integrity Research Journals

Research Journal of Food Science and Nutrition
Volume 5(1), pages 16-29, February 2020
Article Number: 0AD232503
ISSN: 2536-7080
https://doi.org/10.31248/RJFSN2019.079
https://integrityresjournals.org/journal/RJFSN

Full Length Research

Proximate composition, functional properties and oil characterization of 'Kpaakpa' (*Hildegardia barteri*) seed

Ibeabuchi, J. C.*, Bede N. E., Kabuo, N. O., Uzukwu, A. E., Eluchie C. N., Ofoedu, C. E.

Department of Food Science and Technology, Federal University of Technology, PMB 1526 Owerri, Nigeria.

*Corresponding author. Email: julianchidi2@gmail.com

Received 13th September, 2019; Accepted 17th February, 2020

ABSTRACT: Evaluation of proximate compositions, functional properties and oil characterization of 'kpaakpa' (*Hildegardia barteri*) seed was studied. Defatted and undefatted 'kpaakpa' (*Hildegardia barteri*) seed flours were produced. The proximate and functional properties were determined on both the defatted and undefatted flours. The crude 'kpaakpa' seed oil was extracted (using hexane solvent) and characterized. The result of proximate analysis showed the moisture content, ash, fat, crude fibre, protein and carbohydrate contents to be 11.18, 5.6, 37.92, 6.45 31.53 and 7.37% respectively for undefatted flour and 18.6, 6.8, 4.37, 1.99, 26.52 and 41.72% respectively of the defatted flour sample. The results of functional properties did not show a consistent behavior for all the parameters analyzed for both defatted and undefatted 'kpaakpa' seed. However, it showed that defatting operation increased most of the functional properties except for bulk density and wettability which increased in undefatted 'kpaakpa' seed flour. The results obtained for the oil characterization of the extracted crude 'kpaakpa' seed oil showed 0.86 g/g for specific gravity, 0.87g/ml for density, 8.84 mgKOH/g for peroxide value, 55.36% for unsaponifiable matter, 56.48% for iodine value, 0.30% for free fatty acid (FFA) and 0.59% for acid value. The results obtained in this study indicate that both the defatted and undefatted 'kpaakpa' seed flour can be utilized in food system because they are good sources of protein, can be used to substitute or supplement flours with low protein in food production and can as well be useful sources of low-fat fabricated foods as well as animal feeds. The oil however can be utilized commercially for production of vegetable oil.

Keywords: Flour, functional properties, *Hildegardia barteri,* oil, proximate composition.

INTRODUCTION

Hildegardia barteri known as "kpaakpa" in Igbo, "kariya" in Hausa and "Okurugbedu" in Yoruba is an ornamental tree in West Africa, grown for its bright beautiful flowers, which blossom during dry season. The flowers, which are usually borne on leafless branches, mature into one-seeded pods (Hildergadia notes, 2009), each about 50 mm in length, bearing a peanut-like shell in a nut shell. The matured pods drop completely when dry and are usually disposed as refuse in many places, only in few parts of West Africa that the kernels are eaten raw, or roasted as peanuts (Inglett et al., 1973) or used as condiments in traditional food preparations.

Traditional diets in West Africa often lack variety and consist of large quantities of the staple food (cassava, yam, maize) with supplements of plantain, cocoayam, rice and beans depending on availability and season (Achi, 1999). The staple foods provide the calories but are poor in other nutrients. Moreover, soups are the main sources of proteins and minerals and one of the ways to improve the diet have been to improve the nutrient content of soups (Achi, 2005).

Seeds of *H. barteri* may account for up to 30% of dietary protein and may serve as the only source of protein for some groups like those in the rural areas and some others who may not always afford animal protein. With high content of protein, legume condiments can serve as a tasty complement to sauces and soups and can substitute for fish or meat (Achi, 2005).

The current surge in the search for nutritious plant foods is on the increasing rate, soy protein has however been

the main oilseed protein commonly used as a functional ingredient in foods (Adebayo et al., 2013). In view of the urgent need for alternative protein sources in the poor countries of the world, screening efforts for novel sources of concentrated proteins and the development of appropriate technologies to optimize their utilization have become necessary (Onwusu-Ansah and McMurcy, 1991; Apata and Ologholo, 1994; Ezeagu and Gowda, 2006). In this regard, exploitation of some wild legumes and oilseeds has proven to be viable alternatives for expanding protein sources. Also, due to animal protein sources often containing large amounts of saturated fat and cholesterol, most health organizations recommend the frequent consumption of vegetable protein, since it is known that it may reduce serum cholesterol levels, the risk of coronary heart diseases and diabetes (Martínez-Villaluenga et al., 2006). The ultimate has not been achieved as several plants exist with very high nutritive value, which may help in increasing the nutritional value of food products at low cost and yet remain unexploited for human and animal benefits (Oladele and Oshodi, 2007). 'kpaakpa' (*H. barteri*) seeds belong to this group of unexploited food materials and tis is evidenced by the lack of literature available on the subject.

Current trend in nutrition is the consumption of functional foods (foods that not only supply basic nutrients but also help to prevent certain diseases) due to different health related problems associated with wheat flour consumption. These problems include celiac disease, diabetes and coronary heart disease (WHO/FAO, 2003). This situation has created the need for the consumption of low-carbohydrate diets, slowly digested starchy foods as well as an increased intake of functional foods (Hursh and Martins, 2005). Many plants usually in the form of protein extracts, fibre extract or seed flours are being investigated and tested for new products such as low cost fabricated foods with high nutritional value, attractive and acceptable to consumers.

According to Ibironke and Fawale (2015), *H. barteri* contains essential and non-essential amino acid, saturated and unsaturated fatty acid, micronutrients, and completes amino acid profile which is suitable to supplement diets for human development. Nutritional studies have confirmed that *H. barteri* is a plant from polypeptide origin that is underutilized (Ibironke and Fawale, 2015).

Hence, the development of new proteins from such unpopular species requires a pool of information regarding their functional, nutritional and other properties for optimal utilization and consumer acceptance (Alobo, 2004). It is in view of this that this research was designed to evaluate the nutritional compositions and functional properties of raw and defatted 'kpaakpa' (*H. barteri*) seed flours in order to provide useful information for its possible exploitation in food system.

H. barteri seeds have been underutilized in Nigeria. Amongst the southeast region of Nigeria where the seeds are found, only a few parts such as Ebonyi State partly explore it in producing local condiments for cooking soup. In other part where these seeds are found, the seeds are usually disposed as refuse when they mature and fall down. The problem associated with its usage in food industries is unknown. There is little knowledge about its nutrient composition, functional properties and fatty acid composition as an oil seed; thus, the need to properly explore this seed for appropriate product utilization.

Also, the high level of energy protein malnutrition going on in developing countries of the world due to the limited availability of animal protein, there is need to exploit this seed as a rich source of plant protein. Value can be added to the seed of *H. barteri* by incorporating it in food systems for human consumption as protein supplement, as well as extracting the oil commercially for use as vegetable oil instead of just disposing them as refuse. These will help to reduce malnutrition, increase its use for vegetable oil production and also reduce the cost of animal feed. Thus, improve food security in Nigeria.

This work is designed to evaluate the functional properties, proximate properties and characterize the extracted oil of the sample of defatted and undefatted flours of *H. barteri*. The information obtained from this research will help improve the utilization of *H. barteri* seeds in food industries, and also impact knowledge on the nutritional and functional properties of 'kpaakpa' seed, and the composition of 'kpaakpa' seed oil.

MATERIALS AND METHOD

Material collection

The matured seeds of *Hildegardia barteri* used for this research work were collected at Paul University Awka, located along old road by Ukwu Orji bus stop Awka, Anambra State, Nigeria.

Material Preparation

The dried pods of the seed were removed and sorted to separate the bad seeds from the good seeds. The selected seeds were weighed using a weighing scale prior to the dehulling process. Afterwards, the weighed seeds were manually dehulled using a wooden pestle to carefully break the hard shell carefully without crushing the kernels. Then the husks were separated from the kernels, and defective kernels were sorted prior to the milling process.

Production process for undeffated 'Kpaakpa' seed flour

Undefatted 'kpaakpa' seed flour was produced using the procedure described by Emelike et al. (2015). The dehulled seeds were weighed and milled in batches using a heavy waring electronic blender to reduce the particle size and increase the surface area prior to analysis, and also for extraction purposes. The process flow chart for the

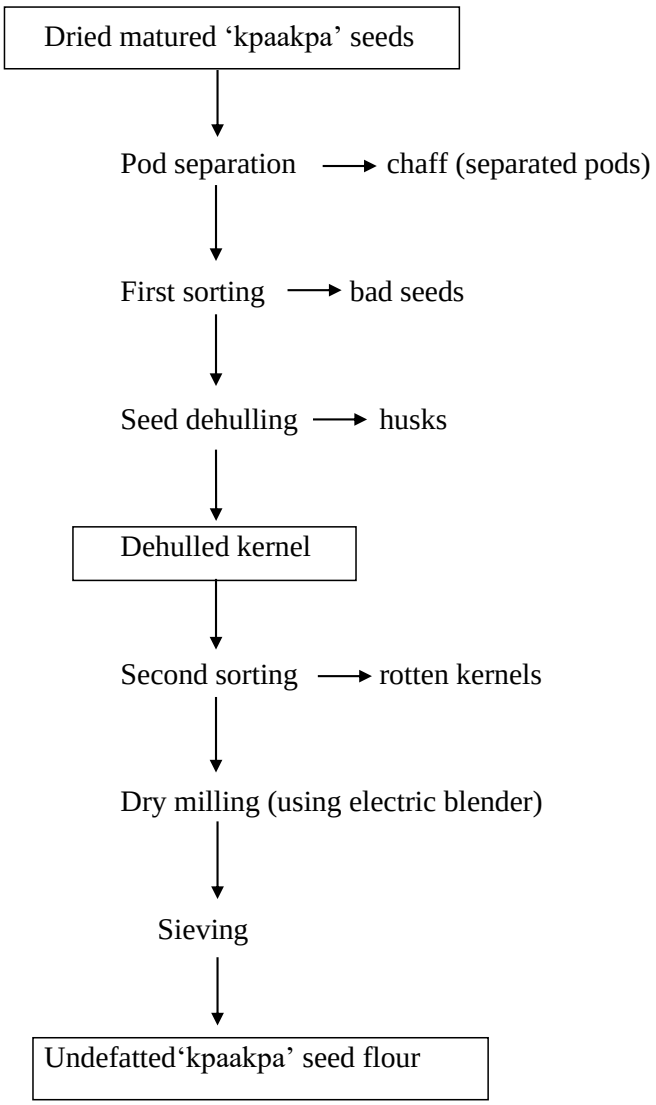

Figure 1. Flow diagram for production of undefatted 'kpaakpa' seed flour.

production of undefatted 'kpaakpa' seed flour is presented in Figure 1.

Production of defatted flour and oil extraction

The defatted flour sample was prepared using the method of Gbadamosi et al. (2012). Some portion of the undefatted 'kpaakpa' seed flour was weighed and wrapped in a white handkerchief and soaked using n-hexane solvent for up to five days, with continuous washing and changing of solvent at interval, until a clear liquid was obtained. The process was repeated for three times using the same quantity. At the end of the extraction process, the collected mixture of the oil and solvent (called miscella) was separated using the soxhlet apparatus. The extracted crude oil was then dried free of solvent in an air oven. And the defatted flour was spread on a tray and dried at about 28ºC to strip off the residual hexane. The oil and the defatted flour were then used for analysis. The process flow diagram for the oil extraction and production of defatted 'kpaakpa' seed flour is presented in Figure 2.

Proximate analyses on defatted and undefatted 'kpaakpa' seed flours

The proximate analysis of each flour samples (of defatted and undefatted ''kpaakpa'' seed) was carried out using standard methods of AOAC (2005).

Determination of moisture content

Five grams (5 g) of the defatted and undefatted 'kpaakpa' seed flours each were weighed in duplicate using an electronic balance into dried, cooled and weighed dishes. The samples in the dishes were then placed into a moisture extraction oven set at 105ºC for 30 minutes, after which the samples were transferred into desiccators and allowed to cool down. The samples were then weighed and recorded accordingly. The process was repeated for each sample until a constant weight was obtained. The percentage moisture content for each sample was calculated as stated below:

$$\% \text{ Moisture} = \frac{W_2 - W_1}{W_2 - W_3} \times \frac{100}{1} \quad (1)$$

Where: W_1 = Initial weight of the empty dish, W_2 = weight of dish + sample before drying and W_3 = weight of dish + sample after drying.

Determination of ash content

Five grams (5 g) of each of the defatted and undefatted flour samples were weighed in duplicate into a dry and weighed porcelain crucible. These were then charred over a Bunsen flame before igniting in the muffle furnace at 600ºC for 6 hours, until samples were completely ashed and whitish in colour. This was followed by cooling in desiccators for one hour and reweighing the crucible with the ash. The percentage loss of weight during combustion was calculated as stated below:

$$\% \text{ Ash content} = \frac{\text{weight of ash}}{\text{weight of sample}} \times \frac{100}{1} \quad (2)$$

Determination of crude fibre content

Five grams (5 g) each of defatted and undefatted 'kpaakpa' seed meal was weighed in duplicate into separate beakers, 100 ml of sulphuric acid solution was added and heated on a hot plate at 70 to 90ºC for 30 minutes. The resultant solutions were filtered and their residues were

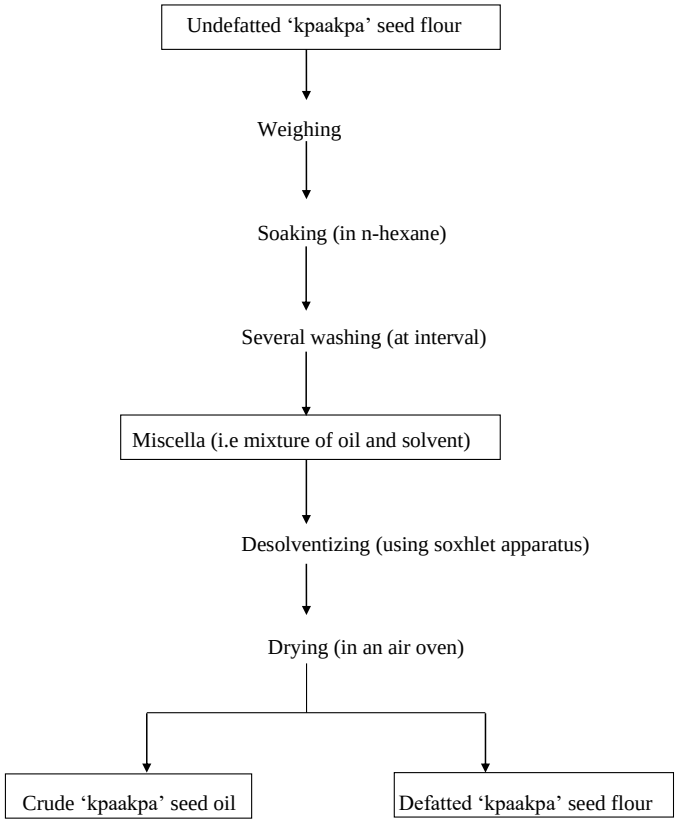

Figure 2. Flow diagram for the production of crude 'kpaakpa' seed oil and defatted 'kpaakpa' seed flour.

washed back into their respective beakers. Also, 100 ml of sodium hydroxide solution was introduced into the residues and were heated on a hot plate at 90 to 100ºC for 30 minutes. Afterwards, the solutions were filtered again and their residues thoroughly washed with hot distilled water and ethanol. The residues were transferred into porcelain crucibles and dried at 120ºC to a constant weight. The dried samples were ashed at 550ºC in the muffle furnace and cooled in desiccators and the samples were reweighed. Percentage fibre content was calculated using the following expression:

$$\%\ \text{Crude fibre content} = \frac{W_{n1} - W_2}{W_0} \times \frac{100}{1} \qquad (3)$$

Where: W_0 = Initial weight of sample, W_1 = weight of oven dried sample and W_2 = weight of ash

Determination of fat content

Five grams (5 g) each of the defatted and undefatted samples of 'kpaakpa' seed meal was weighed in duplicate into a pre-weighed filter papers separately, the filter papers were folded, carefully tied and put into the thimble which was fitted to round bottom flask that has been cleaned, dried and pre-weighed. This was then set up on the soxhlet extraction apparatus individually. The flask contained some quantity of hexane was added to it. Fat was extracted from each of the weighed samples separately and continuously for about three hours, with the solvent condensing at five to six drops per second in the soxhlet extraction unit until extraction was complete. The solvent was distilled off and the extraction flasks containing the fat were allowed to dry further for any residual solvent to be removed. The flasks were reweighed and the values recorded for each flask. The percentage fat was calculated as stated below:

$$\%\ \text{Fat content} = \frac{\text{weight of extracted fat}}{\text{weight of sample}} \times \frac{100}{1} \qquad (4)$$

Determination of crude protein

The crude protein was determined by Micro kjeldahl method according to standard procedure (AOAC, 2005). The analysis was carried out in duplicate. Few boiling regulators (bead) were placed in the Kjeldahl flask, followed by the addition of 3 g of sodium sulphate and copper sulphate ($NaSO_4$:$CuSO_4$) prepared in the ratio of 10:1. Then 2 mg of the sample was weighed out on a grease-proof paper, wrapped and transferred to the kjeldahl flask, followed by the addition of 25 ml sulphuric acid and mixed by gentle swirling. The kjeldahl flask was placed on the heating device of kjeldahl apparatus at an angle of 40 degrees from the vertical in a fume hood and heated gently until foaming had ceased. The content in the kjeldahl flask was digested by boiling vigorously until the solution was clear and a light blue-green colour obtained, cooled to room temperature, diluted with 50 ml of deionized water, transferred to 100 ml volumetric flask and made up to the mark with deionized water. After the digestion, 20 ml of 2% acid solution and 2 drops of methyl red indicator were placed in the receiving flask under the condenser of the distillation apparatus so that the outlet of the adopter of the delivering tube extended below the surface of the boric acid solution. Then 10 ml of the digest was transferred to the distillation flask followed by the addition of 35 ml of 40% sodium hydroxide and the flask attached immediately to the splash head of the distillation apparatus. The mixture was distilled until 30 ml of the distillate was collected and the conical flask lowered before the distillate collected was terminated. The distillate collected was titrated against 0.1N HCl and the titre value recorded. The blank experiment was set up with all the material in the procedure except the sample, and the titre value was also recorded. The digestion, distillation and titration were carried out on each of the defatted and undefatted 'kpaakpa' seed flour samples, and the titre values were also recorded. The percentage crude protein was calculated as stated below:

$$\%\ \text{Crude protein} = \frac{V_2 - V_1 \times N \times 14 \times 6.25}{W} \qquad (5)$$

Where: V_2 = Volume (ml) of the hydrochloric acid solution required for the sample test, V_1 = Volume (ml) of the hydrochloric acid solution required for the blank test, W = weight (g) of the test sample and N = normality of the acid (HCL).

Determination of carbohydrate content

The carbohydrate content of defatted and undefatted 'kpaakpa' seed flours were calculated by "difference". That is deducting the sum of the values obtained from the percentage moisture content, percentage ash content, percentage crude fibre content, percentage fat content and percentage protein content from 100, as stated in Eqn 6:

% Carbohydrate = 100 – (% moisture content + % fat content + % protein content + % fibre content + % ash content) (6)

Functional properties of defatted and undefatted 'kpaakpa' seed meal.

Bulk density determination

The method as described by Ann et al. (2016) was adopted in determining the bulk density. A 10ml graduated cylinder was gently filled to mark with 'kpaakpa' seed meal. The filled cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level after filling to the 10 ml mark. The procedure was adopted for each duplicate sample of both the defatted and undefatted 'kpaakpa' seed meal, and the bulk density was calculated as stated below:

$$\text{Bulk density } (\frac{\text{g}}{\text{ml}}) = \frac{\text{weight of sample}}{\text{volume of sample after tapping}} \quad (7)$$

Ph determination

This was determined according to Udensi and Onuora (1992). Two grams (2 g) of sample dispersed in 10 ml of distilled water. The suspension was mixed thoroughly in a warring micro-blender. After which the pH was measured using a good pH meter and the reading was recorded.

Wettability

The AOAC (2006) method was used to determine the wettability of the defatted and undefatted 'kpaakpa' seed flour samples. The samples were weighed and, in each case, one gram (1 g) was introduced in 25 ml graduated measuring cylinder with a diameter of 1 cm and a finger was placed over the open end of the cylinder. The mixture was inverted and clamped at a height of 10 cm from the surface of a 600 ml beaker containing 500 ml of distilled water. The finger was removed to allow the test sample to be dumped. The wettability was recorded as the time taken for the sample to become completely wet.

Gelation temperature and boiling point temperature

This was determined according to the method of Nwosu et al. (1982). Five grams (5 g) of the samples were weighed into a separate 250 ml Pyrex beaker for each of the 'kpaakpa' seed flour samples containing 50 ml of distilled water to form suspension. A thermometer was clamped on a retort stand with its bulb submerged in the suspension with a magnetic stirrer, and the system was heated. The heating and stirring continued until the suspension began to gel; the corresponding temperature of the samples was recorded as the gelation temperature. Then the temperature at boiling point was also recorded.

Foam capacity and foam stability

Foam capacity and stability of the defatted and undefatted 'kpaakpa' seed flour samples were determined according to the AOAC (2006) method. Two grams (2 g) of the samples were weighed for each of the samples and blended with 100 ml of distilled water using warring blender and the suspension was whipped at 1600 rpm (revolution per minutes) for 5 minutes. The mixture was then poured into a 100 ml of measuring cylinder and its volume was recorded after 30 seconds. Foam capacity is expressed as percent increase in volume and is calculated thus:

$$\text{Foam capacity} = \frac{V_1 - V_0}{V_0} \times \frac{100}{1} \quad (8)$$

Where: V_0 = Volume before whipping and V_1 = Volume after whipping.

Duplicate measures were taken for each sample and mean value recorded. The foam stability of the samples was recorded at 15, 30, 60, 120 seconds after whipping to determine the foam stability. Eqn 9 was used to calculate the foam stability:

$$\text{Foam stability} = \frac{\text{foam volume after timing}}{\text{initial foam volume}} \times \frac{100}{1} \quad (9)$$

Water absorption capacity (WAC)

The method as described by Abbey and Ibeh (1988) was adopted for determination of water absorption capacity. One gram (1 g) of each flour sample was weighed separately (and also together with a clean, dry centrifuge tube, into which it was placed). Distilled water was mixed with the flour to make up to 10 ml of dispersion. It was then centrifuged at 3500 rpm for 15 minutes. The supernatant was discarded and the tube with its contents reweighed as

gram water absorbed per gram of sample. The gain in mass was the water absorption capacity of the flour sample.

Determination of oil absorption capacity

The AOAC (2006) method was used to determine the oil absorption capacity. One gram (1 g) of each of the flour sample was weighed into a conical graduated flask and 10 ml of oil was added to the weighed sample. A warring whirl was used to mix the sample for 30 seconds. The sample was allowed to stand at room temperature for 30 minutes and then transferred to a graduated centrifuge tube and centrifuged at 5000 rpm for 30 minutes. Afterwards, the mixed sample was transferred from the graduated centrifuge tube into a 10 ml measuring cylinder and the volume of the freed oil was noted. The absorption capacity was expressed as grams of oil absorbed per gram of sample. The density of the oil was determined to be 0.926 g/ml.

Determination of swelling index

The swelling indices of the flour samples were determined as done by Ukpabi and Ndimele (1990). Three grams (3 g) of each flour sample were transferred into clean, dry graduated (50 ml) cylinders. The flour samples were gently leveled into it and the volumes noted. Then 30 ml of distilled water was added to each sample, the cylinder was swirled and allowed to stand for 60 minutes while the change in volume (swelling) was recorded every 15 minutes. The swelling power of each sample was calculated as a multiple of the original volume.

Determination of viscosity

The method of Onwuka (2005) was adopted in determination of viscosity of the flour samples. Ten percent (10%) of the flour was suspended in distilled water and mechanically stirred for 2 hours at room temperature. Thereafter, the viscosities of the samples were measured using Oswald type viscometer.

Determination of solubility

The cold extraction method, as described by Udensi and Onuora (1992) was adopted. Flour dispersion (10% w/v, db) was prepared with each of the flour samples by dispersing 1 g (dry bases) of flour in 5 ml distilled water and making it up to 10 ml. It was left for 1 hour while it was stirred every 10 minutes. Then it was allowed standing for the next 15 minutes to settle. Afterwards, 2 ml of the supernatant were weighed in a dry Petri dish, evaporated to dryness and reweighed. The difference in mass is the total soluble solids. The solubility was calculated as follows:

$$\text{Solubility TSS } (\%) = \frac{(V_s M_e - M_d)}{2M_s} \times \frac{100}{1} \quad (10)$$

Where: V_s = total supernatant/ filtrate, M_d = mass of empty, dry petri dish, M_e = mass of petri dish + residual solid after evaporative drying and M_s = mass of flour sample used in the preparation of the dispersion.

Analysis of crude 'kpaakpa' seed oil

Determination of acid value or free fatty acid (FFA)

Method of Onwuka (2018) was adopted in determination of FFA and acid value. Ten grams (10 g) of the extracted crude 'kpaakpa' seed oil sample was weighed into a pre-weighed conical flask and the oil was dissolved with 25 ml petroleum ether and 25 ml ethanol. The solution was slightly heated and shaken to dissolve properly. It was then titrated with 0.1N sodium hydroxide while warm until a permanent slight pink colour was obtained and persists for some minutes. The titre volume difference of the 0.1N sodium hydroxide used was noted. This is calculated as follows:

$$\text{FFA} = \frac{\text{Titre value (ml)} \times 2.82}{\text{Weight of sample used}} \quad (11)$$

$$\text{Acid Value} = \frac{titre\ value\ (ml) \times 5.61}{weight\ of\ sample\ used} \quad (12)$$

Determination of iodine value

The Wiji's method as described Onwuka (2018) was adopted in determining the iodine value. One gram (or less) (0.65 g) of the extracted crude 'kpaakpa' seed oil (CKSO) sample was weighed into a glass bottle with round neck and stopper. This was dissolved in 10 ml of carbon tetrachloride. The glass was wrapped with carbon paper to avoid sunlight, 20 ml of wiji's solution was added and the bottle was sealed effectively by moistening the stopper with minimum quantity of 10% potassium iodide solution. It was allowed to stand for 30 minutes at a temperature of 15 to 20ºC (by immersing in ice container) in a dark place. Afterward, 15 ml of 10% potassium iodide and 100 ml of water were added and mixed by swirling. Free iodide in the solution was titrated with standardized sodium thiosulphate solution, when it became pale yellow, starch indicator was added and the titration continued until the colour changed from blue to colourless. The titre value was recorded. A blank determination was done at the same time with same quantities of reagent but without the sample. The iodine value was calculated as stated below:

$$\text{Iodine value} = \frac{(X - Y) \times I \times 100}{W} \quad (13)$$

Where: X = volume in ml of 0.1N thiosulphate solution required for the blank, Y = volume in ml of 0.1N thiosulphate

solution required for the test sample, W = weight (g) of sample and I = weight (g) of iodine, equivalent to 1 ml of the thiosulphate solution.

Determination of unsaponifiable matter

The unsaponifiable matter of the oil sample was determined using the AOAC (2005) method. A mass of 1.2 g of the crude 'kpaakpa' seed oil sample was weighed into a pre-weighed 250 ml flask and 12.5 ml of 0.4445N alcoholic potassium hydroxide KOH added from a burette. An air condenser was attached to the flask and heated on a boiling water bath for 1 hour with frequent swirling at intervals. After, the flask was transferred to 250 ml water and added to the solution in the funnel. Then 50 ml diethyl ether was used to rinse the flask and that was poured into the separating funnel, stoppered and swirled gently while still warm to avoid emulsion. The separating funnel was allowed to stand until the two layers of liquid separated and clarified. The aqueous alcoholic layer was drawn off into the flask and used for saponification and the ethereal layer remaining was poured into the second 250 ml separating funnel containing 10 ml of water. The aqueous alcoholic soap solution was extracted twice with 25 ml of petroleum ether and added to the extract in the second funnel. The separating funnel was rotated gently and kept for the extract to separate. The water layer was run off. The ethereal layer was washed twice with 20 ml of water and shaken vigorously on each occasion. The washing continued with 10 ml of 0.5N aqueous potassium hydroxide (KOH) and 10 ml of water alternately for three times. Thereafter, washing continued with water until the wash water no longer turned pink on addition of phenolphthalein indicator. The ethereal solution was then transferred to a weighed flask and evaporated to small volume with about 2 to 3 ml solvent remaining. About 2 to 3 ml acetone were added to the flask and then immersed almost entirely in a boiling water bath. It was held obliquely and rotated during that operation in order to remove the solvents in the shortest possible time under the mildest conditions. The flask and contents were dried to constant mass in an oven maintained at 80ºC. The contents were dissolved in 10 ml of 95% ethanol and titrated with 0.1N alcoholic sodium hydroxide solution using phenolphthalein indicator. The unsaponifiable matter was calculated from the expression:

$$\text{Unsaponifiable matter, \% by mass} = \frac{100 \times W_1}{W} \quad (14)$$

Where: W_1 = mass in grams of residue and W = mass in grams of sample taken

Determination of peroxide value

The peroxide vale was determined with the method described by Onwuka (2018). Less than one gram (0.86 g) of crude 'kpaakpa' seed oil sample was weighed into a clean dry boiling tube, then 1 g of powdered potassium iodide and 20 ml of solvent mixture (2 volumes glacial acetic acid + 1 volume chloroform) were added. The mixture was placed to boiling water so that the liquid boils for 30 seconds and allowed to boil vigorously for not more than 30 seconds. The contents were quickly poured into a flask containing 20 ml of 5% potassium iodide solution. The tube was twice washed with 25 ml water and titrated with 0.002M sodium thiosulphate ($Na_2S_2O_3$) solution using starch as indicator. A blank experiment was performed at the same time. The peroxide value was calculated with the expression:

$$\text{Peroxide value} = \frac{800 \times V_b \times N_b}{M} \quad (15)$$

Where: V_b = Volume of NaS_2O_3 solution used in ml of sample – the volume for blank (or titre value – titre value for blank), N_b = normal (molarity) of NaS_2O_3 solution and M = mass of oil sample in gram.

Determination of specific gravity and density

The method of Onwuka (2018) was adopted in determining the specific gravity and the density of the 'kpaakpa' seed oil. A 50 ml pycnometer bottle was thoroughly washed with detergent, water and petroleum ether, it was then dried and weighed. Afterwards, the bottle was filled with water and weighed. The water was discharged after weighing and the bottle dried. After drying, the bottle was filled with the sample of crude 'kpaakpa' seed oil and weighed. The specific gravity and density of the oil were calculated as stated below:

$$\text{Specific gravity} = \frac{\text{Weight of Xml of oil}}{\text{weight of Xml of water}} \quad (16)$$

$$\text{Density} = \frac{\text{Weight of oil}}{\text{Volume of oil}} \quad (17)$$

Statistical analysis

Analysis of variance (ANOVA) was used to ascertain the significant difference between means. Least significant different (LSD) was used to determine if there was significant difference between the means. Significance was accepted at $p<0.05$.

RESULTS AND DISCUSSION

Proximate composition of defatted and undefatted 'kpaakpa' seed flours

The proximate composition of defatted and undefatted 'kpaakpa' seed flours is presented in Table 1 and discussed as follows.

Moisture content

The moisture contents of 'kpaakpa' seed flours showed a significant different ($p<0.05$). The moisture content of undefatted was 11.18%, and that of the defatted was 18.8%. The values obtained are significantly higher than the values (8.8% and 7.17%) reported earlier by Inglett et al. (1973) and Josephat et al. (2017) respectively. The variations in the results could be due to moisture absorption during storage. The moisture content was not desirable and this could be the leading cause of the low shelf stability experienced during this research study, especially for the defatted flour sample which was more susceptible to change in the physical appearance and mold growth.

Protein content

The protein content of the 'kpaakpa' seed flour samples were obtained to be 31.53% for the undefatted and 26.52% for the defatted sample. There was significant difference ($p<0.05$) in the protein content of the flour samples. Upon defatting, the protein content of the defatted flour reduced. The result obtained for undefatted sample is within the range of protein content of soybean (35.1%), melon seed (33.3%) reported by Achinewhu (1983). The result for defatted sample in this study compared favourably with 25.3% for groundnut (Gopalan et al., 2007), for roasted and defatted cashew nut flour (27.31%) reported by Omosuli et al. (2009), and for cashew nut flour (25.3%) reported by Aremu et al. (2006). This result however is significantly higher than the value reported by Inglett et al. (1973) for full fat 'kpaakpa' seed flour (33.2%), and the value obtained by Adebayo et al. (2013) which was 39.20% for defatted flour sample. The variation could be as a result of the processing methods applied which might have reduced the protein content of the raw material. The value obtained for undefatted compares favourably with the value obtained by Adebayo et al. (2013). The recommended daily allowance of protein for children ranges from 23.0 to 36.0 g and 44 to 50 g for adults (NRC, 1989). Thus, it can be evaluated that both the defatted and undefatted 'kpaakpa' seed flours are good sources of protein substitute for enrichment since it can supply the recommended daily intake of protein for children, and can as well be used to fortify cereals and tuber flours which are very low in protein.

Ash content

Ash content of the defatted sample (6.8%) was significantly different ($p<0.05$) compared to the undefatted flour (5.6%). The values obtained in this study are within the range of those reported by Adebayo et al. (2013) for defatted flour (6.72%) and undefatted flour (4.40%). The ash content is an indication of the level of inorganic mineral elements in the sample and high mineral element in food enhances growth and development and also catalyzes metabolic processes in human body (Oyekunle and Omode, 2008). This suggest that the flour could be a good source of both macro and micro mineral element.

Fat content

The crude fat content for 'kpaakpa' seed was obtained to be 37.92% for undefatted flour and 4.37% for defatted flour. This shows that defatting significantly decreased the fat content of the flour as shown in Table 3. There was significant difference ($p<0.05$) in the fat content of the defatted sample. The value obtained for the undefatted flour sample is an in agreement with that reported by Ogunsina et al. (2011) (37.5%) for undefatted 'kpaakpa' seed flour. The fat content can also be compared with 37.1% for mustard and 39% for niger seeds (Gopalan et al., 2007), hence are regarded as oil seeds.

Crude fibre content

The crude fibre of defatted flour (1.99%) is lower compared to that obtained for the undefatted flour (6.45%). There was significant difference ($p<0.05$) in the crude fibre content between the two flour samples. This shows that defatting significantly reduces the crude fibre content of 'kpaakpa' seeed flour. However, the result obtained for the defatted flour is in close proximity with that reported by Ogunsina et al. (2011). According to Okon (1983), diet low in fibre is undesirable as it could cause constipation and that such diets have been associated with diseases of the colon like piles, appendicitis and cancer. This is an indication that 'kpaakpa' seed flour can be incorporated in the formulation of snack products. The consumption of a moderate amount of 'kpaakpa' seed will suffice in providing a reasonable proportion of the dietary protein of individuals.

Carbohydrate content

The defatted flour exhibited increase in carbohydrate content of 'kpaakpa' seed. The obtained values were (7.37%) for undefatted flour and 41.72% for defatted flour. There was significant difference ($p<0.05$) between the two flour samples. The interactive effect of defatting led to increase in the carbohydrate content. The increase in carbohydrate after defatting might be due to the solvent extraction technique employed for the defatting process which led to decrease in fat and protein contents of the defatted seed flour. However, the higher carbohydrate value obtained for defatted flour is an indication that the defatted 'kpaakpa' seed flour is a good source of energy and capable of supplying the daily energy requirement of the body.

Table 1. Mean values for proximate composition of *Hildegardia barteri* seed flours.

Composition	Undefatted sample (%)	Defatted sample (%)	LSD
Moisture	11.18^{b}± 0.01	18.60^{a} ± 0.10	5.34
Ash	5.60^{b} ± 0.01	6.80^{a} ± 0.01	0.87
Crude fat	37.92^{a} ± 0.92	4.37^{b} ± 0.02	2.03
Crude fibre	6.45^{a} ± 0.10	1.99^{b} ± 0.10	3.73
Protein	31.53^{a} ± 0.01	26.52^{b} ± 0.01	3.12
Carbohydrate	7.37^{b} ± 0.03	41.72^{a} ± 0.03	6.99

Values with different superscripts in the same row are significantly different ($p<0.05$).

Functional properties of defatted and undefatted 'kpaakpa' seed flours

The result of analysis on the functional properties of defatted and undefatted'kpaakpa' seed flours were reported in Table 2 and are discussed under the following subheadings:

Bulk density

The result of bulk density for defatted 0.52 g/ml and undefatted 0.62 g/ml showed significant difference ($p<0.05$). From the result, it is obvious that defatting 'kpaakpa' seed flour reduces its bulk density. This observation is in agreement with the result of Hussain et al. (2008); they reported that bulk density of the flours decreases as a result of defatting process. Bulk density plays an important role in packaging, transportation of food products and decreases porosity of materials due to surface properties (Milson and Kirk, 1980).

Foam capacity and foam stability

The result showed that foam capacity (9.80%) and stability (1.96%) at 120 seconds in defatted are significantly higher ($p<0.05$) than those of undefatted sample as shown in Table 2. This is similar to the report of Hussain et al. (2008) who reported decreased in roasted as compared to non-roasted flaxseed flours. Giami and Bekebian (1992) also reported that the foam of the defatted flour was more stable than that of the undefatted sample.

Water absorption capacity

The result obtained for water absorption capacity for defatted flour (3.80 g/ml) was higher than the undefatted flour (2.20 g/ml). There was significant difference ($p<0.05$) between the two flour samples. However, the defatted flour absorbed more water and fat than the undefatted flour. This could be as a result of oil free state of the flour which allowed it to absorb water easily than the undefatted flour sample. Water absorption capacity is important in the development of ready to eat foods such as bread.

Oil absorption capacity

The oil absorption capacity for the defatted flour was significantly different ($p<0.05$) compared to the undefatted sample with the values of 2.38 g/ml and 1.73 g/ml, respectively. It was high than the values of roasted full fat and roasted defatted (1.31 and 1.27 g/g, respectively) for flax seed flours as reported by Hussain et al. (2008). The value obtained from this study compares favourably with that of 1.25 ml/g watermelon seed reported by (Oyeleke et al., 2012). Oil absorption is an indication of the rate at which protein binds to fat in food formulations (Onimawo and Akubor, 2005). Oil absorption is an important property in food formulations as it improves food flavour and palatability (Odoemelam, 2003), and it determines whether the protein materials will perform well as meat extenders or analogs (Alobo et al., 2009; Ogunsina et al., 2010). It is also useful in the formulation of foods such as sausage and bakery product. Hence, defatted 'kpaakpa' flour can be useful in production of low-fat bakery products and used as flavour carriers or modifiers in fabricated foods as meat analogues.

pH

There was no significant difference ($p>0.05$) in the pH value of both the defatted and undefatted 'kpaakpa' seed flours. The values obtained for both flour samples 6.50 which is near neutral on the pH scale. Every food consumed temporarily affects the body acid-alkaline balance. Most nuts, including walnuts, hazelnuts and pecans, are slightly to moderately acid-forming, but a few varieties have an alkalizing effect (Mary West, 2019).

Solubility

The solubility index of the defatted 'kpaakpa' seed flour (4.00%) is significantly different ($p<0.05$) compared to that of undefatted flour (1.00%). Solubility is an index of protein

Table 2. Mean values for functional properties of defatted and undefatted 'kpaakpa' seed flours.

Functional properties	Undefatted	Defatted	LSD
V	$4.59^{b} \pm 0.01$	$4.87^{a} \pm 0.03$	0.17
pH	$6.50^{a} \pm 0.10$	$6.50^{a} \pm 0.10$	1.14
BD	$0.62^{a} \pm 0.02$	$0.52^{b} \pm 0.03$	0.07
WAC	$2.20^{b} \pm 0.20$	$3.80^{a} \pm 0.20$	0.98
OAC	$1.73^{b} \pm 0.01$	$2.38^{a} \pm 0.01$	0.29
SI	$1.83^{b} \pm 0.02$	$2.58^{a} \pm 0.01$	0.42
GT	$54.00^{b} \pm 1.00$	$62.00^{a} \pm 0.50$	5.36
BT	$70.30^{b} \pm 0.61$	$72.30^{a} \pm 0.61$	1.05
FC	$7.84^{b} \pm 0.01$	$9.80^{a} \pm 0.01$	1.01
FS	$0.00^{b} \pm 0.00$	$1.96^{a} \pm 0.01$	0.69
SI	$1.00^{b} \pm 0.01$	$4.00^{a} \pm 0.10$	2.54
W	$38.00^{a} \pm 1.00$	$36.00^{a} \pm 1.00$	4.02

Values with different superscripts in the same row are significantly different ($p<0.05$).
KEY: LSD = Least significant value, V = Viscosity, BD = Bulk density (g/ml), WAC = Water absorption capacity (g/ml), OAC = Oil absorption capacity (g/ml), SI = Swelling index (g/ml), GT=Gelation temperature (ºC), BT = Boiling temperature (ºC), FC=Foam capacity (%), FS=Foam stability (%), SI=Solubility index (%), W=Wettability (sec).

functionality such as denaturation and its potential applications. The higher the solubility, the higher the functionality of the protein in a food.

Viscosity

The viscosity of defatted and undefatted 'kpaakpa' seed flour gave 4.87 and 4.59, respectively. There was significant difference ($p<0.05$) between the two flour samples. Viscosity is an index of the ability of starch based food to swell freely before their physical break down (Sanni et al., 2006; Adebowale et al., 2008). Viscosity is correlated to the texture and the degree of thickness or flow rate of food materials when suspended in water. The results for both flours are close, however, that of defatted flour is slightly higher than the undefatted flour. This makes 'kpaakpa' seed flour better suited for soup thickening.

Gelling and boiling temperatures

At first boiling of 54 and 62ºC for undefatted and defatted flour, respectively, the sample was not able to gel. This is an indication that temperature above the boiling point temperature could be required for the flours to gel. However, the defatted flour showed a more gelation property than the undefatted flour, this is evidenced by the variation in the temperatures of their second boiling which was observed to be 70ºC for the undefatted and 72ºC for defatted flour. However, there was significant difference ($p<0.05$) in the gelling and boiling point temperature of the two sample, with higher values obtained for defatted sample compared to the undefatted sample. Gelation capacity of flour is influenced by physical competition for water between protein gelation and starch gelatinization (Kaushal et al., 2012). From the observations made, it showed that the flour samples will be complemented with other soup thickeners such as 'achi' or 'ofo', this is evidenced by its slow ability to form gel or paste even after the second boiling.

Swelling indices

The values obtained for swelling index was 1.83 g/ml for undefatted flour and 2.58 g/ml for defatted. There was significant difference ($p<0.05$) between the swelling indices of the two flour samples. The defatted flour exhibited a higher swelling index than the undefatted flour. The differences in the swelling indices could be attributed to the difference in the inter-molecular starch bound in each flour which allowed it to absorb water and swell. The swelling depends on the origin of the starch (Konik et al., 2001). Delpeuch and Faviev (1980) reported that other factors such as the amylose content, the extent of chemical cross-binding within the granules and non-carbohydrate substances such as lipids or phosphate could be responsible. However, high amylose content as well as the presence of higher numbers of stronger intermolecular bonds may also reduce swelling (Omeire et al., 2014). This shows that the defatted 'kpaakpa' seed flour with the higher swelling index had the highest swelling power than the undefatted flour.

Wettability

The wettability of the undefatted and the defatted 'kpaakpa' seed flours were obtained to be 38 and 36 seconds, respectively. Wettability is the time required for the sample to become completely wet (Balami et al., 2004). From the results obtained, wettability of the undefatted 'kpaakpa' seed flour is higher than that of the defatted flour. This shows that, it took the undeffatted flour longer time to become completely wet, which implies that

it has less affinity to water, than the undefatted flour. This could mean that the defatted flour will reconstitute easily in food system upon hydration. However, from statistical analysis, there was no significant difference ($p<0.05$) between the two flour samples.

Characterization of extracted crude 'kpaakpa' seed oil

Table 3 showed the results obtained for the composition of crude 'kpaakpa' seed oil extracted using hexane solvent and are discussed as follows:

Table 3. Mean values for fatty acid characterization of crude 'kpaakpa' seed oil.

Oil composition	Values
Specific gravity (g/g)	0.86 ± 0.50
Density (g/ml)	0.87 ± 0.03
Peroxide value (mgKOH/g)	8.84 ± 0.51
Unsaponifiable matter (%)	55.36 ± 0.01
Iodine value (%)	56.48 ± 0.31
FFA (%)	0.30 ± 0.12
Acid value (%)	0.59 ± 0.11

Iodine value

The iodine value was 57.48%. This result corresponds positively with the acceptable range of iodine value of oil samples which falls within the range of 30 to 100 recommended for vegetable oils (Kagwachie and Anozie, 1995). The result obtained for iodine value of crude 'kpaakpa' seed oil compares favourably with that of palm oil in the range of 46 to 60 gI_2/100G (Das et al., 2002) and also for that of palm olein which is ≥56 (Codex, 2005). Most non-conventional seed oils have higher iodine values. Iodine value of a vegetable oil of any given species of plant may be influenced by its varietal genetic and the environment in which the oil is investigated (Encyclopedia Britannica, 2015). It measures the degree of unsaturation of oil. Saturated oils take up no iodine; therefore, their iodine value is zero, but because compounds of unsaturated oils contain molecules with double or triple bonds, they are very reactive towards iodine. The more the iodine is taken, the higher is the iodine value of the oil and the more reactive, less stable, softer and more susceptible to oxidation and rancidity of the oil.

Peroxide value

The peroxide value 8.84 as shown in Table 3 is lower than the maximum acceptable value of 10 meqKOH/g set by the Codex Alimentarius Commission for seed oils (Abayeh et al., 1998). Peroxide value is one of the most widely used chemical tests for the determination of the quality of oils. It measures the rancidity during the initial stages of lipid oxidation because the value increases to a maximum and then decreases as storage time increases (Akinoso et al., 2010).

Acid value and free fatty acid (%FFA)

The acid value obtained was 0.59 which is lower than the maximum acceptable value of 0.6 mgKOH/g of refined oil and 10 mgKOH/g of virgin palm oils set by Codex Alimentarius Commission. The result obtained for free fatty acid was 0.30 which is lower than the maximum acceptable value of crude extracted oil. The amount of acid value (mgKOH/g) and free fatty acid obtained in this study for crude 'kpaakpa' seed oil sample are lower than 1.7 and 0.96 reported by Amoo (2005) for cashew nut oil, 5.99 and 3.01 reported for groundnut by Atasie et al. (2009) and 2.85% reported by Dawodu (2009). Acid value is a common parameter in the specification of oils. It is defined as the weight of KOH in milligram needed to neutralize the organic acid present in 1 g of fat, and it is a measure of free fatty acid present in oil. However, free fatty acid decreases as oil is subjected to refining processes. Free fatty acid is the most commonly used parameter for determining the quality of oil. Acid value is a measure of free fatty acid in the oil as a result of deterioration. These deteriorations result in hydrolysis of triglycerides (oils) to yield free fatty acids. The longer an oil is stored, the higher the free fatty acid. This may be used as a measure of the extent of deterioration.

Specific gravity and density

The specific gravity of oil sample was 0.86. This result compares favourably with 0.90 obtained by Adewale et al. (2015) for solvent extracted ''kpaakpa'' seed oil. The result shows that the oil sample is lighter than water as found with most oil and fat. The result however is below the 0.92, 0.92, 0.93 and 0.96 for groundnut, fluted pumpkin, drumstick and roselle seed oil, respectively (Bamgboye and Adejumo, 2010; Bello et al., 2011; Ogunsina et al., 2014). The density of the oil was obtained to be 0.87 g/ml, and it compared well with the report of Ogunlade and Aremu (2019) who reported 0.9 specific gravity for *Pentaclethra macrophylla* and it falls within the permissible limit of vegetable oils.

Unsaponifiable matter

The value of unsaponifiable matter obtained for crude 'kpaakpa' seed oil was 55.36 as shown in Table 3. This compares with the specification by Codex Alimentarius Commission for rice bran oil which is ≤65 (Codex, 2005). The unsaponifiable matter shows the percentage of material present in fats which after saponification may be extracted by a specified solvent, and also remains non-volatile after evaporating the solvent and drying at 80ºC.

The lower value of unsaponifiable matter in seed oil is because of small quantities of hydrocarbons, higher alcohols, pigments and sterols contained in oil. Lower value is a characteristic quality of being good for soap production

Conclusion

The proximate composition, functional properties and oil characterization of 'Kpaakpa' (*Hildegardia barteri*) seed was investigated, findings from this study showed that underutilized 'kpaakpa' (*Hildegardiabarteri*) seed has the potential of being used in the formulation of new foods and feeds which will foster economic utility. The proximate composition studied revealed that the seed is a good source of protein and has high fat content. This makes the seed a valuable dietary supplement which can help reduce the problem of protein energy malnutrition such as kwashiorkor especially for those in the rural populace where animal protein may not be easily assessable. The functional properties such as swelling, oil absorption and foam capacities will impart textural and quality characteristics when utilized in food formulations such as sausages, meat and baked goods. The oil compositions of the seed studied revealed that the FFA, iodine value, acid value, unsaponifiable matter compared favourably with the specifications set by Codex Alimentarius Commission (CAC) for some named edible oil. This promotes the seed oil as a relevant source of vegetable oil which could be explored commercially in order to reduce the pressure on soy bean and palm kernel which are commonly used today.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

Abayeh, O. J., Aina, E. A., & Okounghae, C. O. (1998). Oil content and oil quality characteristics of some Nigerian oils seeds. *Scientific Journal of Pure and Applied Sciences*, 1, 17-23.

Abbey, B. W., & Ibeh, G. O. (1988). Functional properties of raw and heat processed cowpea (Vigna unguiculata, Walp) flour. *Journal of food science*, 53(6), 1775-1777.

Achi, O. K. (1999). Quality attributes of fermented yam flour supplemented with processed soy flour. *Plant Foods for Human Nutrition*, 54(2), 151-158.

Achi, O. K. (2005). Traditional fermented protein condiments in Nigeria. *African Journal of Biotechnology*, 4(13), 1612-1621.

Achinewhu, S. C. (1983). The saponins content of some Nigerian oil seeds. *Plant Foods for Human Nutrition*, 33(1), 3-9.

Adebayo, W. A., Ogunsina, B. S., & Gbadamosi, S. O. (2013). Some physico-chemical and functional properties of kariya (hildegardia baterii) kernel flours. *Ife Journal of Science*, 15(3), 477-488.

Adebowale, A. A., Sanni, L. O., & Onitilo, M. O. (2008). Chemical composition and pasting properties of tapioca grits from different cassava varieties and roasting methods. *African Journal of Food Science*, 2(7), 077-082.

Adewale, W. A., Babatunde, S. O., & Olasunkanmi, S.G., (2015). The effect of cold-pressing and solvent extraction on some characteristics of kariya (*Hildergadia barteri*) seed oil. *Nutrition & Food Science*, 45(4), 625-633.

Akinoso, R., Aboaba, S. A., & Olayanju, T. M. A. (2010), Effects of moisture content and heat treatment on peroxide value and oxidative stability of un-refined sesame oil, *African Journal of Food, Agriculture, Nutrition and Development*, 10(10), 4268-4285.

Alobo, A. P. (2004). Proximate composition and functional properties of defatted papaya (*cariya papaya L*.) kernel pour. *Plant food for Human Nutrition*, 58, 1-7.

Alobo, A. P., Agbo, B. N., & Ilesanmi, S. A. (2009). Physicochemical and functional properties of full fat and defatted cashew kernel flours. *International Journal of Food Science and Technology*, 44(3), 581-585.

Amoo, I. A. (2005). Proximate composition, minerals and physico-chemical properties of cahsew nut and oil. *Journal of Food Science and Technology*, 42(5), 445-446.

Ann, P. I., Moses, O., Kabuo, N. O., Omeire, G. C., & Bede, E. N. (2016). Comparative evaluation of proximate compositions, functional and physicochemical properties of raw melon seeds of five members of Cucurbitaceae family. *American Journal of Food Science and Nutrition*, 3(1), 8-17.

AOAC (2005). Official Methods of Analysis, Association of Analytical Chemists, Gaithersburg, MD.

AOAC (2006). Official method of analysis. 18th edition, Association of official analytical chemists Washington, D.C. U.S.A.

Apata, D. F., & Ologhobo, A. D. (1994). Biochemical evaluation of some Nigerian legume seeds. *Food Chemistry*, 49(4), 333-338.

Aremu, M. O., Olonisakin, A., Atolaye, B. O., & Ogbu, C. F. (2006). Some nutritional and functional studies of Prosopis africana. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, 5(6), 1640-1648.

Atasie, V. N., Akinhanmi, T. F., & Ojiodu, C. C (2009). Proximate analysis and physicochemical properties of groundnut (*Arachis hypogaea L*.). *Parkistan Journal of Nutrition*, 8(2), 194-197.

Balami, Y. A., Bolaji, P. T., Hamza, F., Bahagor, E. J., Komolafe, G., Onyeiwu S. C., & Hassan A. (2004). Practical Manual on Food Technology, Nutrition and Dietetics for schools and Industries (2nd edition). National Science and Technology Forum. Kaduna Polytechnic. Pp. 73-76.

Bamgboye, I.B. and Adejumo, O.I. (2010). Physicochemical properties of roselle seed oil. *Nutrition and Food Science*, 40(2), 185-192.

Bello, M. O., Akindele, T. L., Adeoye, D. O., & Oladimeji, A. O. (2011). Physicochemical properties and fatty acids profile of seed oil (*Telfairia occidentalis*). *International Journal of Basic and Applied Sciences*, 11(6), 9-10.

Codex (2005). Standard for named vegetable oils CODEX Stan 210. (Amended 2003, 2005).

Das, M., Das, S. K., & Suthar, S. H. (2002). Composition of seed and characteristics of oil from karingda [Citrullus lanatus (Thumb) Mansf]. *International Journal of Food Science and Technology*, 37(8), 893-896.

Dawodu, F. A. (2009). Physico-chemical studies on oil extraction processes from some Nigerian grown plant seeds. *Electronic Journal of Environmental, Agricultural an d Food Chemistry*,

8(2), 102-110.
Delpeuch, F., & Favier, J. C. (1980). Characteristics of starches from tropical food plants; alpha amylase hydrolysis swelling and solubility patterns. *Annales de Technologie Agricole,* 29(1), 53-67.
Emelike, N. J. T, Ebere, C. O. & Kiin-Kabari, D. B. (2015). Physico-chemical and sensory properties of cookies prepared from wheat flour and cashew-apple residue as a source of fibre. *Asia Journal of Agriculture and Food Science*, 3(2), 213-218.
Encyclopaedia Britannica (2015). Iodine value. Retrieved 29th September 2018 www.britannica.com/EBchecked/topic/292677/iodine-value.
Ezeagu, I. E., & Gowda, L. R. (2006). Protein extractability, fractionation and amino acid composition of some leguminous seeds found in Nigeria. *Journal of Food Biochemistry*, 30(1), 1-11.
Gbadamosi, S. O., Abiose, S. H., & Aluko, R. E. (2012). Amino acid profile, protein digestibility, thermal and functional properties of Conophor nut (*Tetracarpidium conophorum*) defatted flour, protein concentrate and isolates. *International journal of Food Science & Technology*, 47(4), 731-739.
Giami, S. Y., & Bekebain, D. A. (1992). Proximate composition and functional properties of raw and processed full-fat fluted pumpkin (*Telfairia occidentalis*) seed flour. *Journal of the Science of Food and Agriculture*, *59*(3), 321-325.
Gopalan, C., Rama Sari, B. V., & Balasubramanian, S. C. (2007). *Nutritive value of Indian foods*. National Institute of Nutrition, Indian Council of Medical Research Press, Delhi, India.
Hildergadia Notes, (2009). Retrieved from Http://www.malvaceae.info/Genera/Hildegardia/Hildegardia.php.
Hursh, H., & Martin, J. (2005). Low-carb and beyond: The health benefits of inulin. *Cereal Foods World*, 50(2), 57-60.
Hussain, S., Anjum, F. M., Butt, M. S., & Sheikh, M. A. (2008). Chemical composition and functional properties of flaxseed (*Linum usitatissimum*) flour. *Sarhad Journal of Agriculture*, 24(4), 649-653.
Ibironke, S. I., & Fawale, O. (2015). Chemical Analysis and Animal Bioassay of Hildegardia Barteri (Kariya Seed) Soy Bean and Maize: Annals. *Food Science and Technology*, 16(1), 245-250.
Inglett, G. E., Cavins, J. F., & Spencer, G. F. (1973). Seed composition of *Hildegardia barteri*. *Economic Botany*, 27(1), 128-130.
Josephat, I. A., Eric, C. O., Roseline, N. A., & Charles, N.I. (2017). The proximate and mineral composition of soaked and germinated 'kpaakpa' (*Hildegardia barteri*) seed flour: A response surface methodology approach. *International Journal of Food Science and Nutrition*, 2(5), 155-161.
Kagwachie, O. C., & Anozie, N. A. (1995). Effect of processing conditions on solvent extraction of oil from rubber seeds. *Journal of Agricultural Technology*, 3(1), 31-40.
Kaushal, P., Suresh, C., Samsher, S., & Durvesh, K. (2012). Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *Journal of Food Science Technology*, 52(6) 3681-3688.
Konik-Rose, C. M., Moss, R., Rahman, S., Appels, R., Stoddard, F., & McMaster, G. (2001). Evaluation of the 40 mg swelling test for measuring starch functionality. *Starch-Stärke*, 53(1), 14-20.
Martínez-Villaluenga, C., Frías, J., & Vidal-Valverde, C. (2006). Functional lupin seeds (Lupinus albus L. and Lupinus luteus L.) after extraction of α-galactosides. *Food Chemistry*, 98(2), 291-299.
Meg Campbell (2017). Which Nuts Are Alkaline Forming? Retrieved from https://www.livestrong.com/article/494847-nuts-alkaline-forming/.
Milson, T. S., & Kirk, P. C. (1980). Legumes in human nutrition. *Food and Agriculture Organisation Nutrition Studies*, 19, 223-235.
National Research Council (NRC) 1989). Recommended Dietary Allowances (10th edition). National Academic Press, Washington, DC, USA, 24.
Nwosu, J. N., Onuegbu, N. C., Kabuo, N. O., Okeke, M. O., Abbey, B. W., Ibeh, G. O., Eke, S. O., Enwere, N. J., Fox, B. A., Cameron, A. G., & Freeman, W. H. (1988). Functional properties of raw and processed winged bean (*Psophocarpus tetragonolobus*) flours. *Pakistan Journal of Nutrition*, 9(8), 1775-1777.
Odoemelam, S. A. (2003). Chemical composition and functional properties of conophor nut (*Tetracarpidium conophorum*) flour. *International Journal of Food Science and Technology*, 38(6), 729-734.
Ogunlade, C. A., & Aremu, A. K. (2019). Influence of processing conditions on some physical characteristics of vegetable oil expressed mechanically from *Pentaclethra macrophylla* Benth kernels: Response surface approach. *Journal of Food Process Engineering*, 42(2), e12967.
Ogunsina, B. S., Indira, T. N., Bhatnagar, A. S., Radha, C., Debnath, S., & Krishna, A. G. (2014). Quality characteristics and stability of Moringa oleifera seed oil of Indian origin. *Journal of Food Science and Technology*, 51(3), 503-510.
Ogunsina, B. S., Olaoye, I. O., Adegbenjo, A. O., & Babawale, B. D. (2011). Nutritional and physical properties of kariya (*Hildegardia barteri*) seeds. *International Agrophysics*, 25, 97-100
Ogunsina, B. S., Radha, C., & Govardhan Singh, R. S. (2010). Physicochemical and functional properties of full-fat and defatted Moringa oleifera kernel flour. *International Journal of Food Science and Technology*, 45(11), 2433-2439.
Okon, B. D. (1983). Studies on the chemical composition and nutritive value of the fruits of African star apple. M.Sc. Thesis University of Calabar, 67.
Oladele, P. E., & Oshodi, A. A. (2007). Nutritional potential of Berlandia Nettle Spurge (*Jatropha caothartica*) seed. *Pallistan Journal of Nutrition*, 6(4), 345-348.
Omeire, G. C., Umeji, O. F., & Obasi, N. E. (2014). Acceptability of noodles produced from blends of wheat, acha and soybean composite flours. *Nigerian Food Journal*, 32(1), 31-37.
Omosuli, S. V., Ibrahim T. A., & Oloye, D. (2009). Proximate and mineral composition of roasted and defatted cashew nut flour. *Pakistan Journal of Nutrition*, 8(10), 1649-1651.
Onimawo, I. A., & Akubor, P. I. (2005). *Functional properties of food*. *Food Chemistry, integrated approach with biochemical background.* Ambik Press Ltd, Benin City, Pp. 208-221.
Onwuka, G. I. (2005). *Food analysis and instrumentation theory and practices*. Napthali prints. A division of HG support Nigeria Limited, Surulere Lagos, Nigeria. Pp. 119-121.
Onwuka, G. I. (2018). *Food analysis and instrumentation: Theory and practices (Second edition)*. Napthali prints. A division of HG support Nigeria Limited, Surulere Lagos, Nigeria. Pp. 179-228.
Onwusu-Ansah, Y. J., & McCurdy, S. M. (1991). Pea proteins: A review of chemistry, technology of production, and utilization. *Food Reviews International*, 7(1), 103-134.
Oyekunle, J. A. O., & Omode, A. A. (2008). Chemical composition

and fatty acid profile of the lipid fractions of selected Nigerian indigenous oilseeds. *International Journal of Food Properties*, 11(2), 273-281.

Oyeleke, G. O., Olagunju, E. O., & Ojo, A. (2012). Functional and physicochemical properties of watermelon (*Citrullus lanatus*) seed and seed-oil. *Journal of Applied Chemistry*, 2(2), 29-31.

Sanni, L. O., Adebowale, A., & Tafa, S. O. (2006). Proximate, functional, pasting and sensory qualities of instant yam flour. A paper presented at the 14th ISTRC Symposium, Central Tuber Crops the Research Institute, Trivandrum, Kerak state, India.

Udensi, B. A., & Onuora, J. O. (1992). Chemical and functional properties of some soya bean flours in Nigeria market. Book of abstracts, 16th Annual conference of-2 NIFST, Enugu.

Ukpabi, U. J., & Ndimele, C. (1990). Evaluation of the quality of garri produced in Imo State Nigeria. *Nigerian Food Journal,* 8, 105-110.

WHO/FAO (2003). Diet, nutrition and the prevention of chronic diseases. Report of a WHO/FAO expect consultation. World Health Organisation Technical report series 916, WHO Geneva.