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# Physicochemical Characteristics of the Oils Extracted from Some Nigerian Plant Foods – A Review

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**Abstract**

Fats and oils are non-volatile substances insoluble in water but soluble in organic solvent. They constitute along with protein and carbohydrates, the major food stuffs and are widely distributed in nature. Oil serves as a good source of protein, lipid and fatty acids for human nutrition including the repair of worn-out tissues, new cells formation as well as a useful source of energy. Oilseeds are those seeds that contain considerably large amounts of oil. Oil can be extracted from oilseed by using traditional methods of extraction (on a very small scale), mechanical expression (hydraulic and screw presses) which can be manual, semi-automated or automated, and solvent extraction (e.g. hexane, fluid carbon dioxide) or a combination of two of these methods. Physicochemical parameters of the oils extracted from some Nigerian plant foods using standard analytical techniques were reviewed. The physicochemical properties of the plant oils reviewed were found to be at the range concentrations as follows: Saponification value (SV): 5.58 - 249.90 mgKOH/g, peroxide value (PV): 0.45 - 290.00 mEq $O_2$/kg of sample, acid value (AV): 0.34 - 68.88 mg KOH/g, iodine value (IV): 2.65 - 153.00 g $I_2$/100g sample, density (Ds): 0.9031 - 0.9208 g/cm$^3$, viscosity (Vs): 0.43 to 302.39 mm$^2$/sec, specific gravity (SG): 0.830 – 1.710, refractive index (RI): 0.147 – 1.792, free fatty acid (FFA): 0.14 – 34.65 % as oleic acid, ester value (EV): 0.54 – 241.04 mgKOH/g and heat of combustion (HC): 8904.25 – 11303.35 gcal/g. The result of the reviewed work confirms the Nigerian seed oils to be of good quality and can find application either in food industry as food additives or industrial purposes such as cosmetics, soaps, paint and even energy generation.

**Keywords:** Physicochemical parameters, seed oils, Nigeria.

## 1. Introduction

The term oil is used in generic sense to describe all substances that are greasy or oily fluid at room temperature (Buba, 2005). Generally, fats are considered as extracted triglycerides/lipids that are liquid under the same condition. Fats and oils belong to a larger group of naturally occurring substances called lipids. Because lipids serve as a convenient means of rapid heat transfer, they have found increasing use in commercial frying operations (Andrew *et al.*, 2012). Fats and oils are non-volatile substance insoluble in water but soluble in organic solvent. They constitute along with protein and carbohydrates, the major food stuffs and are widely distributed in nature. From chemical point of view, oils and fats are products of the reaction between a triol (glycerol) and three molecules of fatty acids. This type of reaction is commonly termed as esterification.

Oils/fats are obtained basically from two sources namely: animal and vegetable sources (Snell & Snell, 1992). Animal fats and oils are derived both from terrestrial and marine animals. Marine fats include liver oils etc. Terrestrial fats and oils derived from animals include lard (from Swine), suet (from oxen or sheep), ghee (from cow or buffalo milk), etc. Vegetable oil is found in greatest abundance in fruits and seeds. Oils obtained from plant source are termed vegetable oils. These include: palm oil, cotton seed oil, ground oil, sunflower oil etc.

Edible oils from plant sources are of interest in various food applications and industries. They provide characteristic flavours and textures to foods as integral diet components (Odoemelam, 2005) and can also serve as a source of oleo chemicals (Morrison *et al.*, 1995). Vegetable oils had made an important contribution to the diet in many countries, serving as a good source of protein, lipid and fatty acids for human nutrition including the repair of worn-out tissues, new cells formation as well as a useful source of energy (Gaydon *et al*., 1983; Grosso & Guzman, 1995; Grosso *et al*., 1997; 1999; Aremu *et al.,* 2013).

Oilseed crops are major sources of lipids for human nutrition as well as for several industrial purposes. They are defined as those seeds that contain considerably large amounts of oil. The most commonly known oilseeds (conventional oil seeds) are groundnut, soybean, palm kernel, cotton seed, olive, sunflower seed, rapeseed, sesame seed, linseed, safflower seed, etc (Ajala & Adeleke, 2014; Akintayo & Bayer, 2002; Adeyeye *et al.,* 1999; Aremu *et al.,2007*). There has been an increase in the world production of oil seeds over the last thirty years (Murphy, 1994): This would appear to be related to the products and by-products as oils seeds are primarily grown for their oil and meal. Vegetable oil is always at a higher price per ton than the cake, this is because the demand for oil is often higher than the cake.

Nut and seed oils are receiving growing interest due to their high concentration of bioactive lipid components which have shown various health benefits. Fats and oils, and their several lipid components can extensively be used in the food and also in cosmetics, pharmaceuticals, biodiesel paints and other. Oils from most edible oils seeds are used in the food industry, though there is growing emphasis on industrial utilization as feedstock for several industries with about 80% of the world production of vegetable oils for human consumption. The remaining 20% utilization is between animal and chemical industries. The ability of a particular oilseed fit into the growing industries depends on its utilization potential, rate of production, availability and ease of the processing technology.

Generally, oils and fats from seeds and nuts constitute an essential parts of man’s diet. Fats and oil, together with proteins, carbohydrates, vitamins and minerals are the main nutrients required by the human body. The chief important of the vegetable oils lies in their food value. Vegetable oils derived from plant seeds have been playing vital roles to provide comfort in human lives in various aspects, they are essential in meeting global nutritional demands and are utilized for many food and other industrial purposes (Idouraine *et al.,* 1996). In the last few decades, there have been growing concerns over vegetable oils as source of material in preference to petroleum or mineral oil. The main factor for this concern is due to environmental issues that regard mineral oil as major contributor of volatile organic components which themselves are responsible for most of our present recalcitrant pollution problems threatening the ecology. Oilseeds are also used in animal feed because of their high protein content. Their seeds contain energy for the sprouting embryo mainly as oil, compared with cereals, which contain the energy in the form of starch (McKevith, 2005).

There are two quality types of oil: (i) Edible oils, used as a food grade oil, that is most often encountered as an odorless frying oil which is low in unsaturated fats, but, it is also an ingredient in many food products, especially where a healthy oil is required. (ii) Industrial oils (although some edible types are also used industrially) - which are not edible, but, have been bred to contain high levels of compounds critical for some industrial processes.

Edible fats and oils are similar in molecular structure; however, fats are solid at room temperature, while, oils are liquid. Fats and oils are essential nutrients, comprising about 40% of the calories in the diet of the average person. Edible vegetable oils are used as salad or cooking oils, or may be solidified (by a process called hydrogenation) to make margarine and shortening. These products supplement or replace animal products (butter, lard), supplies of which are inadequate to meet the needs of an increasing world population. While there are many uses for industrial vegetable oils, but, total world production is only about 3% of that of edible oils. Industrial applications are based on the properties of particular fatty-acid components of these oils. For example, flaxseed oil, rich in the unsaturated fatty acid linolenic, is a drying oil and is used in protective coatings (paints, varnishes). Vegetable oils are used in putty, printing inks, erasers, coating or core oils, greases, plastics, etc. The residue remaining after the oil has been extracted from oilseeds, is an important source of nutrients for farm animals. Oilseed meals from soybean, peanut, rapeseed and flaxseed are rich in protein; when mixed with other ingredients (cereal grains), and they provide nutritionally balanced feeds (Sarwar *et al.,* 2004b; 2011).

The essential fatty acids contained in hemp seed oil are required in our diet more than any other vitamin, yet our bodies do not naturally produce them. They must be obtained from external sources in the food we eat. These are involved with producing life's energy throughout the human body and without them, life is not possible.

Extensive studies have demonstrated that many common illnesses are related to deficiencies or imbalances of specific fatty acids in the body. Symptoms are often related to a lack of omega 3 and omega 6 fatty acids and their derivatives, the postaglandins. Most people eating a healthful diet, one that includes a balanced ratio of essential fatty acids, also have healthy skin and a strong immune system. Yet some individuals may experience shortages in specific fatty acids or their metabolites due to dysfunctional enzyme systems or other inhibitions in their metabolic pathways caused by genetic, immune-system-related, or even environmental factors. Hemp seed oil also provides an adequate supply of antioxidants (Vitamin E), carotene (precursor to Vitamin A), phytosterols, phospholipids and a number of minerals including calcium, magnesium, sulfur, potassium, phosphorus, along with modest amounts of iron and zinc. Oilseed rape is a very useful crop as the seed is typically 42% oil and the meal left after removing the oil is about 42% crude protein. Proteins serve a variety of functions in the human body such as acting as enzymes, antibodies, and the structural components of tissues, hormones and blood protein. The main function of dietary protein is to supply amino acids for the growth and maintenance of body tissue. Digestion disassembles proteins into their basic building blocks - amino acids. Furthermore, the oil is particularly of high quality and high in monounsaturates, and should logically be a premium product. Today's certain varieties of oilseed rape have been bred to provide oil that is suitable for use in cooking and food processing. Known as vegetable oil, the oil is widely used by the food industry and is now being increasingly processed for use as bio-diesel (Sarwar, 2005, 2008, 2009).

Mustard seeds have been highly prized medicinal as well as culinary spice being in use since ancient times. The seeds are obtained from mustard plant (*Brassica juncea*) which also include cabbage, broccoli, Brussels sprouts, etc. Generally perceived as health benefiting spice, mustard seeds are indeed very rich in phytonutrients, minerals, vitamins and anti-oxidants. Mustard greens are an excellent source of essential B-complex vitamins such as folates, niacin, thiamin, riboflavin, pyridoxine (vitamin B-6) and pantothenic acid. These vitamins are essential in the sense that body requires them from external sources to replenish. These B complex groups of vitamins help in enzyme synthesis, nervous system function and regulating body metabolism. Mustards are rich source of many health benefiting minerals. Calcium, manganese, copper, iron, selenium and zinc are some of the minerals especially concentrated in these seeds. Calcium helps to build bone and teeth. Manganese is used by the body as a co-factor for the antioxidant enzyme superoxide dismutase. Copper is required in the production of red blood cells while iron is required for the red blood cell formation and cellular metabolism (Sarwar *et al*., 2009). Mustard seeds and its oil have traditionally been used to relieve muscle pain, rheuamtism and arthritic pain. The mustard oil is applied over scalp and is believed to stimulate hair growth. Its ground seeds act as a laxative, stimulant to gastric mucosa and increase intestinal secretion (Sarwar *et al*., 2009; Sarwar, 2004a,b).

The protein quantity and quality, caloric value, and overall nutrient content of oilseeds are quite good. In many new oilseed protein sources, phenolic compounds are as important as unsaturated lipids, carbonyl compounds, and nonenzymatic browning in the development of adverse flavors and colours in food products. The free phenolic acids are of particular concern because of enzymatic oxidation too-quinones and subsequent binding to lysine and methionine in the proteins. Numerous free phenolic acids have been identified in all oilseed flours with syringic, ferulic and vanillic being the major components in cottonseed, peanut and soybean flours. Gossypol in cottonseed, chlorogenic acid in sunflower, and sinapine in rapeseed are microconstituent phenolics which cause unique problems in the utilization of these defatted flours and their protein isolates in food applications. The roles of bound phenolics and tannins in the binding of essential nutrients or altering chemical and functional properties require further investigation (Sosulski, 1979).

The Cucurbitaceae seeds such as *Cucumeropsis mannii*, *Cucurbita maxima*, *Cucurbita moschata*, *Lagenaria siceraria* and *Cucumis sativus* and their defatted cakes are rich in proteins (28 to 40.49% and 61 to 73.59%, respectively). They also contain high lipid levels similar to those of the other oilseeds. These seeds can thus be considered as sources of proteins and oils (Mercy *et al.,* 2005). Oilseeds and their constituents developed as functional foods or as sources of nutraceuticals provide benefits for consumers and food processors, and represent a significant opportunity for biotechnology and plant breeding companies. Researchers are applying molecular biology and biotechnology approaches to produce soy and canola oils enriched with sitostanols (Kishore & Shewmaker, 1999). Vegetable oils containing 2 to 5% phytsterols/stanols have been generated by expressing the gene encoding the rate-limiting enzyme for sterol synthesis, hydroxymethylglutaryl-CoA reductase, in seeds of crop plants (Venkatramesh *et al.,* 2000).

In Nigeria, the demand for vegetable oil has ever been widening as industrialist rely mostly on the popular vegetable oil such as palm kernel oil, soya bean oil, cotton seed oil and coconut seed oil for preparation of various products (Akintayo, 2004; Aremu *et al.,* 2007). The characteristics of oils from different sources depend mainly on their compositions and no oil from a single source can be suitable for all purposes thus the study of their constituents is important.

## 2. Methodology

### 2.1 Extraction of oilseed's oil

Various techniques such as mechanical extraction, solvent extraction, traditional extraction and super critical fluid extraction are used to obtain the oil from the seeds. The solvent extraction has become the most popular method of extraction of oil because of its high percentage of oil recovery from seeds. Solvent extraction bridges the gap between mechanical extraction which produces oil with high turbidity metal and water content and supercritical fluid extraction which is very expensive to build and maintain its facilities.

Hexane is often used as solvent for oil extraction due to its lower boiling point for easy separation after extraction, its non-polar nature which makes it suitable for extracting vegetable oils which are generally non-polar, yet hexane has been categorized as hazardous air pollution (HAP) by the US Environmental Protection Agency and is included in the list of toxic chemicals (NIOSA, 2007). The maximum permissible limit for hexane in oil and the meal are 5 ppm and 10 ppm, respectively (PFA, 1934). These problems have attracted researchers to find a suitable alternative solvent. A number of solvents and their mixtures such as n-hexane, petroleum ether, alcohols, etc. have been study. Several parameters such as particle size, volume of solvent, operating temperature and extraction time has been found to affect the percentage yield of oil from seeds. Hence, the determination of the effect of these parameters on oil yields from seeds is important to minimize the loss of oil, the cost of extraction in general and the amount of energy expanded over time.

### 2.2 The role of moisture and temperature in oil extraction

Oil and water can each wet the solid components of oilseeds, though the two differ in affinity for the hydrophilic surfaces of particles. Water has a higher affinity and wets the surface of particles at a faster rate than oil due to its polarity and absorption ability. As such, the surface tension on the particles and water interface is insignificant while that of the oil interface is considerable. Research has proven that particles are selectively wetted by liquids with lower surface tension at the interface; hence water will tend to displace oil from the surface of particles. At a certain moisture content all the surface of the particles will be saturated by water and the oil will flow freely from the molecular forces. Thus, moisture increases the flow of oil through the pores of the press cake, hence reducing the amount of oil entrained in the cake and increasing the oil yield mostly in mechanical expression. High moisture content stops oil flow possibly because the structures of the finely milled particles have been altered (high aggregation). Moisture lubricates the pulp during pressing and causes a slower pressure increase and reduces oil yields (Sefah, 2006).

Temperature is increased for oilseeds after pre-treatments such as cracking, dehulling, and milling by heating, roasting and steaming of oilseeds prior to extraction and is termed thermal treatment of oilseeds. Better extraction is achieved by heating, which reduces the oil viscosity and releases oil from intact cells, and also reduces moisture in the cells. Temperature plays an active role in the seed treatment for mechanical extraction and ensures an effective solvent process by heating the solvent which hastens the extraction process. At the right temperature and moisture content, the individual oil droplets unite to form a continuous phase and flow out maximising oil yield.

 

## 2.3 Traditional extraction of seed oil

Traditionally, the commonest way of oil extraction is the water flotation process; oilseeds are thermally treated, crushed and milled into slurry (paste). With the aid of simple domestic utensils, oil is extracted by hand kneading. Water is added to the slurry and the mixture stirred and kneaded by hand until the oil separates to the top and sides of the utensils being used for the kneading. Water plays a vital role in hydrolyzing the paste, which displaces oil from hydrophilic surfaces in the slurry.

Under the traditional method, there are two ways of extracting oil; wet and water assisted extractions. This method is used, however, on a small scale, as it is labour- intensive, slow and tedious in operation compared to other methods but is assumed to produce high oil quality. In the wet extraction method, water is used in relatively large amounts to suspend the oilseeds such that the extracted oil floats on the top of the suspended oilseeds. Hot water flotation method of edible oil extraction is traditionally used in the rural areas of many developing countries. The water-assisted method involves the addition of small quantities of water to the slurry before the oil is extracted by manual kneading. The slurry is suspended in boiling water and boiled for at least 30 min with liberated oil floating on the surface. Further quantities of water are added after boiling to replace the lost water that occurred during evaporation, and to facilitate the floatation of the oil to the surface. The oil is carefully scooped from the surface of the water and boiled.

## 2.4 Mechanical Expression of Seed Oil

The main applications of mechanical expression are in the extraction of oils and juices. Expression is often combined with size reduction to maximize the yield of product. Components are extracted from plant parts either for direct use or for use in subsequent processing such as refining. In oil-bearing seeds, the oil is found inside cells in small droplets (10–80 μm) in diameter (Fellows, 1998). However, a single type of equipment is not suited to all oilseeds owing to variation in oil content, moisture content, porosity and solidity of the material, applied pressure, heating temperature, heating duration, particle size and shape, storage and handling practices, and the proportions of hulls in different oilseeds are factors influencing yield and quality of vegetable oil expressed (Weiss, 2000).

Expression is achieved either in two stages (size reduction to produce pulp or slurry, followed by separation in a press) or in a single stage, which both rupture the cells and express the oil. In general, the single-stage operation is more economical, permits higher throughputs and has lower capital and operational cost but not suitable for hard nuts as the two stage of expression is more effective. The degree of effectiveness varies with the kind of oilseed and method of oil expression (Akinoso, 2006).

## 2.5 Solvent extraction of seed oil

Solvent extraction is the use of chemicals as solvents in the extraction of oil from oilseeds. Solvent extraction is known for its high yielding oil output, ease and swiftness to carry out; relatively cost effective, high overhead cost, and hazardous effects during and after operations. The use of this method requires a complete refining process to ensure traces of the solvents are removed totally. Solvent extraction of cleaned, cracked, dehulled and conditioned thin soy flakes (0.25–0.30 mm) with hexane is commercially practiced to extract oil (Becker, 1971; 1978, Galloway, 1976). Commercial solvent extraction does not include any pre-pressing operation due to the relative disadvantages of low oil content and slower oil recoveries. Becker (1978), Johnson & Lusas (1983) indicated that hexane, apetroleum-derived product has been extensively used as solvent for the oil extraction of soya beans and other oilseeds because of its low vapourisation temperature(boiling point 63 – 69$^{o}$C), high stability, low corrosiveness, low greasy residual effect, and better aroma and flavour productivity for the milled products. Hexane, however, is listed as a hazardous air pollutant by the United States Clean Air Act. Its use in the oilseed extraction plants can adversely affect workers' central nervous system, while its vapour ignites spontaneously with air at 25$^{o}$C (Becker, 1978; Johnson & Lusas, 1983; Lusas *et al*., 1991; Gandhi *et al*., 2003). Hexane is occasionally scarce and its price fluctuates depending on the supply and demand for gasoline (Johnson and Lusas, 1983). Narain & Singh (1988) also reported that the use of hexane in small-capacity plants makes the processing expensive due to high operational losses. Research, however, is being conducted to find solvents that are safer and readily available than hexane. The ideal solvent must be easily removed from the meal and oil, non-flammable, stable, non-reactive with oil; meal or equipment, pure, only slightly soluble in water and readily available at low prices (Johnson & Lusas, 1983).

### 2.6 Determination of physicochemical parameters of seed oils

The determinations of physicochemical parameters of seed oils for refractive index, acid value, iodine value, saponification value, unsaponifiable matter, peroxide value, free fatty acid and specific gravity are always carried out according to the methods of AOAC (1990).

## 3. Overview of the Physicochemical Properties of Seed Oils

The physicochemical properties of some Nigerian seed oils are presented in Table 1a – 1d. The refractive index range between 0.147 and 1.792 in groundnut and castor seed oils respectively. Refractive index of an oil is the ratio of speed of light at a defined wavelength to its speed in the oil/fat itself. This value varies with wavelength and temperature, the degree and type of unsaturation, the type of substitutions of component fatty acids and with accompanying substances. Refractive index is widely used in quality control to check for the purity of materials and to follow hydrogenation and isomerization (Hoffman, 1986). Most of the seed oils reviewed have their refractive index values within the acceptable range of 1.4677 to 1.4707 for virgin, refined and refined-pomace oils according to Codex Standards for fats and oils from vegetable/plant sources (CODEX-STAN, 1999). The specific gravity ranges from 0.830 in pumpkin seed oil to 1.710 in almond seed oil. The result showed that most of the reviewed oils are less dense than water and therefore would be useful in cream production as it will make the oils flow and spread easily on the skin (Oyeleke *et al.,* 2012b). According to Yahaya *et al.* (2012), specific gravity is commonly used in conjunction with other figures in assessing the purity of oil.

The density of the reviewed seed oils is found to be in the range of 0.847 in cotton seed oil to 1.160 in cashew nut seed oil. Density of seed/vegetable oils is dependent on their fatty acid composition, minor components and temperature (Fakhri & Qadir, 2011). The difference in the density of the reviewed oils may be due to the refined and unrefined characteristics of the oils. Viscosity increased with the molecular weight and decreased with increasing unsaturated level and high temperature (Nourrechni *et al.,* 1992). The viscosity of the reviewed oils ranges from 0.43 to 302.39 in castor and almond seed oils, respectively. The more viscous oil is, the better its use as lubricant (Belewa *et al.,* 2010), hence pumpkin, jatroph curcas, cotton and almond seed oils will have high lubricating properties. Those oils with low viscosity value indicate that they are light and so probably highly unsaturated; the high value might be as a result of suspended particles still present in the crude oil sample (Nangbes *et al.,* 2013).

Acid value gives an indication of the quality of fatty acids in oil. From Tables 1a –1b, the acid values range from 0.34 to 68.88 in akee apple and luffa gourd oils, respectively. These values however accounted for the presence of free fatty acids in the oils as an indicator of the presence and extent of hydrolysis by lipolytic enzymes and oxidation (Gordon *et al.,* 1993). Low acid value in oil indicates that the oil will be stable over a long period of time and protect against rancidity and peroxidation. This could be attributed to presence of natural antioxidants in the seeds such as vitamins C and A as well as other possible phytochemical like flavonoids. Acid value is used as an indicator for edibility of an oil and suitability for use in the paint and soap industries (Aremu *et al.,* 2006a). High acid value in oil (e.g. luffa gourd) showed that the oil may not be suitable for use in cooking (edibility), but however, be useful for production of paints, liquid soap and shampoos (Akintayo, 1997; Aremu *et al.,* 2006a). Also appreciable acid value of oils is an indication that the plant might be poisonous for livestock (Aremu *et al.,* 2006a). The saponification value is in the range of 5.58 to 249.90 for castor and palm kernel oils respectively. Saponification value is a measure of oxidation during storage, and also indicates deterioration of the oils. An increase in saponification value in oil increases the volatility of the oils. It enhances the quality of the oil because it shows the presence of lower molecular weight components in 1 g of the oil which will yield more energy on combustion (Engler & Johnson, 1983). The low saponification value is an indication that the oil may not be suitable for soap making, oil-based ice-cream and shampoos. It has been reported by Pearson (1976) that oils with high saponification values contain high proportion of lower fatty acids. Therefore, the low saponification value of some oils under reviewed indicated that they contain high proportion of higher fatty acid and can be regarded as non-edible oils.

The iodine value is a measure of the degree of unsaturation and it is an identity characteristic of seed oils, making it an excellent raw materials for soaps cosmetics industries (Hamilton, 1999). For the reviewed oils, iodine value ranges from 2.65 in almond seed oils to 153.00 in melon seed oil. The iodine value could be used to quantify the amount of double bond present in the oil which reflects the susceptibility of the oil to oxidation. Oils with iodine value less than 100 $gI_2$/100g of oil are non-drying oils; correspondingly, Aremu *et al.* (2006) reported that the lower the iodine value the lesser the number of unsaturated bonds; thus the lower the susceptibility of such oil to oxidative rancidity. Therefore, non-drying oils are not suitable for ink and paint production due to their non-drying characteristics but may be useful in the manufacture of soaps (Kochhar, 1998) and can be regarded as liquid oil. A good drying oil should have iodine value of 130 and above. Thus, most of the oils in Tables 1a – 1b may not be suitable as alkyl resins for paint formulation or use as varnisher since they cannot be grouped as drying oil because of their iodine values. High iodine value is a pointer to the presence of high percentage of unsaturated fatty acids in the seed oil; as such amount of iodine that will be absorbed by the unsaturated acids would be higher (Eze, 2012) and oils with such characteristic may therefore be find useful as raw materials in the manufacture of vegetable oil-based ice cream (Oderinde *et al.*, 2009).

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**Table 1a: Physicochemical Properties of some Nigerian seed oils**

| Plant seed/Parameter | Colour | RI | SG | Ds | VS | AV | SV | IV | PV | USM | FFA | EV | HC | Authors |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Melon seed oil *(Cucurbitaceae)* | Pale Yellow | 1.350 | 0.913 | - | 5.89 | 7.09 | 220.19 | 114.94 | 20.00 | - | 4.51 | 213.10 | 9250.32 | Edidiong and Ubong, 2013 |
| | White | 1.470 | 0.920 | - | - | 4.77 | 197.00 | 150.00 | 5.63 | - | 1.80 | 192.23 | 9427.45 | Olaofe *et al.*, 2012 |
| | Yellow | 1.460 | 0.910 | - | - | 4.75 | 197.00 | 153.00 | 5.66 | - | 2.05 | 192.25 | 9424.45 | Olaofe *et al.*, 2012 |
| | - | 1.470 | 0.850 | - | 2.48 | 2.37 | 183.13 | 121.51 | - | - | 1.19[a] | 180.76 | 9582.45 | Duduyemi *et al.*, 2013 |
| | - | 1.470 | 1.51 | - | - | 8.02 | 8.00 | 3.45 | 1.72 | - | 4.03[a] | - | 11303.35 | Akpambang *et al.*, 2008 |
| | - | 1.470 | 1.670 | - | - | 9.36 | 9.90 | 3.02 | 1.42 | - | 4.71[a] | 0.54 | 11286.40 | Akpambang *et al.*, 2008 |
| | Yellow | 1.450 | 0.930 | - | - | 3.50 | 192.00 | 110.00 | 8.30 | - | 1.76[a] | 188.50 | 9513.20 | Oluba *et al.*, 2008 |
| | - | 1.460 | - | - | - | 2.02 | 208.10 | 114.30 | 0.45 | - | 2.15 | 206.08 | 9361.59 | Igwenyi, 2014 |
| | - | - | 0.910 | - | - | 3.40 | 148.50 | 74.50 | 2.80 | - | 1.71[a] | 145.10 | 9946.73 | Oyeleke *et al.*, 2012b |
| | - | - | - | - | - | 3.13 | 188.00 | 95.50 | 10.20 | - | 3.40 | 184.87 | 9564.30 | Abiodun and Adeleke, 2010 |
| | - | - | - | - | - | 4.22 | 193.00 | 98.00 | 11.60 | - | 3.90 | 188.78 | 9516.05 | Abiodun and Adeleke, 2010 |
| | - | - | - | - | - | 3.67 | 190.00 | 98.20 | 9.70 | - | 3.50 | 186.33 | 9543.30 | Abiodun and Adeleke, 2010 |
| | - | - | - | - | - | 4.10 | 185.00 | 97.67 | 10.40 | - | 3.60 | 180.90 | 9589.58 | Abiodun and Adeleke, 2010 |
| | - | - | - | - | - | 3.23 | 190.04 | 114.10 | 12.00 | - | 3.30 | 186.81 | 9527.03 | Egbebi, 2014 |
| | - | - | - | - | - | 4.26 | 194.80 | 125.13 | 13.20 | - | 3.80 | 190.54 | 9472.45 | Egbebi, 2014 |
| | - | - | - | - | - | 3.67 | 210.00 | 119.00 | 11.69 | - | 3.50 | 206.33 | 9339.50 | Egbebi, 2014 |
| Groundnut seed oil (*Arachis hypogeal*) | Light Yellow | 1.462 | - | - | - | 4.63 | 227.49 | 38.65 | - | - | 2.33 | 222.86 | 9259.82 | Amos-Tauta and Onigbinde, 2013 |
| | - | 1.472 | - | 0.903 | - | - | - | - | 1.18 | - | 0.67 | - | - | Andrew *et al.*, 2012 |
| | - | 0.147 | - | - | - | 2.52 | 170.00 | 100.70 | 0.47 | - | 1.26 | 167.48 | 9723.80 | Ayoola and Adeyeye, 2010 |
| | - | 0.256 | - | - | - | 1.79 | 195.00 | 108.50 | 0.60 | - | 0.89 | 193.48 | 9487.25 | Ayoola and Adeyeye, 2010 |
| | - | 0.247 | - | - | - | 2.35 | 201.00 | 110.70 | 0.74 | - | 1.18 | 198.65 | 9430.15 | Ayoola and Adeyeye, 2010 |
| | - | 1.465 | - | - | - | - | 220.20 | 81.94 | 22.06 | - | 2.45 | - | 9283.23 | Nkafamiya *et al.*, 2010 |
| | - | - | 0.914 | - | - | 1.88 | 175.78 | 95.87 | - | - | 0.94 | 173.90 | 9675.74 | Musa *et al.*, 2012 |
| | - | 1.449 | - | - | - | 5.99 | 193.20 | 38.71 | 1.50 | - | 3.01 | 187.21 | 9573.51 | Atasie *et al.*, 2009 |
| | - | - | - | - | - | 36.14 | 199.20 | - | - | - | 18.23 | 163.06 | - | Afolabi, 2008 |
| Castor (*Ricinus communis*) seed oil | Amber | 1.469 | 0.959 | - | 9.42 | 1.15 | 185.83 | 87.72 | - | - | 0.58[a] | 184.68 | 9591.94 | Akpan *et al.*, 2006 |
| | Amber | 1.467 | 0.959 | - | 6.48 | 0.87 | 181.55 | 84.80 | - | - | 0.44[a] | 180.68 | 9634.02 | Akpan *et al.*, 2006 |
| | - | 1.792 | - | 0.948 | 0.43 | 14.80 | 180.77 | 58.64 | 158.64 | - | 7.40 | 165.97 | 9667.31 | Nangbes *et al.*, 2013 |
| | - | - | - | - | - | 2.39 | 123.30 | 76.93 | - | - | 1.20[a] | 120.91 | 10174.88 | Warra *et al.*, 2011b |
| | - | - | - | - | - | 0.28 | 5.58 | - | - | - | 0.14 | 5.30 | - | Afolabi, 2008 |

 

## Table 1b: Physicochemical Properties of some Nigerian seed oils

| Plant seed/Parameter | Colour | RI | SG | Ds | VS | AV | SV | IV | PV | USM | FFA | EV | HC | Authors |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pumpkin seed oil (*Telfairia occidentalis*) | Yellow | - | 0.830 | - | - | 3.97 | 158.40 | 49.40 | 2.90 | - | 1.98 | 154.43 | 9881.24 | Akubugwo *et al.*, 2008 |
| | - | - | - | 0.921 | 32.220 | 3.56 | - | 101.00 | 25.00 | - | 14.40 | - | - | Bello *et al.*, 2012 |
| | Light Yellow | 1.460 | 0.920 | - | - | 3.48 | 179.04 | 115.60 | 2.26 | - | 1.74 | 175.56 | 9626.18 | Muibat *et al.*, 2011 |
| | - | 1.463 | 0.933 | - | 45.00 | 12.60 | 184.00 | 16.00 | - | - | 6.34[a] | 171.40 | 9680.40 | Bwade *et al.*, 2013 |
| | - | 1.461 | 0.928 | - | 44.70 | 62.60 | 187.00 | 15.80 | - | - | 31.49[a] | 124.40 | 9653.15 | Bwade *et al.*, 2013 |
| | Yellow | 1.476 | 0.911 | 0.911 | 119.00 | 4.77 | 162.69 | 123.83 | - | - | 2.40[a] | 157.92 | 9767.56 | Nwabanne, 2012 |
| Cashew nut seed oil (*Anarcadium occidentale*) | Yellow | 1.654 | 0.964 | - | - | 0.82 | 168.30 | 44.40 | 3.10 | - | 28.40 | 167.48 | 9795.66 | Aremu *et al.*, 2006b |
| | - | 1.470 | 0.900 | - | - | 12.66 | 17.60 | 136.89 | 2.94 | - | 0.73 | 4.94 | 11082.07 | Aletor *et al.*, 2007 |
| | - | 1.470 | 0.910 | - | - | 22.72 | 10.01 | 115.01 | 1.60 | - | 1.18 | - | 11173.40 | Aletor *et al.*, 2007 |
| | - | 1.458 | 0.962 | - | - | 10.70 | 137.00 | 41.30 | - | - | 5.40 | 126.30 | 10085.15 | Akinhanmi *et al.*, 2008 |
| | - | - | 0.960 | - | - | 10.70 | 137.00 | 41.30 | 7.95 | - | 5.40 | 126.30 | 10085.15 | Evbuowman *et al.*, 2013 |
| | Winsor orange | 1.420 | 0.906 | 0.910 | - | 2.24 | 212.00 | 50.61 | 10.58 | - | 2.24 | 209.76 | 9389.59 | Aremu and Akinwumi, 2014 |
| | Yellowish | 1.730 | 0.913 | 1.160 | - | 2.62 | 167.00 | 87.77 | 10.00 | - | 2.45 | 164.38 | 9764.18 | Aremu and Akinwumi, 2014 |
| Jatroph curcas seed oil (*Jatropha curcas* L.) | - | - | - | 0.895 | 41.40 | 35.80 | 193.00 | - | - | - | 18.10 | 157.20 | - | Elizabeth *et al.*, 2012 |
| | - | - | 0.901 | 0.886 | 20.49 | 18.76 | 240.53 | 20.30 | 56.00 | - | 9.39 | 221.77 | 9158.85 | Belewu *et al.*, 2010 |
| | - | - | 0.896 | 0.881 | 76.18 | 23.87 | 230.71 | 26.09 | 44.00 | - | 11.94 | 206.84 | 9242.91 | Belewu *et al.*, 2010 |
| | - | - | - | - | - | 1.20 | 122.49 | 73.46 | - | - | 0.60[a] | 121.29 | 10185.76 | Warra *et al.*, 2011b |
| | - | - | - | - | - | 1.50 | 208.50 | 135.85 | - | - | 0.75[a] | 207.00 | 9336.38 | Akintayo, 2004 |
| Sesame seed oil (*sesamum Indica* L.) | White | - | 0.915 | - | - | 0.50 | 189.00 | 103.00 | 8.00 | - | 0.25[a] | 188.50 | 9547.65 | Mohammed and Hamza, 2008 |
| | Red | - | 0.923 | - | - | 0.45 | 191.00 | 116.00 | 7.45 | - | 0.23[a] | 190.55 | 9516.35 | Mohammed and Hamza, 2008 |
| | Yellow | 1.464 | 0.928 | - | - | 0.49 | 189.54 | 106.00 | 1.80 | - | 0.25[a] | 189.05 | 9539.71 | Njoku *et al.*, 2010 |
| | - | - | - | - | - | 2.48 | - | 121.40 | 7.50 | - | 1.30 | - | - | Ogbonna and Ukaan, 2013 |
| | - | - | - | - | - | 2.63 | - | 106.88 | 4.71 | - | 1.35 | - | - | Ogbonna and Ukaan, 2013 |
| Almond seed oil (*Prunus amygdalus*) | Yellow | 1.46 | - | 0.910 | 302.39 | 40.14 | 151.55 | 12.46 | 2.25 | - | 20.05 | 111.41 | 9980.86 | Ogunsuyi and Daramola, 2013 |
| | - | 1.47 | 1.71 | - | - | 9.66 | 9.40 | 2.65 | 0.93 | - | 4.86 | - | 11291.34 | Akpambang *et al.*, 2008 |
| | - | - | - | - | - | 0.77 | 163.40 | - | - | - | 0.39 | 162.63 | - | Afolabi, 2008 |

Peroxide value (PV) is the most common indicator of lipid oxidation. The unrefined vegetable oils are characterized by greater PV, compared to refined oils. The PV of the oils under reviewed ranges from 0.45 in melon seed oil to 290.00 in bambara groundnut. High values of PV are indicative of high levels of oxidative rancidity of the oils and also suggest absence or low levels of antioxidant; certain antioxidants may, however, be used to reduce rancidity such as propygadlate and butyl hydroxyl anisole (Kyari, 2008). The WHO/FAO (1994) stipulated a permitted maximum peroxide level of not more than 10 mequivalent of oxygen/kg of the oils; therefore, some of the oils reviewed may not be suitable for consumption. The value for unsaponifiable matter is in the range of 0.837 to 41.780 for soy bean and luffa gourd seed seed oils respectively. High unsaponifiable matter content of fats and oils has been reported to be an indication of adulteration or contamination. This may be due to the presence of fuel or lubricating oils in the oil sample (Ihekoronye & Ngoddy, 1985).

Free fatty acid is the percentage by weight of a specified fatty acid (e.g. percent oleic acid) (Nielson, 1994). High concentrations of free fatty acids are undesirable in crude vegetable oils because they result in large losses of the neutral oil during refining. In crude fat, free fatty acids estimate the amount of oil that will be lost during refining steps designed to remove fatty acids (Weiss, 1983). High levels of free fatty acids especially linoleic acids are undesirable in finished oils because they can cause off-favours and shorten the shelf life of oils. The quantity of free fatty acid in oil is an indicator of its overall quality. They may be formed through hydrolysis or in the advanced stages of oxidation. An excessive amount of free fatty acids lowers the smoke point of oil and will cause ‘popping’ of the oil during cooking. High quality oils are low in free fatty acids (Overhults *et al*., 1974). In refined vegetable oils, the lower the free fatty acid the more acceptable the oil is to man in terms of palatability. From the results of the reviewed oils, the percentage of free fatty acid ranges from 0.14 to 34.65 in castor and luffa gourd seed oils respectively. The heat of combustion value range between 8904.25 gcal/g and 11303.35 gcal/g with most of the reviewed oils having the value greater than the approximate value for edible oils 9500 gcal/g (Aremu & Amos, 2010).

**Table 1c: Physicochemical properties of some Nigerian seed oils**

| Plant seed /Parameter | Colour | RI | SG | Ds | VS | AV | SV | IV | PV | USM | FFA | EV | HC | Authors |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| African pear (*Dacryodes edulis*) seed oil | Dark yellow | - | 0.87 | - | - | 5.56 | 246.60 | 40.20 | 21.23 | - | 2.78 | 241.04 | 9083.41 | Akubugwo and Ugbogu, 2007 |
| | - | - | - | - | - | 5.61 | 179.52 | 31.50 | 20.00 | - | 2.81 | 173.91 | 9705.89 | Ajayi and Adesanwo, 2009 |
| | - | 1.458 | 0.882 | - | 17.27 | 5.96 | 193.89 | 130.96 | 5.40 | 2.62 | 3.00[a] | 187.93 | 9474.95 | Akanni *et al.*, 2005 |
| Luffa gourd (*Luffa aegyptiaca*) | Yellowish green | - | 0.920 | 0.91 | - | 20.62 | 168.00 | 130.00 | 280.00 | 3.98 | 10.36 | 147.38 | 9712.80 | Abayeh *et al.*, 2013 |
| | Reddish brown | - | 0.930 | - | - | 68.88 | 108.27 | 102.61 | 20.00 | 41.78 | 34.65 | 39.39 | 10286.72 | Aremu and Amos, 2010 |
| Shea tree/Vitellaria seed oil (*Butyrospermum parkii*) | - | 1.453 | - | - | - | 0.46 | 223.00 | 61.00 | 77.50 | - | 0.23[a] | 222.54 | 9278.55 | Kyari, 2008 |
| | - | 1.464 | 0.895 | - | - | 4.30 | 224.40 | 68.08 | - | - | 2.16 | 220.10 | 9258.66 | Raimi *et al.*, 2014 |
| Kapok tree seed oil (*Ceiva pentandra*) | Light yellow | - | 0.910 | - | - | - | 229.00 | 125.60 | 14.00 | - | 8.50 | - | 9159.05 | Mohammed *et al.*, 2012 |
| | Brightly yellow | - | - | - | - | - | 179.77 | 76.80 | - | - | - | - | 9658.30 | Amigo *et al.*, 2013 |
| Cotton seed oil | - | - | - | - | - | 0.81 | 199.42 | 119.78 | - | - | 0.41[a] | 198.61 | 9435.53 | Warra *et al.*, 2011a |
| | Reddish brown | 1.464 | 0.920 | - | 74.00 | 11.50 | 189.00 | 94.70 | 9.25 | - | 5.78 | 177.50 | 9555.95 | Orhevba and Efomah, 2012 |
| | - | 1.455 | - | 0.847 | - | - | - | - | 1.42 | - | 1.66 | - | - | Andrew *et al.*, 2012 |
| Horse Eye seed oil (*Dioclea reflexa*) | - | 1.466 | 0.915 | - | - | 0.90 | 195.01 | 108.98 | 11.06 | 5.87 | 0.45[a] | 194.11 | 9486.68 | Ajayi and Adefioye, 2012 |
| | - | 1.465 | 0.913 | - | - | 0.98 | 206.09 | 113.88 | 10.13 | 6.20 | 0.49[a] | 205.11 | 9380.40 | Ajayi and Adefioye, 2012 |
| | - | - | 0.946 | - | - | 6.93 | 197.88 | 152.44 | 9.97 | - | 3.49[a] | 190.95 | 9416.96 | Oyeleke *et al.*, 2012a |
| Moringa seed oil (*M. oleifera*) | - | 1.470 | 0.910 | - | - | 7.09 | 180.31 | 55.02 | 15.96 | - | 3.57[a] | 173.22 | 9675.14 | Abiodun *et al.*, 2012 |
| | - | 1.471 | - | - | - | 3.80 | 171.90 | 85.30 | 8.10 | - | 1.91[a] | 168.10 | 9721.82 | Ogbunugafor *et al.*, 2011 |
| Africsan bush mango (*Irvingia gabonensis*) | - | - | - | - | - | - | 256.50 | 8.20 | 0.50 | - | 2.72 | - | 9024.83 | Ogunsina *et al.*, 2012 |
| | - | 1.430 | - | - | - | 20.10 | 202.90 | 7.90 | 1.20 | - | 6.97 | 182.80 | 9515.57 | Igwenyi, 2014 |
| Soy bean seed oil (*Glycine max*) | Golden yellow | 1.466 | - | - | - | 19.21 | 228.19 | 73.02 | - | - | 9.66 | 208.98 | 9219.04 | Amos-Tauta and Onigbinde, 2013 |
| | - | 1.457 | 0.906 | - | 17.99 | 4.28 | 192.30 | 136.81 | 3.50 | 0.837 | 2.15 | 188.02 | 9483.65 | Akanni *et al.*, 2005 |

## Table 1d: Physicochemical properties of some Nigerian seed oils

| Plant seed /Parameter | Colour | RI | SG | Ds | VS | AV | SV | IV | PV | USM | FFA | EV | HC | Authors |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Palm kernel seed oil | - | - | 0.910 | - | - | 10.71 | 249.90 | 20.70 | 4.36 | - | 5.90 | 239.19 | 9072.72 | Evbuowman *et al.*, 2013 |
| | - | 1.473 | - | - | - | 6.20 | 210.50 | 34.74 | 13.40 | - | 3.12 | 204.30 | 9419.19 | Obgunugafor *et al.*, 2011 |
| | - | - | - | - | - | 0.83 | 191.98 | - | - | - | 0.42 | 191.15 | - | Afolabi, 2008 |
| Bambara groundnut seed oil (*Vigna subterrenea*) | Pale yellow | - | 0.880 | - | - | 0.92 | 124.80 | 121.00 | 286.00 | 2.35 | 4.85 | 123.88 | 10117.08 | Aremu *et al.*, 2006a |
| | Yellow | - | 0.885 | - | - | 0.98 | 140.50 | 120.00 | 290.00 | 2.25 | 4.80 | 139.52 | 9974.43 | Aremu *et al.*, 2006a |
| African star apple seed oil (*Chrysophyllum alibidum*) | Pale yellow | - | 0.920 | - | - | 3.56 | 126.30 | 31.06 | 1.80 | - | 1.76 | 122.74 | 10193.30 | Akubugwo and Ugbogu, 2007 |
| | - | 1.400 | 0.900 | 0.711 | - | 2.86 | 195.82 | 33.22 | 1.98 | - | 1.42 | 192.96 | 9555.03 | Ajala and Adeleke, 2014 |
| | - | 1.396 | 0.895 | 0.708 | - | 2.82 | 194.07 | 33.20 | 1.98 | - | 1.41 | 191.25 | 9571.06 | Ajala and Adeleke, 2014 |
| Sunflower seed oil (*Helianthus annuus L.*) | - | - | 0.915 | - | - | 0.95 | 182.14 | 119.92 | 6.32 | - | 0.042 | 181.19 | 9593.50 | Aboki *et al.*, 2012 |
| | Pale yellow | 1.464 | 0.921 | - | - | - | 188.51 | 78.45 | 0.89 | - | 0.22 | - | 9576.68 | Ologunde *et al.*, 2008 |
| | Pale yellow | 1.471 | 0.919 | - | - | - | 190.61 | 82.50 | 0.89 | - | 0.19 | - | 9553.42 | Ologunde *et al.*, 2008 |
| Koto/Pterygota seed oil (*Pterygota macrocarpa*) | - | 1.493 | 0.930 | - | - | 4.12 | 43.85 | 93.31 | 6.07 | 1.23 | 2.16 | 39.73 | 10885.46 | Amoo and Agunbiade, 2009 |
| | - | 1.455 | 0.928 | - | - | 3.98 | 17.88 | 49.68 | 4.87 | 1.02 | 2.05 | 13.90 | 11166.72 | Amoo and Agunbiade, 2009 |
| Bottle gourd | White | 1.510 | 0.940 | - | - | 5.21 | 221.00 | 98.70 | 6.58 | - | 2.60 | 215.79 | 9259.15 | Olaofe *et al.*, 2012 |
| | Yellow | 1.490 | 0.930 | - | - | 4.59 | 225.10 | 100.32 | 6.62 | - | 2.30 | 220.51 | 9220.02 | Olaofe *et al.*, 2012 |
| Rattle box seed oil (*Crotalaria retusa L.*) | Yellow | - | 0.880 | - | - | 1.10 | 161.28 | 46.34 | 5.26 | 1.92 | 0.55 | 160.18 | 9857.95 | Aremu *et al.*, 2012 |
| *Khaya senegalensis* seed oil | Golden yellow | 1.458 | - | 0.053 | - | 2.69 | 195.58 | 88.40 | - | - | 1.35[a] | 192.89 | 9502.04 | Ayo *et al.*, 2013 |
| Calabash seed oil | Yellow | 1.490 | 0.900 | - | - | 5.92 | 159.00 | 4.02 | 5.60 | - | 2.96 | 153.08 | 9921.13 | Olaofe *et al.*, 2012 |
| Akee apple seed oil (*Blighia sapida*) | - | 1.449 | - | - | - | 0.34 | 261.00 | 87.60 | 135.00 | - | 0.17[a] | 260.66 | 8904.25 | Kyari, 2008 |
| Black turtle bean (*Phaseolus vulgaris* L.) | – | – | 0.959 | – | 8.12 | 10.4 | 190.5 | 146.4 | 3.2 | 3.62 | – | – | – | Audu *et al.*, 2013 |

**RI** = Refractive Index, **SG** = Specific Gravity, **VS** = Viscosity, **AV** = Acid Value, **SV** = Saponification Value, **IV** = Iodine Value, **PV** = Peroxide Value, **FFA** = Free Fatty Acid, **Ds** = Density, **USM** = Unsaponifiable Matter, **EV** = Calculated Ester Value [saponification value – acid value]; **HC** = Calculated Heat of Combustion [11380 – iodine value – 9.15 (saponification value)], **[a]FFA** = Calculated Free Fatty Acid [0.503(acid value)], – = Not available

## 4. Conclusion

There has been an increase in the world production of oilseeds over the last thirty years (Murphy, 1994); this would appear to be related to the increasing demand for oilseed products and by-products as oilseeds are primarily grown for their oil and meal. Vegetable oil is always at a higher price per ton than the cake, this is because the demand for oil is often higher than the cake. Generally, oils and fats from seeds and nuts constitute an essential part of man's diet. Fats and oils, together with proteins, carbohydrates, vitamins and minerals, are the main nutrients required by the human body. Fats and oils are rich sources of energy, containing two and a half times the calories of carbohydrates (per unit weight). In addition to being a source of vitamins A, D, E and K, fats and oils also contain essential fatty acids. These essential fatty acids are not manufactured by the body and must be obtained from diets, with linoleic, oleic and linolenic acids as examples of unsaturated fatty acids.

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