CEREALS AND TUBER TECHNOLOGY

(FST 501)

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

UNIVERSITY OF AGRICULTURE, ABEOKUTA

DR. A. A. ADEBOWALE

Prof. L.O. SANNI

CEREALS

Cereals are the edible seeds or grains of the grass family. Cereals have been part of the human diet since prehistoric times. There are many different types of cereal grains, each having unique properties. Most cereals are processed to form other foods or ingredients. Cereals and cereal products are an important source of energy, carbohydrate, protein and fibre. They also contain a range of micronutrients such as vitamin E, some of the B vitamins, sodium, magnesium and zinc. Wheat and rice are the most important cereal crops world-wide as they account for over 50% of the world's cereal production. Each cereal has unique properties which make it suitable for a variety of food products. Cereals require different conditions to grow. For example, rice is grown in damp tropical climates and oats in cold temperate climates, *e.g.* Scotland. Cereals are also known as 'staple foods' as they often make up the bulk of the diet since they are relatively cheap to produce.

TYPES OF CEREALS

Wheat: is usually ground to flour which is used to produce a wide range of products. The type of flour produced differs according to the rate of extraction. Cous cous and cracked wheat or bulgur is also made from wheat. Wheat can be fermented to make beer.

Maize: (or corn) may be processed to make many different ingredients (*e.g.* high fructose corn syrup which can be used as an alternative to sucrose derived from sugar cane and sugar beet) and food products. It may be milled in a similar process to wheat. Its germ is rich in oil, and can be refined to produce corn oil.

Barley: is mainly sold as pearl barley, which is the whole grain with its husk removed. It is also used in bread (as flour) and ground as porridge in some countries.

Rice: brown **rice** has its outer husk removed, and white rice is milled and polished further to remove the bran and germ. There are many different types of rice, categorized by size, shape and the region where they are grown. Rice can be ground to make flour and is used to make Japanese rice wine (saké).

Rye: contains little gluten, so produces breads with low volume and a dense texture, although in Russia, Poland, Germany and Scandinavian countries it is the major bread grain. Rye is also used to produce crisp bread and alcohol.

Oats: are rolled rather than crushed during processing. Coarse, medium and fine grades of oatmeal are available and are used for porridge and oatcakes, while rolled oats are used for porridge, and oat flour is used for baby foods and for ready-to-eat (RTE) breakfast cereals.

Millet: is the name used for a number of different small-grained cereal grasses, *e.g.* pearl, finger (or ragi), proso and foxtail millet. These crops are important in parts of Africa and Asia.

Sorghum: (also known as great millet, guinea corn, kafir corn, jowar and kaoling in different parts of the world) is a staple food in many parts of Africa, Asia and parts of the Middle East. It is also used as animal feed in many other countries.

Triticale: was the first cereal produced by man and is a cross or hybrid of wheat and rye. It is mainly used as feed for animals but can be milled into flour.

In addition to the cereals outlined above, there are several others which have an important role in certain parts of the world. For example:

1. **Buckwheat** is eaten as a cooked grain, as porridge or is used in pancakes in parts of Russia
2. **Quinoa** is used in Chile and Peru to make bread

NUTRITIONAL VALUE OF CEREALS AND CEREAL PRODUCTS

Cereals and cereal products are an important source of energy, carbohydrate, protein and fibre. They also contain a range of micronutrients such as vitamin E, some of the B vitamins, sodium, magnesium and zinc. Because of the fortification of some cereal products they also contribute significant amounts of calcium and iron. There is evidence to suggest that regular consumption of cereals, specifically whole grains, may have a role in the prevention of chronic diseases. The strength of evidence varies and although cause and effect has not currently been established, people who consume diets rich in whole grain cereals seem to have a lower incidence of many chronic diseases, *e.g.* coronary heart disease and type 2 diabetes. It remains to be established whether this is a direct effect, or whether whole grain consumption is merely a marker of a healthy lifestyle or some other factor.

FOOD TECHNOLOGY ASPECTS OF CEREALS

Gelatinisation (thickening): When flour (wheat, corn, rye or rice) is added to a liquid, the starch granules begin to swell on heating. This causes the granules to rupture and starch is released into the liquid. The starch granules absorb liquid, causing the sauce to thicken. Rice flour can be used in acidic sauces as it is resistant to the effects of low pH. Pearl barley may also be used to thicken a soup or casserole. However, the swollen barley grains will remain, contributing to the texture of the casserole.

Processing: Cereals undergo a range of processes, the most common being milling, which affect their technological and nutritional properties. Generally, the final nutrient content of a cereal will depend on the extent to which the outer layers are removed during processing, as this is where the fibre, vitamins and minerals tend to be concentrated.

Products: Cereals are processed and used to produce a range of products *e.g.* breakfast cereals, bread and pasta. Some nutrients are lost during this processing but are added at a later stage known as enrichment/'restoration'.

Protein: The amount of protein in each cereal differs (from 6-15% protein) and this affects the final product. Bread, with its characteristic open texture and appearance, relies on high protein flour, *e.g.* strong wheat flour. In products such as cakes, biscuits and pastry, lower wheat flours are used to produce crumbly and light textures.

Storage: Cereals should be kept in a cool dry place. They are prone to infestation by insects if kept for long periods of time

MAIZE

A cereal native to tropical zones of America, maize is one of the most widely cultivated *gramineous* plants in the world. Maize can be harvested by hand or by a mechanical corn-picker. The harvested maize are stripped of their husks and then shelled manually or mechanically. In small-scale cultivation when the harvest takes place in the dry season, the ears (with or without husks) can be sun-dried, and then stored under cover. In industrial cultivation, on the other hand, the maize is harvested only by machines (corn sheller or combine harvester) capable of supplying grains ready for drying or for sale. At harvest time, particularly in the rainy season, grains of maize have too high a moisture content to keep well; therefore, before storage, the product must be dried, to lower the moisture content to about 14%. Drying could be naturally by sun drying or artificial drying of the grain by dryers. The dried maize is cleaned, and then stored (in bags or in bulk) in warehouses or silos. The dried and cleaned maize is ready for sale or for further processing.

For human consumption, maize can be eaten as fresh ears or in the form of cakes made from dough obtained by cooking the grain. The flour or semolina from husking and grinding can also be eaten. The processing industry also uses maize to produce oil and margarine, cattle-feed, beer, baby food, soap, glue and varnish.

Structure of the maize kernel

Maize kernels develop through accumulation of the products of photosynthesis, root absorption and metabolism of the maize plant on the female inflorescence called the ear. This structure may hold from 300 to 1 000 single kernels depending on the number of rows, diameter and length of the cob. Kernel weight may be quite variable, ranging from about 19 to 40 g per 100 kernels. During harvest the ears of maize are removed from the maize plant either by hand or mechanically. The husks covering the ear are first stripped off, and then the kernels are separated by hand or, more often, by machine.

The maize kernel is known botanically as a caryopsis; a single grain contains the seed coat and the seed, as shown in Figure 1. The figure also shows the four major physical structures of the kernel: the pericarp, hull or bran; the germ or embryo; the endosperm; and the tip cap (dead tissue found where the kernel joins the cob).The weight distribution of the different parts of the maize kernel are shown in Table 1. The endosperm, the largest structure, provides about 83 percent of the kernel weight, while the germ averages 11 percent and the pericarp 5 percent. The remainder is the tip cap, a conical structure that together with the pedicel attaches the kernel to the ear of maize.

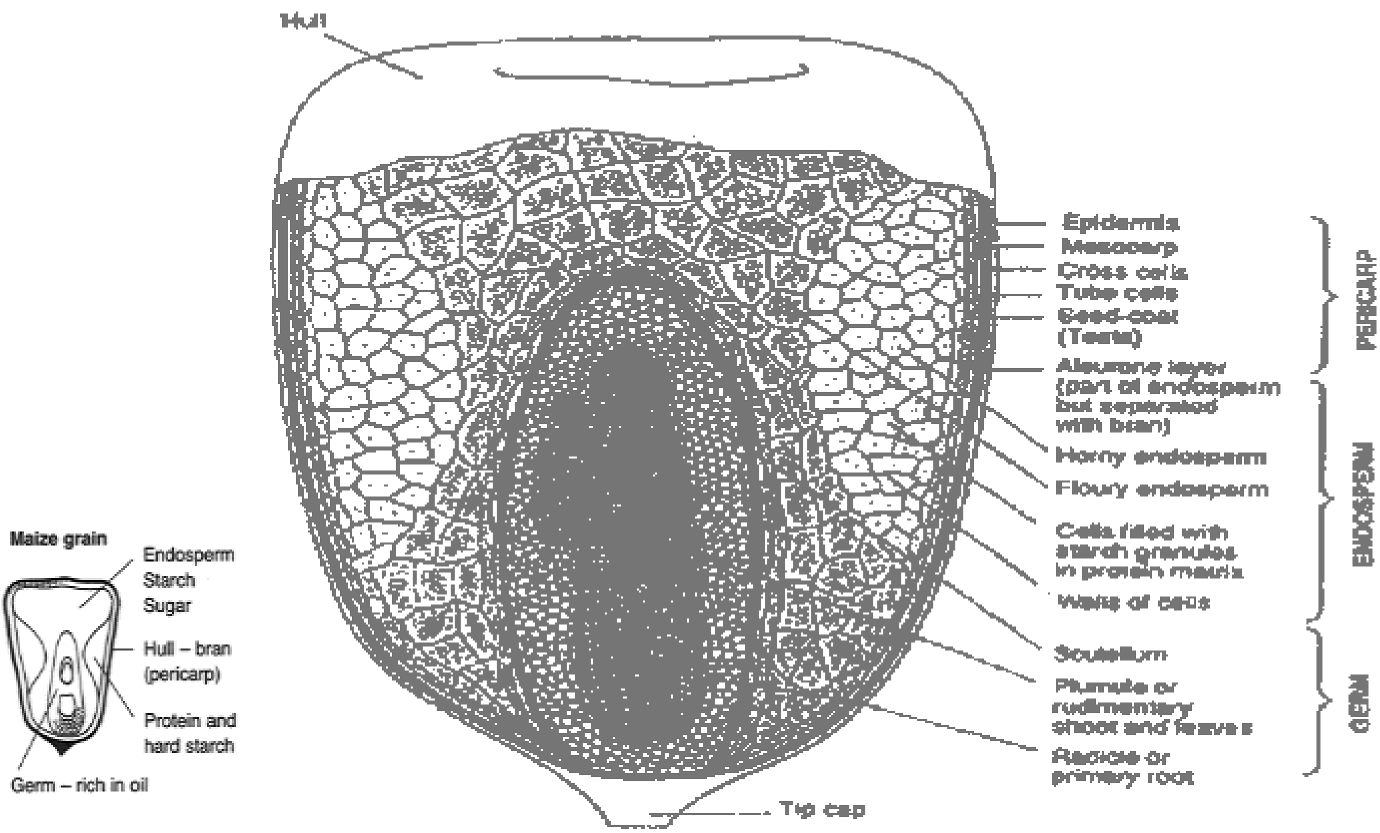


Figure 1: Structure of the maize kernel (caryopsis)

TABLE 1 - Weight distribution of main parts of the maize kernel

Structure	Percent weight distribution
Pericarp	5-6
Aleurone	2-3
Endosperm	80-85
Germ	10-12

Post-harvest technology of maize

Pre-processing: The chemical components and nutritive value of maize do not lose their susceptibility to change when the grain is harvested. Subsequent links in the food chain, such as storage and processing, may also cause the nutritional quality of maize to decrease significantly or, even worse, make it unfit for either human and animal consumption or industrial use.

Threshing: The process of threshing separates the kernels from the stalks or panicles on which they grow. Threshing may take place in the field, or at the homestead or village; it may be carried out manually with the aid of animals, or with machinery. A simple method consists of beating the cereal heads against a wall or the ground; animals or humans can also trample the panicles on a hard surface, or animals can draw a machine or sledge over the grain. Threshing machines may be powered by humans or animals or, in more sophisticated forms, by internal combustion engines. Many designs have been field-tested and found to operate satisfactorily. Maize grains must be separated from the cob after the husk has been removed. A variety of manual and powered systems are available for this operation.

Grading: Grading consists of separating the sound kernels from chaff and impurities, and may be achieved by sieving or winnowing.

Sieving: Impurities are separated on the basis of their differences in size from the kernels. Hand sieves are usually used singly (figure 2). The simpler machines (figure 3) will have two sieves: one with oversized holes (which retain large impurities and let the grain kernel pass through), and one with undersized holes (which retain the kernels but allow smaller impurities to pass through).

Winnowing: In this process impurities are separated on the principle that their density differs from that of the grain kernels. The operation depends on air movement to remove the lighter fractions. The simplest method is to drop a basket of kernels and impurities in a thin stream onto a clean surface through a slight natural breeze (figure 4 and 5). This is a slow and laborious process but it is still widely practiced. Winnowing machines operate on the same principle, but air movement is created by a fan. Sophisticated machinery are available for separating kernels from impurities but these are expensive and are used only in large scale or specialized applications. Hand-picking is an effective but tedious operation that is nevertheless widely practiced by farmers.

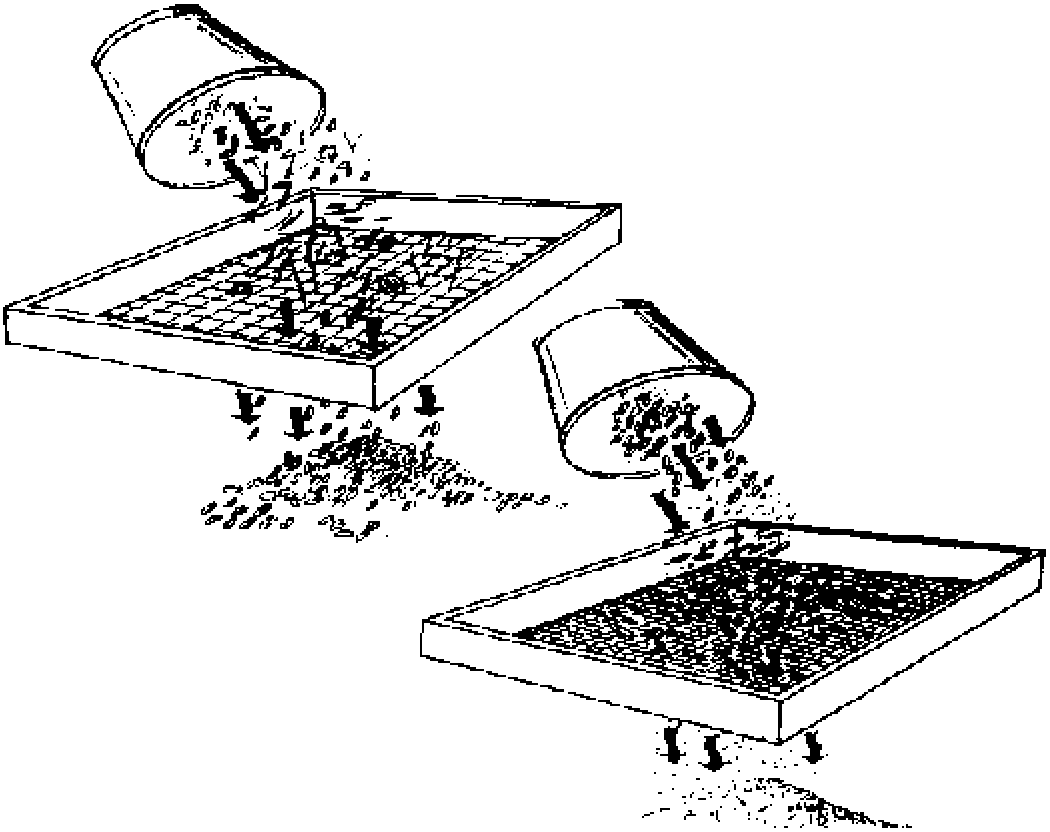


Figure 2: Manual sieving of maize kernels

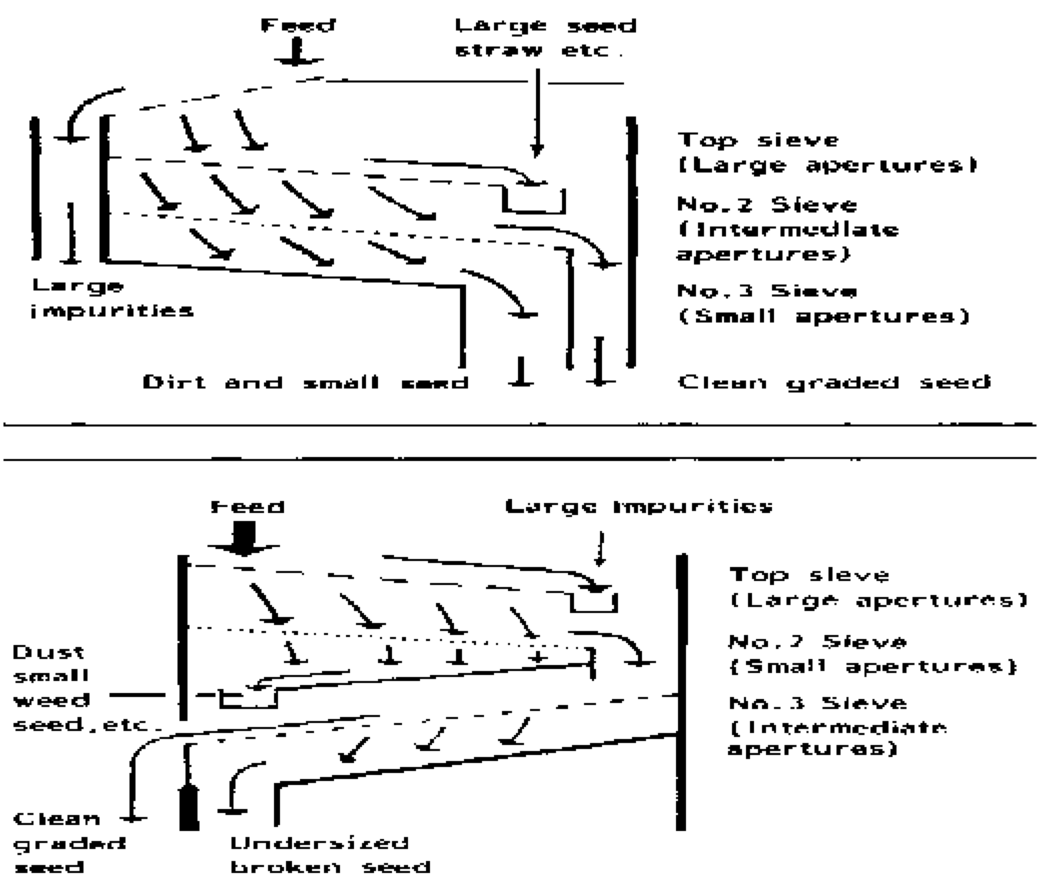


Figure 3: Three-sieve seperator

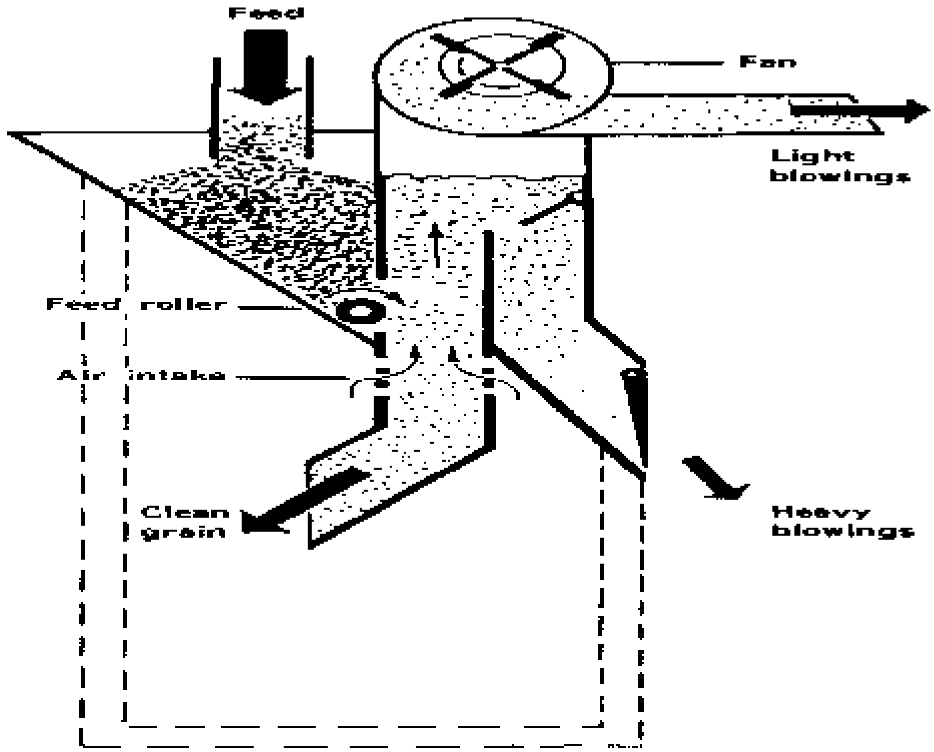


Figure 4: Simple aspirator

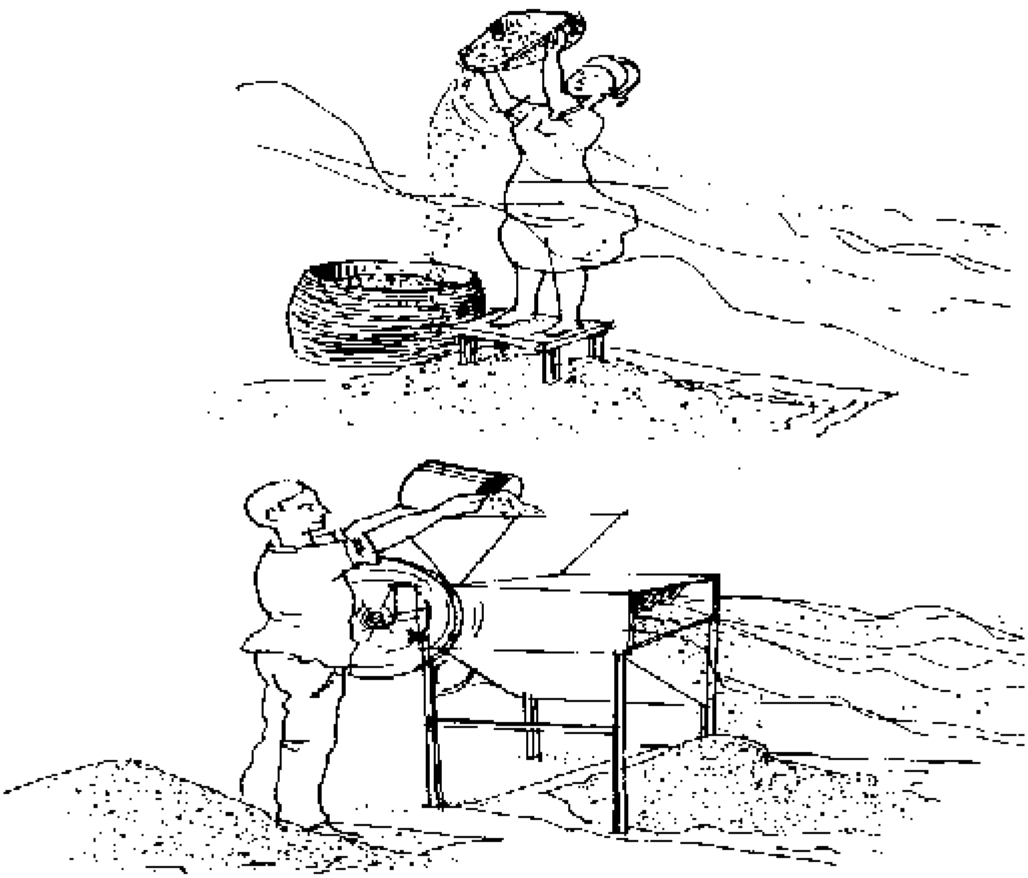


Figure 5: Manual and mechanical winnowing of maize kernels

Drying: In either mechanical or manual harvesting, the maize kernels contain too much moisture for safe storage, and they must be dried to safe moisture levels of about 12 – 14 percent. Storage stability depends on the relative humidity of the interstitial gases, which is a function of both moisture content in the kernel and temperature. Low moisture content and low storage temperatures reduce the opportunity for deterioration and microbial growth. Aeration therefore becomes an important operation in maize storage as a means of keeping down the relative humidity of interstitial gases. Significant maize losses have been reported in tropical countries. Losses of up to 10 percent have been found, not including those losses caused by fungi, insects or rodents. If these were included, losses could go up to 30 percent in tropical humid areas or 10 to 15 percent in temperate areas. Losses due to fungi (mainly *Aspergillus* and *Penicillium*) are important for both economic and health reasons because of aflatoxins and mycotoxins.

Storage

Biotic and non-biotic factors: The efficient conservation of maize, like that of other cereal grains and food legumes, depends basically on the ecological conditions of storage; the physical, chemical and biological characteristics of the grain; the storage period; and the type and functional characteristics of the storage facility. Two important categories of factors have been identified. First are those of biotic origin, which include all elements or living agents that, under conditions favourable for their development, will use the grain as a source of nutrients and so induce its deterioration. These are mainly insects, microorganisms, rodents and birds. Second are non-biotic factors, which include relative humidity, temperature and time. The effects of both biotic and non-biotic factors are influenced by the physical and biochemical characteristics of the grain. Changes during storage are influenced by the low thermal conductivity of the grain, its water absorption capacity, its structure, its chemical composition, its rate of respiration and spontaneous heating, the texture and consistency of the pericarp and the method and conditions of drying.

Nutrient losses have been reported in maize stored under unfavourable conditions. Although damage caused by insects and birds is of importance, a great deal of attention has been paid to the problems caused by micro-organisms, not only because of the losses they induce in the grain, but more importantly, because of the toxic effects of their metabolic by-products on human and animal health.

Inhibition of aflatoxin contamination

Two ways of preserving maize from being destroyed by aflatoxin contamination have been under investigation. One is to inhibit growth of *Aspergillus flavus* or *Aspergillus parasiticus* and the other is to remove the aflatoxins after they have been produced by the *Aspergillus* infection. Most researchers have concentrated on the inhibition of fungal growth, and some chemicals have already been found effective in storage conditions. This, however, does not solve the problem of field contamination by moulds, since the airborne spores of the organisms are readily available in the environment. The spores can germinate on the cob and infect the inner tissues under optimum temperature and moisture conditions. Therefore, other researchers have pursued the possibility of detoxification.

Roasting has been shown to be effective in reducing aflatoxin levels, depending on the initial level of the toxin as well as on roasting temperatures. Higher temperatures may cause up to 77 percent aflatoxin destruction; however, it is well known that heat also destroys the nutritive value of the material. Tempering aflatoxin contaminated maize with aqua ammonia and then roasting it may be a simple and effective way to decontaminate it. It is difficult, however, to remove the smell of ammonia from the treated grain. A process that has received some attention is the use of calcium hydroxide, a chemical used for lime-cooking of maize. Studies have shown a significant reduction in aflatoxin levels, although the extent of reduction is related to the initial levels. Feeding tests with mouldy maize treated with calcium hydroxide have shown a partial restoration of its nutritional value.

Appropriate harvesting and handling can do much to reduce fungal contamination of maize and can thus prevent the need for chemical decontamination measures, which not only increase the cost of the grain but cannot completely restore its original nutritional value. In this respect, if shelled grain was immediately sun-dried the chance of contamination will reduce as compared with that of undried maize shelled mechanically or by hand. Shelling encourages fungal contamination as it causes damage to the kernel base, which is rough compared with the rest of the grain. Corn on the cob, even with its high levels of moisture, resists fungal contamination relatively well.

MAIZE PROCESSING

Forms of maize consumption

There are many ways to convert maize into interesting and acceptable forms which, if presented in attractive and easily prepared products, could to some extent counteract the trend toward greater consumption of wheat derived in developing countries that imports large quantity of wheat.

Milling

The maize kernel is transformed into valuable foods and industrial products by two processes, dry milling and wet milling. The first yields grits, meal and flours as primary products. The second yields starch and valuable derived products.

Dry milling

The dry milling of maize as practiced today has its origins in the technologies used by the native populations who domesticated the plant. The best example is the method used to make arepa flour or hominy grits. The old technology was soon replaced by a grinding stone or stone mill, followed by the grits mill and finally by sophisticated tempering-degerming methods. The products derived are numerous, with their variety depending to a large extent on particle size. They are classified into flaking grits, coarse grits, regular grits, corn meal, cones and corn flour by means of meshes ranging from 3.5 to 60 mm. Their chemical composition has been well established and their uses are extensive, including brewing, manufacturing of snack foods and breakfast cereals and many others.

Wet milling

The largest volume of maize in developed countries such as the United States is processed by wet milling to yield starch and other valuable by-products such as maize gluten meal and feed. The starch is used as a raw material for a wide range of food and non-food products. In this process, clean maize is soaked in water under carefully controlled conditions to soften the kernels. This is followed by milling and separation of the components by screening, centrifugation and washing to produce starch from the endosperm, oil from the germ and food products from the residues. The starch has industrial applications as such and is also used to produce alcohol and food sweeteners by either acid or enzymatic hydrolysis. The latter is done with bacterial and fungal alpha-amylase, glucoamylase, beta-amylase and pullulanase. Saccharides of various molecular weights are liberated yielding sweeteners of different functional properties. These include liquid or crystalline dextrose, high-fructose maize syrups, regular maize syrups and maltodextrins, which have many applications in foods.

TRADITIONAL PREPARATIONS AND USES OF MAIZE IN NIGERIA

Maize is an all-important crop which provides an avenue for making various types of foods. It also has some medicinal values and serves as raw-materials for many industries. Grain is the most important part of maize crop. It is put to many uses.

Pap: The traditional process of making ogi has a number of slight variations described by several authors. Ogi is traditionally prepared in batches on a small scale two or three times a week, depending on demand. Ogi is usually marketed as a wet cake wrapped in leaves, or it may be diluted to 8 to 10 percent solids in water and boiled into Hot-pap known as 'eko-gbona' or 'ogi' (Yoruba), 'akamu' (Ibo and Yala), 'kamun' (Ibira) or cooked to a stiff gel or cold-pap known as 'eko-tutu' (Yoruba), 'kamu' (Isha), 'agidi' (Ibo and Yala), 'kafa' (Hausa). 'Ogi' is synonymous to tea among the indigenous Nigerians.

To prepare paps generally, grains are sorted, graded, and the clean grain is steeped in water for two to five days to soften. Once soft, it is ground with a grinding stone, pounded in a mortar or ground with a power mill. The ground paste is filtered using clean, white cloth to get very smooth paste. The residue of filtration is used to feed animals. Meanwhile, remaining fine paste after filtration is allowed to settle down at the bottom and the water on top decanted. Water is added and leave for days with change of water at interval. Amount desire may be taken, stirred and poured inside boiling water and stirred until a semi-liquid porridge (hot pap) is obtained.

Souring of the maize took place spontaneously without the addition of inoculants or enzymes. Moulds such as *Epholosporium, Fusarium, Aspergillus* and *Penicillium* species and the aerobic bacteria such as Corynebacterium and Aerobacter species has been found in fermenting maize, while the main lactic acid bacterium found was *Lactobacillus plantarum.* There were also yeasts: *Candida mycoderma, Saccharomyces cerevisiae* and *Rhodotorula sp*. Although ogi is supposed to have an improved B-vitamin content, the results observed are quite variable, at least for thiamine, riboflavin and niacin.11 organic acids have been found, with lactic, acetic and butyric acids being the most important.

Preparation of cold-pap is differs a little. The top water is removed while the paste is poured in boiling water and stirred to get a semi-solid porridge. This is then put inside banana leaves, or 'ewe-eko' as called by the local people to give a characteristic doomed shape. Alternatively, it may be put inside polythene paper (nylon) – a recent phenomenon. The hot paste is allowed to cool down and solidified, and thus become thick porridge (i.e. cold-pap). 'Omadidi', which is popular among Isha people, is similar to 'eko' or 'eko'-tutu or agidi but more solid than the latter. There is a slight difference in its ('omadidi') preparation. The half-cooked watery porridge is poured inside nylons at desire amount and re-cooked inside a pot containing hot water, this make it more solidified than eko.

Major difference between hot-pap and cold-pap lies in the states they are eaten or served. While 'ogi' and 'koko' are served hot, eko/agidi and 'omadidi' are served cold. Generally, paps may be taken alone or with sugar or with bean cakes i.e. 'akara' or 'moin moin' (made from cowpea) or with vegetable stew or with ground nut cake, 'kulikuli'

Tuwo: ' Tuwo' (Yoruba), 'tuwo-masara' (Hausa), 'oka' (Egun), 'inioka' (Ibo), 'uka apaapa' (Ibira) is a very important and popular staple food among various ethnic groups in Nigeria. Its preparation seems to be similar among all groups though with minor differences. To prepare 'tuwo', pericarp and germ of the grains is removed by grinding gently inside mortar with pestle or mechanically at the mill. Small water is added to the grains to enhance testa removal. This is then sun-dried. In some localities, the testa is not removed. Dried grains are then ground with local grinding stone or with grinding machine to obtain smooth, whitish flour. Cooking pot containing water is put on fire and the flour reconstituted into slurry. When water is boiling, the slurry is poured in it and stirred with stirring-stick to make a thick paste ('tuwo'). Tuwo is taken with bean soup ('gbegiri') or with 'luru' or with 'kubewa taushe' or with vegetable soups like sesame, okra, celosia, etc.

Donkunnu: 'Donkunnu' is an exotic food to Nigeria. It was introduced to Nigeria from Ghana probably by the emigrant Ghanaians or by Nigerians lived in Ghana. The first option is more likely to be because at most joints of 'donkunnu', the Ghanaians are the sellers. It has become a popular food among middle aged Nigerians. To prepare 'donkunnu', maize grains are soaked for about two days in cold water. Soaked grains are then ground into wet paste and leave in this state for about two days to ferment. The purpose of which is to bring out the characteristic sour taste of the finished product. A desire amount or quantity of fermented paste is put inside maize husk and cooked inside pot until thick, solid porridge ('donkunnu') is obtained. 'Donkunnu' is eaten with pepper stew (i.e. soup made up of mainly coarsely ground pepper and tomato) and fried fish.

Maasa and Wainna: 'Maasa' and 'wainna' are similar thick porridges. While 'maasa' is small in size, 'wainna' is big. 'Maasa' is eaten with sugar sprinkled on it, 'wainna' is eaten with pumpkin soup or with vegetable soups or with honey. Both are made with coarsely, wet-ground grains. Small piles of this are put separately into a frying-pan containing hot groundnut oil (or palm oil, as commonly used among Isha people) to 'maasa'. 'Wainna' on the other hand is prepared by putting some quantities of ground paste inside saucer plates (made of clay soil). The saucer plates are lubricated with groundnut oil initially to enhance easy removal of 'wainna' after heating or cooking. 'Wainna' cakes can also be made with mixture of cassava flour and millet flour.

Cous cous: Grain testa is removed before the grains are ground into powdery flour which can be preserved inside bag, and stored in a dry place until time to use it. At intervals, a required quantity can be measured out and mixed with ingredients like sliced tomato, pepper and onion. All these are cooked together. After sufficient cooking, the mixture (i.e. 'cous cous') is solidified and ready for eating.

Akple: The Ibo mix cassava flour with maize flour together with onion chips, chilies, and palm oil, and moulded into small balls that are deep fried in red palm oil. The balls are called 'akple'.

Gwate: This is prepared like 'cous cous'. While 'cous cous' is solid, 'gwate' is semi-solid porridge. Unlike the 'cous cous', ingredients like pieces of soft-bones, meat, amaranth or bitter leaf and 'efirin' are mixed with the flour and cooked to make 'gwate'.

Nakia: Moistened maize flour is moulded into small round objects which are fried with vegetable oil. 'Nakia' is eaten with honey or sugar.

Dambu alubosa: Maize grains are ground into dry, coarse particles that resemble 'gari'(a foodstuff made from cassava). The particles are mixed with oil and vegetable leaves e.g. *Amaranthus spp* and cooked.

Abari/Sapala: Fresh maize grains are washed with clean water to remove dirt. Onion and pepper are added to the grains and ground together with local grinding stone or with mortar and pestle or with grinding machine. Then palm oil and salt are added to it to turn red and to taste respectively. Desire quantities are measured out and put inside banana leaves or empty milk tins, and steam-cooked with heat of hot water inside a covered pot to become solid porridge ('abari' ‘iroo/sapala’[Yoruba], ‘elili-oka’[Ibo], ‘ekefi’[Isha]. ‘Abari’ may be eaten alone or with paps-hot and cold.

Egbo: Maize grains are cooked intensely until they become very soft and burst open (i.e. ‘egbo’). It may be eaten in this form or with cooked beans or cooked groundnut and/or coconut and with little groundnut oil.

Donkwa: This is a mixture of dried-ground groundnut and maize. The mixture is moulded into small ball shapes (i.e. ‘donkwa’ or ‘dodonkwa’). It is known by the Isha as ‘emumu’. The difference is that sugar and at time small pepper is added to the mixture of groundnut and maize flour to make ‘emumu’.

Popcorn: Locally, there are two types of popcorn- hard and soft. The former is simply called ‘guguru’ while the latter is ‘guguru alakuko’ by the Yorubas. Popcorn is made by putting maize grains inside a saucer-shaped earthen pot containing sand, and heated with firewood. The heat generated by the hot sand roasted and changed the colour of the whitish grains to brownish (i.e. ‘guguru’). Further heating bursted the grains to reflect the internal whitish parts, this is called ‘guguru-alakuko’. The name is synonymous with the cock’s comb (the cock is called ‘akuko’ by the Yorubas). Sometimes, honey or sugar may be added to ‘guguru’ to become ‘guguru-oloyin’ (honey or any sweet object is called ‘oyin’ by the Yorubas). Popcorns may be eaten alone or with roasted groundnut.

Ajepasi: Maize grains are ground with water to moistened paste which is moulded into ribbons, and fried with groundnut oil. Fried ribbons are maize cakes (i.e. ‘ajepasi’).

Aadun: Maize grains are roasted and then ground into powdery particles. This is mixed with palm oil which makes it to solidify or to clump together.

Kokoro: ‘Kokoro’ is also produced in a similar way like ‘aadun’ by roasting, kneading, spicing and frying.

Cooked or boiled maize: Whole freshly harvested maize fruit is cooked or boiled until the seeds are soft and eaten on the cob.

Roasted maize: Whole freshly harvested maize fruit is roasted with hot-charcoal over a wire-gauze until the seeds become brown. It is eaten in this form on the cob.

SORGHUM

Sorghum, *Sorghum bicolor* (L.) Moench, is known under a variety of names: great millet and guinea corn in West Africa, kafir corn in South Africa, dura in Sudan, mtama in eastern Africa, jowar in India and kaoliang in China. In the United States it is usually referred to as milo or milo-maize. Sorghum belongs to the tribe *Andropogonae* of the grass family *Poaceae*. The genus Sorghum is characterized by spikelets borne in pairs. Sorghum is treated as an annual, although it is a perennial grass and in the tropics it can be harvested many times.

Grains and their structure

Sorghum caryopsis is composed of three main parts: seed coat (testa or pericarp), germ (embryo) and endosperm (storage tissue) (figure 6). In some sorghum genotypes the testa is highly pigmented. Kernels of sorghum show considerable diversity in colour, shape, size and certain anatomical components. The principal anatomical components are pericarp, germ or embryo and endosperm. The kernels of sorghum are of the caryopsis type, in which the pericarp is completely fused to the endosperm. The relative distribution of the three main kernel components varies. In the sorghum kernel the distribution by weight is pericarp 6 percent, endosperm 84 percent and germ 10 percent

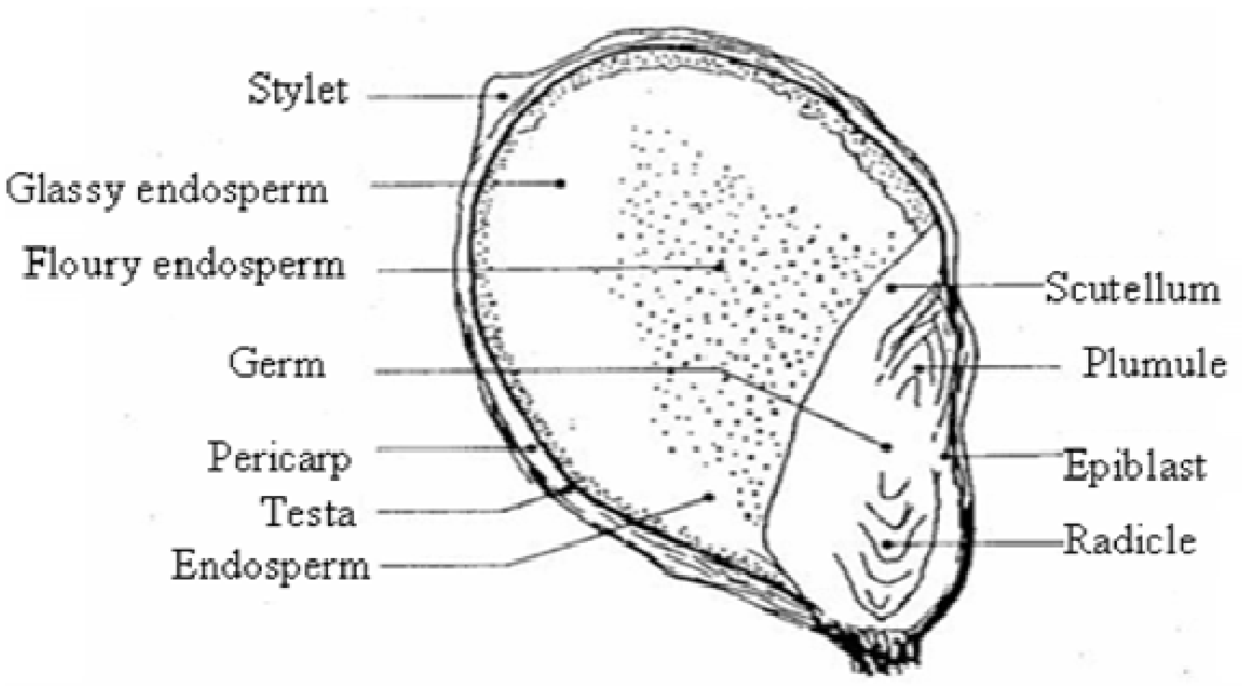


Figure 6: Structure of the sorghum kernel (caryopsis)

Sorghum grain composition and nutritive value

Starch is the main component of sorghum grain, followed by proteins, non-starch polysaccharides (NSP) and fat. The average energetic value of whole sorghum grain flour is 356 kcal/100g. Sorghum has a starch macromolecular composition similar to that of maize and wheat. However, sorghum contains resistant starch, which impairs its digestibility, notably for infants. This resistance is desired in other applications to fight human obesity and to feed diabetic people. Sorghum contains non-starch polysaccharides (NSP), mainly located in the pericarp and endosperm cell walls, with proportions in the kernel ranging from 2 to 7% depending on variety. The NSP in sorghum grain are essentially constituted of arabinoxylans and other β-glucans representing 55% and 40% of the total NSP. Arabinoxylans, being one of the major NSP present in sorghum cell walls, play an important role in the processing of sorghum for baking and brewing These β-glucans are predominantly water-unextractable, and form viscous and sticky solutions. In brewing, together with arabinoxylans, they are associated with processing problems like poor wort and beer filtration rates and the occurrence of haze. Sorghum also contains non-carbohydrate cell-wall polymers such as lignins with proportions constituting up to 20% of the total cell wall materials. The protein content in whole sorghum grain is in the range of 7 to 15%. Sorghum is reported to be a good source of more than 20 minerals. Sorghum is rich in phosphorus, potassium, iron and zinc. Zinc (an important metal for pregnant women) deficiency is more common in corn and wheat than in sorghum.

Sorghum utilization

Total consumption of sorghum closely follows the global pattern of output, since most of it is consumed in the countries where it is grown. Sorghum is used for two distinct purposes: human food and animal feed. , thin porridge, e.g. “bouillie” (Africa and Asia), stiff porridge, e.g. tuwo (West Africa), couscous (Africa), injera (Ethiopia), nasha and kisra (Sudan), traditional beers, e.g. dolo, tchapallo, pito, burukutu, etc (Africa), ogi (Nigeria), baked products (USA, Japan, Africa), etc. Tortillas are a kind of chips prepared from sorghum alone or by mixing sorghum with maize and cassava. Nasha is a traditional weaning food (infant porridge) prepared by fermentation of sorghum flour. Ogi is an example of traditional fermented sorghum food used as weaning food. Often sorghum porridges are characterized by thick pastes that may form rather stiff gels depending on variety used. Porridges prepared with malted sorghums have several order of magnitudes lower viscosities than those of non-malted sorghums These porridges are particularly useful for the formulation of weaning foods for infants because of their high energy density

Couscous is a steamed and granulated traditional African food originating from North Africa. The traditional method of preparing couscous is a steam-cook process in a special pot called “couscoussière”. Couscous is prepared by mixing flour with water to obtain agglomerated flour-water mixtures. The agglomerates are then put on top of the “couscous”. The stew cooks in the bottom pot while the granules are steamed on top.

Sorghum as Human food

While total food consumption of all cereals has risen considerably during the past 35 years, world food consumption of sorghum has remained stagnant, mainly because, although nutritionally sorghum compares well with other grains, it is regarded in many countries as an inferior grain. Per capita consumption of sorghum is high in countries or areas where climate does not allow the economic production of other cereals and where per capita incomes are relatively low. These include especially the countries bordering the southern fringes of the Sahara, including Ethiopia and Somalia, where the national average per capita consumption of sorghum can reach up to 100 kg per year. Other countries with significant per capita consumption include Botswana, Lesotho, Yemen and certain provinces in China and states in India. In most other countries, food consumption of sorghum is relatively small or negligible compared to that of other cereals.

Sorghum as animal feed

Grain use for animal feed has been a dynamic element in the stimulation of global sorghum consumption. The demand for sorghum for feed purposes has been the main driving force in raising global production and international trade since the early 1960s. The demand is heavily concentrated in the developed countries, where animal feed accounts for about 97 percent of total use, and in some higher-income developing countries, especially in Latin America where 80 percent of all sorghum is utilized as animal feed. The United States, Mexico and Japan are the main consuming countries, followed by Argentina and Venezuela. These countries together account for over 80 percent of world use of sorghum as animal feed.

Storage

The objective of storage is to preserve as much as possible of the value of the grain for its intended future use. This means either retaining as high a proportion of viable seeds as possible for planting at the next harvest or preserving as much as possible of the food value of the grain for as long as possible. Several factors lead to the loss of both viability and nutrients, but globally the main causes of loss are the depredations by pests (insects, birds and rodents) and mould damage. Germination of the grain (sprouting) also results in losses. Grain is stored by consumers and by processors for future consumption. It is also stored by commercial traders for resale, usually on the home market but occasionally for export.

Moisture in the grain and the temperature of storage are the most important physical factors that contribute to losses. Most activity that causes losses occurs more rapidly as the temperature increases. With even minor changes in temperature, moisture will migrate and accumulate in certain areas, either near the top of the container or in places that are cooler than the rest. This often allows microbiological activity to occur in comparatively dry grain. Microbiological activity usually produces heat, and in unventilated stores, moist areas can get so hot that charring can occur. At this stage the grain is ruined. It may even burst into flames when it is exposed to air.

Storage bins are best filled early in the day when the air is cool and the humidity is often at its lowest. The grain should be packed as tightly as possible to allow insects the minimum space to move around and to breed. Sand is sometimes mixed with the grain to reduce the free space further. Storage containers vary from small traditional on-farm or domestic containers to silos which are sometimes found on large farms. In many countries, small granaries are made by weaving plant materials such as bamboo, stalks, bark and small branches and then sealing any gaps with mud or dung. These structures may be built directly on the ground or raised off the ground on platforms or stilts.

Storage practices in Africa

In some countries in West Africa sorghum grains are mixed with wood ash and stored in clay pots. In Nigeria sorghum and millets are stored as unthreshed heads in a solid walled container called a rumbu. For short-term storage, bundles of sorghum and millet heads are arranged in layers in the rumbu. For long-term storage of three to six years, the heads are laid out individually rather than in bundles. Some farmers spread the leaves of gwander daji (*Anona senegalensis*) on the bottom of the rumbu and between each layer of grain. When a rumbu is full, the mouth is sealed with clay.

Storage of flour
Flour is usually produced as it is needed and is not often stored for long periods because it tends to turn rancid. This is particularly evident with pearl millet flour, because of its very high fat content, sorghum and millets, particularly pearl millet, are therefore best stored as whole grain.

Processing untreated grains
Flour made by grinding whole grain is occasionally used, but in most places where sorghum are consumed the grain is partially separated into its constituents before food is prepared from it. The objective of processing is usually to remove some of the hull or bran - the fibrous outer layers of the grain. This is usually done by pounding followed by winnowing or sieving. The grain may first be moistened with about 10 percent water or soaked overnight. When hard grains are pounded, the endosperm remains relatively intact and can be separated from the heavy grits by winnowing. With soft grains, the endosperm breaks into small particles and the pericarp can be separated by winnowing and screening.

When suitably prepared grain is pounded, the bran fraction contains most of the pericarp, along with some germ and endosperm. This fraction is usually fed to domestic animals. The other fraction, containing most of the endosperm and much of the germ along with some pericarp, is retained for human consumption. Retaining the germ in the flour will improve aspects of its nutritional quality, but at the same time it will increase the rate at which the flour will become rancid. Dry, moistened or wet grain is normally pounded with a wooden pestle in a wooden or stone mortar. Pounding moist or dry grain by hand is very laborious, time consuming and inefficient. A woman working hard with a pestle and mortar can at best only decorticate 1.5 kg per hour. Pounding gives a non-uniform product that has poor keeping qualities. In a traditional process used in many countries of Africa and Asia, decorticated grain is crushed to coarse flour either with a pestle and mortar or between stones. Grain is then ground to coarse or fine flour in mechanized disk mills now located in many villages.

In wet milling, the sorghum is soaked in water overnight (and sometimes longer) and then ground to a batter by hand, often between two stones. Soaking makes the endosperm very soft and the pericarp quite tough and makes grinding much easier, but it gives a batter or paste instead of flour.

Processing malted grains
Malting involves germinating grain and allowing it to sprout. Typically the grain is soaked for 16 to 24 hours, which allows it to absorb sufficient moisture for germination and for sprouts to appear. However, germinated sorghum rootless and sprouts contain very large amounts of dhurrin, a cyanogenic glucoside, which on hydrolysis produces a potent toxin variously known as prussic acid, hydrocyanic acid (HCN) and cyanide. The fresh shoots and rootless of germinated sorghum and their extracts must therefore never be consumed, either by people or by animals, except in very small quantities (e.g. when the germinated grain is used just as a source of enzymes). Studies have showed that the removal of shoots and roots and subsequent processing reduced the HCN content by more than 90 percent.

Malted sorghum has traditionally been used in several countries in Africa, but always after careful removal of the toxic parts. In the germination process, the grain produces α-amylase, an enzyme that converts insoluble starch to soluble sugars. This has the effect of thinning paste made by heating slurry of starch in water, in turn allowing a higher caloric density in paste of a given viscosity, since as much as three times more flour can be used when the grain has been germinated. The energy that young children can consume is often limited by the bulk that they can consume. Thus using germinated grain can make food more suitable for certain categories of young children. Flour from malted grain is consequently used quite widely in the production of children's food, but when such foods are made from sorghum, great care must always be taken to ensure that the level of cyanide is adequately low, as children are particularly vulnerable to cyanide. Germination of grain changes the amino acid composition, convert starch into sugars and improve the availability of fat, vitamins and minerals. The use of only 5 percent malted sorghum has been found to reduce the viscosity of weaning foods.

RICE

Rice (*Oryza sativa*) is the most important cereal crop in the developing world and is the staple food of over half the world's population. It is generally considered a semi-aquatic annual grass plant. About 20 species of the genus *Oryza* are recognized, but nearly all cultivated rice is *O. sativa.* Small amount of *O. glaberrima*, a perennial species, is grown in Africa. So-called "wild rice" (*Zizania aquatica*), grown in the Great Lakes region of the United States, is more closely related to oats than to rice.

Rice grain structure and composition

The rice grain (rough rice or paddy) consists of an outer protective covering, the hull, and the rice caryopsis or fruit (brown, cargo, dehulled or dehusked rice). Brown rice consists of the outer layers of pericarp, seed-coat and nucellus; the germ or embryo; and the endosperm. The endosperm consists of the aleurone layer and the endosperm proper, consisting of the sub-aleurone layer and the starchy or inner endosperm. The aleurone layer encloses the embryo. The hull (husk) constitutes about 20% of the rough rice weight. The distribution of brown rice weight is pericarp 1 to 2%, aleurone plus nucellus and seed-coat 4 to 6%, germ 1%, scutellum 2% and endosperm 90 to 91%.

The aleurone layer varies from one to five cell layers; it is thicker at the dorsal than at the ventral side and thicker in short-grain than in long-grain rice. The aleurone and embryo cells are rich in protein bodies, containing globoids or phytate bodies, and in lipid bodies. The endosperm cells are thin-walled and packed with amyloplasts containing compound starch granules. The two outermost cell layers (the subaleurone layer) are rich in protein and lipid and have smaller amyloplasts and compound starch granules than the inner endosperm.

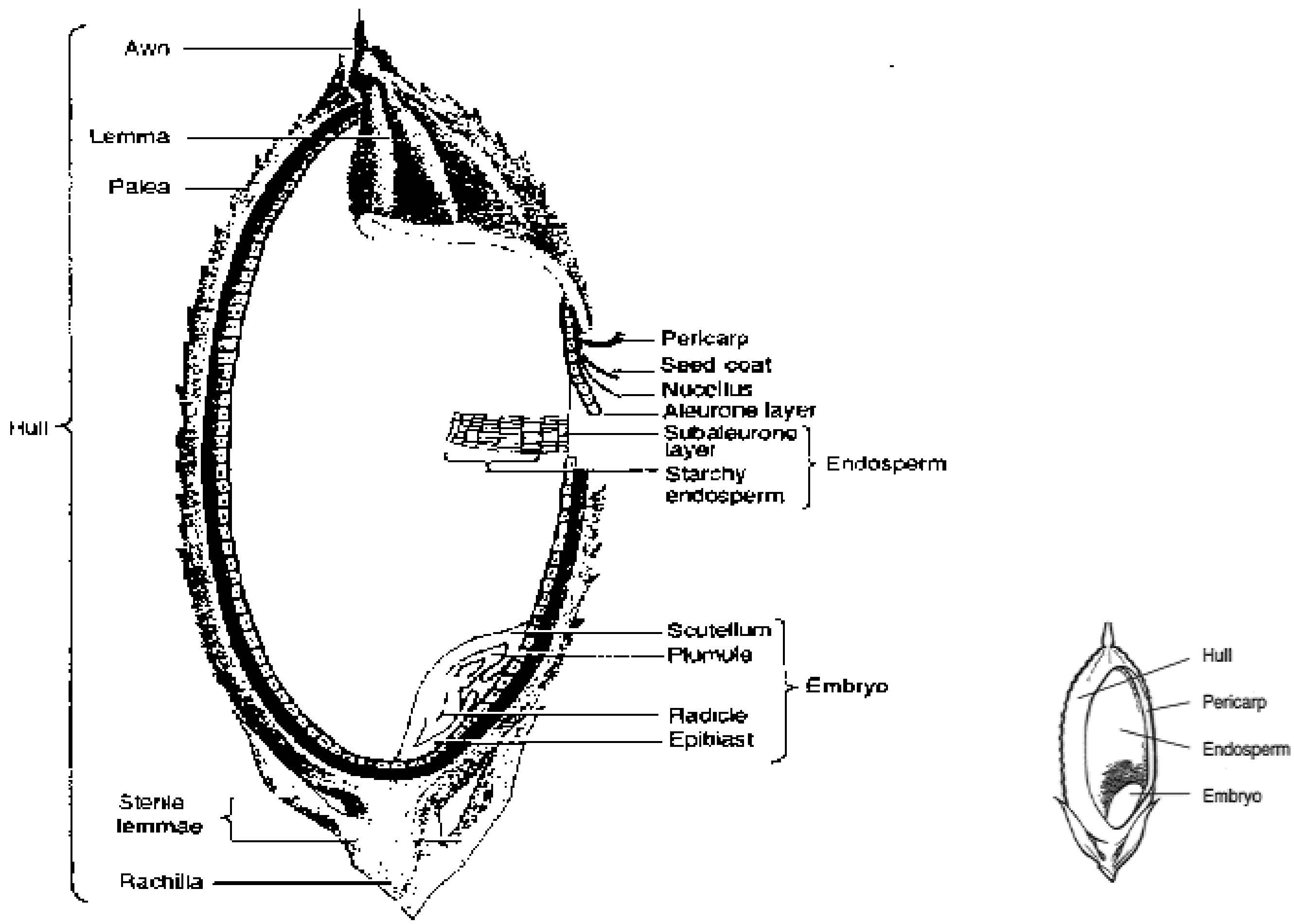


Figure 7: The structure of rice grain

Stages in rice processing

The various stages in rice processing are shown in Figure 8 covering the operations from harvest of the panicle to the production of graded, polished white rice. The moisture content of harvested paddy will usually be in excess of 20 percent. This must be reduced to 12- to 14-percent for efficient hulling and processing operations. Paddy can be hulled outside this moisture content range but the performance of the machines is poor. The normal prehulling operations are as follows:

(a) **Harvesting:** Rice is still most frequently harvested by cutting the panicle with enough stem to allow threshing by hand. Delayed harvest in rainy weather frequently leads to grain sprouting on the panicle and also increase the incidence of aflatoxin contamination.

(b)**Threshing and Grading:** The panicles are sun-dried prior to threshing by hand, treading by people or animals or processing by mechanical threshers. When threshing is delayed while the cut crop is stored in heaps, "stack burning" often results as a consequence of the anaerobic respiration of microorganisms on the straw (70 to 80 percent moisture) and grain.

(c) **Storage**

Storage changes, or ageing, occur particularly during the first three to four months after harvest and are also known as "after-harvest ripening". The grain constituents probably equilibrate to their more stable physical form, which results in a harder, creamier-coloured grain. After-harvest, ripening is accompanied by a higher yield of total and head milled rice. Stored rice expands more in volume and yields a more flaky cooked rice with less dissolved solids in the cooking water than freshly harvested rice. The rice grain is very hygroscopic because of its starch content and equilibrates with the ambient relative humidity. The safe storage moisture content is generally considered to be 14 percent in the tropics. Storage pests (insects and micro-organisms) and rodents cause losses in both quantity and quality of the grains. Gross composition is not affected by storage, but vitamin content decreases progressively.

(d) **Parboiling**. This is a process which involves soaking the paddy, then steaming and drying it. Parboiling improves the nutritional quality of the rice, makes the hulling operation much easier, and gives a greater proportion of whole-grain white rice. Parboiled paddy must be dried before milling. Rice milled from parboiled paddy stores better than non-parboiled rice, and has a different taste, colour and cooking properties. Parboiling is a costly operation but its benefits generally outweigh its cost. The traditional parboiling process involves soaking rough rice overnight or longer in water at ambient temperature, followed by boiling or steaming the steeped rice at 100 °C to gelatinize the starch. The parboiled rice is then cooled and sun-dried before storage or milling.

Modern methods involve the use of a hot-water soak at 60°C (below the starch gelatinization temperature) for a few hours to reduce the incidence of aflatoxin contamination during the soaking step. Leaching of nutrients during soaking aggravates the contamination, with the practice of recycling the soak water. Vacuum infiltration to de-aerate the grain prior to pressure soaking is applied to obtain a good-quality product, as is pressure parboiling. The parboiled product has a cream to yellow colour depending on the intensity of heat treatment. Aged rice may give a greyish parboiled rice, probably because it has a lower pH owing to the presence of free fatty acids.

The major objectives of parboiling are:

i. To increase the total head yield of rice
ii. Prevent the loss of nutrient during milling
iii. Salvage wet or damaged paddy
iv. Prepare rice according to consumer preferences

The parboiling process produces physical, chemical and organoleptic modifications in rice with economic and nutritional advantages.

Changes occurring during parboiling

1. Water soluble vitamins and mineral salts are spread throughout the grain thus altering their distribution and concentration among the various parts. The riboflavin and thiamin contents are 4 times higher in parboiled rice than in unparboiled rice. The niacin content is about 8 times greater.
2. Moisture is reduced to 10 – 11 percent for better storage.
3. Starch grains or granules which are embedded in pertinacious matrix are gelatinized and expand till they fill up the surrounding air spaces.
4. The enzymes present in the kernel are totally or partially inactivated
5. Proliferation of fungal spores, from the growth of eggs and larvae of insect are prevented.
6. The leaching of solids and solubilisation of kernels into the cooking water are considerably reduced

Advantages of parboiling

1. After parboiling, the milling yield is high and the rice quality is improved as there are fewer broken grains. The grains structure becomes compact, translucent and shining.

2. The milled parboiled rice keeps longer and better than in the raw state as germination is no longer possible.
3. The endosperm has a compact texture making it more resistance to attack by insects.
4. The grains remain firmer during cooking and are less likely to become sticky.
5. The nutritional value of parboiled rice is greater because of higher content of vitamin and mineral salts which have spread in the endosperm.
6. The starchy endosperm of the parboiled rice has a greater resistance to milling and therefore the bran and germ are more effectively removed.

Disadvantages of parboiling

1. It is more difficult to mill because the process of parboiling makes the kernel slippery
2. It takes longer time to cook.

(e) **Drying**: There are two main methods of drying (natural and artificial). The prevailing local method is sun drying. The paddy is spread out on a clean surface (tarpaulin, concrete slab or even smooth, clean earth) and regularly turned by hand. Excessively rapid drying results in the development of hairline cracks in the endosperm of the paddy grain (sun checking). These cracks enlarge and produce a higher proportion of broken grains during subsequent operations. The incidence of cracks is reduced by a slower rate of drying which, in turn, can be achieved by increasing the thickness of the layer of paddy during sun-drying up to 150 mm, and by frequent stirring. If artificial drying is employed the manufacturer's instructions should be followed. With very wet paddy, and particularly after parboiling, it is common practice to dry in two stages separated by a resting period during which the paddy is aerated.

(f) **Cleaning**: This is an important operation; small stones and pieces of metal can damage the huller, while pieces of straw may cause an uneven flow of paddy to the huller. All impurities should be removed before the paddy is hulled. A combination of sieving and aspiration is commonly employed to separate the light impurities and a de-stoner is used to remove denser impurities. If the paddy is to be parboiled before hulling, it should be washed and drained before being soaked, in order to remove soluble impurities which may otherwise discolour the grains.

(g) Milling: The production of white rice from paddy is complex and involves many operations. In large-scale plants the machinery and equipment used are very specialized, with each item only carrying out perhaps a single operation of the 20 or more that may be required for commercial rice milling. Large-scale plants must operate at high capacity to justify the investment in equipment. In small-scale rice milling, with capacities up to 500 kg/day, a piece of machinery will carry out several of the operations in producing white rice from paddy, either in a single pass through the machine, or in several passes, with machine adjustments being made between each pass.

Dehulling of rough rice to brown rice can be carried out either manually (hand pounding) or mechanically. Mechanical hullers are of three main types: Engelberg mills, stone dehullers and rubber dehullers. Stone dehullers are still common in tropical Asia, where the surface-bruised brown rice is immediately milled with either an abrasive or friction mill. Rubber rollers are common in Japan, where brown rice is stored instead of rough rice, with a resultant space saving.

High humidity in the atmosphere during milling improves the yield of head rice. Susceptible varieties readily crack below 16 percent moisture when exposed to higher humidity, but resistant varieties become susceptible at 14 percent moisture. Thus breakage is minimized for all varieties by tempering the grain to 16 percent moisture before milling. However, the milled rice may have to be redried to less than14 percent for safe storage. The presence of chalky regions in the endosperm (white belly or white core) contributes to grain breakage during milling. Shelf-life is usually shortest for milled rice, followed by brown rice and then rough rice, because of fat rancidity. Fat in the surface cells of milled rice undergoes fat hydrolysis by lipase followed by lipoxygenase oxidation of the liberated free unsaturated fatty acids.

(h) Polishing: The term "polished rice" refers to milled rice that has gone through polishers that remove loose bran adhering to the surface of milled rice and improve its translucency. The polisher has a horizontal or vertical cylinder or cone, covered with leather strips, that gently removes loose bran as it is rotated in a working chamber made of a wire-mesh screen or a steel screen with slotted perforations. Some rice consumers prefer a very glossy or shiny rice called coated or glazed rice.

(i) Sizing/Grading: The milled rice is separated by length into whole and broken using spring. Factors contributing to the rice breakage during milling may be:

i. Those related to the properties of the rice grain itself or
ii. Those related to the condition under which the rice grain is milled.

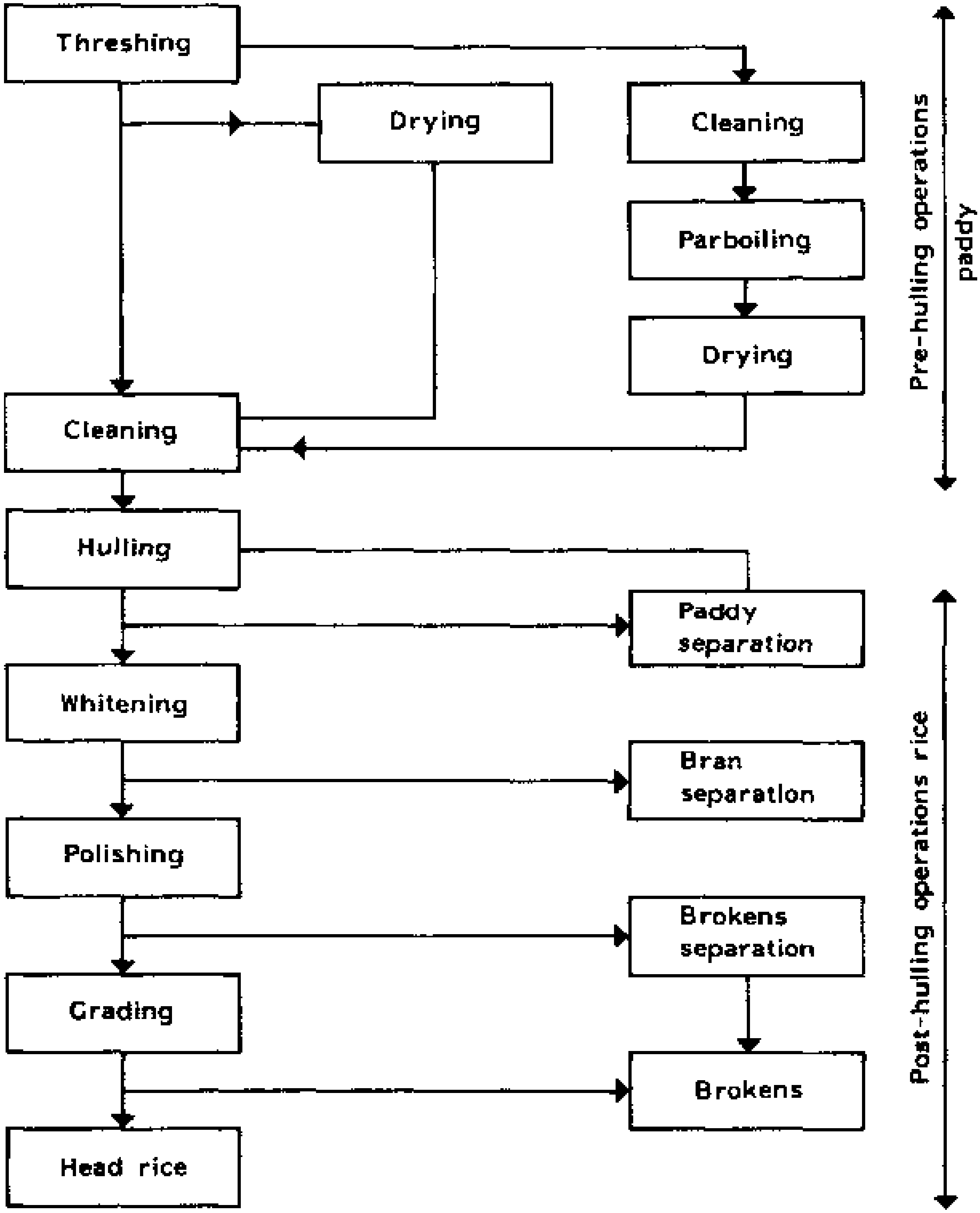


Figure 8: Stages in rice processing

ROOTS AND TUBERS

Roots are plant materials which edible portions grows under the soil but the stem serve as planting materials, while tubers are thick parts or swollen parts of an underground stem bearing small buds from which new plants can be formed. Roots and tubers belong to the class of foods that basically provide energy in the human diet in the form of carbohydrates. The principal root and tuber crops of the tropics are cassava (*Manihot esculenta* Crantz), yam (*Dioscorea* spp.), sweet potato (*Ipomoea batatas* L.), potato (*Solanum* spp.) and edible aroids (*Colocasia* spp. and *Xanthosoma sagittifolium*). They are widely grown and consumed as subsistence staples in many parts of Africa, Latin America, the Pacific Islands and Asia. The increased use of major roots and tubers – cassava, potato, sweet potato, and yam, for food and livestock feed in developing countries will have wide-ranging effects on global public- and private-sector policies and investments. Roots and tubers will continue to play a significant role in developing-country food systems because they:

a. contribute to the energy and nutrition requirements of more than 2 billion people;
b. are produced and consumed by many of the world's poorest households;
c. are an important source of employment and income in rural, and often marginal, areas, especially for women, and
d. adapt to a wide range of uses, from food-security crops to cash crops, raw material for industrial uses, and from fresh to high-end processed products.

Roots and tubers together constitute a significant share of the total volume and value of horticultural crops worldwide. These commodities are particularly important as a source of food, employment, and income in developing countries where the bulk of the world's producers, processors, and consumers reside. In this new millennium, roots and tubers will play an increasingly important role in meeting the food requirements, feed uses, and income needs of the African's food system.

Roots and tubers production

The most important roots and tubers in terms of production are cassava (48.8%) and sweet potatoes (39.8%), while yams (9.4%) and taro (2.0%) are less important. Most of the cassava is produced in Africa, Asia and South America, while sweet potatoes are heavily concentrated in Asia. Africa dominates the production of yams and taro. In Africa the per capita consumption of root crops total 181 kg/capita with cassava (115 kg/capita) and yam (39 kg/capita) being the most important. In North Central America 64 kg/capita of root crops are consumed with potatoes forming 92 per cent of the share. Globally, root crops are important staple foods. If it is assumed that only 10 kg per capita of potatoes (20% of the world production) are produced in the tropics, the tropical root crops accounts for 65 kg/capita on the whole world population basis. The main root and tubers crops produced in Africa are:

- Cassava (53% of the world production), followed by Asia (29%) and South America (17%);
- Yams (96% of the world production);
- Sweetpotatoes (7%), the main producer being Asia (91% of the world production);
- Potatoes (4% of the world production), the main producers being Asia (37%), and the rest of the world (55%);
- Other root crops (70%), followed by Asia (20% of the world production).

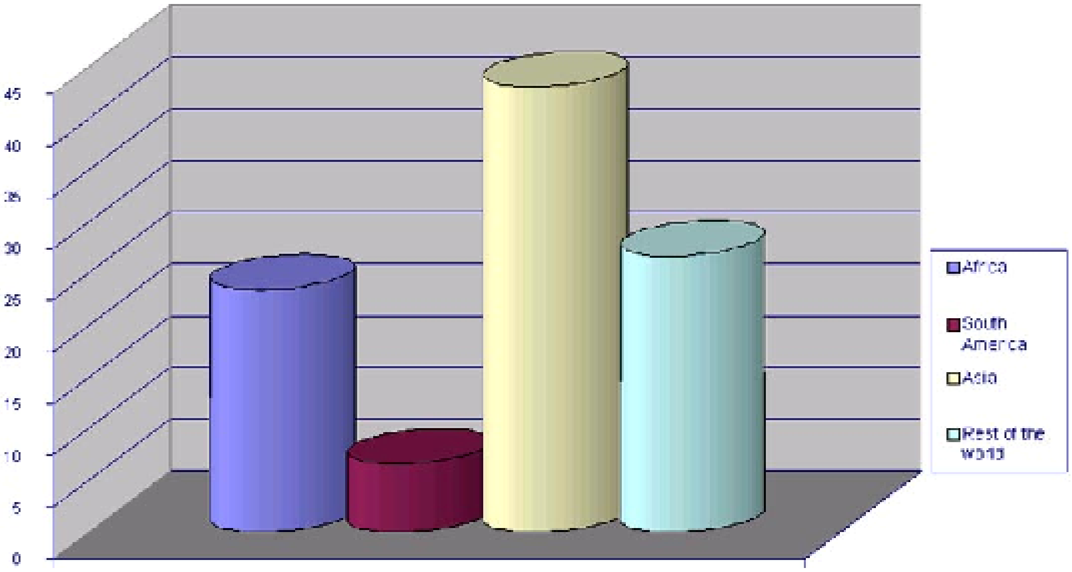


Figure 9: Production of root and tuber crops (in % of the total world production)

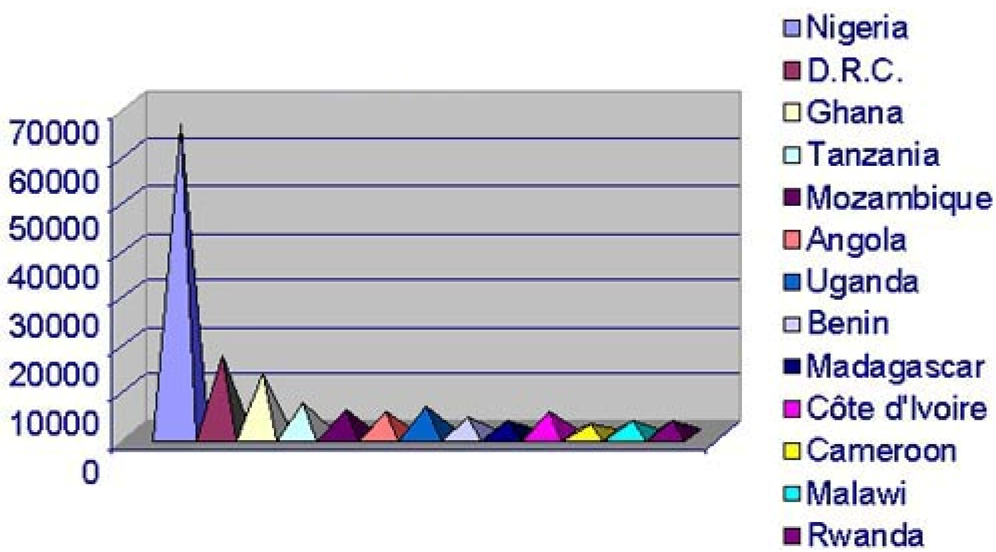


Figure 10: Production of roots and tubers in Africa (1000 Mt)

The role of roots and tubers in nutrition

In terms of contribution of roots, tubers and derived products to calorie requirements, it should be noted that root and tuber crops contribute more than 600 calories per caput per day in the following countries: Angola, DRC, Congo-Brazzaville, Central African Republic, Mozambique, Ghana, Côte d'Ivoire, Rwanda, Togo and Benin Republic. It is interesting to note that, although Nigeria is the largest producer of root and tuber crops in Africa, the contribution of these crops to calorie requirements is not the highest among the concerned countries (about 570). This can be explained by the great variety of sources of calories that are available in Nigeria. In terms of contribution to calorie supply, the importance of root, tubers and derived products crops (all production included and converted into primary product equivalent) is small, compared to the contribution of cereals. The contribution of root and tuber crops to the world supply of calories is only 5% compared to 48% for cereals and 46% for other food. In Africa, the root and tuber crops contribute 14% to the calorie supply as compared to 51% for cereals and 37% for other food, while in South America the roots and tubers contribute 5% and in Asia only 4% to the calorie supply.

Root and tuber crops are second only in importance to cereals as a global source of carbohydrates. They also provide some minerals and essential vitamins, although a proportion of the minerals and vitamins may be lost during processing as, for example, in the case of cassava. In most traditional diets; vegetable soups, meat, groundnuts, grain legumes and fish (which are good sources of protein) are frequently used to supplement root and tuber crops to compensate for their protein deficiencies. In some parts of Africa the diet is supplemented with the tender leaves of sweet potato, cassava and cocoyam which are rich sources of protein, minerals and vitamins.

General characteristics of root and tuber crops

The importance of root and tuber crops as staple foods is because of their particular agronomic advantages:

i. they are well adapted to diverse soil and environmental conditions and a wide variety of farming systems.
ii. they are highly efficient sources of edible carbohydrates when compared to other food crops

Their more important limitations are their bulk, some tubers weigh over 5 kg, and perishability, moisture contents range from 60% to 90%. These are associated with high transport costs, a short shelf life and limited market margins, which impose serious constraints in the urban markets of developing countries. With few exceptions, roots and tubers are produced by small-scale farmers using traditional tools and without any inputs of fertilizers or chemicals for weed and pest control. Traditionally, women have provided most of the labour for production and harvesting. Some form of sequential cropping practice is frequently followed together with intercropping by cereals, legumes and cash crops such as coffee and cocoa.

Table 3: General characteristics of roots & tubers compared with cereals

Cereals and oil seeds	Roots and tubers
1.Low moisture content, typically 10% to 15%	High moisture content, typically 70% to 80%
2. Small unit size, typically less than 1 gram	Large unit size, typically 100 grams to 15 kg
3. Very low respiration rate with very low generation of heat. Heat production is typically 0.05 megajoule/ton/day for dry grain	High respiration rate. Heat production is typically 0.5 to 10 megajoules/ton/day at 0°C to 5 to 70 megajoules/ton/day at 20ºC
4. Hard texture	Soft texture, easily bruised
5. Stable, natural shelf life is several years	Perishable, natural shelf life is a few days to few months
6. Losses usually caused by moulds, insects and rodents	Losses usually caused by rotting (bacteria and fungi), senescence, sprouting and bruising

CASSAVA (*Manihot esculenta* Crantz)

Cassava (*Manihot esculenta*) is a perennial woody shrub of the Euphorbiaceae family. It is grown principally for its tuberous roots but its leaves are also eaten in some parts of Africa and are used as animal feed in parts of Asia. The roots are 25–35 percent starch and the leaves contain significant amounts of protein and other nutrients. Cassava is a hardy crop, tolerant to extreme ecological conditions and even thrives on impoverished soils. It is well suited to the prevailing farming systems across most African countries. The stem is the planting material from which grows the roots and shoots. Cassava produces bulky storage roots with a heavy concentration of carbohydrates, about 80 percent. The shoots grow into leaves that constitute a good vegetable rich in proteins, vitamins and minerals. New knowledge of the biochemistry of the crop has proved that the proteins embedded in the leaves are equal in quality to the protein in egg. Cassava leaves and roots, if properly processed, can therefore provide a balanced diet protecting millions of African children against malnutrition. Cassava provides a major source of energy for over 500 million people; the energy content of cassava in diets in the tropical areas of Africa, America and Asia has been estimated as 37%, 12% and 7% respectively. In recent years a substantial trade has developed in dehydrated cassava chips and pellets which are exported to Europe as a low-cost animal feed ingredient. Cassava flour and starch are used as raw material in baked products such as breads, biscuits, crackers, pearls of tapioca, cream sandwiches. Cassava starch is used for food items as: thickener paste for soups, sauces, gravies, binder and stabilizer for many processed food products (such as sausages and processed meat products), fillers (contributing to the solid content of pills and tablets and other pharmaceutical products) etc. Cassava starch is also a chemical raw material in manufacturing plastics and the tanning of leather, coating, sizing's and adhesives, paper-making and textiles. cassava starch has unique properties, such as its high viscosity and its resistance to freezing, which make it competitive with other industrial starches. Cassava is also used as gelatinized products or manufactured into dextrose and glucose syrup as sweetening agents for confectioneries (candies, jellybeans, toffee, hard and soft gums, boiled sweets), caramel as coloring agent for food and beverages, and canned/preserved fruits. Cassava is also used as raw material for the manufacture of; MSG (monosodium Glutamate), beer products, alcohol, ethanol and vinegar as well as the manufacture of vermicelli ("noodle" or "sotanghon"). The young tender leaves of cassava are consumed as vegetables, containing high levels of protein (8-10% fresh weight).

General morphology and composition of the cassava root

The edible portion of cassava is a starchy root, which matures to harvest within 9 to 24 months of planting, depending on cultivar and climate. It is generally fattest at the proximal end and tapers gently towards the distal end. Transversely a cassava root consists of three principal areas (Figure 11):

i. **The periderm:** Comprises the outermost layer of the root. It is composed mostly of dead cork cells, which seal the surface of the root.
ii. **The cortex** A layer 1 to 2 mm thick located immediately beneath the periderm.
iii. **The starchy flesh:** The central portion of the root, consisting mainly of parenchyma cells packed with starch grains.

The typical shape and morphology of a cassava root are shown in Figure 11 (a) and (b). It is usually elongated, has depressions and crevices along its length and tapers to one end. In most cases, the middle part has a fairly constant diameter. Whereas the head end has a relatively large diameter, the tail end has a considerably smaller diameter when compared with the middle part. The head and tail ends are generally referred to as the proximal and distal ends, respectively. At its proximal end, the tuber is joined to the rest of the plant by a short woody neck. A transverse section of the tuber (see Figure 11 (b)) shows that it consists of a central core called the pith. This is surrounded by the starchy flesh that forms the bulk of the tuber and constitutes the main storage region. It is white or cream in colour and is surrounded by a thin cambium layer. Covering the cambium layer is the tuber peel, which consists of a corky periderm on the outside and cortex on the inside. The outer periderm may be thick and rough or thin and smooth with surfaces varying considerably in colour from pink to grey. The periderm effectively seals the tuber surface. As the tuber continues to increase in diameter, the continuity of this corky layer is broken, so that longitudinal cracks or fissures appear on the surface of the tuber. However, new cork soon forms beneath the cracks to restore the integrity of the protective corky layer. The cortical region is usually white in colour.

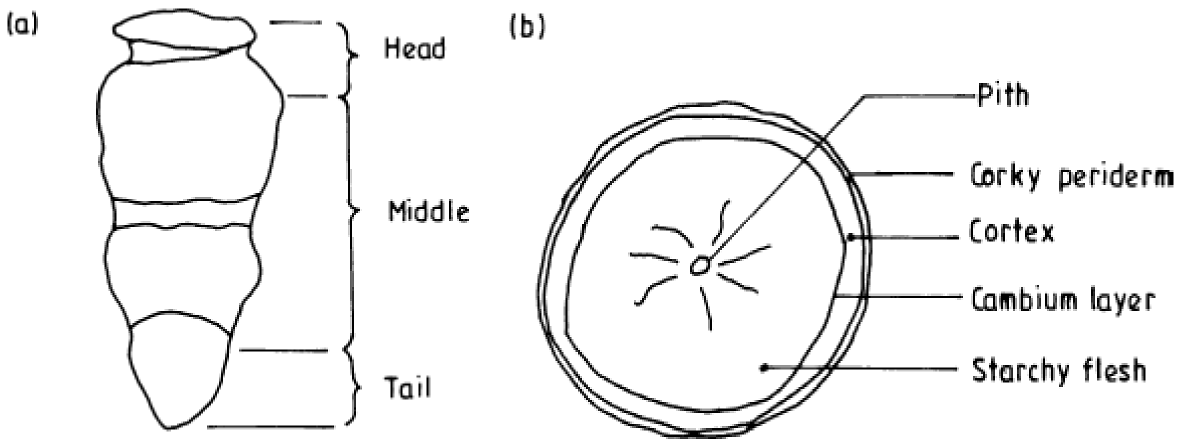


Figure 11: Typical shape and morphology of a cassava root (Source; Adetan et al., 2003)

Cassava contains about 1% protein and some 30-35% of amyloses and amylopectins on a dry weight basis; it is thus a predominantly starchy food. As a human food it has been criticized for its low and poor quality protein content, but the plant produces more weight of carbohydrate per unit area than other staple food crop under comparable agro-climatic conditions. The edible starchy flesh comprises some 80% to 90% of the root and includes: water 62%, fibre 1-2%, carbohydrate 35%, minerals, 1%, protein 1-2%, and fat, 3%.

The problems of cyanogenic glycosides in cassava

Cassava roots and leaves contain cyanides in two different forms: i) the glycosides; linamarin and lotaustraline which are considered "bound" and ii) the non-glycosides; hydrogen cyanide (HCN) and cyanohydride which are considered "free". Free cyanide comprises 8%-12% of the total tuber cyanide. This cyanide can, under some circumstances, lead to human toxicity problems and cassava for food use has to be processed to remove cyanide-containing substances

There is a great variation in toxicity between cultivars. A distinction is usually made between "sweet" cultivars with relatively low contents of cyanogenic glycosides (below 10mg/100g of fresh weight), and "bitter" cultivars with high cyanogenic glycoside content (above 20mg/100g fresh weight), although many intermediate forms exist. Traditionally the sweet cultivars were considered non-toxic while the bitter ones were considered toxic. Although the sweet cultivars are generally less toxic there is no direct correlation between toxicity and taste Cyanide levels in the range 6 to 370 mg/kg have been found depending on the particular cultivar, growing conditions, (i.e. soil type, humidity, temperature) and the age of the plant. The highest proportion of HCN is found in the peels and the cortex layer immediately beneath the peels. It is for this reason the cassava root is always peeled before being processed or consumed. Peeling removes the cortex and the outer periderm layer adhering to it. Peels can represent 10% to 20% of the fresh root weight, of which the periderm accounts for 0.5% to 2.0%.

All the traditional cassava processing methods reduce or remove the toxicity by releasing HCN from the glycosides. Since HCN is soluble in water and has a boiling point of 25°C it can be removed by soaking. Boiling fresh cassava has little effect on its toxicity as the glycoside linamarine is heat resistant and the enzyme linamarase is inactivated at 75°C. The so-called "sweet" types may be eaten raw or lightly boiled without harm. The "bitter" forms are traditionally processed by one or a combination of operations of peeling, grating, fermenting, dehydrating, sun drying, frying or boiling. Hence, for example, fermentation before processing into products such as ***chikwangue*** or ***fufu*** eliminates almost all total and free HCN. The amount of total HCN is reduced by 83% to 96% in such products as ***gari*** and ***attieke*** for which the cassava roots are peeled and grated before processing.

Cassava processing

Cassava root is normally processed before consumption as a means of detoxification, preservation and modification. The traditional processing methods of cassava comprise combinations of various processing steps such as peeling, size reduction (slicing, dicing, grating, rasping), steeping or fermenting, pressing, pounding, frying, roasting, drying and milling. In various parts of Africa, mainly women do the traditional processing of cassava. The objectives of cassava processing are to:

i. Reduce post harvest losses of fresh tubers.
ii. Eliminate or reduce cyanide content.
iii. Improve the taste of cassava products.
iv. Provide raw materials for small-scale, cassava based rural industries. Processed cassava products are also used as raw materials for a number of small or medium-scale industries in Africa.
v. Reduce moisture content and convert it into a more durable and stable product with less volume, which makes it more transportable.
vi. Eliminates or reduces the level of cyanide in cassava and to improve the palatability of the food products.
vii. increase the efficiency of land use by releasing land after harvest for other crops or for fallow to sustain soil productivity
viii. reduce food losses and stabilizes seasonal fluctuation in supply of the crop

Processing for human consumption

The processing of cassava for human consumption can be:

a. Processing of cassava for food with no fermentation which may be in the following ways:

i. boiling in water
ii. pounding/mashing of the root before cooking
iii. Roasting iv. Expression of juice for drinking after boiling
v. boiling followed by some grinding and pounding into flour.

b. Processing of cassava to food with one or more fermentation stage(s): these can be categorize into: (i). solid state fermentations (ii). Submerged state fermentation (iii) Fermentation of cassava liquor.

Solid state fermentation: This is a fermentation process that does not involve soaking of the cassava roots. This is the method used for the production of West African gari. Fresh cassava roots are peeled and grated into mash, and pressed in sacks using a screw jack or heavy objects, to express liquid from the pulp during fermentation. After 1-7 (depending on locality) days the dewatered and fermented mash is sieved and *garified* in a pan. During the process of this fermentation, the pH of the mash has been found to decrease from between 6.4 to about 4.5 as a result of the production of some organic acids. Various types of microorganisms have been implicated in this fermentation process. These include *Corynebacterium manihot*, *bacillus spp*, and some lactic acid bacteria including *Leuconostoc mensenteroids* and *Lactococcus spp* as well as L*actobacillus spp*. The process of fermentation is followed by a special roasting process which is characteristics of gari alone and is therefore referred to as *garification* process. After *garification*, the gari is air dried and is ready for consumption either by soaking in cold water with sugar, coconut, roasted peanut, fish, or boiled cowpea as complements or as a paste made with hot water and eaten with vegetable sauce.

In East Africa, there are other solid state fermented cassava products which processing differs from that of gari. In their own method, the cassava root is peeled, cut into pieces and then spread on roof tops for days ranging from 1 week to 1 month. During this period of exposure both fermentation and dehydration or drying takes place. However, the final product of this type of fermentation is usually coloured black. This is because of the colonization of the root pieces by some moulds such as *Aspergillus spp, Rhizopus spp* and *Penicillium spp.*

Process Flow Charts

Process	**Notes**
Harvest/Sorting of cassava ↓	Select fresh, mature cassava roots without rot
Peeling ↓	Peel by hand and remove woody tips
Washing ↓	Wash in clean water to remove pieces of peel, sand etc.
Grating ↓	Use motorized cassava grater
Fermentation ↓	Pack into baskets made from cane, bark or palm branches and leave for 72h at room temperature
Pressing ↓	The fermented paste is filled into Hessian or polypropylene sacks and placed in a jerk press.
Sifting ↓	Using a wooden sieve, separate fibrous materials to control the size of the particles
Garifying ↓	Roast in a large, shallow cast-iron pan over a fire, with constant stirring, usually with a piece of broken calabash (gourd) or a wooden paddle for 20-30 minutes or use rotary dryer (450kg/day).
Cooling ↓	To room temperature
Sieving (optional) ↓	Sieve to obtain granules of uniform size. Larger particles of gari that are separated on the sieve may be sold as a cheaper grade
Packing ↓	In polythene bags
Storing	In a cool, dry place.

Figure 12: Process Flow Charts for Gari from Cassava

Submerged cassava fermentation: This is the type of cassava fermentation that involves one or more stage(s) of soaking under water. The water submerged cassava is subjected to a low oxygen tension environment. This environment therefore encourages the survival of anaerobic microorganism. Like in the solid state fermentation process, the pH of the root decreases from about 6.4, 6.5 to 4.0 or 3.9 suggesting that more organic acid are produced in submerged processing than in the solid state processing. Investigation has revealed that there is a microbial succession trend during the submerged fermentation process. At the early part of the fermentation bacteria such as *Bacillus spp*; yeast like *Candida spp* are present. Towards the end of the fermentation, only acid tolerant bacteria of the group *Lactobacillus spp* and yeast like *Candida spp* are present. Common products of submerged fermentation process are lafun and fufu.

Process	Notes
Harvest/Sorting of cassava	Select fresh, mature cassava roots without rot
↓ Peeling	
↓ Size Reduction (optional)	Using knives
↓ Washing	Wash in clean water to remove pieces of peel, sand etc.
↓ Steeping/Fermenting	soak inside water in a bowl for 72h at room temperature
↓ Sieving	Using a plastic sieve, separate fibrous materials to control the size of the particles
↓ Settling	Allow fufu mash to be concentrated before decanting
↓ Pressing	The fermented paste is filled into Hessian or polypropylene sacks and placed in a jerk press.
↓ Grating	Use motorized grater, to pulverise cake into smaller particle size and increase surface area for easy drying
↓ Drying	Dry using rotary dryer (185^{o}C, 450kg/day).
↓ Cooling	To room temperature
↓ Milling	To obtain powder
↓ Packing	In polythene bags
↓ Storing	In a cool, dry place.

Figure 13: Process Flow Charts for Fufu from Cassava

Process	Notes
Harvest/Sorting of cassava	Select fresh, mature cassava roots without rot
↓	
Peeling	Peel by hand and remove woody tips
↓	
Size Reduction (optional)	
↓	
Washing	Wash in clean water to remove pieces of peel, sand etc.
↓	
Steeping	Soak inside water in a bowl for 72-96h at 28-35^{o}C
↓	
Crushing/pulping	Using hand
↓	
Dewatering	The fermented paste is filled into Hessian or polypropylene sacks and placed in a jerk press.
↓	
Drying	on rocks, black inclined surfaces, ambient temp
↓	
Milling	To obtain powder
↓	
Packing	In polythene bags
↓	
Storing	In a cool, dry place.

Figure 14: Process Flow Charts for Lafun from Cassava

Industrial cassava products

Chips

Cassava chips are dried irregular slices of roots, which vary in size but should not exceed 5 cm in length. For human consumption, it is chips from peeled roots that are used. Chips are also used for animal feed and industrially. Fresh uprooted cassava roots are preferred because it gives a better quality product. However, tubers that are from 1 - 3 days old after harvest may be used if there is no obvious spoilage. The cassava roots are peeled, washed and chipped. These are then dried to moisture content of 6 - 8%. The chips is then packaged and stored. Chips store better than flour. It can be ground or milled into flour and then sieved when needed.

High quality cassava flour

High quality cassava flour is simply unfermented cassava flour. Freshly harvested cassava roots are peeled, washed, grated, pressed, pulverized, dried and then milled into flour using a hammer mill. High quality cassava flour can be used as partial replacement for many bakery and pasta products. The successful substitution of wheat flour by cassava flour has also been confirmed by the International Institute of Tropical Agriculture, Nigeria where up to 30% of wheat flour has been replaced by cassava flour in bread making and 100% cassava flour is used for other pastries and confectioneries.

Process	**Notes**
Harvest/Sorting of cassava ↓	Select fresh, mature cassava roots without rot
Peeling ↓	Using knives
Washing ↓	Wash in clean water to remove pieces of peel, sand etc.
Grating ↓	Using mechanical grater
De-watering ↓	Using screw or hydraulic press to remove water
Pulverising ↓	The cassava cake is pulverized by motorized pulverizing machine to reduce the size of the cake into smaller particle size and increase the surface area for easy drying
Drying ↓	Dry using cabinet dryer, flash dryer or sun drying
Cooling ↓	To room temperature
Milling ↓	Using a hammer mill to obtain fine flour
Sieving ↓	To remove fibre
Packaging ↓	In polythene bags
Storage	In a cool, dry place.

Figure 15: Process Flow Charts for Production of High Quality Cassava Flour

Cassava pellets

Pellets are obtained from dried and broken roots by grinding and hardening into a cylindrical shape. Pellets could be made from chips. The chips are (hammer-milled) and then preconditioned. Here, the moisture content is increased to between 16 - 18%. This is usually achieved either by spraying water or by adding steam. The addition of moisture and heat increases the effectiveness of the pellets making machine in terms of output, die life, energy savings, volume reduction and nutritive value of the product. The heat generated by steam treatment and high pressure during pelletization can release the cellulose from the lignin-cellulose bounds, thereby increasing the digestibility of starch and fiber. The milled chips when forced through small holes in the die causes a rise in temperature through friction. After pressing, the pellets are 8 - 10 mm in diameter. The pellets are cooled, during which the moisture content drops to 14% and packed in jute or polyethylene bags.

Cassava starch

Cassava starch is an important domestic and industrial raw material that is used in the manufacture of a number of products including food, adhesives, thickening agent, paper and pharmaceuticals. Cassava roots contain 20% starch by weight. Fresh roots are peeled, washed and grated. Grating is important because it affects the quality of the starch released from the cassava. The percentage of starch set free (rasping effect) determines the quantity and quality of the cassava starch (fine screen is recommended because it adequately remove all fibrous materials). The pulp is washed through clean muslin cloth until no more milky starch solution comes out. The collected milky starch solution is then allowed to settle. The supernatant is then discarded and the top surface of the starch cake is scrapped clean; the bottom parks of the cake also need scrapping. The recovered starch cake is broken into small bits and dried. Then pulverize or dry mill the dried starch cake to produce cassava starch powder.

Process	**Notes**
Harvest/Sorting of cassava ↓	Select fresh, mature cassava roots without rot
Peeling ↓	Using knives
Washing ↓	Wash in clean water to remove pieces of peel, sand etc.
Grating ↓	Using mechanical grater
Mixing with water ↓	To obtain a free flowing slurry
Filtering/screening ↓	Using a muslin sloth, separate fibrous materials to control the size of the particles
Settling ↓	Allow Starch to be concentrated at the bottom before decanting
Starch washing ↓	To obtain a white clean starch paste
Settling and dewatering ↓	Allow Starch to be concentrated and remove water prior to final drying
Drying ↓	Dry using cabinet dryer, flash dryer or sun drying
Milling ↓	Using a hammer/disc mill to obtain fine powder
Packaging ↓	In polythene bags and sealed with a sealing machine
Storage	In a cool, dry place

Figure 16: Process Flow Charts for Production of Cassava Starch

YAMS (*Dioscorea spp*.)

Yam is the name given to many plants with tubers belonging to the family of *Dioscoreaceae*. Yams, or *Dioscorea,* are herbaceous plants. Their stem consists of two parts: an aerial stem which climbs by winding round a stake and lasts only a year; and an underground stem that can live a long time. The underground stem thickens to produce one or more tubers called yams. In the humid tropical countries of West Africa, yams are one of the most highly regarded food products and are closely integrated into the social, cultural, economic and religious aspects of life. The ritual, ceremony and superstition often surrounding yam cultivation and utilization in West Africa is a strong indication of the antiquity of use of this crop. Nigeria, the world's largest yam producer, considers it to be a "man's property" and traditional ceremonies still accompany yam production indicating the high status given to the plant. There are many varieties of yam species widespread throughout the humid tropics but the edible yams are derived mainly from about ten. The most economically important species are:

i. **White yam (*Dioscorea rotundata* Poir):** Originated in Africa and is the most widely grown and preferred yam species. The tuber is roughly cylindrical in shape, the skin is smooth and brown and the flesh usually white and firm. A large number of white yam cultivars exist with differences in their production and post-harvest characteristics.
ii. **Yellow yam (*Dioscorea cayenensis* Lam.):** Derives its common name from its yellow flesh, which is caused by the presence of carotenoids. It is also native to West Africa and very similar to the white yam in appearance. Apart from some morphological differences (the tuber skin is firm and less extensively grooved), the yellow yam has a longer period of vegetation and a shorter dormancy than white yam.
iii. **Water yam (*Dioscorea alata* L.):** Originates from South East Asia, it is the species most widely spread throughout the world and in Africa is second only to white yam in popularity. The tuber shape is generally cylindrical, but can be extremely variable. Tuber flesh is white and "watery" in texture.
iv. **Bitter yam (*Dioscorea dumetorum*):** Also called trifoliate yam because of its leaves. Originates in Africa where wild cultivars also exist. One marked characteristic of the bitter yam is the bitter flavour of its tubers. Another undesired characteristic is that the flesh hardens if not cooked soon after harvest. Some wild cultivars are highly poisonous.

The major problems presently facing yam production are its high labour requirement, its low yield per hectare compared to crops such as cassava or sweet potato, the relatively large amount of planting material that is required and its long growing season. By far the most critical of these problems is labour requirement, which exceeds that of other comparable crops. For these reasons and problems of storing harvested yam, the costs of yam production are high and yam is slowly losing ground to cassava. It has been estimated that the cost per 1,000 calories of yam is four times greater than those of cassava. But, despite these high costs, the nutritional value of yam is sufficiently high to justify further work into its general improvement.

General morphology and composition of the Yam tuber

The tuber shape and size can vary greatly due to genetic and environmental factors. However, cultivated forms of yam generally produce tubers that are more or less cylindrical in shape and 3-5 kg in weight. The yam tuber grows from a corm-like structure located at the base of the vine (Figure 17). Occasionally this corm remains attached to the tuber after harvest and sprouts will develop from it. When the corm separates from the tuber sprouting occurs from the tuber near to the point at which the corm was attached.

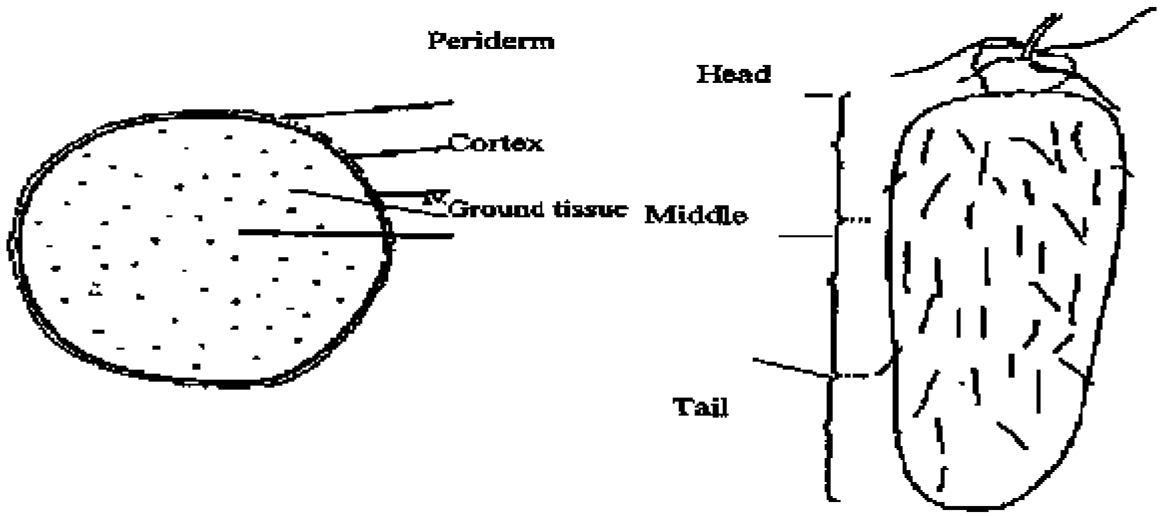


Figure 17: General Morphology and cross section of yam tuber

A transverse section of a mature yam tuber shows it to be composed of four concentric layers:

i. **Corky periderm:** The outer portion of the yam tuber; it is a thick layer of cork cells, often cracked, but which provides a protective barrier against water loss and invasion by pathogens.
ii. **Cortex**: A layer located immediately beneath the cork, comprising thin-walled cells with very little stored starch.
iii. **Meristematic layer:** Elongated thin-walled cells under the cortex. Sprouts are initiated from this layer.
iv. **Ground tissue:** The central portion of the tuber composed of thick-walled starchy cells, with vascular bundles ramifying throughout the mass.

Yam (*Dioscorea alata*) has been suggested to have nutritional superiority when compared with other tropical root and tuber crops. Starch (75.6-84.3%) is the predominant fraction of the dry matter of yam tuber. The average crude protein content of different yam cultivars was 7.4%, that was higher than those reported for other tropical roots and protein from yam also showed a better amino acid balance for human nutrition. The vitamin C content of yam tubers ranged from 13.0 to 24.7 mg per 100 g (fresh weight), and yam has been suggested to be a moderately good sources of minerals.

Table 4: Composition of species of yams (% wb).

Variety	Moisture content	Carbohydrate	Fats	Crude Protein
D. alata	65 – 73	22 - 29	0.1 - 0.3	1.1 -2.8
D. rotunda	58 – 80	15 - 23	0.1 - 0.2	1.1 -2.0
D. esculenta	67 – 81	17 - 25	0.1 - 0.3	1.3 - 1.9
D. bulbifera	63 – 67	27 - 33	0.1	1.1 - 1.5

Yam processing

The major unit operations involve in the processing of yam are: Peeling, boiling or parboiling, pounding and dehydration.

Peeling of yam: This is the removal of the outer corky periderm. The method of peeling varies. The general method applied includes:

i. **Steam peeling:** This involves the exposure of the root or tubers to steam pressure for a period of time. The process may be batch or continuous. During this steam exposure, the steam penetrates the cortex, softens the peel and results in a slight expansion of the space between the peel and the cortex. This makes it easy for the peels to be removed when subjected to minor abrasion. Steam peeling therefore is always in conjunction with other abrasive or mechanical processing.
ii. **Chemical peeling:** This involves the immersion of tuber in some non-toxic chemical such as caustic soda solution of low concentration which helps to soften the peel. Usually when this method is used they are coupled with use of heat. The process is controlled by varying the concentration of the lye and its temperature for effective peeling process. One major setback of this method is the need to use a large volume of water to remove the effect of chemicals during the post-peeling washing.
iii. **Mechanical peeling:** 3 mechanical methods are used namely:

a. **Abrasive peelers**: This peeler consists of a vertical cylinder with a rotating disc in the bottom and a hinge cover at the top. Abrasive grits may be applied to the inner walls of the chambers or to the rotating disc or both. A measured load of the root or tuber is put into the cylinder and when the disc is rotated, the root or tubers spins or tumble so that the peels are rubbed off when the roots or tubers falls against the abrasive surface. Other types are rotary laid mounted rim peelers and use of belt conveyor.

Yam boiling: Nearly all varieties of yam are eaten in the boiled form. The process of boiling involves cooking of the unpeeled or peeled yam tuber in water. The process of boiling has some effects on the tuber which includes:

i. Boiling softens the tissue of the yam thus making it easily digestible and masticable.
ii. It renders impotent some heat labile toxic materials such as alkaloids, saponins and tannins which are present in yam.
iii. Boiling reduces the microbial load of yam thus making it to be safe for consumption.
iv. Boiling inactivate some enzymes present in unprocessed yam.
v. Boiling cause the release of some desirable flavours present in yam.

Yam Pounding: This takes place after yam boiling. The most desirable specie for pounded yam is *Discorea rotundata.* Various factors affects the viscosity of yam during pounding:

i. The starch quality of the yam specie
ii. The intensity of cooking
iii. The intensity of comminution..

Yam Parboiling: This is used traditionally for the production of local yam flour (elubo). The traditional parboiling process usually last for 8-13 hours. The process usually starts after the day's work (about 5-6 pm). Normally, the yam tubers are peeled, although in some areas they are not peeled. This is followed by slicing of the peeled tubers. The sliced pieces are then soaked in hot water contained in big pot placed on simmering or glowing charcoal or wood fire. The traditional processor leaves the yam in the hot water till morning, a period that last for 8 hours. This process of soaking yam in water at elevated temperature is called yam parboiling. Traditionally, the temperature of parboiling has been found to be about 60°C. The parboiled yam is then removed from the water and sundried for about 2 – 5 days to a moisture content of about 12%. The sundried yam is then size reduced by milling to flour to produce the local yam flour called elubo.

SWEET POTATO (*Ipomoea batatas* L.)

Sweet potato is a crop with a significantly unrealized potential. It is capable of producing high yields of dry matter per unit area of land and labour and this potential can be achieved under a wide range of agro-climates and farming systems. The largest producers in Africa are: Uganda (1.9 million tons), Rwanda (0.7 million tons), Burundi (0.68 million tons) and Kenya (0.63 million tons). Sweet potato has the shortest growing cycle of the root crops grown in the tropics. The crop is lifted by hand; great care being taken to avoid damage to the tubers, with only the amount needed for immediate consumption being dug. If the crop is grown for sale or when there is a pronounced dry season, the whole crop may be lifted at once. On a larger or commercial scale effective harvesting machines have been developed; some consist simply of a plough that lifts the tubers to the surface. More sophisticated mechanical harvesters combine a vine cutter (rotary or flail type mower) to remove the vines incorporated with a plough to lift the tubers and a sorter and loading elevator.

Table 5: Chemical composition of Sweet Potato (*Ipomea batatas* L.)

Constituent	Percent or (mg/100g)
Moisture	50 - 81
Protein	1.0 - 2.4
Fat	1.8 - 6.4
Starch	8.0 - 29
Non-starch Carbohydrates	0.5 - 7.5
Reducing Sugar	0.5 - 7.5
Ash	0.9 - 1.4
Carotene (average)	4 mg /100 g
Thiamine	0.10 mg /100 g
Ascorbic Acid	25g /100 g
Riboflavin	0.06 mg /100 g

General morphology and composition

There are many cultivars of sweet potato each with its own characteristics size, shape, colour, storage life, levels of nutrition and suitability for processing. A single plant may produce 40 to 50 tubers ranging in length from a few to 30 cm; they may be spindle-shaped or spherical and weigh from 100 g to 1 kg. Tubers may have a smooth or irregular surface and the skin and the flesh may range from almost pure white through cream, yellow, orange and pink, to a very deep purple. The chemical composition of sweet potatoes varies greatly according to genetic and environmental factors.

Sweet potato utilization

Sweet potatoes are utilized as food as well as livestock feed all over the world. In the tropics the fresh roots are commonly boiled, fried or roasted and eaten as a carbohydrate constituent of the diet. Recent attention has been paid to the nutritional value of the leaves, which can contain as much as 27% protein (dry basis). In Africa, both the roots and the leaves are consumed. In parts of East Africa tubers are sometimes sliced and sun-dried to produce chips, which are later ground into flour. In Northern Cameroon sweet potato plays an important role in rural food security; dried chips are stored for use during the hungry period when the stocks of the staples sorghum and millet are depleted. In Asia, particularly Japan, Taiwan and South Korea, sweet potato is widely used as animal feed. In the USA, one third of sweet potato production is dehydrated and processed for animal feed.

POTATO (*Solanum tuberosum* L.)

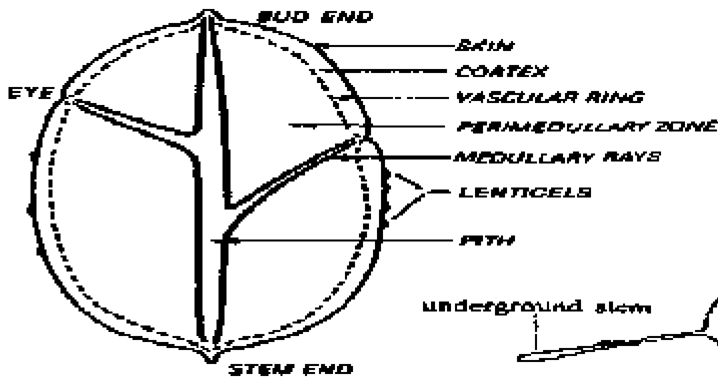
The potato originated in highland tropical areas of South America from where it was introduced into Europe towards the end of the 16th century. There the potato developed as a temperate crop before it was later distributed throughout the world, largely as a consequence of the colonial expansion of European countries. Late maturing potato varieties from temperate zones can usually be grown successfully in the tropics at high altitude (1, 200 m or more above sea level) down to areas at sea level where there is a marked cool season. In the tropics potatoes are harvested about four months after planting which results in higher yields, as compared to temperate climates where the main crop growing season can extend to six months. Main crop potatoes should not be harvested until they are fully mature, considered to be about two weeks after the tops have died off, at which stage the skin of the tuber is well set and be less prone to damage during harvesting. Early or "new" potatoes, which are harvested in an immature condition before the skins have set, can be easily damaged and do not store well or for long periods.

General morphology and composition of the potato tuber

The potato is basically a swollen stem mainly composed of water (80%) making it a bulky commodity and one which responds strongly to its prevailing environment. In cross section there are four clearly distinguishable areas (Figure 18):

i. **Skin or Periderm:** Usually thicker at the stem than at the bud end although the total skin thickness can vary substantially depending on variety and growing conditions. The skin can easily be removed in immature tubers but not when the tubers have reached full maturity. If the tuber tissue is wounded, the tuber is able to form a new layer of suberized cells, known as wound periderm. **Lenticels**, which are a circular group of suberized cells, are formed in the periderm and are essential for the respiration of the tuber since the skin is almost impermeable to CO_2 or O_2. **Potato eyes** (effectively buds on the stem), **the bud and stem ends** are also present on the periderm surface.
ii. **Parenchyma tissue**. Composed of cells of the cortex and the perimedullary zone. It represents the major part of the tuber and contains starch grains as reserve material.
iii. **The ring of vascular bundles**. When the tuber is cut lengthwise part of the vascular tissue is revealed as a ring, known as the xylem.
iv. **The medullar rays and medulla**. Also known as the pith.

The chemical composition of potatoes is very variable and is greatly influenced by variety, environment and farming practices. Starch constitutes 65% to 80% of the dry weight of the tuber. Potatoes are also an important source of protein, iron, riboflavin and ascorbic acid. An average range of composition is given in Table 5.



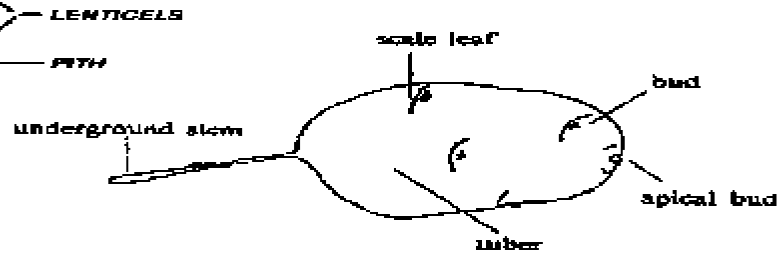


Figure 18: Diagram of a longitudinal section of a potato tuber

Table 6: Average constituents of Potato (*Solanum tuberosum* L.)

Constituents	Percentage (wb)
Moisture	50 – 81
Protein	1.0 - 2.4
Fat	1.8 - 6.4
Starch	8 – 29
Non-starch Carbohydrates	0.5 - 7.5
Reducing Sugar	0.5 - 2.5
Ash	0.9 -1.4
Carotene (average)	4 mg /100 g
Thiamine	0.10 mg /100 g
Riboflavin	0.06 mg /100 g
Ascorbic Acid	12 mg /100 g

Glycoalkaloids in potato (Solanin)

When potato tubers are exposed to light during harvesting, handling and marketing a green colour will develop in the periderm and in the outer parenchyma cells of the cortex caused by the synthesis of chlorophyll which causes a bitter taste. Also bitter-tasting and resulting from exposure is a substance which is attributed to the formation of glycoalkaloids but the formation of chlorophyll and glycoalkaloids are independent processes. The glycoalkaloids content of potato tuber varies between 210mg/100g (fresh weight). The highest levels of glycoalkaloids are found in the periderm and cortex; hence about 60% will be removed by peeling. Potatoes containing amounts greater than 1mg/100g are generally considered unsuitable for human consumption.

COMPOSITE FLOUR TECHNOLOGY

Composite flour is defined as that which contains wheat flour and one or more non-wheat flours from indigenous cereals, roots, tubers, legumes or oilseeds mixed together for baking purposes. The wheatless mixture may also be used for preparing other local recipes. Currently, limits have been set for the maximum allowable level of wheat flour substitution with flours from other sources to between 10 and 30%, depending on the flour's origin and uses. The maximum allowable level of cassava flour or starch substitution into wheat flour for bread making in Nigeria stands at 10% as specified by the Standard Organization of Nigeria.

The use of composite flour (CF) in food product manufacture has recently assumed great relevance both in the developed and developing worlds due to some social, cultural, economic, agronomical and nutritional/health reasons. For example, the increasing incidence of celiac disease, which is an allergic reactions/intolerance to wheat gluten, has caused food markets to be filled with wheatless breads in Europe. Consumption of *missi rotti* from composite of wheat, Bengal gram and/or barley has been recommended for diabetic patients in India because it helps maintain blood glucose level. The trend towards partial replacement of wheat flour with flours from other plant sources in the developing worlds is mainly dictated by agronomic and economic reasons. Many developing countries have unfavourable agronomic/climatic conditions that cannot support cultivation of wheat. Therefore, partial replacement of wheat is one way of cutting down huge foreign expenses on wheat importation.

One of the most researched food applications of CF is in the production of baked products such as bread, cake, biscuits and pastas. It has been established from various studies that wheat substitution up to about 10-50% with other flours has been found to give acceptable bread, biscuits and cakes depending on the product, nature of the substitute flour and ingredients used.

BREAD MAKING TECHNOLOGY

Bread dough is the visco-elastic mass produced when wheat flour is mixed basically with water while other ingredients like fat or butter, salt, sugar etc are added to present varieties in consumption. However, when some other flour are added to wheat flour, the solid mass gradually reduces its visco-elastic property as the level of substitution increase, producing what is called batter. The unique dough making property of wheat flour is due to the presence of gluten, a sulphur containing protein that causes the visco-elastic behavior of dough. There are two major ways of making bread dough:

(1) Straight dough process: In this process all the ingredients are mixed together at one time and the dough is allowed to rise. This process takes place in the presence of yeast. The dough then passes through seven further steps namely, kneading, rising, kneading, molding, rising, baking and cooling before it is turned to edible bread.

(2) Sponge and dough process: In this process only half of the amount of flour is used at first with practically all the liquid and leavening agents (yeast, or cereal or vegetable water). This dough is allowed to rise very slowly and for long time (6 to 10h). The remaining flour and liquid are mixed to make separate dough which is later mixed with the raised dough. The mixture is then handled as in the straight dough process. This process is especially suitable for small bakeries where there are no mechanical mixers. It allows baker some rest and gives excellent flavour development if properly executed.

Over the years, there have been several developments in the baking industries on the method used in dough development. A typical example is that of Chorleywood Bread Process (CBP). The process was developed in 1961 by the *Flour Milling and Baking Research Association at Chorleywood* and is now used to make 80% of the world's bread. CBP uses low protein wheats combined with chemical improvers and intense mechanical working of the dough using high-speed mixers. The process substantially reduces the long fermentation period by introducing high energy mixing for just a few minutes, dramatically reducing the time taken to produce a loaf. The CBP method of making bread cannot be reproduced in a normal kitchen because of the requirement for a high-speed mixer.

COMPOSITE BREAD TECHNOLOGY: PROBLEMS AND PROSPECTS

When wheat flour is mixed with water, the visco-elastic dough formed due to the presence of gluten is the major factor of quality in baked products. Increasing level of wheat flour substitution with other flour in baked products had always resulted into reduction in sensory and keeping quality of baked products like bread. Generally, the problems of composite bread stem from reduced level of gluten and the interaction between the protein, starch and other properties of composite flour which include reduction in loaf volume caused by the poor gas retention and thermal instability of composite dough, impairment of sensory qualities (appearance, texture, flavour), poor keeping quality (changes in crumb and crust firmness, microbial spoilage etc.). This is usually exhibited in terms of higher loaf density, collapsed cellular structure of crumb, gumminess, reduced loaf elasticity, unattractive crust and crumb colour, taste as well as shorter shelf life.

Baked products from composite flour obtained from different non-cereal plants like it is found in cassava-wheat composite flour, may have poorer properties and more serious technological challenges than when cereal flours are mixed together. The reason for this is that there is a wide difference in the functional properties of their flours stemming from the difference in the behaviour of their starches. Therefore, optimal processing and product formulation are required for successful composite flour utilization.