UDS International Journal of Development [UDSIJD]
Volume 5 No. 2, 2018
http://www.udsijd.org
ISSN: 2026-5336

NUTRITIONAL AND INDUSTRIAL POTENTIALS OF ROSELLE (Hibiscus Sabdariffa L) AND BAOBAB (Adansonia Digitata)

***Seweh, E. A., ** Xiaobo, Z., ***Bart-Plange, A., ****Abubakari, Mutari**

**School of Food and Biological Engineering, Jiangsu University, Xuefu Road, 301, Zhenjiang 212013, Jiangsu, P.R. China*
***Department of Agricultural Engineering, Bolgatanga Polytechnic, Bolgatanga, Ghana*
****Department of Agricultural and Biosystems Engineering, KNUST, Kumasi, Ghana*
*****Council for Scientific and Industrial Research-Savanna Agricultural Research Institute (SARI), Nyankpala, Ghana*
**Corresponding author's email: seweh@bpoly.edu.gh, Tel: +233 202839055/ +233 243288233*

Abstract

This study was conducted to investigate the industrial and nutritional potentials of under-utilised Roselle and Baobab seeds from Ghana. Proximate compositions and the physicochemical properties of their oil were compared to conventional oilseeds. The results of the proximate analyses showed that moisture contents of the seeds were very low. The fat, protein and fibre contents were relatively high suggesting that the seeds are excellent economic sources of oil for industrial, pharmaceutical and domestic usage. Physicochemical properties of the oil extracted from the seeds' powders using Soxhlet extractor revealed that the colour of roselle seed oil (RSO) was yellow while that of baobab seed oil (BSO) was dark brown. At room temperature, both oils were liquid. The low free fatty acid and peroxide values make the seeds and the oil suitable for human consumption. The results compared favourably with other premium vegetable oils and were within the ranges set by FAO/WHO. This research has contributed additional information to the recent call for research on alternative, novel and under-utilised sources of vegetable oil for domestic and industrial applications.

Keywords: ***Nutritional and Industrial potential, Under-utilised seeds, Proximate composition, Physicochemical properties, Baobab, Roselle.***

Introduction

Fat and oil are utilised for domestic food processes such as frying, baking and texturing and industrially in the manufacture of cosmetics, soaps and paints (Birnin-Yauri and Garba, 2011). Vegetable oil is vital in meeting the world's nutritional requirements and for commercial functions (Idouraine et al., 1996). Palm dominates the world vegetable oil consumption, sunflower, rapeseed soybean oil though there exist several other non-conventional sources (Stevenson et al., 2007). With the increase in world's population, the conventional sources cannot meet the food and industrial demands (Idouraine et al., 1996). To achieve the ever-increasing demand for vegetable oil for both domestic and commercial usage, different sources of seed oil are currently under investigation for possible adoption (Birnin-Yauri and Garba, 2011).

To reduce huge spending of limited and scarce resources in the importation of oil for food and commercial use, research on non-conventional sources has been intensified to obtain oil that can supplement the conventional sources (Salisu et al., 2015). Research interest has been directed towards under-utilised and readily available cheap sources of local seeds for a possible utilisation. Food scientists have started to identify wild local plants as potential sources of food (Vietmeyer and Janick, 1996). Murray et al., (2001) stated that many reports had indicated the high nutritional properties of lesser-known native plants which could be exploited for human use to reduce shortage and promote food security if the needed research attention is given. Several of these under-exploited plant seeds are found in Ghana and research efforts to tap into their potential is slow probably due to funding.

Williams and Haq, (2002) reported that absence of information on the nutritional composition and consumption of the underexploited plants is a bigger challenge than even the inadequacy or unavailability of the oil. The effective application of under-utilised seed oil hinges on the availability of information on their compositional characteristics (Tsiaganis et al., 2006). Available reports on the importance of utilising non-conventional plants and their seeds showed that significant number have useful potentials for direct use as food component or as a raw material for extraction of nutrients (Ezeagwu et al., 2003).

The leaves and calyces of Roselle (Hibiscus sabdariffa L) and for the Baobab (Adansonia digitata) the leaves, buds, and fruits are eaten as food in Northern Ghana for centuries now. The seeds are in most cases discarded, and no attention has been paid to their nutritive and industrial uses. The nutritional and physicochemical characteristics of their oil are yet to be explored commercially. The economic potentials of these seeds in products like oil for soap and oilcake for protein production for human and animal consumption are yet to be researched. Scientific reports about the nutritional and chemical characteristics of these seeds oil from Ghana are scanty. The objectives of this study was to determine the proximate compositions of Roselle Seeds Powder (RSP) and Baobab Seeds Powder (BSP) as well as the physicochemical characteristics of Roselle Seeds Oil (RSO) and Baobab Seed Oil (BSO) from Ghana. The results were compared with those of commonly used vegetable oil to ascertain their suitability or otherwise for human consumption and or for industrial applications. This will expand the scope of knowledge on the quality and utilisation of the extracted oil and oilcakes of the seeds.

Materials and methods

Plant materials and preparation

10 kg roselle seeds (RS) were obtained from a farmer in Navrongo while 10 kg of baobab seeds (BS) were obtained from Bolgatanga market. Both towns are in the Upper East region of Ghana. After cleaning and removal of sand and foreign materials, the dried RS were pounded into powder using a mortar and pestle, and the resulting powder sieved through a 60-mesh screen until a fine powder was obtained. It was then passed through a 40-mesh sieve. The same procedure was used for the BS. They were labelled as "RSP" and "BSP" representing roselle seed powder and baobab seed powder respectively and stored in a refrigerator at 5ºC in a sealed vessel wrapped with a polyethene bag until analysis and oil extraction. Oil was later extracted using soxhlet extraction with petroleum ether (AOAC Method 945.16). The reagents used in this study were of standards analytical reagent grade and were purchased from Merck (Darmstadt, Germany) and Sigma Aldrich (St. Louis, MO).

Oil Extraction Procedure

The oil were extracted with n-hexane (1:4 w/v) by agitation in a shaker at room temperature in the dark for 36 h. The solvent was evaporated at 40 °C to dryness. The extracted oil was stored in sealed dark bottles until analysis.

Proximate Composition of Seeds

Proximate analysis is a significant index for identification and classification of the nutritional value of food materials. The proximate analyses of the seeds were determined according to the Association of Official Analytical Chemists (AOAC, 2000). The moisture content was determined by drying in an oven at 105°C until a constant weight was obtained. Ash was determined by weighing the incinerated residue obtained at 550°C for 8-12 h. Total nitrogen and the protein content were determined based on the Kjeldahl method using the conversion factor of 6.25. The total lipid in samples was determined by Soxhlet method. After evaporation of the solvent, the oil content was determined gravimetrically. Crude fibre was determined according to the gravimetric procedure. The total available carbohydrate was determined by compositional percentage difference. It was obtained by subtracting the percentage of (crude protein + crude oil + ash + crude fibre) from 100%. Triplicate determinations were performed for each sample and their means recorded.

Physical and Chemical Analysis of Extracted Oil

The colour and state of the oil were noted using visual inspection at room temperature (Oderinde et al., 2009). The refractive indices were determined (at room temperature) with Abbe refractometer (Atago Co. Ltd, Tokyo, Japan) (Alamu et al., 2008). Specific gravity was measured using Oderinde et al., (2009) procedure. Free fatty acids and peroxide values were determined by the American Oil Chemists Society (AOCS, 2009) official method (Ca 5a-40; Cd 8-53) while saponification and iodine value were determined by the Association of Official Analytical Chemists (AOAC, 2000) official methods (920.160; 920.158) respectively.

Statistical analysis

All analyses were done in triplicates (n=3). Data collected were subjected to analysis of variance (ANOVA) using Minitab Version 17 Statistical software and comparisons of the treatment means were done using Tukey's HSD (Honest Significant Difference) test at a probability level of 5% $p<0.05$.

Results and Discussions

Proximate composition of seeds

Results of Proximate analyses of RSP and BSP as compared with other seed powders are presented in Table 1. The results in Table 1 showed that moisture content of RSP and BSP were slightly lower than those reported by Okonkwo and Okafor (2016), Olagbemide and Alikwe (2014) and Pele et al., 2016) for CSP, MSP and SBSP respectively but higher than those reported by Raimi et al. (2014) and Aishwarya and Anisha (2014) for SKP and SSP respectively. The low moisture content of the seeds is an advantage for the longer shelf life of the seeds (Akanni et al., 2005). This enhanced storage stability by preventing mould growth and reduced moisture dependent biochemical reactions (Onimawo and Aklubor, 2012). It also showed that the seeds are very high in dry matter content which is an advantage because it reduced microbial activities, prevent an oxidation-reduction reaction, algae and fungi growth and increase their shelf life when properly stored (Okonkwo and Okafor, 2016).

From Table 1, the crude protein content of RSP and BSP were significantly lower than those reported by Olagbemide and Alikwe (2014) for MSP but significantly higher than those reported by Raimi et al. (2014), Aishwarya and Anisha, (2014) and Pele et al. (2016) for SKP, SSP and SBSP seeds respectively. The percentage proteins obtained were similar to the values of seeds rich in protein (cowpeas, pigeon peas) which were between 23.1-33.0% (Olaofe et al., 1994). Their high protein contents will make them serve as proper sources of amino acids and protein for both man and animal. This value exceeded (WHO, 2003) recommended value of 19.80% as reported by (Okonkwo and Okafor, 2016). Proteins are for growth and repair of tissues and as an alternative energy source in the absence of carbohydrate and fat (Ujowundu, 2010). The protein contents of the RSP and BSP suggest that they can contribute to the daily protein need of 23.6 g/100 g for adults as recommended by some authorities (Ajayi et al., 2006). The relatively high fat and protein contents indicate that these seeds could become excellent economic sources for edible oil production, and the meal could be more efficiently used in animal feeding and possibly for human use. The crude lipids content of RSP and BSP varied significantly at $p<0.05$. RSP yielded the lowest crude lipids content among all the oilseeds compared while SSP yielded the highest crude lipid content. The oil contents were within commercial ranges. Crude lipids content of BSP varied significantly from BSP but compared closely with CSP and SBSP. The crude oil contents of the RSP and BSP in this study were found to exceed those of some common edible oils like safflower (30-35%), soybean (18-22%), rapeseed (40-48%), and olive (12-50%) (Nichols and Sanderson, 2003). The high values suggest that they can be produced in commercial quantities for industries, pharmaceutical use, cooking and other purposes. The differences in the oil contents can be attributed to genetic diversity and climate conditions (Stevenson et al., 2007). The ash content of RSP is significantly lower than that of BSP ($p<0.05$). Values of both oils are higher than those reported by Raimi et al. (2014), Okonkwo and Okafor (2016), Olagbemide and Alikwe (2014), Aishwarya and Anisha (2014) and Pele et al. (2016) for SKP, CSP, MSP, SSP and SBSP respectively. Ash content determination is important because it provides information about the total mineral content of the food. It is an index of the quality of feeding materials used by animal feed producers for poultry and cattle feeding.

Crude fibre content of RSP and BSP varied significantly ($p<0.05$) (Table 1). Comparing these results with the reported values, RSP contained the highest crude fibre content after CSP. Statistically, BSP contained high crude fibre content than MSP, SSP, and SBSP but lower than values for CSP, RSP, and SKP. Both seeds have enough fibre for dietary nutrition which will help to maintain intestinal distention, reduce constipation, colon diseases and cancer. The therapeutic effects of fibre in the prevention of heart diseases, colon cancer and diabetes and their role in the treatment of digestive disorders and constipation are widely documented by Anderson et al. (2009). There was a significant difference in total carbohydrates content of RSP and BSP (Table 1). BSP and CSP have almost identical total carbohydrate content. Except for SBSP that had the highest carbohydrate content, all other seeds had values below that of RSP.

Table 1: Comparison of the proximate compositions of RS and BS powders with other seed powders

Properties	Obtained values		Reported values				
	RSP	**BSP**	**SKP**	**CSP**	**MSP**	**SSP**	**SBSP**
(%)			Raimi et al., (2014)	Okonkwo and Okafor, (2016)	Olagbemide and Alikwe(2014)	Aishwarya and Anisha, (2014)	Pele et al., (2016)
	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std
MC	5.99±0.46d	4.25±0.55e	2.84±0.13g	9.87 ± 0.10b	9.97±0.09a	3.1± 0.06f	7.23 ± 0.27c
CPC	25.81±1.75c	23.85±2.62e	9.30±0.05g	27.27 ± 0.03b	35.97±0.19a	19.69± 0.15f	23.98 ± 0.97d
CLC	21.69±0.53g	22.67±2.31f	49.16±0.13b	27.83 ± 0.35d	38.67±0.03c	53± 0.57a	26.20 ± 0.75e
AC	5.95±0.67b	8.45±3.26a	4.18±0.10f	4.55 ± 0.06d	3.87±0.09g	4.49±0.02e	4.76 ± 0.90c
CFC	16.66±0.50b	10.72±0.86d	12.68±0.13c	22.94±0.28a	2.87±0.03f	0.96±0.03g	6.58 ±0.38e
TCC	23.89±2.70d	30.06±3.59c	21.84±0.27e	30.49 ± 0.41b	8.67±0. 12g	18.72± 0.480f	38.48 ±0.68a

Means in the same row that do not share a letter are significantly different using Tukey's Method at 95% Confidence
RSP=Roselle Seed Powder, BSP= Baobab Seed Powder, SKP= Shea Kernel Powder, CSP=Cotton Seed Powder, MSP=Moringa Seed Powder, SSP=Sunflower Seed Powder, SBSP=Soya Bean Seed Powder, MC= Moisture Content (%), CPC= Crude Protein Content (%), CLC= Crude Lipids Content (%), AC= Ash Content (%) CFC= Crude Fibre Content (%), TCC= Total Carbohydrate Content (%).

Physico-chemical characteristics of Roselle and Baobab seeds oil

The colour of RSO was yellow while that of BSO was dark brown, like that of cotton seed oil. RSO and BSO are liquid at room temperature. The states of the liquids showed that RSO and BSO were unsaturated oil, meaning that, they are liquids at room temperature. Comparison of the physicochemical characteristics of RSO and BSO with those of other vegetable oils are presented in Table 2. From Table 2, significant differences existed between the moisture content (MC) of RSO and BSO ($p<0.05$). The very low MC suggests that the oils can be safely stored for extended periods without getting rancid. Low MC of food enhances storage stability by preventing mould growth and reducing moisture-dependent biochemical reactions (Onimawo and Aklubor, 2012).

Refractive index (RI) is widely used in quality control to check for the purity of oil. RI of oil increased with an increase in unsaturation and chain length of fatty acids. The RIs of RSO and BSO varied significantly, but both compared closely to the other studied oils. The two oils have their RIs within the acceptable range of 1.4677 to 1.4707 for virgin, refined and refined-pomace oil according to Codex Standards for fats and oils from plant sources (Codex Alimentarius, 2005) (Table 2).

At $p<0.05$, there were significant differences in the specific gravity (SG) of RSO and BSO. From Table 2, the SGs of both oils were lower than those reported by Seweh et al. (2016), Orhevba and Efomah (2012), Abiodun et al. (2012), Akanni et al. (2005) and Ologunde et al. (2008) for SKO, CSO, MSO, SBSO and SSO respectively. The results showed that RSO and BSO were less dense than water and therefore would be useful in cream production as it will make the oil flow and spread easily on the skin (Oyeleke et al., 2012). According to Yahaya et al. (2012), specific gravity is commonly used in conjunction with other figures in assessing the purity of the oil.

Free Fatty Acid (FFA) is the percentage by weight of a specified fatty acid (oleic acid) (Nielson, 1994). A high level of FFA in oil is unacceptable since it results in the loss of some oil during the refining stage of crude oil. The higher the FFF, the higher the quantity of oil lost. Vegetable oil with lower FFA are more acceptable to man in terms of palatability (Aremu et al., 2015). The FFAs of RSO and BSO showed a significant difference. The FFAs of the RSO and BSO were the lowest as compared with the reported values (Table 2). FFAs are significant in identifying oil with commercial and domestic potentials. High FFA of fats and oil is because of the breakdown of the oil to form peroxides, and this increases the acidity of the oil (Kapilan and Sekar, 2011). A study by Abdellah and Ishag (2012) also showed that high acid levels of oil obtained from stored seed may be as a result of the breakdown of glycerol into fatty acids by enzymes. FFA can also be used to determine the suitability of oil for the paint and soap industries (Aremu et al., 2006). The results of this study were in line with the acceptable limit of 0-3 for oil used as food and could, therefore, be used as edible oil (Olatidoye et al., 2010). The results also revealed that the two oils could be consumed directly without further refining to improve their quality or for commercial purposes (Barku et al., 2012).

The iodine value (IV) is a measure of the degree of unsaturation of fats and oil. Kyriakidis and Katsiloulis, (2000) and Knothe (2002) indicated that higher IV suggested higher unsaturation of the fats and oil. The IV is used to measure the number of double bonds in the oil. Highly unsaturated oil and fats are susceptible to rancidity. Aremu et al. (2006) stated that the smaller the IV, the less unsaturated the oil and so, the more stable oil is to decomposition. Kochhar (1998) reported that non-drying oil are not suitable for ink and paint making because they do not rapidly dry as is required for inks and paints but could be useful in the manufacture of soaps. Results presented in Table 2 show that IVs of RSO and BSO were statistically different. SBSO had the highest IV and may be suitable for paint making. Eze (2012) reported that high IV is an indication of the occurrence of a high proportion of unsaturated fatty acids in the oil. Such oils could be useful in the manufacture of vegetable oil-based ice cream (Oderinde et al., 2009).

The number of milligrams of potassium hydroxide (KOH) needed to neutralise the fatty acids resulting from the complete hydrolysis of 1g of fat is referred to as saponification value (SV). It is an index of the mean molecular weight of the fatty acids of glycerides comprising a fat. The lower the SV, the larger the molecular weight of fatty acids in the glycerides and vice-versa. Lower SV is an indication that the oil could not be suitable for soap making but may be good for ice-cream and shampoos making. Higher SV in oil increases the volatility of the oil. The SVs of RSO and BSO were significantly different ($p<0.05$). Both were higher than that of SKO and lower than those of CSO, MSO, SSO, and SBSO. Their high SVs make them suitable for soap making.

Nawar (1996) described peroxide value (PV) as a technique used to quantify lipid deterioration, and suitable for determining peroxide formation in the early stages of rancidity. Unsaturated fatty acids in oil will react with oxygen to form peroxides (Marina et al., 2009). Unrefined vegetable oil contained higher PV compared to refined oil. High PVs are suggestive of high levels of oxidative rancidity; this can also mean that the oils are low in antioxidants. Kyari (2008) reported that butyl hydroxyl (antioxidants) anisole might be used to reduce rancidity. Nahm (2011) also stated the antioxidant effects of rosmarinic acid, gallic acid and butylated hydroxytoluene (BHT) on fat oxidation as triggered by high temperature and air. FAO/WHO/UNU (2007) stipulated a permitted maximum peroxide level of not more than 10 meq O_2/kg oil for oil. The low PVs are indications of low levels of acidity of the oil and suggest a high level of antioxidants (Kyari, 2008). The PV is an index of rancidity; thus, the low PVs of the oil indicated a good resistance to peroxidation during storage. Rancid oils have very high PV (Anhwange, 2004). However, subjecting such oil to alkaline treatment, bleaching, or improving method of storage by adding antioxidants can reduce the magnitude drastically

(Mohammed et al., 2012). From Table 2, since the PVs of RSO and BSO were within the reported limits, they can be regarded as stable edible oil with good qualities.

Table 2: Comparison of physicochemical characteristics of RSO and BSO with those of other vegetable oil

Properties	RSO	BSO	SKO	CSO	MSO	SSO	SBSO
	Obtained value	Obtained value	Seweh et al., (2016)	Orhevba and Efomah, (2012)	Abiodun et al., (2012)	Ologunde et al., (2008)	Akanni et al., (2005)
	Mean± Std	Mean± Std	Mean± Std	Mean± Std	Mean± Std	Mean± Std	Mean± Std
OC	Yellow	Dark brown	Light yellow	Dark brown	ND	ND	ND
SRT	Liquid	Liquid	Solid	Semi liquid	ND	ND	ND
MCO	2.66±0.54a	1.78±2.03b	ND	ND	ND	ND	ND
RI	1.47±0.01a	1.46±0.01b	1.46±0.00b	1.46±0.00b	1.47±0.00a	1.46±0.00b	1.46±0.00b
SG	0.89±0.04f	0.87±0.08g	0.97±0.00a	0.92±0.00c	0.91±0.00d	0.92±0.00b	0.91±0.00e
FFA	1.94±0.95e	1.06±1.25f	7.61±0.35a	5.78±0.00b	3.57±0.00c	0.22±0.00g	2.15±0.00d
IV	100.03±3.45b	80.00±24.40d	49.18±2.83g	94.70±0.00c	55.02±0.00f	78.45±0.00e	136.81±0.00a
SV	196.91±1.79a	178.87±17.79f	160.79±1.50g	189.00±0.00c	180.31±0.00	188.51±0.00	192.30±0.00b
PV	2.84±1.49e	5.79±4.48c	2.25±0.15f	9.25±0.00b	15.96±0.00a	0.89±0.00g	3.50±0.00d

Means in the same row that do not share a letter are significantly different using Tukey's Method at 95% Confidence
OC=Oil Colour, RSO=Roselle Seed Oil, BSO =Baobab Seed Oil, SKO=Shea Kernel Oil, CSO=Cotton Seed Oil, MSO=Moringa Seed Oil, SSO=Sunflower Seed Oil, SBSO=Soya Bean Seed Oil, SRT=State at Room Temperature (^{0}C), MCO=Moisture Content of oil (%), RI=Refractive Index (at room temp ^{o}C), SG=Specific Gravity, FFA=Free Fatty acid (% Oleic Acid), IV=Iodine Value (gI_2/100g), SV=Saponification Value (mgKOH/g), PV=Peroxide Value (meq O_2/kg oil) and ND=Not Determined.

Conclusions

Analyses of the seeds and oil of Roselle and Baobab proximate compositions revealed that they could be used as alternative sources of human food and could find immediate utility in a mixed animal feed. The low acid, iodine and peroxide values of the oil make the seeds and the oil suitable for human consumption. The saponification values are however high, suggesting that they may be ideal for industrial soap making. The seeds are of high nutritional value and therefore can be cheap potential sources of nutrients, especially proteins. The physicochemical properties: refractive index, specific gravity, free fatty acid value, acid value, iodine value, peroxide value and saponification value were generally like those of other premium vegetable oils and were found to be within the range set by FAO/WHO/UNU (2007). The oils are not inferior to other edible oils currently used for cooking. The seeds have good nutritional composition while the oil have excellent yield with a low degree of unsaturation. These make the oil ideal for various industrial applications, human and animal consumption. It can be concluded that the seeds can be considered as potential sources of food because of their nutrient composition. They can also be used as industrial raw materials for oil, animal feed, and soap production. It is recommended that more research is carried out to explore their anti-nutritional characteristics (protease inhibitors, phytates, tannins, and gossypol) to ensure that their toxic levels are within acceptable ranges.

References

Abdellah, A. M., and Ishag, K. E. A. (2012). Effect of storage Packaging on sunflower oil Oxidative stability. ***American Journal of Food Technology***, *7:* 700-707.

Abiodun, O. A., Adegbite, J. A. and Omolola, A. O. (2012). Chemical and physicochemical properties of moringa flours and oil. ***Global Journal of Science Frontier Research Biological Sciences***, 12(5): 12–18.

Aishwarya, S. and Anisha, V. (2014). "Nutritional Composition of Sunflower Seeds Flour and Nutritive Value of Products Prepared by Incorporating Sunflower Seeds Flour" ***Int. J. of Pharm. Res. and All. Sci.***; 3(3):45-49.

Ajayi, I.A., Oderinde, R.A., Kajogbola, D.O. and Uponi, J.I. (2006). Oil content and fatty acid composition of some underutilized legumes from Nigeria. ***Food Chemistry***, *99*(1): 115-120.

Akanni, M. S., Adekunle, A.S. and Oluyemi, E.A. (2005). Physicochemical properties of some non- conventional oilseeds, ***Journal of Food Technology***, 3(2): 177-181.

Alamu, O. J., Waheed, M. A., and Jekayinfa, S. O. (2008). Effect of ethanol–palm kernel oil ratio on alkali-catalyzed biodiesel yield. ***Fuel***, *87*(8-9): 1529-1533.

Anderson, J.W., Baird, P., Davis, R.H., Ferreri, S., Knudtson, M., Koraym, A., Waters, V. and Williams, C.L., (2009). Health benefits of dietary fiber. ***Nutrition reviews***, *67*(4): 188-205.

Anhwange, B.A., Ajibola, V.O. and Oniye, S.J., 2004. Chemical studies of the seeds of Moringa oleifera (Lam) and Detarium microcarpum (Guill and Sperr). ***J. Biol. Sci***, *4*(6):711-715.

American Oil Chemists' Society (2009). Official methods and recommended practices of the AOCS. 6th ed. AOCS, Champaign, IL.

Association of Official Analytical Chemists (2000). Official Methods of Analysis of AOAC International, 17th ed.;AOAC International: Gaithersburg, MD, USA.

Aremu, M. O., Olaofe, O., and Akintayo, E. T. (2006). Chemical composition and physicochemical characteristics of two varieties of bambara groundnut (Vigna subterrenea) flours. ***Journal of Applied Sciences***, 6*:* 1900-1903.

Aremu, M. O., Ibrahim, H. and Bamidele, T.O. (2015). Physicochemical Characteristics of the Oil Extracted from Some Nigerian Plant Foods – A Review. ***Chemical and Process Engineering Research****,* 36:32-52.

Barku, V.A., Nyarko, H.D. and Dordunu, P., 2012. Studies on the physicochemical characteristics, microbial load and storage stability of oil from Indian almond nut (Terminalia catappa L.). ***Food Science and Quality Managemen****t*, 8: 9-17.

Birnin-Yauri, U.A. and Garba, S. (2011). Comparative Studies on some physicochemical properties of baobab, vegetable, peanut and palm oil. ***Nigerian Journal of Basic and Applied Sciences***, *19*(1).

CODEX Alimentarius Commission (2005). Codex standard for named vegetable oil- "Codex standard 210- 1999''. Food and Agricultural Organisation of the United Nations and the World Health Organisation.

Eze, S. O. O. (2012). Physicochemical Properties of Oil from some Selected Underutilized Oil Seeds available for Biodiesel Preparation, ***African Journal of Biotechnology***, 11(42): 10003 10007.

Ezeagu, I. E., Maziya-Dixon, B., and Tarawali, G. (2003). Seed characteristics and nutrient and antinutrient composition of 12 Mucuna accessions from Nigeria. ***Tropical and subtropical Agroecosystems***, *1*(2-3): 129-139.

FAO/WHO/UNU (2007). Energy and protein requirements, ***WHO Technical Series*** 936: 1–265.

Idouraine, A., Kohlhepp, E. A., Weber, C. W., Warid, W. A., and Martinez-Tellez, J. J. (1996). Nutrient constituents from eight lines of naked seed squash (*Cucurbita pepo* L.). ***Journal of agricultural and food chemistry***, *44*(3): 721-724.

Kapilan N, Sekar CB. (2011). Production and evaluation of storage stability of honge biodiesel. ***Annals of the Faculty of Engineering Hunedoara***. 9(3):267.

Knothe, G. (2002). Structure indices in FA chemistry. How relevant is the iodine value? ***Journal of the American Oil Chemists' Society***, 79(9): 847-854.

Kochhar, S. L. (1998). ***Economic Botany in the Tropics***. 2nd Edition, Macmillan India Ltd, pp 354–355.

Kyari, M. Z. (2008). Extraction and characterization of seed oil. ***International Agrophysics***, *22* (2): 139.

Kyriakidis, N. B., and Katsiloulis, T. (2000). Calculation of iodine value from measurements of fatty acid methyl esters of some oil: comparison with the relevant American oil chemists society method. ***Journal of the American Oil Chemists' Society***, *77*(12): 1235-1238.

Marina, A. M., Che Man, Y. B. and Nazimah, S. A. H. (2009). Chemical properties of virgin coconut oil. ***Journal of American Oil Chemists' Society***. 86: 302-307.

Mohammed M. I., I. Sule, M. Abubakar and A. A. Salisu (2012). Extraction and physicochemical investigation of oil from the seeds of *Ceiva pentandra* Linn grown in Katsina, Nigeria. ***Journal of Chemical and Pharmaceutical Res****earch*, 4(7):3737-3739.

Murray, S. S., Schoeninger, M. J., Bunn, H. T., Pickering, T. R., and Marlett, J. A.(2001). Nutritional composition of some wild plant foods and honey used by Hadza foragers of Tanzania. ***Journal of Food Composition and Analysis***, 14(1), 3-13.

Nahm, H.S., (2011). Quality characteristics of West African shea butter (Vitellaria paradoxa) and approaches to extend shelf-life (Doctoral dissertation, Rutgers University-Graduate School-New Brunswick).

Nawar WW. (1996). Lipids. In: Fennema O, ***Food chemistry***. New York: Marcel Dekker Inc. p 225–319.

Nichols, D. S., and Sanderson, K. (2003). The nomenclature, structure, and properties of food lipids. ***Chemical and functional properties of food lipids***, 29-59.

Nielson, S. S. (1994). Introduction to the chemical analysis of foods. Chapmakinetin and Hall, New York, pp. 93–207.

Oderinde, R. A., Ajayi, I. A., and Adewuyi, A. (2009). Characterization of seed and seed oil of *Hura crepitans* and the kinetics of degradation of the oil during heating. ***Electron. J. Environ. Agric. Food Chem***, *8*(3): 201-208.

Okonkwo S. I., Okafor E. C. (2016). Determination of the Proximate Composition, Physicochemical Analysis and Characterization of Fatty Acid on the Seed and Oil of *Gossypium hirsutum*. ***International Journal of Chemistry***; 8(3): 57-61.

Olagbemide, P.T. and Philip, C.N.A., 2014. Proximate analysis and chemical composition of raw and defatted Moringa oleifera kernel. ***Advances in Life Science and Technology***, *24:* 92-99.

Olaofe, O., Adeyanri, F. O., and Adediran, G. O. (1994). Amino acid, mineral composition and functional properties of some oilseeds. ***Journal of Agricultural and food Chemistry***, 42(5): 878-884.

Olatidoye, O.P., Adeleke, A.E., Adegbite, S.A. and Sobowale, S.S., 2010. Chemical composition and nutritional evaluation of Sandbox (*Hura crepitan*) seed flour for domestic consumption and industrial. ***Journal of medical and applied biosciences***, *2:*72-83.

Ologunde, M. O., Adelani, A., and Liasu, M. O. (2008). Chemical compositions of sunflower (*Helianthus Annuus* L.) hybrids planted in different natural locations in Northern Nigeria. ***American Eurasian journal of Sustain Agriculture***, *2*(2): 229-234.

Onimawo IA, Akubor PI (2012). Food Chemistry (Integrated Approach with Biochemical background). 2nd edn. Joytal printing press, Agbowo, Ibadan, Nigeria.

Orhevba, B. A., and Efomah, A. N. (2012). Extraction and characterization of cottonseed (*gossypium*) oil. ***International journal of basic and applied science***, *1*(2): 398-402.

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

Pele, G.I.; Ogunsua, A.O. Adepeju, A.B.; Esan, Y.O.; and Oladiti, E.O. (2016). Effects of Processing Methods on the Nutritional and Anti- Nutritional Properties of Soybeans (*Glycine max*). ***African Journal of Food Science and Technology*** 7(1): 009-012.

Raimi, Monsurat M., Adegoke, Bosede M. and Afolabi, Olumide (2014). Nutritional Composition of Seed and Physicochemical Properties of Seed Oil of *Vitellaria* *paradoxa*. ***Scientific Research Journal*** (SCIRJ), 2(5): 35-39.

Seweh E. A., P. A. Asagadunga, S. Apuri and G. Owusu (2016). Effects of Extraction Method and Geographical Location on the Physico-chemical Properties of Shea (*Vitellaria paradoxa*) Butter. *SCIENCEDOMAIN* ***International-Asian Research Journal of Agriculture*** 1(1): 1-13.

Salisu A., Veronica Etim, David Bwai, Michael Afolayan (2015). Nutraceutical evaluation of baobab (*Adansonia digitata* L.) seeds and physicochemical properties of its oil. ***Annals of Biological Sciences*,** 3 (2):13-19.

Stevenson, D. G., Eller, F. J., Wang, L., Jane, J. L., Wang, T., and Inglett, G. E. (2007). Oil and tocopherol content and composition of pumpkin seed oil in 12 cultivars. ***Journal of agricultural and food chemistry*,** *55*(10): 4005-4013.

Tsiaganis M.C., Laskari K., Melissari E. (2006). Fatty acid composition of Allium species lipids. ***Journal of Food Composition and Analysis***; 19: 620-627.

Ujowundu C. O., F. N. Kalu, O. E. Okafor, N. C. Agha, C. S. Alisi and R. N. Nwaoguikpe, (2010). Evaluation of the chemical composition of Dacryodesedulis (G. Don) seeds, ***International Journal of Biological and Chemical Sciences***, 4(4): 1225-1233.

Vietmeyer N. and J. Janick (1996). In: Proceedings of the Third National Symposium of American Society of Horticultural Scientist, Alexandria, USA, 2–8.

World Health Organization, 2003. ***Diet, nutrition, and the prevention of chronic diseases: report of a joint WHO/FAO expert consultati****on* (Vol. 916). World Health Organization.

Williams, J.T. and Haq, N. (2002). Global research on underutilized crops. An assessment of current activities and proposals for enhanced cooperation. ICUC, Southampton, UK.

Yahaya, A. T., Taiwo, O., Shittu, T. R., Yahaya, L. E., and Jayeola, C. O. (2012). Investment in cashew kernel oil production; Cost and return analysis of three processing methods. ***American Journal of Economics***, 2(3): 45–49.