Forests and Forest Products Journal 21: 16-27

Proximate and antioxidant properties, oil yield and characterization of vegetable tallow tree (*Allanblackia floribunda* Oliv.)

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Abstract

Proximate and antioxidant compositions, yield and characterization of *Allanblackia floribunda* seed oil were investigated using appropriate analytical methods. Oil extraction was done with petroleum ether as a solvent for Soxhlet extraction apparatus. Carbohydrate (33.69%), fat (46.98%) and crude fiber (8.79%) contents of *A. floribunda* seed were high while crude protein (9.05%) content was moderate. Moisture (4.35%), ash (1.49%) and all anti-nutrient contents of the seed were low, implying that *A. floribunda* seed has high nutritional compositions and that its consumption would not be detrimental to human health. The seed has high antioxidant compositions with mean phenol, flavonoid, FRAP, ABTS, DPPH and Fe^{2+} of 9.75mg.g^{-1}, 17.73mg.g^{-1}, 88.4mg.g^{-1}, 85.5 mMol/g, 29.54% and 20.39%, respectively, suggesting that the seed is a potential source of natural antioxidants and can be used as supplement in food and nutritional drinks. Mean oil yield was 46.5%, revealing that it is a high oil-yielding seed. The oil *is* suitable for human consumption due to its peroxide value (2.20 mEqO_2/kg of oil). The FFA of 1.55mg NaOH/g implies good quality oil that would not easily go rancid, with long shelf life. To harness the commercial potentials of *A. floribunda* seed oil, domestication of the species is recommended.

Keywords: *Allanblackia floribunda*, forest food tree species, oil yield and characterization, proximate and antioxidant compositions.

Introduction

Tropical forests harbor many indigenous tree species that produce nutritionally and socio-economically important Non-Timber Forest Products (NTFPs) like fruits and seeds. About 3,000 forest tree species with edible parts grow naturally in forests, farmlands, fallow or uncultivated lands in Africa (Pye-Smith, 2010; Onyekwelu *et al*., 2015). The contributions of forest food tree species to diets and healthcare delivery, their potential in ameliorating food problems in developing nations, provision of oil, pharmaceuticals and cosmetic products and potentials in economic empowerment are enormous. Specifically, oils from plant seeds have a rich history of use as food, energy, medicine, cosmetics, lubricants, soaps; treatments of conditions like hair dandruff, muscle spasms, wounds , etc. Globally, about one billion people depend on wild foods (mostly from plants) (Onyekwelu *et al*., 2015). Between 300 and 350 million people depend almost entirely on the forest for nutrition and livelihood supports (Aberoumand, 2009). More recently, forest fruits and seeds are being evaluated for antioxidant compositions and oil yield. *Vitellaria paradoxa* (Shea butter), *Dacryodes edulis* (Bush butter), *Pentaclethra macrophylla* (African oil bean) are examples of oil seed producing tree species. Their seeds could yield as much as 30–60% oil, with potential of producing 7–8 tons of oil per hectare depending on species, variety and extraction method (Bharucha and Pretty, 2010; Onyekwelu and Stimm, 2016; Agu *et al*., 2020).

In recent years, demand for seed oils has increased greatly due mainly to industries and consumers seeking natural alternatives. This has resulted in a dramatic increase in global production of seed oils, estimated at 113 million metric tons (Vermaak *et al*., 2011). The increasing demand is also driven by demand for biodiesel, high prices of some agricultural oils, fluctuations in oil seed yield due to poor climatic conditions, among others. The annual large quantities of seeds produced by trees allows for relatively rapid adjustment in the supply of their oils to meet changing market demands. The wide uses of edible tropical forest seeds, their high antioxidant contents and/or oil yield, coupled with their emerging high demand, necessitate the search for and characterization of oils from more tree seeds to augment the available ones.

Allanblackia floribunda (vegetable tallow tree) oliv. is a multi-purpose fruit tree species with a potential of becoming an important source of alternate income to farmers. The species, which produces oil seeds, has been relatively unknown, thus its numerous potentials are relatively untapped. The species, which belongs to the Guttiferae family, is a medium-sized evergreen tree species that thrives in moist tropical rainforest zones of African countries like Angola, Benin, Cameroon, Congo, Ghana, Nigeria, Sierra Leone, Tanzania and Uganda (Orwa and Munjuga, 2007; Orwa *et al*., 2009, Alenyoregem *et al*., 2015). The tree can attain a total height of about 30 m, with a cylindrical or slightly fluted bole and a narrow crown supporting horizontal branches. A mature tree produces 100 to 150 egg-shaped fruits, each weighing 1.2 kg to 4.0 kg and containing 40 to 50 oil-rich brown seeds that are brittle-shelled, 2-5 cm long and 1.5-3.2 cm in diameter (Orwa and Munjuga, 2007; Orwa *et al*., 2009). The seed kernels account for 60-80% of seed weight. Both seeds and fruits are edible. The species is useful for medicinal (Armah *et al*., 2021), human nutrition, poultry, livestock and fish feed production purposes.

A. floribunda seed oil can be used to supplement or substitute other oils in domestic and commercial production of food and non-food products (Alenyoregem *et al*., 2015). The oil consists mostly of stearic (45-58%) and oleic (39-51%) acids, which has always been part of the human diet and are reported to lower plasma cholesterol levels, thus reducing the risks of heart attacks (Alenyoregem *et al*., 2015). Currently, due to the growing importance of plant seed nutrition and plant seed oils, much attention is being focused on identifying suitable oil seed species and developing appropriate extraction technologies. This study intends to contribute to this quest by investigating the proximate and antioxidant compositions of *A. floribunda* seed as well as the yield and characterization of oil extracted from the seeds

Materials and Methods

The study site, collection and processing of plant material

Fresh *A. floribunda* fruits were collected from Okomu National Park, located in the lowland rainforest region of Nigeria. The Park covers an area of 202.24 km² and lies between latitude 6^{o} 15′N to 6^{o} 25′ N and longitude of 5^{o} 23′ E to 5^{o} 90′E. The climate is tropical, with distinct rainy and dry seasons and characterised by high mean monthly temperature (about 30 ºC) and well distributed high annual rainfall (1,525–2,540 mm). The rainy season lasts from March to November while dry season spans December to February. Elevation is about 300 meters asl. Mean monthly humidity is not lower than 65% at any time of the year. The soil is acidic (mean pH of 5.0) with nutrient poor sandy loam.

A total of 20 matured *A. floribunda* fruits were harvested from Okomu National park. The fruits were opened and the seeds manually extracted through maceration. The seeds (600 to 800) were washed with distilled water and sun–dried until a constant weight was attained. Afterwards, the seeds were weighed to obtain their initial weights.

Determination of proximate and anti-nutritional compositions

The seeds were analyzed for the proximate compositions: moisture, ash, fat, crude fiber, carbohydrate, and crude protein, while the anti-nutritional compositions examined were: tannin, saponin, alkaloid, oxalate and phytate. Proximate compositions were determined using AOAC (2005) methods. Tannin content was estimated using Marker and Goodchild (1996) method while saponin was determined using spectrophotometric method (Brunner, 1984). Chromatographic analysis was performed for alkaloid using the modified Lee *et al*.

(2007) method. Oxalate was determined following the AOAC (2005) method while phytate was determined using the Wheeler and Ferrel (1971) method.

Determination of antioxidant compositions

Total phenolic content, total flavonoid, ferric reducing property, Fe^{2+} Chelation, DPPH (1, 1-diphenyl–2 picrylhydrazyl) and ABTS scavenging ability were the antioxidants determined. Each analysis was repeated three times. Total phenolic content was determined by Folin-Ciocalteu assay using gallic acid as standard (Enujiugha, 2010) while total flavonoid content was determined using a colorimetric assay developed by Bao *et al*. (2005). For ferric reducing property, 0.25 ml of the extract was mixed with 0.25 ml of 200 mM of Sodium phosphate buffer pH 6.6 and 0.25 ml of 1% KFC and incubated at 50 ^{o}C for 20 minutes, thereafter 0.25 ml of 10% Trichloroacetic acid was added and centrifuged at 2000 rpm for 10 minutes, 1 ml of the supernatant was mixed with 1 ml of distilled water and 0.1% of $FeCl_3$; the absorbance was measured at 700 nm (Pulido et al., 2000). The ability of the seed extract to chelate Fe^{2+} was determined by adding 150 mM $FeSO_4$ to a reaction mixture containing 168 ml of 0.1 M Tris-HCl, pH 7.4, 218 ml saline and the extract and the volume made up to 1 ml with distilled water. The mixture was incubated for 5 minutes, before adding 13 ml of 1, 10-phenantroline and the absorbance read at 510 nm (Punte *et al*., 2005). For DPPH determination, seed extracts were measured in terms of hydrogen donation or radical scavenging activity using the stable radical DPPH (Gyamfi *et al.,* 1999). 1 ml of the extract was mixed with 1 ml of 0.4 mM methanolic solution of DPPH. The mixture was left in the dark for 30 minutes before measuring the absorbance at 516 nm. ABTS scavenging ability was generated by reacting an ABTS (7 mM) aqueous solution with $K_2S_2O_8$ (2.45 mM/l, final conc.) in the dark for 16 hours and adjusting the absorbance at 734 nm to 0.700 with ethanol (Re *et al*., 1999). About 0.2 ml of the appropriate dilution of the extract was then added to 2.0 ml of ABTS solution and the absorbance read at 732 nm after 15 minutes.

Oil extraction and analysis

For oil extraction, *A. floribunda* seed coat was removed, the cotyledon weighed and macerated with a mortar and pestle. Extraction was carried out using petroleum ether as solvent for Soxhlet apparatus. Dried and crushed seeds were introduced into a Soxhlet extractor. After 5 hours of extraction with cyclohexane as solvent, the extract was dried with sodium sulphate. The solvent was evaporated in a rotary vacuum evaporator and the solvent traces eliminated by drying the oil in an oven at 103°C for 6 hours. The extracted oil was dried and weighed and percentage oil yield estimated with equation (1):

$$\%\text{Yield} = \overline{h \times 100 \quad h}$$

…………………………………Equation (1)

For analyses of oil physical properties, standard test procedures described by AOAC (2005) were adopted to determine the specific gravity, refractive index, density and viscosity of the oil. Standard chemical analyses were also carried out using the procedures contained in Ajiwe *et al*. (1997) to determine the free fatty acid (FFA), saponification, iodine, peroxide and pH values of the oil.

Results and Discussion

Proximate Compositions

The results revealed that *A. floribunda* seed has high nutritional contents (Table 1), which is an indication that it can play an important role in food security and fight against malnutrition. Traditionally, *A. floribunda* seed is used for food and nutrition, it has been collected by people in Ghana, Tanzania, Nigeria, and Sierra Leone for food and more recently, to produce soap and oil (Orwa and Munjuga, 2007; Lee *et al*., 2007; Adubofuor *et al*., 2013). Edible forest food trees play important role in human nutrition and healthy living. They are essential for growth, maintenance of good health and vitality, impart strength, give power of endurance, vigor of intellect, etc. because of their richness in essential nutrients, vitamins, minerals and antioxidants (Onyekwelu *et al*., 2015).

Allanblackia floribunda seed has high mean carbohydrate composition of 33.69% (range: 31.44% to 35.96%) as well as high mean fat content of 46.98% (range: 46.87% to 47.09%) (Table 1). Carbohydrates enable the human body to produce the energy required for normal functions. The mean carbohydrate content of 33.69% for *A. floribunda* seed in this study is similar to the about 32.6% reported for the species by Dike and Asuquo (2012) and Crockett (2015). The carbohydrate content of *A. floribunda* is higher than those of *A. paviflora* (17.06%), *Chrysophyllum albidum* (14.7%) and *Garcinia kola* (21.8%); compares favorably with those of *Irvingia gabonensis* (26.0–38.8%) and *P. macrophylla* (20–39%) and lower than that of *Treculia africana* (40.0–58.5%) (Ejiofor *et al*., 1987; Enujiugha and Akanbi, 2005; Adubofuor *et al*., 2013; Onyekwelu *et al*., 2015). Thus, *A. floribunda* seed is a good source of plant carbohydrate. High fat content seems to be characteristic of *A. floribunda* seed considering the over 60% fat content reported for it (Adubofuor *et al*., 2013, Crockett 2015, Folarin *et al*. 2017). The high fat content of *A. floribunda* seed may be associated with its high oil content.

Similar oil seeds like *Irvingia gabonensis, Dacryodes edulis* and *Treculia africana* have high fat contents of 26.0–38.8%, 50% and 47.4%, respectively. Based on its high fat content, *A. floribunda* seeds could be considered for production of margarine, soaps, cosmetic and other related products. The international food industry has become interested in the fat from *A. floribunda* seed as a natural solid component for margarines and similar products (Orwa *et al*., 2009).

The mean crude fiber content of *A. floribunda* seed was 8.79% (range: 7.49 – 10.08%) while mean crude protein composition was 9.05% (range: 8.23 – 9.87%) (Table 1). The presence of fiber in any food is important for reducing cholesterol levels in the body, thus minimizing the risks of cardiovascular diseases caused by high plasma cholesterol. The high crude fiber content indicates that *A. floribunda* seeds will play an important health function when ingested. Any plant food that provides about 12% of its calorific value from protein is considered a good protein source (Effiong *et al*., 2009). Consequently, the 9.05% crude protein content of *A. floribunda* seed implies that it is not a good source of plant protein.

Table 1: Nutritional compositions of *Allanblackia floribunda* seed

Nutrients	Nutritional Composition (Dry weight basis)			
	Minimum	Maximum	Mean	Standard deviation
Moisture content (%)	4.33	4.37	4.35	0.03
Ash (%)	1.45	1.52	1.49	0.05
Fat (%)	46.87	47.09	46.98	0.16
Crude fiber (%)	7.49	10.08	8.79	1.83
Crude protein (%)	8.23	9.87	9.05	1.16
Carbohydrate (%)	31.44	35.96	33.69	3.20

The low protein contents of *A. floribunda* seeds as well as those of seed species fortifies the widely held opinion that seeds are generally not considered as excellent sources of proteins. However, given the protein-poor diets of the rural poor where animal protein can be scarce, consuming *A. floribunda* seed can still contribute to the protein requirements in rural areas.

The mean moisture content of of 4.35% for *A. floribunda* seed in this study is lower than the 12.03% reported for the species by Dike and Asuquo (2012). Moisture content of a food is used as a measure of stability and susceptibility to microbial contamination. High moisture contents in food items could make them vulnerable to microbial attack, hence spoilage (Onyekwelu *et al*., 2014). Thus the low moisture content of *A. floribunda* seed would be an advantage against microbial attack, prevent its spoilage, improve its shelf-life and preservation. Ash content is a reflection of the nutritionally important mineral contents in foods. The mean ash content of 1.49% for *A. floribunda* seed in this study compares favorably with the 1.70% reported for the species by Dike and Asuquo (2012) and 1.48 − 1.66% reported for *C. albidum* (Onyekwelu *et al*., 2015) but higher than the 0.26% - 0.81% for *G. kola* seeds (Onyekwelu *et al*., 2015). The ash content of *A. floribunda* seed indicates that it would provide essential, valuable and useful minerals needed for body development.

Anti-nutrtional Compositions

Generally, the quantity of anti-nutrients present in *A. floribunda* seeds is low as indicated by the low mean values of tannin (0.52 mg.g^{-1}), oxalate (0.86 mg.g^{-1}) and phytate (2.25 mg.g^{-1}) (Table 2). Saponin (4.15 mg.g^{-1}) and alkaloid (2.36 mg.g^{-1}) contents were higher than other anti-nutrients (Table 2). Comparison with the anti-nutritional factors of some edible forest seed species, confirms that *A. floribunda* seed contains low anti-nutrients, thus consuming the seeds would not be harmful to human health. Some researchers reported ranges of 0.24− 1.26 mg.g^{-1} for oxalate; 0.65−7.31 mg.g^{-1} for saponin; 0.02−18.54 mg.g^{-1} for tannin; 0.43−5.21 mg.g^{-1} for phytate and 0.02−14.17 for alkaloid for *C. albidum*, *G. kola*, *A. floribunda*, *Adansonia digitata*, etc. (Ingweye *et al*., 2010; Dike and Asuquo 2012; Onyekwelu *et al*., 2015), which are within the range reported in this study. The presence of anti-nutrients is one of the major drawbacks limiting the direct use of some foods; high quantity of anti-nutrients can prevent the absorption of some minerals that are essential for metabolism. High contents of anti-nutrients could also affect homeostasis of zinc and iron and inhibit enzymatic digestion of proteins by forming complexes with large quantities of protein and would therefore be toxic (AOAC, 2005). The low oxalate content in *A. floribunda* seed implies that its consumption would not cause metabolic calcium deficiency (Anhwange *et al*., 2015). The low saponin and other alkaloids in *A. floribunda* implies that its ingestion would not expose humans to risk of haemolysis of blood tissues and injury to the digestive mucosa (Desai *et al*., 2009). The low phytate in *A. floribunda* seed indicates that it might not reduce the bio-availability of minerals in the seed and will not inhibit proteolytic enzymes and amylases during digestion.

Table 2: Anti-nutritional composition of *Allanblackia floribunda* seed

	Anti-nutritional Composition (Dry weight basis)			
Anti-nutrients	Minimum	Maximum	Mean	Standard deviation
Oxalate (mg.g^{-1})	0.83	0.89	0.86	0.02
Phytate (mg.g^{-1})	2.10	2.40	2.25	0.01
Tannin (mg.g^{-1})	0.50	0.54	0.52	0.02
Saponin (mg.g^{-1})	4.00	4.30	4.15	0.01
Alkaloid (mg.g^{-1})	2.33	2.39	2.36	0.02

Relatively small amounts of tannins, such as in this study, may have a potential role as protective factor against free radical mediated pathologies in humans like cancer and atherosclerosis (Kehrer, 1993). Associating polyphenols (including tannins) to free radicals scavenging and metal chelating activities, suggests their potentially beneficial implications in the treatment and prevention of cancer (Hangen and Bennin, 2002).

Antioxidant Compositions

Results revealed that *A. floribunda* seed has high antioxidant compositions (Table 3), which suggest that it could be a potential source of natural antioxidants, thus it can be used as supplements in food manufacturing and development of nutritional drinks. Dietary antioxidants are essential for human health; they are nature's way of protecting the cells from damaging free radicals; they play important roles in controlling oxidative stress and are considered potential therapeutic agents against many diseases resulting from oxidative stress (Boudjeko *et al*., 2015). The *mean* total phenol and *flavonoid* contents of *9.75* $mg.g^{-1}$ *and 17.73* $mg.g^{-1}$, respectively for *A. floribunda seeds* (Table 3) are higher than the values reported for various nuts and oil seeds (Sreeramulu and Raghunath, 2011). Onyekwelu *et al*. (2015) reported higher total phenol for *C. albidum* and *G. kola* seeds but much lower flavonoid contents for seeds of the two species compared to *A. floribunda* seeds. Due to its high phenol content, *A. floribunda* seed has potential to act as reducing agents, hydrogen donators, metal chelating and single oxygen quenchers (Rice-Evans *et al*., 1996).

The high mean FRAP value of 88.39 $mg.g^{-1}$ *for A. floribunda seed, which can be attributed to the presence of phenolic compounds in the seed,* indicates a strong reducing power. Generally, reducing properties are associated with the presence of compounds which exert their actions through breaking of the free radical chain by donating a hydrogen atom. DPPH and ABTS tests show the ability of the test compound to act as a free radical scavenger. The mean ABTS and DPPH compositions of *A. floribunda* seeds were 85.49 mMol/g and 29.54%, respectively while mean Fe^{2+} chelation content was 20.39% (Table 3). The DPPH and ABTS contents *A. floribunda seeds in this study were higher than what was recorded for A. floribunda leaves and fruits by* Ayoola *et al*. (2008). Onyekwelu *et al*. (2015) reported much higher DPPH values of 50.4% and 54.59% for *C. albidum* and *G. kola* seeds, respectively, while Ourradi *et al*. (2021) range of 17.28% to 47.37% for eight varieties of date palm seeds oils. The DPPH scavenging activities of *A. floribunda seeds* indicates its free radical scavenging potentials and thus the potential effectiveness of the seed as natural antioxidants.

Table 3: Antioxidant composition of *Allanblackia floribunda* seed

	Antioxidant Composition (Dry weight basis)			
Antioxidants	Minimum	Maximum	Mean	Standard deviation
Phenol (mg/g)	9.61	9.90	9.76	0.21
Flavonoid (mg.g)	17.71	17.75	17.73	0.03
FRAP (mg/g)	87.87	88.92	88.40	0.74
ABTS (mMol/g)	85.28	85.71	85.50	0.30
DPPH (%)	29.46	29.63	29.55	0.12
Fe^{2+} chelation (%)	20.06	20.72	20.39	0.47

The Fe^{2+} ion is the most powerful pro-oxidant, able to form complexes with ferrozine. The Fe^{2+} chelating ability of *A. floribunda seed (*20.39%) *in this study is lower than the* 54.25% *reported for the stem bark of the species* (Boudjeko *et al*., 2015), which may be an indication that the stem bark of the species could also be a better source of Fe^{2+}. The percentage Fe^{2+} chelating ability of *A. floribunda seed indicates its ability to* accelerate lipid peroxidation by breaking down hydrogen and lipid peroxides formed by the Fenton free radical reaction (Boudjeko *et al*., 2015).

Oil Yield and Characterization

Traditionally, *A. floribunda* seed is being used for oil (Orwa and Munjuga, 2007). In Tanzania, Ghana, Nigeria, and Sierra Leone, the seed (especially *A. parviflora* and *A. floribunda*) have been collected by local communities for production of cooking oil (Adubofuor *et al*., 2013). The seed has high economic values due to the high nutritional values and the unique physical properties of its oil, which are similar in some ways to *Elaeis guineensis* Jacq. seed oil (Crockett, 2015). High oil content in plant seed implies that processing it for oil would be profitable. *A. floribunda* seed oil yield in this study was high, with a mean value of 46.46% (Table 4), the oil was observed to be light-yellow. Comparison of *A. floribunda* seed oil yield and its characteristics with those of some tropical forest and agricultural seeds (Table 4) indicated that the species is among seed species with very high oil contents. While *A. floribunda* seed oil yield in this study was 46.5%, those of *Hevea brasiliensis*, *Dacryodes edulis* and *Moringa oleifera* seeds were 38.8%, 27.3%, and 38.4%, respectively (Table 4). Much lower oil yield (6.05 to 10.25%) was reported for date palm (*Phoenix dactylifera* L.) seeds (Ourradi *et al*., 2021). Agu *et al*. (2020) reported 60.45% oil yield for *Terminalia catapa* seed kernel using solvent extraction method. The comparable and higher *A. floribunda* seed oil yield with those of *Arachis hypogaea* (Groundnut) (35.0–46.4%) and oil palm (28.0%) indicates that the species has potential for high oil yield. Matchet (1963) suggested a minimum of 30% oil yield for a seed to be a suitable candidate for commercial and industrial oil production, implying that *A. floribunda* seed will be viable for for commercial oil production considering its 46.5% oil yield, thus it would contribute to economic empowerment and poverty alleviation. Allanblackia oil is useful in the production of margarine, soaps, cosmetics and ointments (Agu *et al*., 2020). Thus, companies like Unilever PLC purchase Allanblackia seeds form farmers, a situation which has created a guaranteed market for the product (Sefah *et al*., 2019). Much higher oil yield can be obtained from *A. floribunda* seed if more efficient extraction method is used. Using Soxhlet extraction (cyclohexane) method, 60%–65% oil yield from was obtained from *A. floribunda* seeds (Loumouamou *et al*., 2014). Also, 62.5% oil yield was obtained from *A. floribunda* seeds using Soxhlet extraction (hexane) technique (Noumi, 2011).

The Iodine value of oil is a measure of the degree of unsaturation and an identity characteristic of seed oils, which makes them excellent raw materials for soap and cosmetic industries. The lower the iodine value, the less the number of unsaturated bonds and the lower the susceptibility of such oil to rancidity. Oils with iodine value less than 100 $gI_2/100g$ are non-drying oils (Aremu, 2015). Our results revealed that *A. floribunda* seed oil had a low mean iodine value of 69.42 $I_2g/100$ g of oil, which suggests that the oil is non-drying. Thus, *A. floribunda* seed oil is suitable for soap making but may not be suitable for ink and paint production due to its non-drying characteristics (Kochhar, 2011).

Compared to refined oils, unrefined vegetable oils are characterized by higher peroxide values (Ikhuoria *et al*., 2008). High peroxide values are indications of high levels of oil oxidation. Mean peroxide value of *A. floribunda* seed oil was 2.20 $mEqO_2/kg$ of oil while mean Free Fatty Acids (FFA) was 1.55 mg NaOH/g of oil. Our initial observation was that the peroxide value for *A. floribunda* oil in our study is within the WHO/FAO (WHO/FAO, 1995) recommended maximum peroxide level of not more than 10 mEqO_2/kg of oils, which implies that the *oil is* suitable for human consumption. The European Union Novel Food Regulations has certified *A. floribunda* seed oil safe for use in food products (Hermann, 2009). High FFA value is undesirable in finished oils as it could result in large losses of neutral oil during refining and shorten oil shelf-life (Aremu *et al*., 2015). High quality oils have low FFAs. In refined vegetable oils, the lower the FFA, the more palatable the oil. The FFA value of 1.55 mg NaOH/g of oil for *A. floribunda* seed oil, which is lower than the 5.90 and 28.40 for Palm kernel and cashew nut oils, respectively (Evbuowman *et al*., 2013), implies that the quality of *A. floribunda oil* is good. The oil would not easily go rancid and its shelf-life would be long.

A. *floribunda* oil has a low mean saponification value of 122.60 mg KOH/g of oil, unsaponification value of 0.38 mg KOH/g of oil and mean pH value og 5.28 (Table 4). Our saponification value for *A. floribunda* oil *i*s lower than 199.39 mg KOH/g for the species by Wilfred *et al*. (2010) while our unsaponification value is lower than the range of 0.84 to 41.78 mg KOH/g for soybean and luffa gourd seed oils (Aremu *et al*., 2015). Refractive index is used in quality control to check the purity of materials. Our mean refractive index of 1.41 for *A. floribunda* seed oil is within the range of 0.15 – 1.79 for some seed oils (Kochhar, 2011) and falls within the acceptable range of 1.46– 1.47 for virgin, refined and refined-pomace oils based on Codex Standards for vegetable/plant oil (CODEX, 2017).

At 25^{o}C, *A. floribunda* seed oil had mean viscosity and specific gravity of 7.51 mPa.s and 0.96 kg/dm^3, respectively. The viscosity index for *A. floribunda* seed oil compares favorably with 9.42 mPa.s for castor oil but lower than 32.45 and 302.39 mPa.s for sesame and almond oils, respectively (Akpan *et al*., 2006, Aremu *et al*., 2015). The more viscous an oil, the better its use as lubricant, hence oils with low viscosity value indicate that they are light in colour and probably highly unsaturated. Thus, *A. floribunda* oil can be regarded as unsaturated without suspended particles, which suggest its high purity. Specific gravity is commonly used in conjunction with other figures to assess oil purity. The specific gravity of 0.96 kg/dm^3 for *A. floribunda* oil suggests that it is less dense than water and would be useful in cream production as it will flow and spread easily on the skin.

Harnessing the Potentials of *A. Floribunda* Seed Oil

Though *A. floribunda* seed oil yields reported in present and earlier studies are higher than the 30% recommended by Matchet (1963) as the minimum for commercial and industrial oil production, there is no known commercial production of *A. floribunda* oil. The comparable *A. floribunda* seed oil yield with those of common vegetable oils (Table 4) further suggests that the species is a suitable candidate for commercial oil production. The high *A. floribunda* seed oil yield provides a justification for commercial oil production. Recently, new uses of Allanblackia oil at industrial scale were reported by Unilever for manufacture of margarine and cosmetic products, thus increasing demand (Ofori *et al*., 2013). The potential demand for Allanblackia oil, estimated at over 100,000 tons/year (Ofori *et al*., 2013), cannot be met by seed supply from the wild. Currently, demand for the oil is higher than the supply from natural forests and remnants on farms. Thus, if the only source of *A. floribunda* seeds is from the wild, the probability of obtaining its oil and other products on sustainable basis will be very low.

This high potential of *A. floribunda* seed can be harnessed through domestication. The need to rapidly domesticate tropical forest food tree species is one of the three pillars of the International Centre for Agroforestry Research (ICRAF) programme. Analysis of the genetic diversity of *A. floribunda* trees is very important for its domestication due to its large genetic diversity (Atangana *et al*., 2010).

Table 4: Comparison of the yield and physico-chemical characteristics of *A. floribunda* oil (this study) with oil from different forest and agricultural oil seeds

Physico-chemical characteristics	Forest oil seed species						Agricultural oil seed species		
	A. floribunda (Tallow tree)	*Pentaclethra macrophylla* (African oil bean seed)	*Dacryodes edulis* (Afri. Pear)	*Blighia sapida* (Ackee)	*Lophira lanceolate* (Red ironwood)	*Moringa oleifera* (Moringa)	*Elaeis guineensis* (Oil palm)	*Ricinus Communis* (Castor seed)	*Arachis hypogaea* (Groundnut)
% Oil Yield	46.5	47.9	27.3	26.0	40.0	38.43	28.0	33.2	35.0–46.4
Color	Light yellow	Light brown	Light yellow	ND	ND	ND	Milk white	Amber	
pH value	5.28	ND	ND	ND	ND	ND	ND	6.11	
Iodine Value (I_2g/100 g of oil)	69.42	57.6	121.03	87.6	65.0	68.06	18.30	87.72	90.20
Peroxide value (mEqO_2/kg of oil)	2.20	5.2	ND	135.0	95.0	1.20	2.12	ND	18.0
Saponification value (mg KOH/g of oil)	122.60	171.1	121.03	261	219	178.02	246.60	185.83	209.23
Unsaponification value (mg KOH/g of oil)	0.38	ND	ND	ND	ND	ND	ND	0.3-0.7	
Free fatty acids (mg NaOH/g of oil)	1.55	1.64	1.68	ND	ND	0.45	7.06	ND	
Refractive index	1.41	1.46	ND	ND	ND	1.4621	ND	1.4686	1.468
Viscosity at 25^{o}C (mPa.s)	7.51	ND	ND	ND	ND		ND	9.42477	
Specific gravity (kg/dm^3)	0.96*	ND	0.93***	1.45** **	1.46****		0.88	0.9587	1.10
Reference	This study	Ikhuoria *et al*. (2008)	Ikhuoria *et al*. (2008)	Kyari (2008)	Kyari (2008)	Faisal *et al*. 2018)	Akubugwo and, Ugbogu (2007)	Akpan *et al*. (2006)	Sharma *et al*. (2017), Bello and Agge (2012)

* at 25^{o}C (kg/dm^3); ** at 20 ^{o}C; *** at 28^{o}C (kg/dm^3); **** at 20 – 40 ^{o}C

However, there is need to overcome constraints like low and irregular seed germination, long juvenile phase to fruiting at least 12 years, etc. The foreseen returns from planting *A. floribunda* trees will compare favorably with crops like cocoa and oil palm (Asaah *et al*., 2011). Vegetative propagation techniques are needed to capture certain desirable fruit traits to produce planting materials with the same genetic characteristics as the mother trees. Suitable vegetative propagation techniques for the species (e.g. rooting of leafy stem cuttings, grafting and air layering) could result in first flowering one to two years after grafts (Asaah *et al*., 2011).

Conclusion

Allanblackia floribunda seed has high nutritional compositions, indicating that it can play important role in human nutrition and food security. The seed has low anti-nutritional contents, thus it is safe for consumption. The seed of *A. floribunda* has high antioxidant compositions, suggesting that it could be a potential source of natural antioxidants. The oil yield of *A. floribunda* seed is higher or comparable with those of some common vegetable seed oils. *A. floribunda* seed has potential for commercial production of good quality oil. The *oil is* suitable for human consumption, it is a useful raw material for cream, soaps and cosmetics industries. The oil is light yellow, unsaturated without suspended particles, which suggest its high purity. The seed *oil* has long shelf-life. To harness the commercial potentials of *A. floribunda* seed oil, domestication of the species is recommended

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