

Sesame Seed

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1. Introduction

Sesame (*Sesamum indicum* L.), otherwise known as sesamum or benniseed, member of the family *Pedaliaceae*, is one of the most ancient oilseeds crop known to mankind. Sesame plays an important role in human nutrition. Most of the sesame seeds are used for oil extraction and the rest are used for edible purposes (El Khier et al, 2008). Sesame is grown primarily for its oil-rich seeds. Before seeds were appreciated for their ability to add nutty flavour or garnish foods, they were primarily used for oil and wine (Ghandi, 2009). After the extraction of oil, the cake is mostly used for livestock feed or often as manure. Its colour varies from cream-white to charcoal-black but it is mainly white or black. Other colours of some sesame seed varieties include, yellow, red or brown (Naturland, 2002). In Nigeria, the notable colours for sesame seed are white, yellow and black (Fariku et al., 2007). The lighter varieties of sesame which are considered to be of higher quality are generally more valued in the West and Middle East, while both the pale and black varieties are prized in the Far East. (www.wikipedia-sesame). There are numerous varieties and ecotypes of sesame adapted to various ecological conditions (Nzioku et al., 2010).

The major world producers include India, Sudan, China and Burma (who contribute about 60% of the total world production) (El Khier et al, 2008). It is also one of main commercial crops in Nigeria, Sudan and Ethiopia (www.nutritionandyou.com). Sesame is an important crop to Nigerian agriculture: it is quite extensively cultivated especially in Northern Nigeria. It yields in relatively poor climatic conditions, and it is widely used within Nigeria. Moreso, it is an important component of Nigeria's agricultural exports (Chemonics, 2002).

Sesame seed is rich in fat, protein, carbohydrates, fibre and some minerals. The oil seed is renowned for its stability because it strongly resists oxidative rancidity even after long exposure to air (Global AgriSystems, 2010). The oil fraction shows a remarkable stability to oxidation. This could be attributed to endogenous antioxidants namely lignins and tocopherols (Elleuch et al., 2007; Lee et al., 2008).

The seed is rich in protein and the protein has disable amino acid profile with good nutritional value similar to soybean (NAERLS, 2010). The chemical composition of sesame shows that the seed is an important source of oil (44-58%), protein (18-25%), carbohydrate (~13.5%) and ash (~5%) (Borchani et al., 2010). Sesame seed is approximately 50 percent oil (out of which 35% is monounsaturated fatty acids and 44% polyunsaturated fatty acids) and 45 percent meal (out of which 20% is protein) (Ghandi,2009; Hansen, 2011).

Sesame seeds are small, almost oblate in shape and have a mild and delicious aroma and taste. Sesame seed is used whole in cooking and also yields sesame oil (www.wikipedia.org, sesame; Hansen, 2011). It has a rich nutty flavour (although such heating damages their healthful polyunsaturated fats) and is used mainly as a food ingredient in whole, broken, crushed, shelled, powdered and paste forms. Its use is country based, in the US; it is used as some form of whole seed product for the confection and baking industries. A small percentage percent of total production is however processed into oil, meal or flour (Hansen, 2011). In Nigeria, the seeds are consumed fresh, dried, fried or when blended with sugar. It is also used as a paste in some local soups. (Fariku et al., 2007).

Sesame seeds are not only used for culinary purposes but also in traditional medicines for their nutritive, preventive and curative properties. Its oil seeds are sources for some phyto-nutrients such as omega-6 fatty acids, flavonoid phenolic anti-oxidants, vitamins and dietary fiber with potent anti-cancer as well as health promoting properties (www.nutrition-and-you.com). Sesame oil is an edible vegetable oil derived from sesame seeds used in various countries. It is used as a cooking oil in South India and Asia and often as a flavor enhancer in Chinese, Japanese, Korean, and to a lesser extent Southern Asia cuisine (www.wikipedia.org, sesame.oil).

It is stable and free from undesirable nutrition or flavor component. Beniseed oil has a natural oxidant which prevents aging and is vital for the production of liver cells (NAERLS, 2010; Weiss, 2000). The oil also contains oleic (35.9-47%), linoleic (35.6-47.6), palmitic (8.7-13.8%), stearic (2.1-6.4%), as well as arachidic acids (0.1-0.7%) (Elleuch et al., 2007; Borchani et al., 2010).

2. History

Sesame seeds are the seeds of the tropical annual *Sesamum indicum*. The species has a long history of cultivation, mostly for its yield of oil. The oil plant has been grown since the beginning of arable cultivation, and originates from the dry bush savannah of tropical Africa, and spread from there to India and China, where it is still widely cultivated. (Naturland, 2002). The original area of domestication of sesame is obscure but it seems likely to have first been brought into cultivation in Asia or India (www.nigeriamarkets.org). Archeological records indicate that it has been known and used in India for more than 5,000 years and is recorded as a crop in Babylon and Assyria some 4,000 years ago (Borchani et al., 2010).

Sesame was cultivated during the Indus valley civilization and was the main oil crop. It was probably exported to Mesopotamia around 2500 BCE and was known in Akkadian and Sumerian as 'ellu'. Prior to 600 BC, the Assyrians used sesame oil as a food, salve, and medication, primarily by the rich, as the difficulty of obtaining it made it expensive. Hindus used it in votive lamps and considered the oil sacred.

3. Production of sesame seed

Global production of sesame seed is estimated by FAO at 3.15 mn tonnes per year (2001) having risen from 1.4 mn tonnes in the early 1960's. However only a small proportion of the global sesame harvest enters international trade. For the most part, the oil is expressed locally and used locally for cooking or the seeds themselves are eaten, particularly after being fried.

Sesame is grown in many parts of the world on over 5 million acres (20,000 km²). The largest producer of the crop in 2007 was India, China, Myanmar, Sudan, Ethiopia, Uganda and Nigeria. Seventy percent of the world's sesame crop is grown in Asia, with Africa growing 26% (Hansen, 2011)

The largest producers are China and India, each with an annual harvest around 750,000 tonnes followed by Myanmar (425,000 tonnes) and Sudan (300,000 tonnes). These figures are only rough estimates of the situation as sesame is a smallholder crop and much of the harvest is consumed locally, without record of the internal trade and domestic processing (Figure 1). Nigeria has a great market potential for sesame seed production for domestic and export markets noting that the production figures of the commodity has been on a steady increase since 1980, reaching 67000 MT by 1997 and was estimated to reach 139, 000 MT by the year 2010, according to the federal ministry of agriculture and natural resources (Joseph, 2009). This is agreement with the 2008 annual report of the Central Bank of Nigeria which states there has been a rise in production of sesame seed from 98,000,000 to 152,000,000 kg from 2003 to 2007 (CBN, 2009).

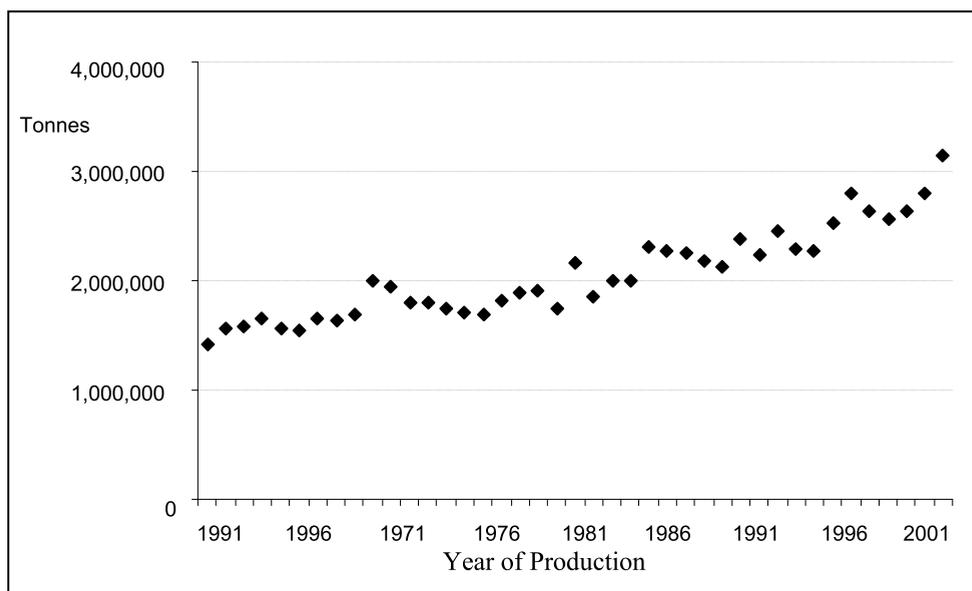


Fig. 1. World Production of Sesame Seed

Out of the estimated 3.5million hectares of Nigeria's arable land suitable for the growth of sesame seed, only 300,000 is currently used for the crop. However average yield of crop is about 300kg/ha which is 4 times lower than the average yield of other seed crops eg groundnut and soybeans. In major production zones in the country, it is used in traditional food recipes and snacks rather than for export purposes (NAERLS, 2010). Nigeria was the largest supplier to the Japanese market, the world's largest import market for sesame (Chemonics, 2002). Thus, the potentials for beniseed production in Nigeria is high since Japan, as well as Taiwan and Korea, generate global demand and offer opportunity for

Nigerian growers. Nigeria has a 6% share of the \$600 million global market for sesame seed (Nigeria's Harvest, 2009).

Sesame was widely grown in Middle Belt, Northern and Central Nigeria as a minor crop initially in 1974 when it became a major cash crop in many Northern States eg Benue, Kogi, Gombe, Jigawa, Kano, Nasarawa, Katsina, Plateau, Yobe and Federal capital Territory (NAERLS, 2010). Sesame is commonly grown by smallholder farmers. The major producing areas in order of priority are Nasarawa, Jigawa and Benue States. Other important areas of production are found in Yobe, Niger, Kano, Katsina, Kogi, Gombe and Plateau States (Figure 2). Harvesting begins in late December and continues through July. Each producing area has only one season.

There are 2 types of sesame produced in Nigeria

1. White/raw = Food-grade used in bakery industry. 98-100% whitest grade seeds
2. Brown/mixed = Primarily oil-grade

The White (Food Grade) seed is grown around the towns of Keffi, Lafia/Makurdi, Doma, and in Nassarawa, Taraba, and Benue States. It is easier to sort and the Fumani/Denin people consume sesame locally. The Brown/mixed grows in the North, in Kano State and in Jigawa State near Hadejia, and somewhat in the southern part of Katsina State. There is some local consumption of the brown grade, but not much. The brown can be upgraded to Food Grade through bleaching, as discussed earlier (Chemonics, 2002). Several varieties of sesame are cultivated in Nigeria. The basic agronomic characteristics of some of the varieties are shown in Table 1 below.

Variety	Days to Maturity	Seed Color	Seed Size (mm)	Oil Content (%)	Potential Yield (kg/ha)
NCRI BEN-01M	102-115	White	3	45	1000
NCRI BEN-02M	102-115	Light	3	45	750
NCRI BEN-032	125-140	Brown	2	40	600
E-8	90	White	3.6	50	1000
Yandev-55	125	Light	2.5	45	600

Table 1. Characteristics of Sesame Grown in Nigeria

Growth conditions

Sesame has important agricultural attributes: it is adapted to tropical and temperate conditions, grows well on stored soil moisture with minimal irrigation or rainfall, can produce good yields under high temperatures, and its grain has a high value (Bennet, 2011). Sesame is found growing in most tropical, sub tropical and southern temperate areas of the world (Ghandi, 2009). However it is now cultivated around the dry tropics between the latitudes of 40° N and S. It is scarcely cultivated in the USA or Europe, not only because of climate but also because of the low returns per unit area (Chemonics, 2002). It has been reported to be a typical crop for small farmers in the developing countries (Bennet, 2011).

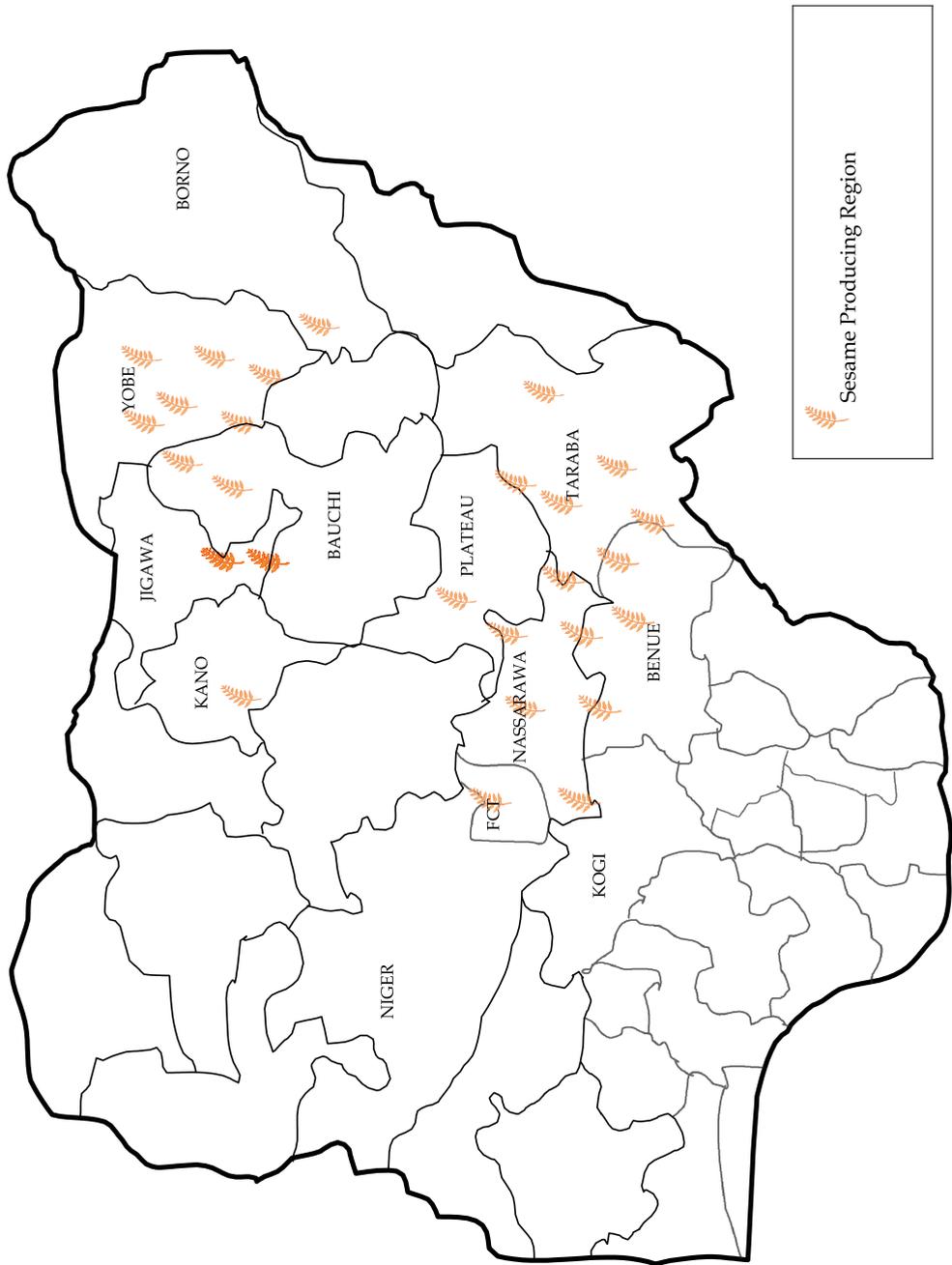


Fig. 2. Map of Nigeria Showing Sesame Producing Regions

This is because it has deep roots and are well adapted to withstand dry conditions. It will grow on relatively poor soils in climates generally unsuitable for other crops, and so it is widely valued for its nutritional and financial yield from otherwise inclement areas. It is well suited to smallholder farming with a relatively short harvest cycle of 90 -140 days allowing other crops to be grown in the field (Nigeria's Harvest, 2009; Naturland, 2002, Chemonics, 2002) and is often intercropped with other grains. This makes it favourable to Nigerian farmers and production can thus be sustained by small scale farmers with minimum management with an average yield of 700 kilograms per hectare (Nigeria's Harvest, 2009).

Sesame world production areas have remained generally stable over the years, but in some countries the crop is being marginalized (Bennet, 2011). Competition from more remunerative crops and a shortage of labour have pushed sesame to the less fertile fields and to areas of higher risk. Left unchecked, sesame production may decrease in the foreseeable future.

Sesame cultivation can be carried out on a wide range of soils but optimum are well-drained, loose, fertile and sandy alluvial soils that have a pH value between 5.4 and 6.75. Very low pH values have a drastic effect on growth, whereas some varieties can tolerate a pH value up to 8 (Naturland, 2002). Good drainage is crucial, as sesame is very susceptible to short periods of waterlogging. Sesame is intolerant of very acidic or saline soils (Bennet, 2011). The total amount of water required to grow sesame crop ranges from 600 to 1000 mm, depending on the cultivar and the climatic conditions (Hansen, 2011). Good harvests can be expected when rainfall of 300-600 mm is optimally spread throughout the vegetation period. During each of its development stages, the plant is highly susceptible to water-logging, and can therefore only thrive during moderate rainfall, or when irrigation is carefully controlled in drier regions (Naturland, 2002). The water requirement can be met from available soil moisture at sowing, rainfall during the growing season and irrigation (Hansen, 2011). This is because due to its tap roots, the plant is highly resistant to drought, and can provide good harvests even when only stored soil water is available. When irrigated, or during summer rain spells, sesame grows better in sandy than in heavy soils. This is due to its sensitivity to high soil moisture contents (Naturland, 2002).

Sesame needs long periods of sunshine, and is generally a short-day plant - whereby varieties exist which are unaffected by the length of the day (Naturland, 2002). Sesame needs a constant high temperature, the optimum range for growth, blossoms and fruit ripeness is 26-30°C. The minimum temperature for germination is around 12°C, yet even temperatures below 18°C can have a negative effect during germination (Naturland, 2002). Pollination and the formation of capsules is inhibited during heat-wave periods above 40°C. In regions visited by strong, hot winds, the plants only form smaller seeds with a lower oil content. Sesame is sensitive to strong winds when the main stem is fully grown. Tall varieties should not be planted in regions which have strong winds during the harvesting season (and, if necessary, hedges to protect against the wind should be planted) (Naturland, 2002). The response of sesame to both temperature and daylength indicates that it should be cultivated in the wet season in the tropics, or in the summer in the warmer temperate areas. While there is some variation between cultivars, the base temperature for germination is about 16°C (Bennet, 2011). This warm-season annual crop is primarily adapted to areas with long growing seasons and well-drained soils (Hansen, 2011, www.nutrition-and-you.com).

Sesame is an annual plant, which grows either bush-like or upright, depending on variety. The plant is usually 60 to 120cm and bears plenty of pink-white color fox-glove type flowers (Figure 3). The pod or fruit which is a dehiscent capsule held close to the stem, appears soon containing white, brown or black seeds depending up on the cultivar type, arranged in rows inside. Each pod (2-5 cm in length) is a long rectangular box like capsule with deep grooves on its sides and may contain up to 100 or more seeds (www.nutrition-and-you). When ripe, the capsule shatters to release a number of small seeds. The seeds are protected by a fibrous 'hull' or skin, which may be whitish to brown or black depending on the variety. 1000 seeds weigh some 4-8g (Chemonics, 2002).



Fig. 3. A Picture of the Sesame Plant with the Seeds

4. Harvesting and post harvesting handling of sesame seed

Sesame seed is harvested when about 50% of capsules turn yellow in colour from green. Other indications of the optimum time for harvesting (physiological ripeness) include; lowest capsules turning brown and beginning to pop open, stem turning yellow, leaves beginning to fall off, end of blossoming, leaves turning yellow (Kimbonguila et al., 2009). Harvesting should not be delayed in order to prevent seed loss through shattering. The size and shape of sesame seed (ie small and flat) makes it difficult to move much air through it in a storage bin. Therefore, the seeds need to be harvested as dry as possible and stored at 6 percent moisture or less (Hansen, 2011, Nigeria's Harvest, 2009; Langham et al., 2008). If the seed is too moist, it can quickly heat up and become rancid. High levels of humidity can cause sesame to take on moisture again and go mouldy; it should therefore only be stored

for a short while, or in air-tight containers. If the critical 6% cannot be reached by using only sun drying then artificial methods must be employed. This is because sesame above 5.1% starts getting docked for moisture weight, and above 6.9% moisture, there are quality discounts.

Sesame is generally harvested manually by cutting stems with sticks, and then left to dry for the first 2-3 days after cutting in a windrow (Naturland, 2002). The leaves dry out quickly there, making it easier to bundle them into sheaves. Plants are tied with a rope into small bundles or sheaves (diameter of 15 cm, bottom: 45-80 cm) and positioned erect on a mat or tarpaulin for drying to complete. This prevents seed wastage and contamination. The sheaves should be positioned so that the sun can shine down directly onto the capsules. This results in less drying time, better heat and air circulation, avoidance of fungi infection, ease of turning when shaking bundles, more extensive shaking/threshing with fewer losses. The sheaves should not need to be dried for longer than 15 days. After the sheaves have dried out fully, they are tipped out onto sturdy cloths or canvases and threshed with sticks. The cloths/canvases should be at least 6 m², to avoid contamination with stones and soil.

Mechanical harvest is better, as the unripe plants are cut, and then the pre-dried sheaves threshed out. This reduces the amount of seeds lost, and the hay makes better fodder. Most threshing machines with a sheaf pick-up function are suited to the task. Varieties that open are easier to thresh mechanically than those that remain closed, as less force is needed. . Sesame seed is easily threshed and relatively delicate, so drum speed should be reduced to about half of that required for cereals, and the concave clearance made as wide as possible. Seed damage during harvesting affects both the viability of the seed, storage and the quality of the oil.

After the seeds have been harvested and dried, the storage sacks must be checked and free of insects. Packaged sesame should be stored in a dark place at low temperatures (below 18°C) and low relative humidity. Also sesame contain more of unsaturated fats hence should be stored in air-tight containers to avoid them turning rancid. Under optimum storage conditions, sesame can be stored for several months even up to 1 year. For safe long-term storage, sesame seed should be clean, have moisture content no more than 6% and be stored at a relative humidity of approximately 50% and at a temperature less than 18°C (Bennet, 2011).

5. Nutritional benefits of sesame seed

Sesame seed (*Sesamum indicum L.*) is an oilseed with a chemical composition of about 50-52% oil, 17-19% protein and 16-18% carbohydrate (Tunde-Akintunde and Akintunde, 2004). Its seed contains about 42-54 % quality oil, 22-25 % protein, 20-25 % carbohydrates and 4-6% ash. The hull contains large quantities of oxalic acid, crude fiber, calcium and other minerals. When the seed is properly dehulled, the oxalic acid content is reduced from about 3 % to less than 0.25 % of the seed weight (Akinoso et al., 2010). Sesame seed contains antioxidants which inhibit the development of rancidity in the oil. In the food industry, where synthetic antioxidants are used extensively, there is an increasing demand for more of these natural products (Bennet, 2011). The nutritional benefits derived from sesame seeds are based on the variety being utilized.

Sesame seed (*Sesamum indicum* L.), from Northern Congo were reported to contain 5.7% moisture, 48.5% crude oil, 20% crude proteins, 7.78% carbohydrate (by difference), 9.4% crude fiber and 4.2% ash (Nzikou et al., 2009; 2010). The protein content of White Sudan sesame seed was high (~25%) similar to other foodstuffs rich in proteins such as almond, hazelnut protein the contents of which were respectively, 20% and 21% (Borchani et al., 2010). The ash content in raw sesame was relatively high (~5%) compared to other products of great consumption such as almond (3%), and the pistachio (2.7%) (Borchani et al., 2010). Other Sudanese local and improved varieties considered by El Khier et al (2008) had protein content of 32.50 to 35.94 and 33.43 to 40.00 respectively.

The seeds also contained significant amount of important minerals with the Potassium concentration being the highest, followed by Phosphorus, Magnesium, Calcium and Sodium (Loumouamou et al., 2010). For White sesame seed (*S. indicum* L.) from Sudan, oil was 52.24%, protein 25.97%, fibre 19.33% and ash 4.685 (El Khier et al, 2008). The predominant mineral composition was calcium followed by potassium, magnesium and phosphorus. All other elements were present in comparatively low concentrations (Elleuch et al., 2007). This is similar to the results obtained by Borchani et al. (2010) for white Sudanese sesame. Potassium is an essential nutrient and has an important role in the synthesis of amino acids and proteins. Calcium and Magnesium plays a significant role in photosynthesis, carbohydrate metabolism, nucleic acids and binding agents of cell walls. Calcium assists in teeth development Magnesium is essential mineral for enzyme activity, like calcium and chloride; magnesium also plays a role in regulating the acid-alkaline balance in the body. Phosphorus is needed for bone growth, kidney function and cell growth. It also plays a role in maintaining the body's acid-alkaline balance. The presence of these minerals also confirms the fact that sesame seed is of high nutritional benefit to its consumers.

6. Description / Physical properties of sesame seed

The seed characteristics or physical properties of sesame seeds vary and this variation may likely be as a result of variability in genotypic effects (El Khier et al., 2008). The physical properties i.e length, width, thickness, geometric mean diameter, sphericity and surface area of the two common local sesame seeds varieties in Nigeria varied from 2.9 – 3.2mm, 1.9 – 2.1mm, 0.85 – 0.91mm, 1.59 – 1.72mm, 0.575 – 0.58 and 7.05 – 10.2mm² respectively (Tunde-Akintunde and Akintunde, 2007). The values obtained for the local varieties were close to that obtained for improved varieties obtained at the National Centre for Genetic Resources and Biotechnology (NACGRAB), Moor plantation, Ibadan, Oyo State, Nigeria which include NCRI BEN 01M, NGB\04\026, NCRI BEN 03L, NG\SA\07\179, NG\SA\07\090, NG\SA\07\095, NG\SA\07\106, NG\SA\07\052, NG\SA\07\137, OM1, OKENE MKT, NCRI BEN 02M, KANO 05. The length of the improved varieties varied from 2.26mm – 3.01mm, width 1.55 – 1.86mm, thickness 0.74 – 0.97mm and the geometric mean diameter varied from 1.32 – 1.7mm. The variation in degree of sphericity and that of surface area was from 0.57 – 0.64 and 5.84 – 8.94 mm² respectively (Adebowale et al., 2010). The length, width, and thickness of a local sesame seed variety Giza 32 from the Agricultural Engineering Research Institute, Egypt was 2.5, 1.65, and 0.94 mm respectively while the geometric diameter, sphericity and flat surface area were 1.57 mm, 62.84 % and 3.24 mm² respectively (Arafa, 2007).

7. Utilization of sesame seed

Sesame is grown for its seeds, and the primary use of the sesame seed is as a source of oil for cooking. The young leaves may also be eaten in stews, and the dried stems may be burnt as fuel with the ash used for local soap making, but such uses are entirely subordinate to seed production (Table 2). In West Africa, the shoots and young leaves of the varieties *S. alatum* and *S. radiatum* are eaten as a vegetable.

Input	Products	Description and Uses
Seeds	Confectionery	Fried seeds may be bound together with sugar syrup to give sweetmeats.
Seeds	Biscuits	The whole seeds can be baked into biscuits.
(Hulled) seeds	Bakery	Popular in northern Europe either incorporated into breads or as decorative toppings. May be used hulled or whole.
Seeds, sometimes roasted	Oil	Particularly used in oriental cuisine. The flavor is quite strong and rarely compatible with traditional Western style cooking but also used as a salad oil.
Oil	Medicinal treatment	Ulcers and burns
Oil	Margarine	Once an important use, now other cheaper vegetable oils are available
Oil	Aerosol	Reported use as a synergist for pyrethrum sprays
Low grade oil	Various	Soaps paints, lubricants, and illuminants. Local uses, of no importance in international trade
Hulled seeds	Tahini	A paste of sesame seeds which is used as an ingredient in eastern Mediterranean and Middle Eastern foods
Tahini	Dips & spreads	Various ingredients, such as chickpeas or eggplants, are added to tahini to make dips and spreads such as hummus
Tahini	Halva	A sweet made from tahini and sugar with other added flavorings
Cake	Animal feed	Protein rich useful supplement
Cake from hulled seeds	Ingredient	Used in some Indian cooking. Also as a snack in, for example, the Nigerian Kulikuli.

Source: Chemonics International Inc. (2002)

Table 2. Sesame Products

Sesame is commercialized in a number of forms. Most sesame is processed directly into oil by the grower or within the producing region, but can also be sold in various stages of processing, for various uses, such as meal, paste, confections, and bakery products. Sesame seeds can also be consumed directly as a highly nutritious foodstuff (Naturland, 2002). Sesame seeds have delicate nutty flavor. Their flavor indeed becomes more pronounced once they are gently roasted under low flame just for few minutes. De-hulled sesame seed is mainly used to add texture, taste and aesthetic value to a variety of bakery products like bread, bread sticks, cookies, sesame bars etc; and also as an additive to cereal mixes and crackers. It is also used in the making of tahin or sesame butter - a paste of ground sesame

seeds, which is used as an ingredient (in Greece) and halva, placed within breads or sprinkled on the surface of bread and breadsticks as a garnish (Germany and the Netherlands) and for the preparation of rolls, crackers, cakes and pastry products in commercial bakeries (Nzikou et al., 2009). Ground and processed seeds can also be used in sweet confections, candies are made from sesame mixed with honey or syrup and roasted (in South Asia, middle East and East Asia) while sesame paste and starch are used to make *goma-dofu* (Japan). Sesame seed can also be in the manufacture of margarine, sprinkled over salads and desserts, particularly sundaes and other ice cream based preparations, preparation of gomshino (a Japanese delicacy) and soybean oil. It can also be used in other food dishes including Mexican and East Asian cuisines.

Sesame seed is primarily grown for its oil in Nigeria and the oil is a primary source of cooking oil in Eastern Nigeria. The major portion of sesame seed produced in countries like Nigeria and India is used for extraction of oil. Sesame oil is mostly used as traditional cooking oil in Chinese food items and in Japan. Sesame seed is an excellent source of high quality oil and protein, its oil is odourless and close in quality to olive oil (Tunde-Akintunde and Akintunde, 2007). Sesame oil has no odour, it is straw-like in colour and has an excellent taste. Sesame seed oil is a natural salad oil, requiring little or no winterization, is one of the few vegetable oils that can be used directly without refining and is used widely as cooking oil. Because of the excellent quality of the edible oil it produces, sesame is often called queen of the oil seed crops. Light sesame oil have a high smoke point and is suitable for deep-frying, while dark sesame oil (from roasted sesame seeds) has a slightly lower smoke point and is unsuitable for deep-frying. Instead it can be used for the stir frying of meats or vegetables, or for the making of an omelette. East Asian cuisines often use roasted sesame oil for seasoning. It is also used widely for production of margarine, shortening, canned sardine and beef as well as in soap and confectionary industries (NAERLS, 2010). Sesame oil has a high preservative effect though the seeds are prone to rancidity because of its high oil content. The oil prevents rancidity due to a preservative within the oil called sesamol. Sesame oil obtained during the first, cold pressing is one of the costliest produced. The oil is light yellow, does not dry out, and can be used with strong heat. Sesame oil obtained from the second, warm pressing and extraction has a lower quality than cold-pressed.

In the industry, sesame oil may be used as a solvent in injected drugs or intravenous drip solutions, a cosmetics carrier oil, to coat stored grains to prevent weevil attacks. The oil also has synergy with some insecticides. Lower grade sesame oil can be used locally in soaps, lubricants, and illuminants. Sesame oil can also be used as a raw material in the manufacture of inks (sesame oil yields a top quality ink after it is burnt), paints, and pharmaceuticals (as healing oil or a vehicle for drug delivery). The oil also has additional use in the industrial preparation of perfumery, cosmetics (skin conditioning agents and moisturizers, hair preparations, bath oils, hand products and make-up), insecticides and paints and varnishes. However, all of these uses are comparatively insignificant in terms of the quantities used.

The seed is typically crushed intact for the oil. This, however, yields a meal that is made bitter and somewhat indigestible by the presence of the fibrous husk. As such the meal is only useful as cattle feed. The quality of the meal can however be improved by removing the seed coat, dehulling, before crushing. In India, where sesame meal is an important food, this process is a standard feature of an oil extraction plant. The meal remaining after oil extraction has unique nutritional properties. It has a high protein concentration which is rich

in methionine, cysteine and tryptophan. Since these amino acids are missing from a number of other sources of vegetable protein, such as soya, sesame meal or flour can be added to recipes to give a better nutritional balance to health food products thus complementing most oil seeds and vegetable proteins very well. The seed cake is also an excellent protein supplement in the animal feed industry. The press cake can also be used for food enrichment of infant weaning foods (NAERLS, 2010).

Different cultures have different traditional uses for sesame. In Nigeria, industrial processing and utilization of sesame have not been fully developed. However, the product is locally processed and utilized in various forms in the states where the crop is cultivated. Principal among the products are: "*Kantun Ridi*" and "*Kunun Ridi*". At the local level, oil is also extracted from the seed and the cake is made into "*Kulikuli*" which together with the leaves are used to prepare local soup known as "*Miyar Taushe*". The oil is used locally for cooking as well as for medicinal purposes such as the treatment of ulcers and burns. The stem and the oil extract are equally used in making local soap. In all the states where sesame is cultivated, women are more involved in the local processing of sesame seed into commercial products.

In Japan, tan and black sesame seed varieties are roasted and used for making the flavoring gomashio. In Greece the seeds are used in cakes, and in Togo they are a main soup ingredient. The seeds are also eaten on bread in Sicily and France (called "*ficelle sésame*", sesame thread). In Congo and Northern Angola, ground sesame or *wangila* is a delicious dish, especially when cooked with smoked fish or lobsters. In Manipur (North Eastern State of India), black sesame is used in the preparation of a favorite side dish called '*Thoiding*' and in '*Singju*' (a kind of salad). Also in Tamil Nadu, India, a ground powder, *Milagai Podi*, made of sesame and dry chili is used to enhance flavor and consumed along with other traditional foods

8. Oil characterization

The different variety of sesame plant, cultivation climate, soil type, ripening stage, the harvesting time of the seeds and the extraction method used has an important effect on the yield and quality of oil obtained from sesame (Nigeria's Harvest, 2009; El Khier et al., 2008). Black seed types have been reported to contain less oil than white and brown seeded strains (Akinoso et al., 2010). Composition of fatty acids in sesame oil was also reported to be variable among the different cultivars worldwide (El Khier et al., 2008).

The chemical properties of oil are amongst the most important properties that determines the present condition of the oil. Free fatty acid and peroxide values are valuable measures of oil quality. The chemical properties of white and black sesame seed varieties from Hong, Adamawa State, Nigeria was determined. The unsaponifiable matter (% of oil), saponification value (mg KOH/g), iodine value (g/100 g) and free fatty acid (% Oleic) was 0.76, 150.26, 98.20 and 0.78 while that of the black variety was 0.71, 158.04, 106.26 and 0.73 respectively (Fariku et al., 2007). Oil obtained from another Nigerian variety (Goza-25) had the following properties; peroxide value varied from 3.9 and 15.4 meq/kg while oxidative stability varied from 13 h to 63.3 h (Akinoso et al., 2010). These values are significantly different from values obtained from varieties in other locations.

The iodine value of some local Sudanese and imported sesame seed cultivars varied from 101.52 to 114.85g/100g for the local cultivars and 97.70 to 111.30 g/100g for the introduced

cultivars (El Kheir et al., 2008). Saponification value varied from 174 – 196.32 mg/g for local and 182.31 – 198.02 mg/g for improved, while the Peroxide value varied from 2.22 – 15.07 meq/H₂O₂/Kg for local and 2.24 – 10 meq/H₂O₂/Kg for improved. The acid value however varied from 3.1 – 6.6 mg/g for local and 3.1 – 9.3 mg/g for introduced. The chemical properties of oil obtained from white Sudanese sesame seed are iodine value 113.35 g of I₂ 100 g⁻¹ of oil, saponification value 186.60 mg KOH g⁻¹ oil, peroxide value 0.14 meq O₂ kg⁻¹ oil, acid value 1.64 mg KOH g⁻¹ oil, and free fatty acids 0.82 % of Oleic acid (Borchani et al., 2010). Oil obtained from solvent extraction of Northern Congo sesame seed had the following chemical properties; iodine value of 117.2 w ijs, free fatty acid value of 0.06 % oleic acid, saponification value of 197 and peroxide value of 0.06 (Nzikou et al., 2009; 2010).

Generally the high iodine values of sesame oil is an indication of the presence of unsaturated fatty acid and this places the oil in the drying groups, The low value of free fatty acid shows that this oil is stable. The higher oxidative stability of raw sesame oil could be attributed to the presence of such natural antioxidants as tocopherols, sesamin and sesamol (Elleuch et al., 2007). The saponification value is high and this suggests the use of the oil in production of liquid soap, shampoos and lather shaving creams. The peroxide value is lower than that expected of rancid oil, which ranges from 20.00 to 40.00 mg.g⁻¹ oil (Nzioku et al., 2010). This shows that sesame oil is not rancid is considered stable.

9. Processing methods of sesame seed and products

Sesame seed processing is basically done to clean and dehull seed as well as to extract oil from seed. Sesame can be processed to several different stages, such as simply cleaning, or cleaning and dehulling, cleaning/dehulling/drying, cleaning/dehulling/drying/crushing for oil, etc. Generally, sesame seeds are cleaned, dehulled (important because of presence of tannins which are located in hulls). In Nigeria, dehulling is done by soaking in a salt solution overnight. Seeds are rubbed in a mortar to loosen pericarp and then kernel is separated from oat by sedimentation washing (NAERLS, 2010). After dehulling, seeds are washed and then dried usually with sun-drying.

Conditioning of oil seeds is an important operation in the production line of sesame oil. These activities include roasting, flaking, size reduction, cooking, pre-pressing and drying. Dehydrating and roasting of sesame seeds before oil expression improves sesame oil yield and quality. Also the oxidative stability of oil and by-products has been reported to depend on processing techniques and variety of seeds (Akinoso et al., 2010). Beniseed oil extraction is done traditionally in Nigeria by pounding the seeds in a mortar and pouring water into it (Tunde-Akintunde and Akintunde, 2007). The oil floats to the surface from where it can be removed by skimming. This method is slow and laborious and results in low oil yield. Other traditional methods involve crushing to paste using a local grinding machine. Boiling water is added to the paste, stirred and left for 24h. The oil floating on top of the paste is decanted and the process is repeated until negligible oil is formed (Fariku et al., 2007). Another oil extraction method is to roast seeds for 5 – 19 minutes at 180 – 210°C and then mill. Oil is pressed out by adding water to the milled product (NAERLS, 2010). After oil extraction, the cake is dried by sun drying and milled to obtain defatted flour.

The processing of sesame products in the US is similar but the facilities used are different (Hansen, 2011). After harvesting, the seeds are cleaned and hulled. The seeds pass through

an air separation stage to remove any foreign particles. About 10 percent of this "cleaned natural seed" moves directly into food use as whole seed to be blended into flour for baked goods. Next, a combination of water and friction work together as the seeds are passed against the chamber of the hulling machine to separate the hull from the seeds. This dust-free de-hulled seed makes up 30 percent of domestic production and has a 99.97 percent purity for the baked goods market. Once the seeds have been hulled, they are passed through an electronic color-sorting machine that rejects any discolored seeds to ensure perfectly colored sesame seeds. Immature or off-sized seed is removed but saved for oil production. Sesame oil is extracted by pressure in a mechanical expeller and is tolerant of only minimal heating by the extraction process. This pure, mechanically expressed oil is called "virgin" oil and is preferred by many food handlers. The oil is often blended with other vegetable oils for salads and other food uses. Sesame oil should be kept refrigerated. Sesame seeds can become rancid if exposed to prolonged heat. If properly stored, the packed seeds have a 2-year shelf life with little reduction in quality (Hansen, 2011). A dehulling method used for sesame in India is usually done by soaking the seeds overnight in water, followed by drying and rubbing against a rough surface. The separated hulls are removed by winnowing. This method is also laborious, time consuming and suitable for processing small quantities only. A more convenient dehulling technique has been developed through addition of 3% Sodium Chloride (salt) and soaking over night (Chemonics, 2002).

The dehulled seed can be expeller pressed for obtaining good quality oil. The cake is further subjected to solvent extraction to recover the residual oil and the protein rich cake is used for protein fortification of various food preparations. An oil extraction process in India involves preliminary cleaning and grading, placing in a boiling solution of sodium hydroxide for a prescribed time and then thoroughly washing by a stream of water. The hulls are removed by washing and brushing seeds under a current of water. The dehulled wet seeds are then dried in a cross-flow or fluidized bed drier (www.nisc).

Sesame oil can be extracted from sesame by solvent extraction or mechanical expression. A solvent extraction procedure (soxhlet method) was reported by Nzioku et al. (2010). Dried sesame seeds were ground in the dry mill of a blender. 50 g of ground seeds were placed into a cellulose paper cone and extracted using light petroleum ether (b.p 40-60°C) in a Soxhlet extractor for 8 h. The oil was then recovered by evaporating of the solvent using rotary evaporator and residual solvent was removed by drying in an oven at 60°C for 1 h and flushing with 99.9% nitrogen. The hot pressed oils are usually refined before consumption to remove free fatty acids, residues and all aromatic compounds resulting in a bland colorless oil. Refined oils are suited to the cooking of the Western hemisphere where highly aromatic oils are not appreciated.

10. Derivable benefits for sesame seed processing

Sesame seeds are widely considered to be healthful foods. They are high in energy but contain many health benefiting nutrients, minerals, antioxidants and vitamins that are essential for wellness and have positive effects on human health (www.nutrition-and-you, Borchani et al. 2010). They are very good sources of B-complex vitamins such as niacin, folic acid, thiamin (vitamin B1), pyridoxine (vitamin B6) and riboflavin. The seeds are incredibly rich sources of many essential minerals which include Calcium, iron, manganese, zinc,

magnesium, selenium and copper in concentrated amounts. Many of these minerals have vital role in bone mineralization, red blood cell production, enzyme synthesis, hormone production as well as regulation of cardiac and skeletal muscle activities (www.nutrition-and-you). The seeds are especially rich in mono-unsaturated fatty acid *oleic acid* which comprise up to 50% fatty acids in them. Oleic acid helps to lower LDL or "bad cholesterol" and increase HDL or "good cholesterol" in the blood. The seeds are also very good source of dietary proteins with fine quality amino acids that are essential for growth, especially in children. In addition, sesame seeds contain many health benefiting compounds such as sesamol and sesaminol which are phenolic anti-oxidants and help stave off harmful free radicals from the body. As a result of the benefits of sesame, seed exportation offer highest potential for farmers due to the demand for the seed, but Sesame's potential for commercial processing in Nigeria is also great (Nigeria's Harvest, 2009). This is because sesame can be processed into various forms which include oil, meal, paste, confections, and bakery products.

These products of sesame have a number of benefits that can be derived from processing the seeds. The nutritional value of the meal makes it a potential source of livestock feed, this is because it is a relatively good source of CP- crude protein (Omar, 2002). Studies carried out on incorporation of sesame oil cake in rations had positive effects on calves' performance (Omar, 2002). Thus the use of sesame cake in areas where sesame is produced will be beneficial to farmers. The sesame paste contains high monounsaturated to saturated fatty acid ratios, and might be desirable substitutes for highly monounsaturated oils such as olive oil in diets (Borchani et al., 2010). Thus the paste can be utilized as a potential source of edible oils for human consumption.

Raw sesame oil has a high free fatty acids content and is stable in oxidative conditions. The high percentage of oil in the seed makes this seed a distinct potential for the oil industry (Nzioku et al., 2010). This oil may find application as a raw material in industries for the manufacture of vegetable oil-based ice cream (Ibiyemi et al., 1992). All these characteristics lead to more diverse and novel applications of sesame oil in food, cosmetics and pharmaceutical products. Apart from these applications, raw oil from sesame also has a lot of potential as a renewable resource considering its viscosity which is close to those of soybean and sunflower (Fariku et al., 2007). Its flash point is lower but comparable to values reported for soybean and sunflower oils. The calculated fuel value is also comparable to those of soybean and sunflower oils hence, it has high energy density. The iodine value obtained for sesame seed oil also shows that it is a non drying oil and as such it is unsaturated thus making it suitable for utilization as fuel as well as raw material in industries for the manufacture of soap and vegetable oil - based ice cream (Fariku et al., 2007).

Sesame oil has a high percentage of polyunsaturated fatty acids (omega-6-fay acids) but keeps at room temperature uniquely due to the presence of sesamol and sesamin, two naturally-occurring preservatives. The presence of high polyunsaturated fatty acids content make it possible to use sesame oil for cooking in place of other edible oils and to help reduce high blood pressure and lower the amount of medication needed to control hypertension. Sesame oil can also be used for medicinal purposes which include reduction of cholesterol levels, anti-bacterial effects, and even slowing down certain types of cancer (www.nutrition-and-you). Apart from these various constituents present in the sesame oil have anti-oxidant and anti-depressant properties.

11. Adverse effects

Though sesame seeds have a wide range of health and commercial benefits, they have some anti-nutritional properties. Sesame seeds contain a high amount of the phytic acid which is an anti-nutrient. Another disadvantage of the seed is that it produces allergic reactions in some people. The allergy may be mild and appear as hives, dermatitis and itching or be severe and lead to severe physical symptoms like vomiting, pain abdomen, swelling of lips and throat leading to breathing difficulty, chest congestion and death. The laxative effect of sesame also indicates that sesame oil should not be used by people who have diarrhea.

12. Further studies

Based on different research studies carried out on sesame seed, the following studies can be further carried out on sesame seeds and its products to enhance its utilization especially in Nigeria:

- The seed could be further explored to develop a high crude oil yield variety that would be of immense nutritional and economic advantage (Adebowale et al, 2010)
- The high percentage of oil makes this seed a distinct potential for the oil industry (Nzikou et al., 2009).
- The high unsaponifiable matters content (1.87%) of sesame oil guarantees the use of the oil in cosmetics industry. The oil extracts exhibited good physicochemical properties and could be useful for industrial applications (Nzikou et al., 2010).
- Extensive research work still needs to be carried out on sesame seed for its industrial utilization as a biofuel resource material in Nigeria (Fariku et al., 2007)

13. Conclusion

Sesame seed is an oil-seed crop, with edible and odourless oil, and with good source of protein for man and livestock. Its utilization in Nigeria is however mainly for exports and limited local household use within regions in which it is grown in the nation. This is because the low level of information on the Nigerian variety has limited its utilization nationally but information available on international varieties has however made its utilization as an export crop more prominent than being used for home consumption.

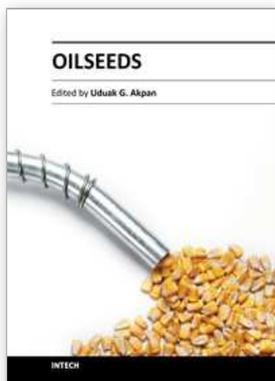
This chapter is aimed at documenting relevant information of Nigerian variety of sesame seed (making a comparison with international varieties) and also examining and presenting the results of studies that have been carried out on the oilseed generally. The information thus documented is expected to bridge the gap and provide people involved in the food chain of sesame seed- with useful literature on the crop. This information will also enhance utilization of the crop and enable producers, processors and consumers to effectively exploit the potential benefits of sesame seed with regards to the Nigerian food and agricultural system.

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