



Processing and utilization of edible Nuts/Kernels in Nigeria: A review

Oluwagbotemi Edu ^{1*}, Olamide Durodola ², Olumide Falana ³, Toby Adjuik ⁴, Ayanlade Timilehin ⁵, Blessing Ademola ⁶, Samuel Olaoni ⁷, Michael Babalola ⁸, Ogunsina Peace ⁹

^{1, 2, 3, 7, 8} Department of Agricultural and Environmental Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria

^{2, 3} Department of Biosystem Engineering, Auburn University, Auburn, USA

⁴ Department of Agronomy, Iowa State University, Ames, Iowa, USA

⁵ Department of Mechanical Engineering, Iowa State University, Iowa, USA

⁶ Faculty of Agricultural and Food Science and Environmental Management, University of Debrecen, Hungary

⁷ Department of Food Science, University of Arkansas, Arkansas, USA

⁵ Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria

⁹ Department of food science and technology, Obafemi Awolowo University, Ile-Ife, Nigeria

* Corresponding Author: **Oluwagbotemi Edu**

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Abstract

Edible nuts/kernels in Nigeria have been of great importance over the years; they have been a good source of food (usually consumed as snacks), useful in the treatment of ailments, are crucial to the farmers' economic survival, and contributed immensely to the country's economic growth. If properly processed and utilized, nut/kernels in Nigeria could employ more than half of the youth population and cause rapid growth in the nation's GDP. This review summarizes available data and information from the scientific literature on the processing and use of edible nuts/kernels in Nigeria. Additionally, the nutritional value, economic importance, and income generation potential of the nuts/kernels were also discussed. Despite the use and enormous income generation potential, many farmers are still not aware of the economic importance of edible nuts/kernels. Creation of awareness by extension workers by organizing programs to enlighten farmers on the advantages of cultivating and investing in edible nuts/kernels.

Keywords: Edible nuts/kernels, economic importance, chemical composition, processing, utilization, income generation

1. Introduction

Tree nuts, also known as drupes, are fruits with a single seed encased in a hard shell ^[1]. The fruit known as a nut is a dry, hard, single-seeded fruit with an oily kernel enclosed in a tough, brittle shell. Nuts fall under the monocarpic or dicarpic categories. The majority of nuts, also known as kernels, are the seeds or dried fruits of immature trees, or indehiscent plants. The hulls of some edible seeds, such as pumpkin and sunflower seeds, are also edible since they are softer than the hulls of nuts and grow on either vegetable or floral plants ^[2]. Humans use edible nuts for food, cooking, seasonings, condiments, and snacks. They are among the most nutritionally dense foods for humans and have been major food sources since prehistoric times. They are rich in protein, oil energy, minerals, and vitamins ^[3]. Additionally, edible nuts are utilized in the food service sector to improve the nutritional content of foods or to add flavor ^[4]. Edible nut seeds have always been widely regarded as a necessary part of the human food supply. Tree nuts are prized for their nutritional value and sensory qualities all throughout the world ^[1]. Before agriculture was introduced, people were harvesting nuts for food. ^[5]. The following categories apply to edible nuts ^[2].

1. True nuts: True nuts have an outside wall made of involucre tissue, which is not a component of the ovary wall or pericarp, and an inner wall made of the complete ovary wall (pericarp), which is the hard, indehiscent covering enveloping the seed in true nuts. The term "real nuts" refers to chestnuts, filberts, and walnuts.

2. Botanical seed: is used to describe legumes, pistachios, cashews, and Brazil nuts (e.g., peanuts). Because the peanut produces fruit in the shape of pods (shells) containing one or more seeds, it is regarded as a legume (usually two per pod).
3. Drupe: A drupe is a fleshy fruit that has a hard inner layer (endocarp or stone) surrounding the seed (e.g., almonds). Some botanists also include the fruits of walnuts, cashews, pecans, macadamia nuts, and pistachio nuts as drupes because of their outer, green, fleshy husk and stony, seed-bearing endocarp.

Nuts and kernels are a source of nourishment for both people and wildlife. Due to their high oil content, nuts and kernels are highly sought as food and energy sources. Nuts that are fit for human consumption can be utilized in different ways, such as as a culinary ingredient, raw, sprouted, or roasted snack food, or pressed into oil for use in cooking and personal care products. They are a good source of feed for wildlife. This is particularly true in regions with a moderate climate, where animals like squirrels and jays gather acorns and other nuts in the fall to avoid going hungry in the late autumn, winter, and early spring.

The harvesting and processing of edible nuts/kernels under series of similar unit operations, it has been observed that this series of unit operation could be confused for each other if not carefully observed.

This operations in time past has been done manually which made processing operations to be challenging. Therefore, the objective of his review is to highlight the processing operations involved each of the nuts/kernels, to know the utilization, nutritional, health and economic importance of nuts/ kernels and finally, to know the process of cultivation and production involved in nuts/kernels.

2. Nutritional, health, and economic Importance of Edible nuts/kernels

The USDA Food Guide Pyramid's meat/meat substitute group includes nuts. As long as they are consumed in moderation everyday as part of a healthy diet, nuts can be classified as either meat or a meat alternative [6]. According to [6], nuts offer plant protein, fat (mainly unsaturated), dietary fiber, and a number of vital vitamins and minerals. Most people consume nuts and/or nut hulls as a special portion of their daily diet. As a result, several public health groups advise including nuts in a balanced diet on a daily basis. Nuts are a great source of protein, dietary fiber, and good mono- and polyunsaturated fats [7]. Unsaturated fatty acids, vitamin E, fiber, magnesium, and potassium are mostly found in nuts [6]. The chemical makeup of nuts is typically thought to be responsible for their nutritional value [3]. The chemical makeup of various nuts and kernels in Nigeria is shown in Table 1.

Numerous epidemiological studies have found an unfavorable relationship between frequent nut consumption

and mortality from cancer and coronary heart disease in humans [8]. Humans that consume nuts have been found to have higher levels of antioxidants [9]. According to [9], an antioxidant is "a redox active compound that limits oxidative stress by reacting non-enzymatically with a reactive oxidant". Antioxidant-rich foods help maintain a healthy balance between the body's antioxidants and free radicals, which have been related to a number of ailments, including cancer, autoimmune diseases, aging, cataracts, and rheumatoid arthritis. Tree nuts, pecans, chestnuts, and walnuts have the highest antioxidant levels, according to research by [9]. Because nuts contain enough antioxidants, their health advantages are increased, the reason why the U.S. Food and Drug Administration has granted a health claim for lowering the risk of heart disease, advocating the inclusion of nuts in the suggested dietary guidelines in the United States, Canada, and Spain [10].

Eating edible nuts has many health and nutritional advantages, but they can also be grown and sold for a source of foreign currency. Farmers can make a good living from nuts, especially in West Africa where subsistence farming is the primary source of income [11]. The cultivation of cashews in tropical nations is a typical example. The cashew business could be viewed as a major contribution to the achievement of the United Nations Millennium Development Goals since it plays a significant part in the economic development of West African nations including Nigeria, Ghana, and the Ivory Coast [11]. According to [12], West Africa alone generated 45% of the world's cashews in 2015, highlighting the demand for and significance of edible nuts for the economic development of West African nations.

2.1. Walnut

Tetracarpidium conophorum or Plukenetia conophora, both names for the tropical African walnut, is a member of the Euphorbiaceae family [13, 14]. According to [16, 3], walnuts are a good source of proteins, fiber, melatonin, sterols, folate, tannins, and other polyphenols in addition to important fatty acids (mostly linoleic acid). Walnuts are particularly high in omega-6 and omega-3 polyunsaturated fatty acids when compared to other nuts, which mostly contain monounsaturated fatty acids [15, 3, 15, 16], plant sterols [20, 21], folate, tannins, and polyphenols [22, 23, 16], are just a few of the additional chemical components that walnuts contain that may be good for human health overall. Walnuts are referred to as "inflammation fighters" since they offer anti-inflammatory compounds for conditions like eczema and psoriasis as well as conditions like asthma, rheumatoid arthritis, and other skin conditions linked to inflammation [7]. According to [24] walnuts are a great source of a number of vitamins, minerals, and antioxidants that support healthy bones, nerves, and immune systems as well as inhibit the growth of cancer in the breasts, prostate, colon, and kidneys. According to various walnut cultivars and environmental factors, walnut oils, fatty acids, and tocopherols might change greatly [15, 16].

Table 1: Chemical composition of some Kernels/Nuts (g/100g)

Nuts	Energy (KJ)	Protein (g)	LA (g)	MUFA (g)	SFA (g)	ALA (g)	Fiber (g)	FAT (g)	Folate (µg)	PS (mg)	Carbohydrate (g)	Sodium (mg)	Cholesterol (mg)
Cashew	2314	18.2	7.7	27.3	9.2	0.15	5.9	46.4	25	158	30.19	12	0.00
Almond	2418	21.3	12.2	32.2	3.9	0.00	8.8	50.6	29	120	19.74	1	0.00
Walnut	2738	15.2	38.1	8.9	6.1	9.08	6.4	65.2	98	72	13.71	2	0.00
Groundnut	2220	25.2	15.6	24.4	6.8	0.00	8.5	49.2	145	220	16.13	18	0.00

Data for raw nuts, except where specified. *SFA, saturated fatty acids; *MUFA, monounsaturated fatty acids; *LA, linoleic acid; *ALA, a-linolenic acid; *PS, plant sterols.

Source: USDA (2010)

2.2. Cashew Nut

One of the most valuable processed nuts sold on the international commodities markets is the cashew (*Anacardium occidentale* L.), sometimes known as the "wonder nut" [17]. In many nations in Asia, Africa, and South America, cashews are widely farmed for its nuts, which are used for food, medicine, and as a source of revenue [25]. Humans can gain a variety of health advantages from cashews and its products [18]. According to [26] and [18], cashew helps control blood sugar levels, lowers cholesterol levels, and lowers the risk of coronary heart disease. Magnesium, found in abundance in cashew nuts, is essential for the growth of strong bones and the control of high blood pressure [11]. The chemical makeup of cashew nuts is displayed in Table 1 above. The nutritional profile of cashews, according to [27], includes 46-47% lipids (of which 87% are unsaturated fatty acids), 18 to 21% protein, and 29 to 31% carbs. Phosphorus (593 mg), magnesium (292 mg), potassium (660 mg), vitamin E (0.90 mg), and vitamin K (34.1 mcg) are also present in cashews in varying amounts [28, 29, 18].

2.3. Almond Nut

One of the most nuts consumed across the globe is the edible tree nut known as the almond. Due to their fatty acids and bioactive substances, almonds have health advantages [19]. Due to their antioxidant content, which is known to reduce the amount of free radicals in the body, almond consumption is linked to various health advantages [9]. Almonds also inhibit the growth of cancer cells and control inflammatory and immunological reactions in the body [20]. Almonds include polyphenols, which are known to enhance human health [19], as well as unsaturated fatty acids, which are good for human health [30, 19]. According to [7], unsaturated fatty acids can lower blood pressure and prevent cardiovascular illnesses. In comparison to other nuts, almonds have higher levels of calcium (269mg/100g; approximately 27% of DRA), riboflavin (1.138/100g; 87.5% of DRA), fiber (12.5g/100g; approximately 33% of DRA), protein (21.15g/100g), and vitamin E (alpha-tocopherol-25.63mg/100g; about 170% of DRA of Vitamin E).

2.4. Groundnut

According to [31], groundnut (*Arachis hypogaea* L.) is the sixth most significant oil seed crop in the world. According to [32], groundnut includes 48–50% oil, 26-28% protein, 11-27% carbohydrate, minerals, and vitamins. Due to groundnut's high carbohydrate and protein content, groundnut is a staple in the diets of rural people, especially children. Calcium, potassium, phosphorus, magnesium, and vitamin E are all abundant in groundnut. An essential component of cattle feed is groundnut meal, a byproduct of oil extraction. According to [33], groundnut haulms are a popular and nutrient-rich source of feed for livestock. The edible seeds of a legume are known as groundnuts [34]. Everywhere in the world, diverse traditional cuisines use groundnuts. People on excursions to places like Antarctica and space use groundnuts as a comprehensive food source. In recent years, groundnut has significantly contributed to the eradication of malnutrition among the people of numerous African nations [34, 35].

The primary ingredients of groundnuts include protein, lipids, and fiber (Table 1). Groundnuts provide plant-based protein, unsaturated fat, and complex carbohydrate fiber, all of which are beneficial nutrients for human intake [34].

[34] cite the American Peanut Council as saying that the groundnut (peanut) lipid profile contains roughly 50% monounsaturated fatty acids (MUFAs), 33% paraformaldehyde (PFAs), and 14% saturated fatty acids, which is a combination of fatty acids that is good for the heart. According to the [36, 34], peanuts are the main source of the amino acid arginine and contain all 20 amino acids in varying amounts. According to [34], the amino acid profile of peanut meals indicates that they can be used as a protein-fortification element. Peanuts are a good source of fiber as well, according to [34]. Groundnuts' main sources of carbs are sucrose and starch, with reducing sugars making up a much smaller amount [34]. Although eating groundnuts has several health advantages, their carbs may cause blood glucose levels to rise. Simple sugars, for example, have a sudden, significant impact on your blood sugar levels. On the other hand, fiber- or starch-containing carbs affect blood sugar more gradually and subtly. Groundnuts and other nuts are listed as foods that cause diabetes by the American Diabetes Association [34].

Vitamin E, which is regarded as a nutrient that is difficult to obtain, is abundant in groundnuts [34]. According to certain research, more than 90% of men and women did not consume enough vitamin E [34]. Low doses of vitamin E intake can guard against coronary heart disease in people [34]. Additionally, groundnuts are a rich source of folate, which is necessary for the development and upkeep of cells in young children and pregnant women [34].

The body needs essential nutrients including proteins, carbs, fats, vitamins, minerals, and fiber, and groundnuts are a great and inexpensive source of these nutrients [37].

3. Cultivation, production, and processing of nuts/kernels in Nigeria

Nuts and nut kernels can be used in large part effectively by processing. According to [38, 39], food processing encompasses methods for transforming raw ingredients into semi-finished and finished goods that can be consumed or stored. Food can be processed on a variety of scales, including at home and at the industrial level, which can be small-scale or large-scale [39].

Before they may be decorated or processed further for food, the majority of edible nuts need thermal treatment in the form of roasting, heating, or drying [40, 41, 42, 43]. The majority of tree nuts go through similar processing procedures; frequent drying to prepare for cracking, size separation, air aspiration to separate shell pieces, color sorting to remove additional flaws, and a last hand sort and inspection before packaging.

3.1. Walnuts

Tetracarpidium conophorum, sometimes known as African walnut, is a member of the Euphorbiaceae family [44]. According to [45, 46], the plant is also known as Nigerian walnut, Black walnut, and African walnut. In the hot, humid regions of tropical Africa, it is typically grown by small subsistence farmers in backyards and compound gardens just for use inside the household and on the neighborhood market. Both primary and secondary woods contain walnuts [47]. Walnuts can be found in plenty in all of Nigeria's cocoa-producing states as well as in the southern portion of the country, including Ajaawa, Akpabuyo, Akamkpa, Akure, Ibadan, Kogi, Lagos, Ogbomoso, Uyo, [48], Ekiti, Ife and Ijeshaland [46]. About 81.7% of farmers in the southwest of Nigeria grow *T. conophorum* on farms where cocoa, kola, oil palm, and oranges are grown. In south western part of Africa

(Nigeria), among the Yoruba tribe, the walnut is known as “asala” “awusa” or, “oke okpokirinya” or “ukpa”, in Igbo and “gawudi bairi” in Hausa; while it is known as “okhue” or “okwe” among the Bini tribe of Edo State [14, 49]. As depicted

in Figure 1, walnut processing includes all steps from harvest to the creation of edible parts. Walnuts must be harvested, hulled, dried, and shelled in order to obtain the edible portion (meat or kernel) [50].

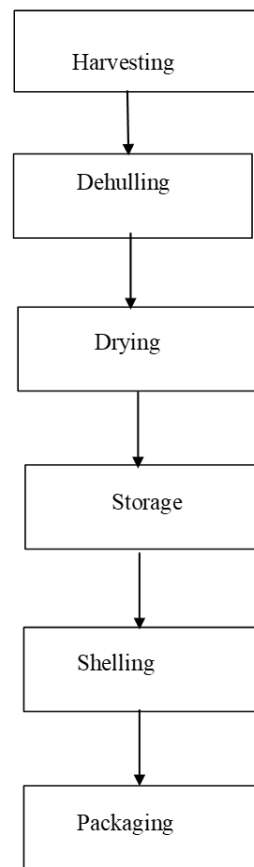


Fig 1: Walnut processing method

a) Harvesting

When a large proportion of the walnuts on the tree have split hulls and only a few nuts have fallen to the ground, it is time to start harvesting [50]. Applying an ethylene-producing substance, such as ethephon, can speed the last stage of maturity and hull break in walnuts [21, 51]. According to [5], nuts are often gathered by shaking trees, a technique that can be automated or done by hand.

b) Dehulling

After being harvested, walnuts have an outside green hull that must be removed. Dehulling, which is removing the green hull from the walnut after harvest, is a crucial postharvest procedure in the processing of walnuts. It significantly affects the quality, chemical composition, and microbiological characteristics of walnuts. The dehulling process must be carried out using a mechanical huller before the drying operation, however the majority of growers do it by hand or foot, which can lead to several skin conditions and ruin their clothing by leaving unsightly stains [50] and the procedure takes a lot of effort and time [52].

c) Drying

The most important post-harvest procedure right after harvesting is drying. To extend the shelf life and preserve the nuts at a safe moisture level for storage, the walnuts must be fully dried from their initial moisture content (MC) to an MC of 8% (wet basis) using hot air at a temperature of about

43°C. Walnuts become moldy and lose quality quickly when the drying process is delayed [52]. According to Food and Drug Administration (FDA) rules for tree nuts, a safe moisture level must be at least 8% wet basis, with a matching water activity (aw) of roughly 0.70 at 25 °C, and must not allow fungal development [53].

d) Storage

Both qualitative and quantitative losses can be avoided by managing nuts properly after harvest [54]. You can store nuts with or without their shells. Following the drying process, the storage of in-shell walnuts is a crucial process step [50]. Depending on the grower's inclination, walnuts will be simpler to handle if shelled first even if they would keep longer if stored in their shell. In order to keep nuts at the right moisture level, it's critical to store them in an airtight container or plastic freezer bag. Since they have a propensity to absorb smells from their surroundings, nuts should be kept away from meals with strong aromas like onions in order to maintain their quality. Unshelled nuts can be kept in a refrigerator for up to six months or frozen for a year or longer, while shelled nuts should be kept at room temperature for up to three months. For simple identification and appropriate use in the, the packages should be correctly labeled with dates [54].

e) Shelling

In order to provide the need for walnut kernels in the consumer and industrial markets, dried walnuts are often kept

in shelled form until needed ^[50]. When walnuts are stored in their shells, the shells are fractured and taken off during the shelling process. After the shell is taken off, the kernels are divided into giant, half, and small pieces according to their size ^[55].

f) Packaging

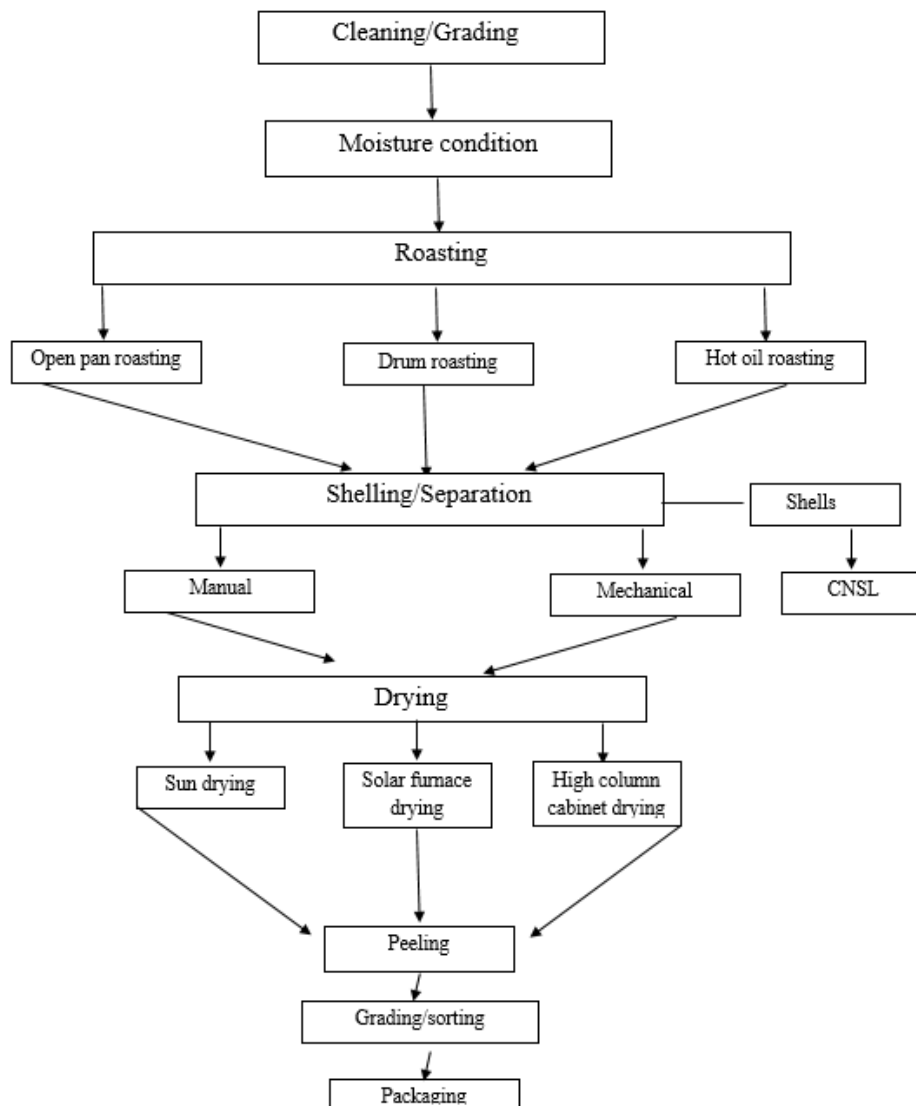
The dried kernels are subsequently vacuum packaged in various weight amounts to meet market demand ^[52]. The product is then packaged for delivery to the appropriate markets. The shelled walnut kernels are either consumer packaged or put in bulk cartons or cans depending on whether they are being used for commercial or institutional purposes ^[50].

3.2. Cashew Nut

According to ^[56], the cashew (*Anacardium occidentale* L.) is a member of the Sapindales order, family Anacardiaceae, and genus *Anacardium*. The cashew tree was first brought to Nigeria more than 400 years ago, but it wasn't until the early 1950s that it was widely cultivated. From 1965 through 1990, cashew production averaged 25,000 Mt per year, with an

estimated 50,000 hectares of land under production. According to ^[57], cashew is grown in 20 states in Nigeria, including Kwara, Kogi, Oyo, Edo, Ondo, Anambra, Enugu, Benue, Cross River, Imo, Sokoto, Nassarawa, Ogun, and Osun. In the last 12 years, production of cashews has expanded by about thirty times, from 30,000 Mt in 1990 to 836,500 Mt in 2012, from an estimated land area of 366,000 ha ^[56]. Currently, cashew agriculture has extended to around 27 states of the nation. With an estimated nut production of 650,000, 813,023 and 835,500 Mt in 2010, 2011, and 2012, Nigeria was ranked second in the world ^[58, 59, 60]. Following Tanzania, Cote d'Ivoire, and Guinea Bissau as the leading cashew nut producers in Africa, Nigeria is currently rated seventh globally ^[57, 61]. Nigeria contributes over 16% of the total production in Africa and 5% of the global production, producing an average of 80,000 Mt yearly from a total area of 10,000 ha ^[57, 62].

Over time, Nigeria's cashew nut processing technique has improved. Processing cashews primarily aims to separate the pricey cashew kernel from the shell with the least amount of damage feasible ^[63]. The following is a discussion of the steps required in cashew processing as indicated in Figure 2:



Source: Ogunsina & Bamgboye, (2012)

Fig 2: Cashew nut processing methods

a) Sorting

Separating the nuts that are free from molds and full sized. Sorting can be done manually or mechanically.

b) Drying

By removing the water from the kernel, drying prevents microbial growth ^[64]. In many locations, cashew nuts are mechanically dried or sun-dried for days on end until the kernel can be felt moving inside the shell ^[63]. Nuts can be stored for two years before shelling if they are properly dry.

c) Shelling

This is the removal of the outer shell and Cashew nut Shell Liquid (CNSL). The importance of the shelling operation is to produce clean, whole kernels.

d) Peeling

Peeling involves the removal of the testa (the skin covering the kernel)

e) Grading

Grading involves sorting into different sizes and colors in accordance with standard grading.

f) Packing

Packaging involves putting the kernels into airtight bags or cans depending upon the scale of operation.

3.3. Almond Nut

With the botanical name *Terminalia catappa* and the common name "stone fruit," almonds are a well-known, high-energy fruit belonging to the Rosaceae family ^[65]. It is regarded as a very sustainable food source and grows best in Mediterranean temperatures ^[65]. According to ^[66], almonds are a type of nut with a hard shell that protects a single edible kernel. Almond production is the highest in the world for tree nuts ^[67]. About 700,000 tons of almonds are produced worldwide each year ^[68, 69, 70], with Nigeria producing 100,000 tons, or 14%, of that total ^[69, 70]. Nigeria produced about 1.4 tonnes of almonds in 2015, which was a decrease of 67.7% from the previous year's total. However, production over the examined time has remained in a rather flat trend pattern. The output volume climbed by 129% over the prior year in 2010, which gave the speed of expansion the appearance of being the fastest. Thus, production hit its greatest level of 8.6 tonnes. Production remained at a lower level from 2011 to 2015 (see "Almond Market in Nigeria," 2022). Italy, Spain, Morocco, France, Greece, and Iran are among the biggest producers of almonds. Between April and May and September and October, it blooms ^[71]. According to ^[72], the fruiting season runs from October to April. In nations where almond production is at its commercial peak, there are numerous types of the fruit.

The next section discusses the procedures involved in processing almond nuts in accordance with ^[65], as depicted in fig 3.

a) Harvesting

The almonds are harvested once the fruit get rip either manually, by knocking the nuts from the tree limbs with long pole, or mechanically, by shaking them from the tree. The ripe fruits are distinguished by their reddish or purplish

yellowish coloration.

b) Washing

The harvested almonds which are usually dirty due to their contact with the ground are washed with water.

c) Peeling/de-pulping

This is the process of removing the mesocarp or pulp. And it is usually done locally or traditionally with knife.

d) Sun-drying

It involves drying of the de-pulped fruits under the sun for 5-7days to reduce its moisture contents to 4-6% wet basis, a vital step to avoid/reduce breakage of kernel during de-husking. Even after de-husking and sorting, kernels are further dried to ensure they are within safe moisture content for storage.

e) De-husking/Shelling

This is the removal or cracking of the shell to expose the kernel. This is achieved traditionally using hammer and a de-husking stone. Almond nuts are usually cracked along the margin to release the brown spindle-shaped kernel from the endocarp.

f) Winnowing

This is the process of removing debris through air action. The cracked kernels are usually placed on winnowing tray pan and thrown up and down within the tray as air is blown over it is using the mouth to remove the debris which are lesser weight when compared to weight of the kernel.

g) Sorting

This is the process of separating the broken kernels from the whole kernels. This is usually achieved locally by hand picking. Sorting is quite important because the broken kernels are more prone to spoilage.

h) Packaging

This is process of positioning the nut for marketing.

3.4 Groundnut

The majority of groundnut production occurs in Asia and Africa, where the crop is mostly raised by smallholder farmers using minimal inputs and rain-fed farming techniques ^[32]. With 11.6 million ha (47.15%) and 11.7 million ha (47.56%), respectively, Asia and Africa have the largest global areas under groundnut. Over 97% of the world's groundnut producing area and 95% of the total production are in developing nations in Asia, Africa, and South America ^[60]. Nigeria produced 16,114,231, 6,933,000, and 2,962,760 tonnes of groundnuts in 2011, placing it third in the world behind China and India ^[32]. Nigeria produces 51% of the groundnuts in West Africa, making it the top producer in the region ^[60]. Niger, Kano, Jigawa, Zamfara, Kebbi, Sokoto, Katsina, Kaduna, Adamawa, Yobe, Borno, Taraba, Plateau, Nasarawa, Bauchi, and Gombe States are some of Nigeria's top producers ^[73]. According to ^[60] the following phases and processes are used to produce groundnuts in Nigeria, and they are depicted in Figure 4 along with the suggested varieties and planting times for each of these states:

a) Harvesting

Groundnut processing begins with the gathering of the nuts. Because groundnut is an indeterminate plant, the maturity of the pods varies. Because waiting for all the pods to develop will cause the already matured pods to sprout, harvesting should be timed when the majority of the pods are mature. Looking for darkening of the internal surface of the pericarp (i.e., the shells turning dark brown inside) and when the seed

coat is thin and tight on the kernel is one simple and useful approach to identify the ideal time for harvest. The crop should be harvested as soon as the seeds reach this level of maturity, which is indicated by this symbol. Harvesting is also advised when 70–80% of the pods are fully developed, the seeds are puffed up, and the seeds exhibit the actual hue of the cultivar being used.

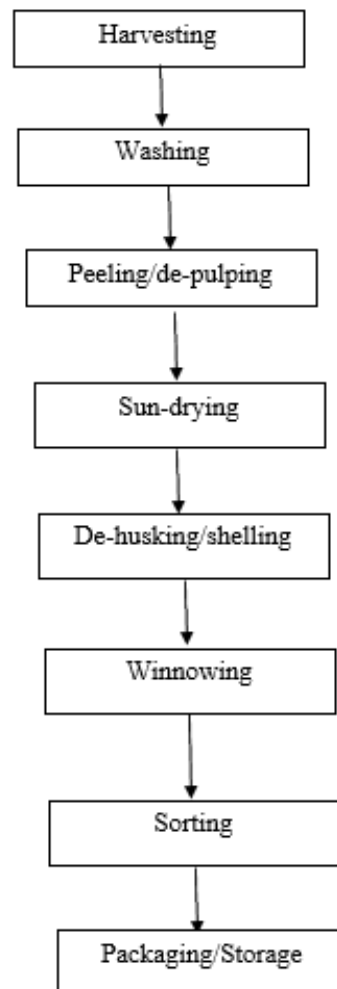


Fig 3: Almond nut processing method

Groundnuts can be harvested using a hoe or ox-drawn plow (often used for spreading groundnut variety on thick soils and during dry weather), or by physically uprooting the entire plant (this is only possible when there is enough moisture in the soil). The entire crop can be lifted from the soil with little pod loss using a hoe or an ox-drawn plow.

b) Drying

Before removing the pods, the groundnut plants are stacked in the field for a few days to allow for air and sun drying. Until the moisture content is below 10%, the pods are constantly dried. Drying keeps seeds viable and prevents the growth of aflatoxin, a toxin brought on by yellow mold (*Aspergillus flavus*)⁵.

c) Stripping

After being lifted and often dried, groundnuts are stripped and removed from the haulm. The process of stripping is often carried out by hand and takes a lot of time. Picking or

flailing are used to remove the pods.

Picking is the process of cleaning the stripped groundnut of debris.

g) Grading

Grading involves sorting into different sizes and colors in accordance with standard grading.

d) Decortication or Shelling

Shelling is usually done by hand in Nigeria; however, hand-operated decortivating machines are currently available. Care should be taken to prevent cracking of the kernels. The following steps are important for maximum benefit in groundnut decortication:

1. Separate immature pods as well as those infested with pests and diseases
2. Do not shell by beating or trampling
3. Either manual or motorized shelling can be used, but only if the shellers do not damage the pods

4. Remove shriveled, discolored, moldy and damaged grains from the lot including groundnuts with damaged testae and dispose of them
5. Remove dust, and foreign material which can provide a source of contamination.

Table 2: Agroecologies, recommended varieties and planting time for groundnut production in Nigeria

Agroecological zones (AEZ)	State	Recommended varieties	Planting dates
Wet season			
Sahel	Sokoto, Yobe,	Samnut 25	Early July
Savanna	Borno, Jigawa	Samnut 26	
		Samnut 24	
Sudan Savanna	Kebbi, Sokoto,	Samnut 24	Early June to July
	Zamfara, Katsina,	Samnut 25	
	Kano, Jigawa	Samnut 26	
Northern Guinea Savanna (NGS)	Kebbi, Zamfara,	Samnut 21	Mid-to-end June
	Katsina, Kano,	Samnut 22	
	Kaduna, Bauchi	Samnut 23	
Southern Guinea Savanna (NGS)	Niger, Kwara,	Samnut 10	1st Planting; May
	Nasarawa, Borno.	Samnut 21	1st Planting: End
	Bauchi, Gombe	Samnut 22	July
Derived Savanna	Kwara, Nasarawa,	Samnut 10	1st Planting; May
	Benue, Taraba,	Samnut 21	1st Planting: End
	Kogi, Oyo	Samnut 22	July
Dry Season	All States	Samnut 24	End October or Early February
		Samnut 25	
		Samnut 26	

Source: A Farmer's Guide to Groundnut Production in Nigeria. Patancheru 502 324, Telangana, India: International Crops Research Institute for the Semi-Arid Tropics. 36 pp.

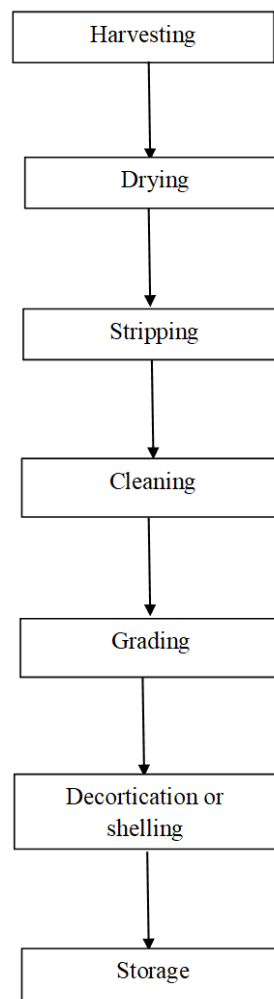


Fig 4: Groundnut processing method

e) Storage

The dry pods are stored in bags stacked up to 10 bags high in separate stacks after washing and grading to allow for free air circulation or ventilation. To prevent damage from getting wet, the bags should be stacked on wooden planks rather than on the ground. The pods are shielded from a variety of storage pests by being dusted with 5% Lindane in the bags.

4. Utilization of some Kernels/Nuts

4.1. Cashew Nut

Cashew nuts can be used in confections and baked goods and are typically roasted and consumed as a dessert. Other beneficial cashew nut products include cashew butter and cooking oil, and the husk is a valuable component of animal feeds. Due to its distinct chemical characteristics, CNSL is another popular by-product produced during the processing of cashew nuts [76, 77]. According to [96], the nutshell liquid makes up about 30–35% of the raw nutshell. The CNSL is mostly used in the polymer industry as a raw material for surface painting, varnish, and brake manufacture [78, 77]. After the nutshell liquid has been eliminated, cashew shell cake is produced [77]. In factories that process cashew nuts, the finished product is burned to extract liquid from the shell [79]. According to [80], cashews have a higher calorific value than sawdust. Cashew oil, cashew powder, cashew butter, and cashew milk are further minor items mentioned by [79]. Cashew nut shells have been used in hydraulic paints, ruminant feeds, and fertilizer formulation [56]. The cashew tree and its products are apparently one of the most extensively used plants in the world due to its significance as a culinary, industrial, and medicinal resource. According to [80], cashew offers ongoing prospects for investment and significant potential for accelerating economic development.

4.2. Almond

Children adore almond seeds and can eat them [81]. Although it is largely starch-free, it is high in protein [82]. Many rural residents of southern Nigeria utilize almond to fortify regional complementary meals, which are typically poor in protein [81]. For diabetes patients' cakes and biscuits, almond flour is frequently prepared [82]. Vegetable oil can be produced from almond almonds, yielding over half of their weight. According to [82], processed oil is used medicinally to treat bronchial disorders, tickling coughs, hoarseness, costiveness, and nephritic pains as well as to calm acrid juice, soften, and relax solids.

4.3. Walnut

There are many applications for African walnut (*T. conophorum*) [83]. The main purpose of walnut is as a culinary ingredient. The nut is consumed as a snack, much like cashew and groundnut. Walnuts can be consumed on their own or mixed to other foods to create a variety of dishes and desserts [84].

T. conophorum is utilized as a male fertility enhancer in southern Nigerian ethnomedicine, and the leaves are also used locally to cure dysentery and increase male fertility [83]. The development of a biscuit-like snack food from walnuts sheds some information on the functional importance of the oilseed [85]. Due to the seeds' popularity as snacks and drinks [14], there is currently a considerable demand for walnuts as a delicacy and snack [83]. Walnut seeds are utilized in Nigeria to treat fibroid [47]. When consumed, the juice from walnut plant leaves may lessen persistent hiccups [47]. In Nigeria,

walnut seeds are used to boost male sperm counts, while walnut leaf juice is said to boost female fertility and control menstrual flood [86, 47].

One of the least used oils is walnut oil, mostly because it is expensive and can become bitter when heated. Walnut oil can be used as a finishing oil on foods that are served at room temperature or as a sophisticated accent to a dish that is served cold. With cooled noodles, aged cheeses, and robust veggies, walnut oil adds a somewhat sweet, nutty flavor. Walnut flour has been used to create a variety of useful food items, including bakery, dairy, and meat products. Some biologically active ingredients found in walnut flour may be incorporated into food products by using it in their composition [50].

4.4. Groundnut

Groundnuts, sometimes known as peanuts, are a high-value commodity that requires little preparation before marketing. Due to their tremendous adaptability, groundnuts can be employed in a variety of goods.

An essential component of cattle feed is groundnut meal, a byproduct of oil extraction. Nutritious groundnut haulms are frequently used to feed cattle. Important to the confectionary industry are groundnuts. Since the stable oil has a smoke point of 229.4oC as opposed to 193.5oC for soybean oil, deep-frying industries prefer it [87]. Mayonnaise and margarine are also made using the oil [88]. High-grade nuts from the crop are used to make confectionary items such as snack nuts, sauce, flour, peanut butter, and cookies [88]. In the Northern region of Nigeria, edible groundnuts are processed into or used as an ingredient in a variety of other products in addition to being consumed whole. These products include salted groundnut, groundnut candy, groundnut soup, and a gruel or porridge made with millet and groundnut, all of which are referred to as "kunun gyada" [32]. Some nearby oil factories burn the shells as fuel, and they are also occasionally placed on the ground to improve the soil. Additionally, groundnut shells can be used to make chipboard for carpentry or as bulk in cattle feed [88].

5. Processing and Income generation

Treating edible nuts can potentially extend their shelf life and boost growers' profitability. Edible nuts and kernels can be processed to make milk, wheat, oil, soap, and a variety of other goods.

5.1. Groundnut

Groundnut has helped the Nigerian economy grow and generate income during the past few decades. Groundnut products, including cake and oil, made almost 70% of Nigeria's total export earnings between 1956 and 1967, making them the nation's most valued export crop over others including rubber, cotton, cocoa, and oil palm [89]. According to [90], the sale of groundnut products such as seeds, cakes, oil, and haulms offered important sources of income in 1999. A sizeable portion of Nigeria's total export revenue was made up of groundnut products like oil and cake. Groundnut was one of the main sources of income and foreign exchange earnings for Nigeria prior to the fossil oil boom [60].

According to [91], the agriculture sector contributed an average of 56% of the GDP between 1960 and 1964, 47% between 1965 and 1969, and 35% between 2003 and 2004. Before Nigeria gained independence, groundnut production, marketing, and trade were important sources of employment,

income, and foreign exchange. The groundnut industry served as the cornerstone for agro-industrial growth and helped to monetize, commercialize, and integrate the rural natural sector ^[92]. Groundnut production was a successful business with a gross margin of N8,466.00/ha and a sizable profit of N6,067.00/ha, according to a study of production analysis in the Ezeagu Local Government Area of Enugu State ^[93, 92]. The study's findings revealed that the total revenue (TR), gross margin (GM), and net farm income (NFI) per hectare in Taraba State's northern region were N100,818.00, N42,422.00, and N41,172 respectively, while the gross margin per naira invested and net farm income per naira invested were N0.73 and N0.69, respectively ^[92]. Depreciation on fixed costs was N1250.00 (2.1% of the total farming cost), and the average variable cost/ha was N58,396.00 (97.9% of the total farming cost). As a result, the farming operation's total cost (TC) per hectare was N59,646. According to [92], the total revenue (TR), gross margin (GM), and net farm income (NFI) per hectare were each N100,818.00, N42,422.00, and N41,17.00. The aforementioned numbers suggest that groundnut growing is profitable.

5.2. Walnut

The walnut industry is one of Nigeria's undervalued industries despite its inherent ability to boost the country's economy ^[84].

There are no numbers or data available for walnut in Nigeria, but the crop has the potential to generate N100 billion in revenue year and, as a result, provide jobs for more than 5,000 people ^[84]. This can be accomplished through streamlining the process of the commodity's production, handling, processing, and marketing ^[84]. Using inferential and descriptive test statistics, the data collected within and around the Omo and Shasha Forest Reserves in the states of Osun and Ogun were examined. An estimated 30.01kg of African walnut was taken out of the forest reserves each month between May and September, bringing in around N615, 833.30 for the economies of the two regions. ^[84] reports that 17.0% of respondents earn between N11, 000.00 and N20, 000.00 per month, which can account for up to 50.0% of their monthly income during the production season. Per walnut tree, 40 to 50 kg of nuts can be harvested. In Akwa Ibom State, five walnut pieces cost N200 ^[84].

Walnuts can be harvested for up to 30 years after walnut trees reach full maturity and output. Experts and industry players believe that strategic investments in the walnut industry can support an industrial revolution in Nigeria and beyond through hybrid walnut farms and processing factories in various communities while involving millions of Nigerians in its cultivation and processing ^[84]. This is because of the many advantages and potential of walnuts.

Some of Nigeria's and Africa's economic issues could be solved by walnut. For instance, if young farmers were to cultivate industrial walnut on 5 million hectares of Nigeria's 84 million hectares of arable land, it would provide employment for more than 1 million youths each year ^[84].

5.3. Cashew nut

The cashew nut, which accounts for 18,000 to 23,000 metric tonnes of annual export to India ^[62], is one of the most important components. The cost of a metric tonne of Nigerian cashew nuts on the international market increased from

N24,753 in 1993 to N180 in 2003 and then decreased to N552,757.24 in 2020 (source: Trigde. Intelligence cashew Nigeria).

Nigeria is estimated to have the potential to earn over \$200 million (N72 billion) a year from the export of cashew nuts, according to stakeholders in the agriculture industry ^[94]. According to ^[94], Nigeria exported roughly 240,000Mt of cashew nuts in 2019—220,000Mt of raw cashew nuts and another 220,000Mt that had been locally processed before export. Nigeria was predicted to have made about \$34,848,000 from sales of the processed kernel and about \$198,000,000 from sales of the raw nut in 2019 at the stated average Free on Board (FOB) prices of \$7,200/Mt for processed cashew kernel and \$900/Mt for raw cashew nut. For the reviewed year [94], this deal would have generated a total of \$232,848,000 for Nigeria's export revenues. According to basic classical economics, Nigeria would have made roughly \$383,328.00 instead of \$232,848,000 ^[94] if all 242,000Mt were processed prior to export.

5.4. Almond

The market for almonds in Nigeria reached a total of \$2.7K in 2014, remaining flat from the previous year. (Logistics expenses, retailer margins, and retail marketing expenses are not included in this figure because they would be added to the ultimate consumer price.) The statistic represents the combined revenues of manufacturers and importers. Almond production was valued at \$3.7K in 2015, based on expected export prices. Nigeria exported about 2.4 tonnes of almonds in 2015, a decrease of 55.7% from the previous year. In 2010, the largest amount of export was 10 tons, and from 2011 to 2015, exports decreased. Almond exports dropped sharply in value to \$11,000 in 2015. Exports expanded significantly overall. The surge was most noticeable in 2014, when there was a 71,274% year-over-year increase. Exports peaked at \$16,000 as a result ^[95].

6. Conclusions and future research needs

This paper has reviewed the classification, nutritional, and economic importance of edible nuts in Nigeria, with a focus on the common types available such as walnut, almond, cashew nut, and groundnut. To provide an extensive review, the paper also reviewed the cultivation and production methods employed in Nigeria for processing these nuts. Edible nuts are promising and rich sources of nutrition such as healthy fat, protein, carbohydrates, minerals, and fibers. Edible nuts have been widely produced across Nigeria for food and industrial purposes. Proper post-harvest processing technologies are essential to convert them to forms suitable for export. Edible nuts have been shown to be a good source of raw materials for the health industry, as processing has a good potential to be useful for making pharmaceutical products. However, the mechanical production and processing of edible nuts in Nigeria are challenging, making manual methods still a popular approach. Thus resulting in quantitative and qualitative losses. There is a need for the development of technologies for processing edible nuts, especially for small-scale manufacturing, to strengthen the edible nuts value chain across the country. Furthermore, studies on the optimization of production techniques and storage technologies of edible nuts are required due to the perceived lack of feasible technologies to store this commodity

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