observed. The ash contents were also comparable to values reported by Barminas et al., 2013 for *Xylopia aethiopica* also used as a thickener. The measure of ash content could be a measure of the food quality. The moisture contents were low ranging from 5.00±0.92%, 14.53±0.42%, and 11.87±0.83% for fried, boiled, and roasted *Mucuna flagellipes* respectively and a significance difference was observed between the processed *Mucuna flagellipes* seed flour. These values were low and will discourage deterioration due to microbial attack (Okechukwu et al. 2021). This was also expected given the hard and dry nature of the seeds and seed coats. Although the water content of a food is expressed as a percentage. The results were generally comparable to values obtained by Igwenyi and Azoro (2014). The percentage carbohydrate content of the samples, fried, boiled and roasted *Mucuna flagellipes* were 75.65$\pm 0.,47$, 68.91± 1.76 and 69.04 ± 1.03respectively. No significant difference (P < 0.05) was observed in the carbohydrate contents of the samples. The carbohydrate contents were comparable to 57–59% reported for *Brachystegia eurycoma* and *Detarium microcarpbum* (Uhegbu et al., 2011) and 50–60% reported for *Afezlia africana* (Omokpariola et. al. 2021a) all used as soup thickeners. Dietary carbohydrate is a primary source of energy to the body; it spares fats and proteins in the body (Omokpariola *et. al.*2021a, b). *Mucuna flagellipes* can be said to belong to the carbohydrate class of food because it contains the highest concentration of carbohydrate when compared to other parameters in Table 2 which have negligible concentrations,

Vitamin Contents

Table 3 shows the effect of the different processing methods on the Vitamin composition of *Mucuna flagellipes* seed flour. The results obtained showed a significant difference ($p < 0.05$) in vitamin D and vitamin B_2 in the processing methods on the Vitamin composition of *Mucuna flagellipes* seed flour.

Table 3
Vitamin composition of *Mucuna flagellipes* seed flour processed by frying, boiling and roasting

Parameters	Fried	Boiled	Roasted
Vitamin A.(mg/100ml)	1.92 ± 0.33^a	0.83 ± 0.20^a	2.71 ± 0.63^a
Vitamin B1. (mg/100ml)	0.77 ± 0.15^a	2.14 ± 1.51^a	1.00 ± 0.91^a
Vitamin B2. (mg/100ml)	401.62 ± 15.95^a	345.41 ± 19.78^b	350.81 ± 22.99^b
Vitamin C. (mg/100ml)	38.76 ± 3.37^a	48.20 ± 2.50^a	42.23 ± 9.94^a
Vitamin D.(mg/100ml)	6.48 ± 7.48^a	36.83 ± 31.98^b	8.81 ± 8.75^a
Vitamin E.(ug/g)	0.21 ± 0.33^a	0.21.±0.19^a	0.58 ± 0.51^a
Vitamin K. (ug/g)	5.73 ± 4.97^a	5.43 ± 4.75^a	3.09 ± 3.33^a

*Values are Means ± standard deviations of triplicate determinations. Values in the same row having the same superscript letters are not significantly different ($p < 0.05$).

Vitamin C content of the processed *Mucuna flagellipes* seed samples were 38.76mg/100ml, 48.20mg/100ml, and 42.23mg/100ml for fried, boiled, and roasted respectively. No significant difference ($P < 0.05$) was observed. This agrees with Vasudevan and Sreekumari, 2013 who reported that vitamin C is generally poor in seeds but rich in citrus, guava, and leafy vegetables. The poor level of vitamin C in diets causes scurvy in animals. Deficiency of vitamin C causes scurvy(Morrison et al,2018).Vitamin A is the precursor of rhodopsin, promotes growth and repair of body tissues; reduces susceptibility to infections (immune function); regulates gene expression (Adebayo,2013). Deficiency of vitamin A causes night blindness (Morrison et al, 2018).The riboflavin (Vitamin B_2) and thiamine (Vitamin B_1) contents of the processed seed samples were low compared to 4.24mg/100g and 2.75 mg/100 g of *Amaranthus hybridus* (Akubugwo et al., 2012). This is in line with literature that reports that grains are poor sources of these vitamins but green leafy vegetables, yeast, and milk are rich sources of vitamins (Mc Donald *et al.*, 2014). Riboflavin is necessary for growth and health while thiamine has antineuritic factor (Finar, 2014). Deficiency of riboflavin causes skin inflammation whereas deficiency of thiamine causes a type of paralysis called beriberi (Morrison et al, 2018). Vitamin D is the antirachitic vitamin essential for bone formation by regulation of calcium and phosphorus metabolism. However, vitamin D may be supplied in food or produced in the skin by irradiation of sterols (Finar, 2014). Vitamin E content of the processed seed samples were 0.21$\pm 0.33\%$, 0.21 $\pm$ 0.19%, and 0.58$\pm 0.51\%$ for fried, boiled, and roasted *Mucuna flagellipes* respectively. No significant difference ($P < 0.05$) was observed. Vitamin E protects the body tissue from damage caused by a substance called free radicals, which can harm cells, tissues, and organs (Etong et al, 2013). It serves mainly as a fat-soluble anti-oxidant. Vitamin E has anti-sterility factor. Vitamin K helps in blood clothing, a deficiency of it lengthens the time of blood clothing (Finar, 2014). Considering Table 3 and Fig. 3 above, the decreasing order of the mineral contents of the various seed samples is vitamin B_2 > vitamin C > vitamin D > vitamin K > vitamin A > vitamin B > vitamin E showing that the different seed samples has the highest content of vitamin B_2 (88.17%,78.67% and 85.72%)and lowest content of vitamin E(0.05%, 0.05% and 0.14%).

Mineral Composition

Table 4 shows the effects of different processing methods on the mineral composition of *Mucuna flagellipes* seed flour. The results obtained showed no significant difference ($p < 0.05$) between the processing methods on the mineral composition except the Iron content which significantly differed ($p < 0.05$).

Table 4
Mineral contents of *Mucuna flagellipes* Seeds as affected by frying, boiling, and roasting.

Parameters	Fried	Boiled	Roasted
Calcium (mg/100ml)	5.79 ± 5.03^{a}	8.08 ± 2.52^{a}	6.86 ± 2.18^{a}
Iron(mg/100ml)	4.75 ± 1.44^{b}	8.42 ± 4.89^{a}	9.61 ± 3.33^{a}
Phosphorus(ug/g)	3.06 ± 0.15^{a}	2.69 ± 0.08^{a}	2.88 ± 0.06^{a}
Potassium (mg/100ml)	0.30 ± 0.14^{a}	0.37 ± 0.03^{a}	0.30 ± 0.13^{a}
Sodium(ug/g)	119.48 ± 10.45^{a}	108.93 ± 7.58^{a}	102.20 ± 13.38^{a}
Magnesium(ug/g)	8.53 ± 0.13^{a}	7.12 ± 0.58^{a}	7.03 ± 6.18^{a}

*Values are Means ± standard deviations of triplicate determinations. Values in the same row having the same superscript letters are not significantly different ($p < 0.05$).

The Calcium contents of the processed seed samples as shown in Table 4 were 5.79 ± 5.03mg/100ml, 8.08 ± 2.52mg/100ml, and 6.86 ± 2.18mg/100ml for fried, boiled and roasted *Mucuna flagellipes* respectively, no significant difference was observed. The values were low compared to the values of (Obiakor *et al* 2014) for cooked and raw *Mucuna soneli*, Calcium accounts for about 75% of the weight of the mineral elements present in the body (Ogungbenle *et al* 2015). Calcium is the principal contributor to bone and teeth formation. It plays a universal role as a messenger and mediator for cardiac, skeletal and smooth muscle contractions. When there is a lack of calcium in the body, it results in osteoporosis (bone thinning), high blood pressure and colon cancer. The side effects of relative high doses of calcium are constipation, bloating and arrhythmia. Calcium ions interfere with the absorption of antibiotics. E.g. tetracycline and quinolone antibiotics can chelate Ca^{2+} ions to form complexes which cannot be absorbed anymore. Ca^{2+} is a component of limestone, cement, lime scale, fossils, insecticides, antacids, food additives, disinfectants, bleaching agents, deodorants, fungicides, supplement for animal feed, fertilizer, glass, and dental products (Strohfeldt, 2015). Iron is nutritionally important. Iron is present in protein based foods such as milk, egg white, meat, poultry and fish. It performs many vital functions in the human body. It is highly required for blood formation. Iron incorporated into hemoglobin in human body is the oxygen transport metalloprotein in the red blood cells; myoglobin facilitates the oxygen use and storage in muscles (Strohfeldt, 2015). The value of iron was 4.75± 1.44 mg/100ml, 8.42± 4.89 mg/100ml, and 9.61± 3.33Mg/100ml for fried, boiled, and roasted *Mucuna flagellipes* respectively. Fried *Mucuna flagellipes* differed significantly (P < 0.05) from boiled and roasted *Mucuna flagellipes*. This value of iron in the sample was lower than those of Spanish green olives (14.8 mg/kg) (Ogungbenle and Omaejalile 2015). Iron also facilitates the oxidation of carbohydrates, protein, and fats. Iron can be lost via gastrointestinal bleeding and menstruation bleeding in women. Lack of functional iron leads to anemia, which is characterized by lethargy and weakness (Strohfeldt, 2015). The sodium content of the processed seed samples were 119.48$\pm 10.45(ug/g)$, 108.93$\pm$7.58(ug/g), and 102.20$\pm$13.38(ug/g) for fried, boiled and roasted *Mucuna flagellipes* flour. No significant difference was observed. Foods that is rich in sodium contained in processed *Mucuna flagellipes* has the potential to maintain body fluid pH via osmoregulation, support nerve impulse transmission, muscular contraction in livestock and humans and is involved in the mode of action of several enzymes. (McDonald et al., 2014; Strohfeldt, 2015). Magnesium has the following values 8.53$\pm 0.13(ug/g)$, 7.12$\pm$0.58(ug/g), and 7.03$\pm$6.18(ug/g) for fried, boiled, and roasted Mucuna *flagellipes*. No significant difference was observed. The Magnesium content was low compared to 128-145mg/100g, 92.3mg/100g, 183mg/100g, and 55.6 mg/100 g reported for Nigerian cowpea, *M. obanensis*, and mung beans respectively (Mubarak, 2015). The sources of magnesium include green vegetables, whole grain, milk and nuts. ATP (Adenosine triphosphate) has to be coordinated to magnesium ion in human body so as to be biologically active. Mg2+ ions stabilizes DNA and RNA; it facilitates the process of photosynthesis in green plants by forming the redox active center in chlorophyll and also facilitate carbon fixation in green plants. Magnesium is being incorporated into bones, muscles and soft tissue. The kidney is the major excretory organ for magnesium ions and regulates magnesium ions in plasma. Hyper-magnesia results from retention of high levels of magnesium ions in plasma causing muscle weakness and arrhythmia. Hypo-magnesia known as low magnesium levels in the blood plasma is a consequence of excessive diarrhea; it is often followed by low calcium ions in plasma as wellas hypokalemia and hyponatremia. Magnesium ions are used in the preparation of $Mg(OH)_2$ used as antacids as well as given to patients suffering from indigestion, heartburns and peptic ulcers (Strohfeldt, 2015). The phosphorus contents of the processed seed samples were 3.06±0.15 ug/g, 2.69±0.08 ug/g and 2.88 ± 0.06ug/g for the fried, boiled and roasted *Mucuna flagellipes* seed samples respectively; no significant difference was observed. In human body, phosphorus in conjunction with calcium build up genetic materials as well as in the energy supply of cells and many biochemical process as phosphates such as ATP, ADP and AMP. Phosphate is a part of DNA backbone. Phosphorus containing compounds are mostly found in milk, meat, grains, dried fruits and carbonated soft drinks. Low level of phosphate in serum called hypophosphatemia is caused by starvation or alcoholism or drug interactions. Imbalance of phosphate ions lead to bone defects or cardiovascular problems due to hardening of soft tissues. Biphosphates can be used for the treatment of hypercalcemia and pain from metastatic bone cancer in patients with breast cancer (Strohfeldt, 2015). The potassium contents include 0.30±0.14mg/100ml, 0.37±0.03mg/100ml and 0.30±0.13mg/100ml for the fried, boiled and roasted *Mucuna flagellipes* seed samples; no significant difference was observed. Potassium ions are essential for the functioning of neurons by influencing the balance of osmosis between the cells and interstitial fluid. Hypokalemia is a severe health problem where a patient has low levels of potassium ions in the blood plasma which results to weakness of muscles or electrocardiogram abnormalities. Hypokalemia is caused by diarrhea and vomiting or increased excretion of potassium ions caused by diuresis or abusive use of laxatives. Potassium is excreted through the kidneys (Strohfeldt, 2015). The greatest amount of mineral contained in the seeds is sodium while the least amount of minerals present in the seeds is potassium. The amount of sodium is extremely high compared to other mineral contents. From nutritional point of view as shown in Fig. 4, one can say that *Mucuna flagellipes* is a valuable seed providing minerals such as sodium(84.19%,80.33%,79.30%), calcium(4.08%,5.96%,5.32%), iron(3.35%,6.21% and 7.46%), phosphorus(2.16%,1.98% and 2.23%), potassium(0.21%,0.27% and 0.23%) and magnesium(6.01%, 5.25% and 5.45%) Thus, from Table 4, it could be said that the amount of these mineral elements consumed on daily basis falls within the required daily intake, as a little quantity of the plant sample is used on daily basis either as food or drug.

Anti-Nutritional Components

Table 5 shows the effects of different processing methods on the anti-nutritional composition of *Mucuna flagellipes*. The results showed that Flavonoid, Alkaloid, and Cyanide showed a significant difference ($p < 0.05$) in the antinutritional content of the processed samples.

Table 5
Anti-nutritional contents of *Mucuna flagellipes* seeds produced by processing methods

Parameters	Fried	Boiled	Roasted
Tannin(μg/100g)	9.55 ± 0.62^a	7.25 ± 6.19^a	6.11 ± 6.42^a
Alkaloid (μg/100g)	311.67 ± 44.09^a	348.33 ± 31.14^b	417.78 ± 39.52^c
Cyanide (μg/100g)	65.73 ± 1.92^a	58.54 ± 3.57^a	58.82 ± 3.30^a
Saponin (μg/100g)	1.32 ± 0.06^a	1.26 ± 0.03^a	1.38 ± 0.02^a
Flavonoid(ug/100g)	74.48 ± 41.32^a	85.18 ± 64.44^a	149.80 ± 5.70^b
Terpenoid(μg/100g)	214.40 ± 42.41^a	179.22 ± 3.03^a	190.91 ± 6.57^a
Phytate(μg/100g)	3.06 ± 0.15^a	2.69 ± 0.08^a	2.88 ± 0.06^a
Oxalate(μg/100g)	0.02 ± 0.01^a	0.01 ± 0.00^a	0.01 ± 0.00^a

*Values are Means ± standard deviations of triplicate determinations. Values in the same row having the same superscript letters are not significantly different ($p < 0.05$).

Phytochemical is the term used to describe the large number of secondary metabolic compounds from plants (Adodo, 2012). Anti-nutrients are known to protect against insect attacks and plant diseases. The concentration of alkaloids in Table 5 was 311.67 ± 44.09ug/100g, 348.33 ± 31.14ug/100g, and 417.78 ug/100g for fried, boiled and roasted *Mucuna flagellipes* seed flour. A significant difference ($p < 0.05$) was observed between the processed samples. These values were higher than 1.28–1.64mg/100g reported in the phytochemical composition and nutritional quality of *Glycine max* and *Vigna unguiculata* (L) Walp (Okwu and Orji, 2007). Alkaloids are famous analgesics and have been utilized in a variety of ways in the treatment of diseases and during surgery due to their medicinal and pharmacological efficacy. Alkaloids could be used for the treatment of hypertension, pupil dilation and mental disorders (Bako and Jonah, 2016).The level of cyanide was high in both processed samples. The concentrations of cyanide were 55.50ug/100g, 58.54ug/100g, and 58.82 μg/100g in fried, boiled and roasted *Mucuna flagellipes* seed flour respectively which show no significant difference ($P < 0.05$). These were higher than the values obtained from the same seed 10.50 mg/100g and 25.32mg/100g respectively by (Okaka et al, 2016), which is considered unsafe and poisonous in extreme concentrations. The concentrations of tannins were 9.55μg/100g, 7.25 μg/100g, and 6.11μg/100g for fried, boiled and roasted *Mucuna flagellipes* seed flour respectively. The values of the tannin contents were higher than 57.10% in the ethnomedicinal and phytochemical profiles of some savannah plant species in Nigeria (Bako et al., 2005). Tannins are astringent, bitter plant polyphenols that either bind and precipitate or shrink proteins. The astringency from the tannins is what causes the dry and puckery feeling in the mouth following the consumption of red wine or an unripen fruit (Schiavone et al., 2014). Tannins have been reported to possess antibacterial properties (Parekh and Chanda, 2007). Oxalate in large amounts binds with calcium, magnesium, iron and zinc to form their respective metal oxalates, which is insoluble and not absorbed by the body (Agoreyo et al, 2012). They are therefore considered poisonous but harmless when present in small amounts as shown in Table 5. The amount of oxalate in the processed samples of *Mucuna flagellipes* seed is therefore not harmful, more so, when cooking has been reported to effect a significant reduction in total oxalate contents of seeds (Eka, 2014). Like oxalates, phytates chelates di- and trivalent metal ions like zinc, iron, magnesium, and calcium to form complex compounds that are not readily absorbed by the intestine, thereby making them unavailable for metabolism (Thompson, 2016). They are easily removed by cooking, frying, roasting, fermentation, and soaking (Igwenyi et al 2015). The level of phytates in the processed seed samples was 3.83± 0.73 μg/100g, 2.12± 0.10 μg/100g and 2.69± 0.05 μg/100g for fried boiled and roasted *Mucuna flagellipes* seed flour respectively. It is lower than 5.44 obtained by Nwaogu et al. (2015) for tropical almonds. The concentration of flavonoids in fried and boiled *Mucuna flagellipes* seed flour in Table 5 was significantly lower ($p<0.05$) than roasted *Mucuna flagellipes* seed flour. Flavonoids have been referred to as "nature's biological response modifiers" because of strong experimental evidence of their inherent ability to modify the body's reaction to allergens, viruses, and carcinogens. They show anti-allergic, anti-inflammatory, anti-microbial, and anti-cancer activity (Igwenyi and Azoro, 2014). The saponin contents of the fried, boiled, and roasted seeds of *Mucuna flagellipses* (1.32±0.06 ug/100g, 1.26±0.03 ug/100g and 1.38±0.02 ug/100g respectively) have no significant difference. Saponins and tannins are reported to exhibit cytoxic effects and tumor growth inhibition (Agoreyo et al 2012). Saponins has relationship with sex hormones like oxytocin and has expectorant action through the stimulation of a reflex of the upper digestive tract (Bako and Jonah, 2016). The terpenoid contents of the fried, boiled, and roasted seeds of *Mucuna flagellipes* were 214.40±42.41ug/100g, 179.22±3.03ug/100g and 190.91±6.57 ug/100g respectively which has no significant difference. Terpenoids exhibit strong antiseptic, antioxidant antibacterial, antifungal, and anti-inflammatory effects (Nzekwe and Nzekwe, 2019). Finally, the observed anti-nutritional factors in the seeds of the studied plant, symbolize that they are judiciously rich in anti-nutrients. From Fig. 5, the increasing order of the phytochemicals' concentrations present in the various *Mucuna flagellipses* seed samples are in the order oxalate(0.29%, 0.15% and 0.12%) < phytate (0.45%,0.39% and 0.35%) < tannins(1.40%, 1.06% and 0.74%)< cyanide(9.66%, 8.58% and 7.11%) < flavonoids(10.95%, 12.48% and 18.10%) < terpenoids (31.52%,26.26% and 23.07%) < alkaloids(45.82%, 51.04% and 50.48%) indicating that the various seed samples contain highest concentration of alkaloids and lowest concentration of oxalate.

Conclusion

There is a need for readily available, high-quality alternative vegetable protein, and energy sources legume seeds that are inexpensive and capable of reducing production costs of meat and other animal products. The present study showed that some under-utilized tropical legumes, such as *Mucuna flagellipes* (Ukpo), possessed a high quantity of nutritive and anti-nutritive content. The high iodine and saponification values, as well as the low iodine values of the oil samples extracted from the seed, suggest that it could be used in the manufacture of soaps and easily digestible margarine, creams, and salad oils. The oil is semi-drying due to its moderately high iodine value and thus can be used in the manufacture of surface coating agents. The low level of anti-nutrients makes the seed flour of *Mucuna flagellipes* nutritionally valuable. The results show that *Mucuna flagellipes* is a good source of carbohydrate, protein, essential minerals, and vitamins and contain good quality and little quantity of oil for domestic and industrial uses. With a few exceptions, the results of the experiments presented here show that the subjection of *Mucuna flagellipes* seeds, before oil extraction, to different processing methods (frying, boiling, and roasting) caused no significant loss or change in the content of proximate, mineral, vitamin, anti-nutrients, and physicochemical properties.

Abbreviations

Mucuna flagellipes seed
a brownish or black oval shaped seed
Ukpo
local igbo name of *Mucuna flagellipes*
AOAC
Association of Official Analytical Chemists
ANOVA
analysis of variance

$p < 0.05$
significance difference of a series is less than 0.05
DMRT
Duncan's Multiple Range Test

Declarations

Availability of data and materials

All the data generated in the work are included as tables and figures.

Code availability

Not applicable.

Ethics approval

Not applicable.

Consent to participate

Not applicable.

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Consent for publication

All the authors agreed to submit the manuscript for possible publication.

Conflict Of Interest

The authors declare that there is no conflict of interest whatsoever regarding this manuscript.

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Figures

Figure 1

seeds of *Mucuna flagellipes*

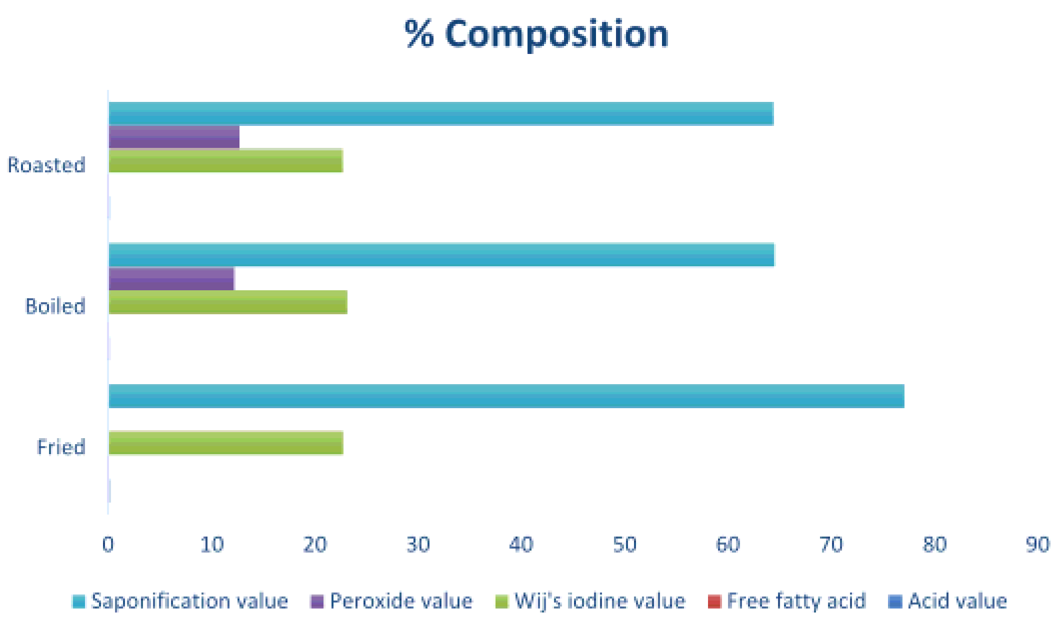

Figure 2

Multiple bar chart showing the chemical characterization of the oil from the processed *Mucuna flagellipes* seeds

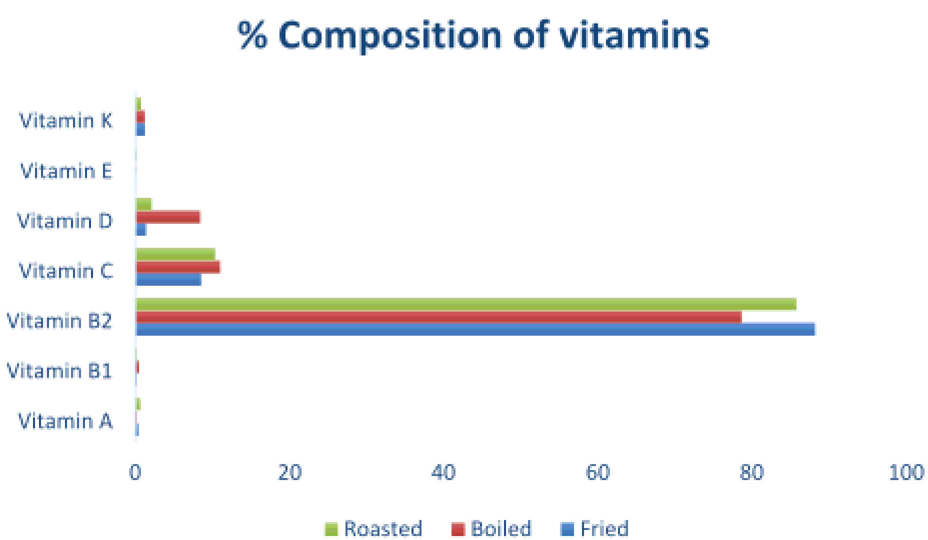

Figure 3

Multiple bar chart showing the presence of different vitamins in the processed seeds of *Mucuna flagellipes*

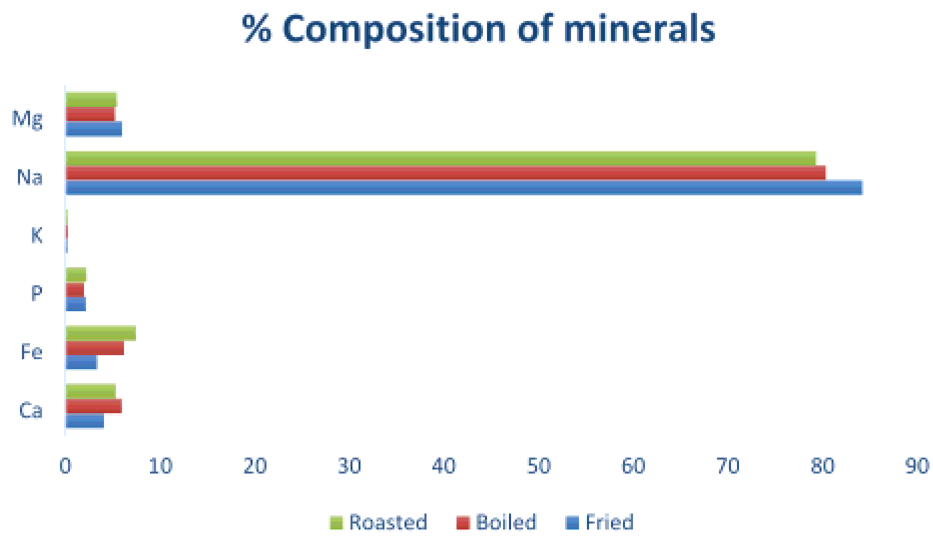

Figure 4

Multiple bar chart showing the minerals present in *Mucuna flagellipes* processed seeds

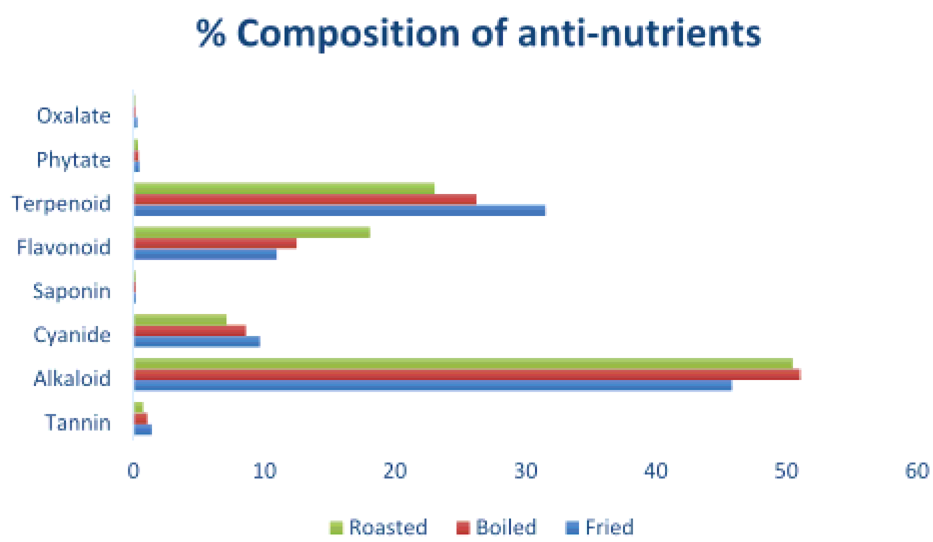

Figure 5

Multiple bar chart representing the various anti-nutrients/phytochemicals present in the processed seeds of *Mucuna flagellipes*