ISSN 1010-1365

Small-scale palm oil processing in Africa

FAO AGRICULTURAL SERVICES BULLETIN

148

FOREWORD

Various techniques may be used to process palm oil fruits for edible oil, which may be grouped into four categories according to throughput and degree of complexity of the unit operational machinery: traditional methods, small-scale mechanical units, medium-scale mills and large industrial mills. Generally, processing units handling up to 2 tonnes of fresh fruit bunches per hour are considered to be small-scale, while large-scale mills are able to process more than 10 tonnes per hour.

While there is considerable literature concerning traditional technologies and medium- and large-scale mills, information on small-scale processing units is scarce. The current demand for small-scale oil mills is shifting from the present simple machine-assisted equipment to equipment that is more integrated, but still simple in design and easy to operate and maintain.

The FAO has been motivated to undertake this publication, which is the first on palm oil processing in the Agricultural Services Bulletin Series. This bulletin reviews the various processing technologies and machinery that can be used for the extraction of palm oil and palm kernel oil, and provides information on several suppliers of equipment in Africa.

It is hoped that this document will contribute to the improvement of the yield and quality of palm oil and to the modernisation of small-scale palm oil mills in Africa.

Geoffrey Mrema,
Director
Agricultural Support Systems Division (AGS)

CONTENTS

1. INTRODUCTION

Modern processing of oil palm fruit bunches into edible oil is practiced using various methods, which may be grouped into four categories according to their throughput and degree of complexity. These are the traditional methods, small-scale mechanical units, medium-scale mills and large industrial mills.

Generally, processing units handling up to 2 tonnes of fresh fruit bunches (FFB) per hour are considered to be small-scale. Installations that process between 3 and 8 tonnes FFB per hour are termed medium-scale, while large-scale refers to mills that process more than 10 tonnes per hour.

Much has been written about traditional technologies and medium- and large-scale mills, but information on small-scale processing units is scarce. The historical reason for the ready availability of information on medium- to large-scale operations and machinery is that most development work was undertaken in Europe, based on the observation of the traditional methods practiced in West Africa.

Machinery manufacturing is a recent development in the West African sub-region, and until recently it has not been possible to develop the sophisticated machines required to improve on traditional methods. Machinery manufacture in Africa must be carefully considered if progress is to be made in joining the rest of the industrialised world. Even now it is difficult to manufacture and sell bolts and coiled springs in the Central and West African sub-region. However, the manufacture of machines and combining them in processing assemblies for small-scale rural industries is not within the scope of this publication. The main objective of this publication is to provide a detailed description of the various processes involved in small-scale palm oil processing, the type of machinery and equipment required, and their performance, energy and water consumption. The effect on the environment caused by waste and by-product uses is considered in Chapter 6.

At the outset it must be stated that small-scale palm oil processing in the sub-region has systematically acquired sophistication, efficiency and reliability. It is agreed that traditional methods of extracting palm oil were inefficient and tedious for making oil for sale.

Generally women in the villages are responsible for the processing and sale of farm produce. Small-scale agro-processing seems to hold the key to rural poverty reduction and the prolific oil palm tree provides the best raw material for starting rural industries.

Today small-scale processors who appreciate the value of using machines, are asking for them to be more sophisticated. Thus current demand for small-scale palm oil mills is shifting from simple stand-alone unit operational machines to a more integrated system which is easy to operate and maintain. Machinery manufacturers have responded with machines that combine several operations into one machine unit. The complete range of operational machines – covering bunch stripping, fruit sterilization, digestion, pressing, clarification, oil drying and storage have been developed for small-scale processing applications. The processors can change and/or combine equipment to suit their purchasing power.

In this publication the palm tree and its fruit are first considered; then the principles underlying palm oil extraction and preservation are examined. A general description of palm oil processing and the associated unit operations necessary to obtain the oil will follow. Once each step in the oil extraction process has been explained, it will be possible to apply the criteria for the selection of equipment required to meet the processor's needs and investment potential.

A by-product of palm oil extraction is the palm nut which, when cracked, yields a kernel containing a completely different kind of oil which can be used as a valuable substitute for cocoa butter. Unfortunately not many palm oil processors include palm kernel extraction at the same location. It is more usual that a completely different group undertakes palm kernel extraction.

To explain why this occurs, a description is included of how palm kernel oil is extracted and the relevant machinery and equipment needed, is indicated.

Finally, the major machinery manufacturers and designers of equipment in Central and West Africa are presented, listing their main products, innovations and achievements. Photos have been included to illustrate what manufacturers are doing in this sector.

Palm oil and palm kernel processing involve many different procedures. Therefore, the ability to make machinery that can handle the many unit operations involved is indicative of a generalised ability to produce processing machines for other crops. Many machines developed for the palm industry can undertake the same functions for other crop applications with minor modifications. For instance, sterilizers are capable of cooking vegetables, cereals and grains as well as roots and tubers. The vertical digester may be modified to function as a mixer while the screw-presses and expellers can be used for extrusion and de-watering applications. Therefore, readers are urged to contact the manufacturers as to the application of their machinery in other industrial applications.

2 OIL PALM

2.1 Origin of oil palm

It is generally agreed that the Oil Palm *(Elaeis guineensis)* originated in the tropical rain forest region of West Africa. The main belt runs through the southern latitudes of Cameroon, Côte d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, Togo and into the equatorial region of Angola and the Congo. Processing oil palm fruits for edible oil has been practiced in Africa for thousands of years, and the oil produced, highly coloured and flavoured, is an essential ingredient in much of the traditional West African cuisine. The traditional process is simple, but tedious and inefficient.

During the 14th to 17th centuries some palm fruits were taken to the Americas and from there to the Far East. The plant appears to have thrived better in the Far East, thus providing the largest commercial production of an economic crop far removed from its centre of origin.

Palm oil is rich in carotenoids, (pigments found in plants and animals) from which it derives its deep red colour, and the major component of its glycerides is the saturated fatty acid palmitic; hence it is a viscous semi-solid, even at tropical ambients, and a solid fat in temperate climates.

Because of its economic importance as an high-yielding source of edible and technical oils, the oil palm is now grown as a plantation crop in most countries with high rainfall (minimum 1 600 mm/yr) in tropical climates within 10^{o} of the equator. The palm bears its fruit in bunches (Fig.1) varying in weight from 10 to 40 kg. The individual fruit, (Fig. 2) ranging from 6 to 20 gm, are made up of an outer skin (the exocarp), a pulp (mesocarp) containing the palm oil in a fibrous matrix; a central nut consisting of a shell (endocarp); and the kernel, which itself contains an oil, quite different to palm oil, resembling coconut oil.

Diagram 1: Structure of the palm fruit

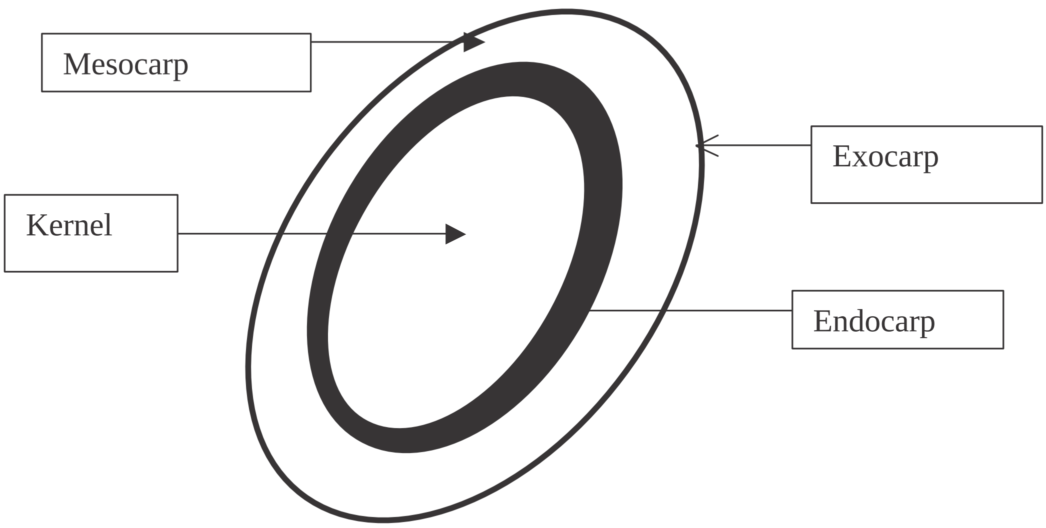


Fig. 1. Fresh fruit bunch (ffb)

Fig. 2. Fresh fruit (on the left is a cut fruit)

The wild oil palm groves of Central and West Africa consists mainly of a thick-shelled variety with a thin mesocarp, called Dura. Breeding work, particularly crosses between Dura and a shell-less variety (Pisifera), have led to the development of a hybrid with a much thicker mesocarp and a thinner shell, termed Tenera. All breeding and planting programs now use this latter type, the fruits of which have a much higher content of palm oil than the native Dura.

The extensive development of oil palm industries in many countries in the tropics has been motivated by its extremely high potential productivity. The oil palm gives the highest yield of oil per unit area compared to any other crop and produces two distinct oils – palm oil and palm kernel oil – both of which are important in world trade.

Modern high-yielding varieties developed by breeding programs, under ideal climatic conditions and good management, are capable of producing in excess of 20 tonnes of bunches/ha/yr, with palm oil in bunch content of 25 percent. This is equivalent to a yield of 5 tonnes oil/ha/yr (excluding the palm kernel oil), which far outstrips any other source of edible oil.

Ideal composition of palm fruit bunch

Bunch weight	23-27 kg
Fruit/bunch	60-65 %
Oil/bunch	21-23 %
Kernel/bunch	5-7 %
Mesocarp/bunch	44-46 %
Mesocarp/fruit	71-76 %
Kernel/fruit	21-22
Shell/fruit	10-11

However, such high yields are rarely achieved in practice because climatic conditions are usually less than ideal. Rainfall is erratic in Central and West Africa and hence the tree suffer water-related stresses. The management of costly inputs of labour, imported fertilizers, pesticides and harvesting machinery, is also a difficulty that hampers the yield of plantations.

2.1.1 Early trading in palm products

International trade in palm oil began at the turn of the nineteenth century, while that of palm kernels developed only after 1832. Palm oil became the principal cargo for slave ships after abolition of the slave trade. The establishment of trade in palm oil from West Africa was mainly the result of the Industrial Revolution in Europe. As people in Europe began to take sanitation and hygiene seriously, demand for soap increased, resulting in the demand for vegetable oil suitable for soap manufacture and other technical uses. Tinplating required technical oil for which palm oil was found suitable. In the early 1870s exports of palm oil from the Niger Delta were 25 000 to 30 000 tonnes per annum and by 1911 the British West African territories exported 87 000 tonnes.

The export of palm kernels also began in 1832 and by 1911 British West Africa alone exported 157 000 tonnes of which about 75 percent came from Nigeria. Nigeria was the largest exporter until 1934 when the country was surpassed by Malaysia.

Africa led the world in production and export of palm oil throughout the first half of the 20th century, led by Nigeria and Zaire. By 1966, however, Malaysia and Indonesia had surpassed Africa's total palm oil production. According to *Oil Palm Review*, published by the Tropical Development and Research Institute in the United Kingdom, over 3 million tonnes of palm oil was produced by Malaysia alone in 1983, compared with a total of about 1.3 million tonnes of African production.

This publication does not intend to discuss the factors leading to the spectacular performance of Indonesia and Malaysia. However in these countries solid research and development has been undertaken backed by a conscious desire to implement research findings. The plantation development culture acquired from long cultivation and processing of latex rubber was a good foundation on which to introduce the large-scale plantation cultivation of palm oil. Mastery of technology and rapid mechanisation, together with government support to the industry as a systematic and strategic industrial development policy, facilitated private sector investment in this sector. These factors as well as many others have all played a part in the development of the Far East's rise to prominence in the oil palm industry.

2.2 Oil palm farm systems in Africa

The primary unit of production of the palm oil industry is the farm where the oil palm tree is cultivated to produce palm fruits. There are also wild groves of oil palm. The farm units are of different sizes and may be classified as small, medium, and large-scale estates.

The wild groves, as the name implies, grow untended in the forest. They are found in clusters and are mainly the result of natural seed dispersal. Dura, the main variety found in the groves, for decades has been the source of palm oil – well before modern methods of oil palm cultivation were introduced to Africa in the second quarter of the 20th century.

The other varieties are Pisifera and Tenera, which is a hybrid variety obtained by crossing Dura and Pisifera. The Dura has a large nut with a thick shell and thin mesocarp. The Pisifera is a small fruit with no shell. By crossing the Dura with Pisifera a fruit is obtained with a thick mesocarp containing much more oil and fat (chemically saturated oil) than either of its parents. The Tenera nut is small and is easily shelled to release the palm kernel. The Tenera palm kernel is smaller than the Dura kernel although the Tenera bunch is much larger than Dura. In all, the Tenera is a much better variety for industrial and economic purposes.

Unfortunately, traditional farmers in Africa have not embraced the Tenera because consumers complained that the palm oil produced from the variety was too fatty. This means that when the oil cools to ambient temperature it 'goes to sleep' or solidifies instead of remaining fluid and red. The oil did not have the right taste as oil or as a soup base. Extension officers failed to position the Tenera as high-yielding industrial purpose oil, as opposed to oil for home cooking. The negative perception of Tenera led to its slow adoption and the failure of Africa to maintain its lead in palm oil production.

2.2.1 Small-scale farms

Plantation farming is a new phenomenon to West African culture. In most parts of Africa the farm culture is basically subsistence. The family cultivates a small plot for their food needs and interplant tree crops. After three years or more the tree crop takes over the plot and the farmer moves to another. The new plot may be acquired from the Chief in a location far removed from the old plot. Farm-holdings are therefore small and scattered. The land tenure system does not permit large-scale farming unless the government steps in to acquire the land for public use. Thus it is difficult to think of one family owning a large contiguous estate suitable for plantation farming.

A small-scale palm oil farm may cover 7.5 hectares. The farm's production of fruits may be processed by the farmer, using the traditional method of palm oil extraction, or sold to other processors. During the lean season the farmer sells to the small-scale processors at prices higher than those offered to the larger mills. The small-scale farms are normally well maintained even though they may not adopt modern agronomic practices such as application of fertilizer, cover cropping, etc. to improve soil fertility and yields.

2.2.2 Medium-scale farms

The medium-scale farm ranges from 10 to 500 hectares. This type of farm normally uses modern agronomic practices such as plant spacing, cover cropping, fertilization, ring weeding, pruning, etc. Some farmers in this category own processing facilities and therefore use their own output as well as buying from neighbours. Those who do not own mills face marketing problems during the peak season when fruit is abundant and processors do not have to forage for raw materials.

Because the fruits are perishable and lose weight once harvested, farmers need prompt payment and evacuation of their fruits. If the roads are impassable they may suffer great loss of produce and income making it difficult for these farmers to finance their operations. As a result a number of farmers in this category are unable to adequately maintain their farms, resulting in decreased output from year to year.

2.2.3 Large-scale farms

Large-scale farms cover an area in excess of 500 hectares. These are state owned enterprises which were established to meet the internal consumption needs of the country and provide a surplus for export. The estates are well run and maintained. They employ the best farming techniques and employ highly skilled professionals to work their operations. Unfortunately they are always considered intruders in the communities where they operate, simply because they employ people who are not natives of the immediate catchment area.

Most estates are being privatised or sold to private interests in an effort to wean the respective governments from directly engaging in competitive businesses. Most estates had nucleus farms with out-growers and private smallholders supplying raw palm fruit to the central processing factory. The processing facilities were generally in the large-scale category.

Because of privatization exercises some large-scale processing operations have closed, leaving plantation output to be sold to small-scale processors. It is not unusual today to find many small-scale processing operations exploiting the splitting up of a plantation estate. The Republic of Benin, Cameroon and Ghana abound with examples of this type of take-over by small-scale operators.

2.3 Principles of preservation and processing methods

The general principles of preservation include:

- destruction of enzymes (a complex organic substance which in solution produces fermentation and chemical changes in other substances apparently without undergoing any change itself) in the raw material and contaminating micro-organisms by heat (sterilization) during processing;
- elimination of as much water as possible from the oil to prevent microbial growth (bacterial activity, or disease-causing germs) during storage. The oil therefore has a long shelf life due to its low moisture content.
- Proper packaging and storage of the extracted oil to slow down chemical deterioration (rancidity).

The method used to extract vegetable oil depends on the type of raw material available. Raw materials may be grouped according to the part of the plant that contains the fat or oil (seed, bean, nut or fruit). The main difference in raw materials is the moisture content. Raw materials with low moisture content include seeds and beans and some nuts, which are dried on harvest. Palm fruit, olive fruits and some coconuts are processed wet.

Only seeds, nuts and fruits that contain considerable amounts of edible oil are used for small-scale oil extraction. Other types (for example maize) may contain edible oil, but the quantities are too small for economic processing on a small-scale. However, not all oil-rich seeds and fruits have edible oil; some contain toxins (poisons, usually of bacterial origin) or have unpleasant flavours; these are used only for varnishes, paints, etc. Others, (for example castor oil) need very careful processing to make them safe for use as medicines. These are not suitable for small-scale processing.

Palm fruit contains about 56 percent oil (25 percent on a fresh fruit bunch basis) which is edible with no known toxins. It is thus suitable for small-scale processing.

3. PALM OIL PROCESSING

3. 1 General processing description

Research and development work in many disciplines – biochemistry, chemical and mechanical engineering – and the establishment of plantations, which provided the opportunity for large-scale fully mechanised processing, resulted in the evolution of a sequence of processing steps designed to extract, from a harvested oil palm bunch, a high yield of a product of acceptable quality for the international edible oil trade. The oil winning process, in summary, involves the reception of fresh fruit bunches from the plantations, sterilizing and threshing of the bunches to free the palm fruit, mashing the fruit and pressing out the crude palm oil. The crude oil is further treated to purify and dry it for storage and export.

Large-scale plants, featuring all stages required to produce palm oil to international standards, are generally handling from 3 to 60 tonnes of FFB/hr. The large installations have mechanical handling systems (bucket and screw conveyers, pumps and pipelines) and operate continuously, depending on the availability of FFB. Boilers, fuelled by fibre and shell, produce superheated steam, used to generate electricity through turbine generators. The lower pressure steam from the turbine is used for heating purposes throughout the factory. Most processing operations are automatically controlled and routine sampling and analysis by process control laboratories ensure smooth, efficient operation. Although such large installations are capital intensive, extraction rates of 23 - 24 percent palm oil per bunch can be achieved from good quality Tenera.

Conversion of crude palm oil to refined oil involves removal of the products of hydrolysis and oxidation, colour and flavour. After refining, the oil may be separated (fractionated) into liquid and solid phases by thermo-mechanical means (controlled cooling, crystallization, and filtering), and the liquid fraction (olein) is used extensively as a liquid cooking oil in tropical climates, competing successfully with the more expensive groundnut, corn, and sunflower oils.

Extraction of oil from the palm kernels is generally separate from palm oil extraction, and will often be carried out in mills that process other oilseeds (such as groundnuts, rapeseed, cottonseed, shea nuts or copra). The stages in this process comprise grinding the kernels into small particles, heating (cooking), and extracting the oil using an oilseed expeller or petroleum-derived solvent. The oil then requires clarification in a filter press or by sedimentation. Extraction is a well-established industry, with large numbers of international manufacturers able to offer equipment that can process from 10 kg to several tonnes per hour.

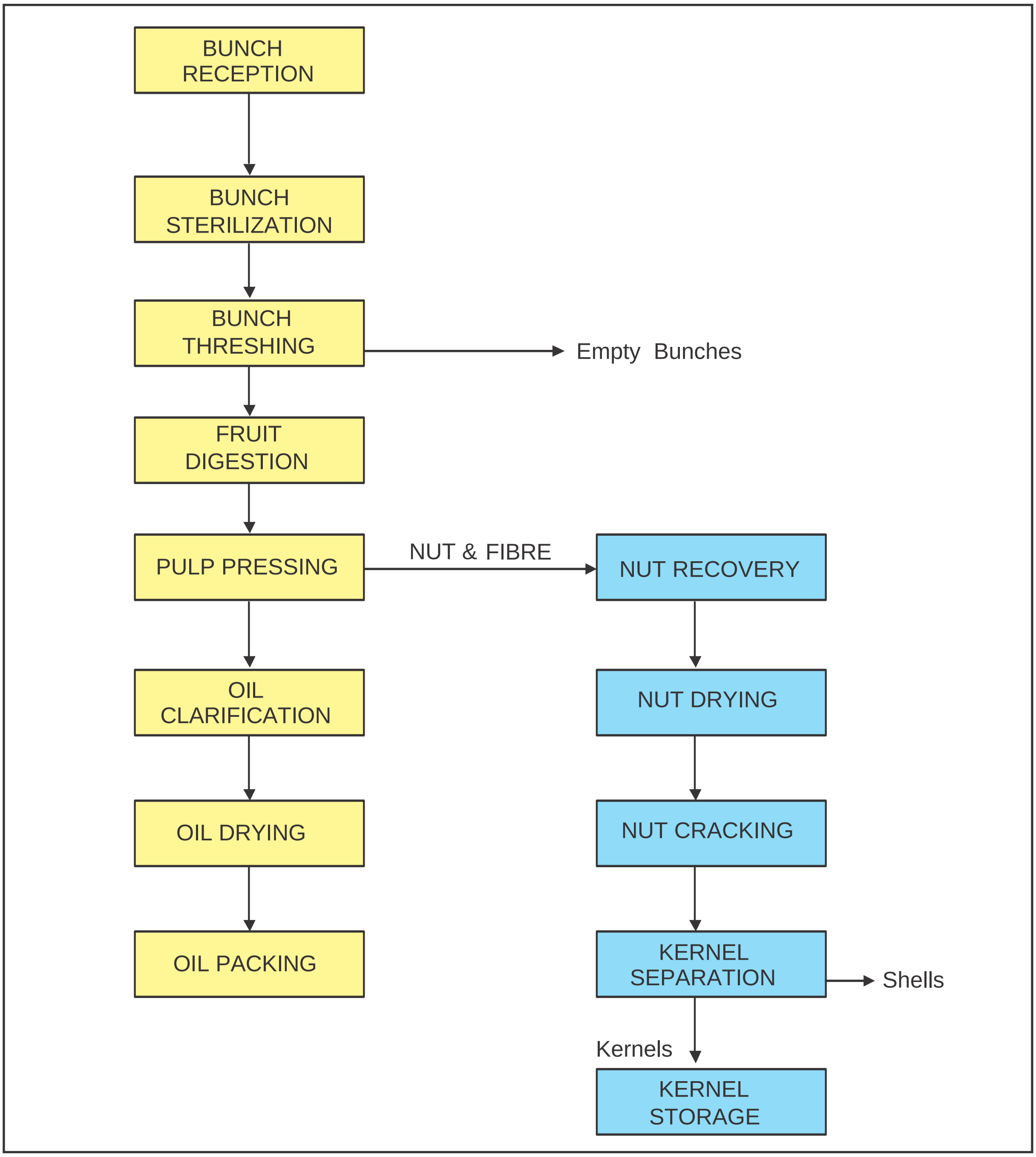
Alongside the development of these large-scale fully mechanised oil palm mills and their installation in plantations supplying the international edible oil refining industry, small-scale village and artisanal processing has continued in Africa. Ventures range in throughput from a few hundred kilograms up to 8 tonnes FFB per day and supply crude oil to the domestic market.

Efforts to mechanise and improve traditional manual procedures have been undertaken by research bodies, development agencies, and private sector engineering companies, but these activities have been piecemeal and uncoordinated. They have generally concentrated on removing the tedium and drudgery from the mashing or pounding stage (digestion), and improving the efficiency of oil extraction. Small mechanical, motorised digesters (mainly scaled-down but unheated versions of the large-scale units described above), have been developed in most oil palm cultivating African countries.

Palm oil processors of all sizes go through these unit operational stages. They differ in the level of mechanisation of each unit operation and the interconnecting materials transfer mechanisms that make the system batch or continuous. The scale of operations differs at the level of process and product quality control that may be achieved by the method of mechanisation adopted. The technical terms referred to in the diagram above will be described later.

The general flow diagram is as follows:

PALM OIL PROCESSING UNIT OPERATIONS



Harvesting technique and handling effects

In the early stages of fruit formation, the oil content of the fruit is very low. As the fruit approaches maturity the formation of oil increases rapidly to about 50 percent of mesocarp weigh. In a fresh ripe, un-bruised fruit the free fatty acid (FFA) content of the oil is below 0.3 percent. However, in the ripe fruit the exocarp becomes soft and is more easily attacked by lipolytic enzymes, especially at the base when the fruit becomes detached from the bunch. The enzymatic attack results in an increase in the FFA of the oil through hydrolysis. Research has shown that if the fruit is bruised, the FFA in the damaged part of the fruit increases rapidly to 60 percent in an hour. There is therefore great variation in the composition and quality within the bunch, depending on how much the bunch has been bruised.

Harvesting involves the cutting of the bunch from the tree and allowing it to fall to the ground by gravity. Fruits may be damaged in the process of pruning palm fronds to expose the bunch base to facilitate bunch cutting. As the bunch (weighing about 25 kg) falls to the ground the impact bruises the fruit. During loading and unloading of bunches into and out of transport containers there are further opportunities for the fruit to be bruised.

In Africa most bunches are conveyed to the processing site in baskets carried on the head. To dismount the load, the tendency is to dump contents of the basket onto the ground. This results in more bruises. Sometimes trucks and push carts, unable to set bunches down gently, convey the cargo from the villages to the processing site. Again, tumbling the fruit bunches from the carriers is rough, resulting in bruising of the soft exocarp. In any case care should be exercised in handling the fruit to avoid excessive bruising.

One answer to the many ways in which harvesting, transportation and handling of bunches can cause fruit to be damaged is to process the fruit as early as possible after harvest, say within 48 hours. However the author believes it is better to leave the fruit to ferment for a few days before processing. Connoisseurs of good edible palm oil know that the increased FFA only adds ‘bite’ to the oil flavour. At worst, the high FFA content oil has good laxative effects. The free fatty acid content is not a quality issue for those who consume the crude oil directly, although it is for oil refiners, who have a problem with neutralization of high FFA content palm oil.

3.1.1 Bunch reception

Fresh fruit arrives from the field as bunches or loose fruit. The fresh fruit is normally emptied into wooden boxes suitable for weighing on a scale so that quantities of fruit arriving at the processing site may be checked. Large installations use weighbridges to weigh materials in trucks.

The quality standard achieved is initially dependent on the quality of bunches arriving at the mill. The mill cannot improve upon this quality but can prevent or minimise further deterioration.

The field factors that affect the composition and final quality of palm oil are genetic, age of the tree, agronomic, environmental, harvesting technique, handling and transport. Many of these factors are beyond the control of a small-scale processor. Perhaps some control may be exercised over harvesting technique as well as post-harvest transport and handling.

3.1.2 Threshing (removal of fruit from the bunches)

The fresh fruit bunch consists of fruit embedded in spikelets growing on a main stem. Manual threshing is achieved by cutting the fruit-laden spikelets from the bunch stem with an axe or machete and then separating the fruit from the spikelets by hand. Children and the elderly in the village earn income as casual labourers performing this activity at the factory site.

In a mechanised system a rotating drum or fixed drum equipped with rotary beater bars detach the fruit from the bunch, leaving the spikelets on the stem (Fig. 3).

Most small-scale processors do not have the capacity to generate steam for sterilization. Therefore, the threshed fruits are cooked in water. Whole bunches which include spikelets absorb a lot of water in the cooking process. High-pressure steam is more effective in heating bunches without losing much water. Therefore, most small-scale operations thresh bunches before the fruits are cooked, while high-pressure sterilization systems thresh bunches after heating to loosen the fruits.

Small-scale operators use the bunch waste (empty bunches) as cooking fuel. In larger mills the bunch waste is incinerated and the ash, a rich source of potassium, is returned to the plantation as fertilizer.

3.1.3 Sterilization of bunches

Sterilization or cooking means the use of high-temperature wet-heat treatment of loose fruit. Cooking normally uses hot water; sterilization uses pressurized steam. The cooking action serves several purposes.

- Heat treatment destroys oil-splitting enzymes and arrests hydrolysis and autoxidation.

- For large-scale installations, where bunches are cooked whole, the wet heat weakens the fruit stem and makes it easy to remove the fruit from bunches on shaking or tumbling in the threshing machine.

- Heat helps to solidify proteins in which the oil-bearing cells are microscopically dispersed. The protein solidification (coagulation) allows the oil-bearing cells to come together and flow more easily on application of pressure.

- Fruit cooking weakens the pulp structure, softening it and making it easier to detach the fibrous material and its contents during the digestion process. The high heat is enough to partially disrupt the oil-containing cells in the mesocarp and permits oil to be released more readily.

- The moisture introduced by the steam acts chemically to break down gums and resins. The gums and resins cause the oil to foam during frying. Some of the gums and resins are soluble in water. Others can be made soluble in water, when broken down by wet steam (hydrolysis), so that they can be removed during oil clarification. Starches present in the fruit are hydrolyzed and removed in this way.

Fig. 3 Bunch thresher (Centre de Formation Technique Steinmetz-Benin)

Fig. 4 Fruit sterilizer (Centre de Formation Technique Steinmetz-Benin)

- When high-pressure steam is used for sterilization, the heat causes the moisture in the nuts to expand. When the pressure is reduced the contraction of the nut leads to the detachment of the kernel from the shell wall, thus loosening the kernels within their shells. The detachment of the kernel from the shell wall greatly facilitates later nut cracking operations. From the foregoing, it is obvious that sterilization (cooking) is one of the most important operations in oil processing, ensuring the success of several other phases.

- However, during sterilization it is important to ensure evacuation of air from the sterilizer. Air not only acts as a barrier to heat transfer, but oil oxidation increases considerably at high temperatures; hence oxidation risks are high during sterilization. Over-sterilization can also lead to poor bleach ability of the resultant oil. Sterilization is also the chief factor responsible for the discolouration of palm kernels, leading to poor bleach ability of the extracted oil and reduction of the protein value of the press cake.

3.1.4 Digestion of the fruit

Digestion is the process of releasing the palm oil in the fruit through the rupture or breaking down of the oil-bearing cells. The digester commonly used consists of a steam-heated cylindrical vessel fitted with a central rotating shaft carrying a number of beater (stirring) arms. Through the action of the rotating beater arms the fruit is pounded. Pounding, or digesting the fruit at high temperature, helps to reduce the viscosity of the oil, destroys the fruits' outer covering (exocarp), and completes the disruption of the oil cells already begun in the sterilization phase. Unfortunately, for reasons related to cost and maintenance, most small-scale digesters do not have the heat insulation and steam injections that help to maintain their contents at elevated temperatures during this operation.

Contamination from iron is greatest during digestion when the highest rate of metal wear is encountered in the milling process. Iron contamination increases the risk of oil oxidation and the onset of oil rancidity.

3.1.5 Pressing (Extracting the palm oil)

There are two distinct methods of extracting oil from the digested material. One system uses mechanical presses and is called the 'dry' method. The other called the 'wet' method uses hot water to leach out the oil.

In the 'dry' method the objective of the extraction stage is to squeeze the oil out of a mixture of oil, moisture, fibre and nuts by applying mechanical pressure on the digested mash. There are a large number of different types of presses but the principle of operation is similar for each. The presses may be designed for batch (small amounts of material operated upon for a time period) or continuous operations.

3.1.5.1 Batch presses

In batch operations, material is placed in a heavy metal 'cage' and a metal plunger is used to press the material. The main differences in batch press designs are as follows: a) the method used to move the plunger and apply the pressure; b) the amount of pressure in the press; and c) the size of the cage.

The plunger can be moved manually or by a motor. The motorised method is faster but more expensive.

Different designs use either a screw thread (spindle press) (Fig. 4, 5, 6) or a hydraulic system (hydraulic press) (Fig. 7, 8, 9) to move the plunger. Higher pressures may be attained using the hydraulic system but care should be taken to ensure that poisonous hydraulic fluid does not contact the oil or raw material. Hydraulic fluid can absorb moisture from the air and lose its effectiveness and the plungers wear out and need frequent replacement. Spindle press screw threads are made from hard steel and held by softer steel nuts so that the nuts wear out faster than the screw. These are easier and cheaper to replace than the screw.

The size of the cage varies from 5 kg to 30 kg with an average size of 15 kg. The pressure should be increased gradually to allow time for the oil to escape. If the depth of material is too great, oil will be trapped in the centre. To prevent this, heavy ‘layer plates’ can be inserted into the raw material. The production rate of batch presses depends on the size of the cage and the time needed to fill, press and empty each batch.

Hydraulic presses are faster than spindle screw types and powered presses are faster than manual types. Some types of manual press require considerable effort to operate and do not alleviate drudgery.

3.1.5.2 Continuous systems

The early centrifuges and hydraulic presses have now given way to specially designed screw-presses similar to those used for other oilseeds. These consist of a cylindrical perforated cage through which runs a closely fitting screw. Digested fruit is continuously conveyed through the cage towards an outlet restricted by a cone, which creates the pressure to expel the oil through the cage perforations (drilled holes). Oil-bearing cells that are not ruptured in the digester will remain unopened if a hydraulic or centrifugal extraction system is employed. Screw presses, due to the turbulence and kneading action exerted on the fruit mass in the press cage, can effectively break open the unopened oil cells and release more oil. These presses act as an additional digester and are efficient in oil extraction.

Moderate metal wear occurs during the pressing operation, creating a source of iron contamination. The rate of wear depends on the type of press, method of pressing, nut-to-fibre ratio, etc. High pressing pressures are reported to have an adverse effect on the bleach ability and oxidative conservation of the extracted oil.

3.1.6 Clarification and drying of oil

The main point of clarification is to separate the oil from its entrained impurities. The fluid coming out of the press is a mixture of palm oil, water, cell debris, fibrous material and ‘non-oily solids’. Because of the non-oily solids the mixture is very thick (viscous). Hot water is therefore added to the press output mixture to thin it. The dilution (addition of water) provides a barrier causing the heavy solids to fall to the bottom of the container while the lighter oil droplets flow through the watery mixture to the top when heat is applied to break the emulsion (oil suspended in water with the aid of gums and resins). Water is added in a ratio of 3:1.

The diluted mixture is passed through a screen to remove coarse fibre. The screened mixture is boiled from one or two hours and then allowed to settle by gravity in the large

Fig. 5 Spindle press (Luapula, Zambia)

Fig. 6 Spindle press (Luapula, Zambia)

Fig. 7 Another model of spindle press (Nova Technologies Ltd, Nigeria)

Fig. 8 Hydraulic press (manual)

tank so that the palm oil, being lighter than water, will separate and rise to the top. The clear oil is decanted into a reception tank. This clarified oil still contains traces of water and dirt. To prevent increasing FFA through autocatalytic hydrolysis of the oil, the moisture content of the oil must be reduced to 0.15 to 0.25 percent. Re-heating the decanted oil in a cooking pot and carefully skimming off the dried oil from any engrained dirt removes any residual moisture. Continuous clarifiers consist of three compartments to treat the crude mixture, dry decanted oil and hold finished oil in an outer shell as a heat exchanger. (Fig. 10, 11, 12)

The wastewater from the clarifier is drained off into nearby sludge pits dug for the purpose. No further treatment of the sludge is undertaken in small mills. The accumulated sludge is often collected in buckets and used to kill weeds in the processing area.

3.1.7 Oil storage

In large-scale mills the purified and dried oil is transferred to a tank for storage prior to dispatch from the mill. Since the rate of oxidation of the oil increases with the temperature of storage the oil is normally maintained around 50°C, using hot water or low-pressure steam-heating coils, to prevent solidification and fractionation. Iron contamination from the storage tank may occur if the tank is not lined with a suitable protective coating.

Small-scale mills simply pack the dried oil in used petroleum oil drums or plastic drums and store the drums at ambient temperature.

3.1.8 Kernel recovery

The residue from the press consists of a mixture of fibre and palm nuts. The nuts are separated from the fibre by hand in the small-scale operations. The sorted fibre is covered and allowed to heat, using its own internal exothermic reactions, for about two or three days. The fibre is then pressed in spindle presses to recover a second grade (technical) oil that is used normally in soap-making. The nuts are usually dried and sold to other operators who process them into palm kernel oil. The sorting operation is usually reserved for the youth and elders in the village in a deliberate effort to help them earn some income.

Large-scale mills use the recovered fibre and nutshells to fire the steam boilers. The super-heated steam is then used to drive turbines to generate electricity for the mill. For this reason it makes economic sense to recover the fibre and to shell the palm nuts. In the large-scale kernel recovery process, the nuts contained in the press cake are separated from the fibre in a depericarper. They are then dried and cracked in centrifugal crackers to release the kernels (Fig. 13, 14, 15, 16). The kernels are normally separated from the shells using a combination of winnowing and hydrocyclones. The kernels are then dried in silos to a moisture content of about 7 percent before packing.

During the nut cracking process some of the kernels are broken. The rate of FFA increase is much faster in broken kernels than in whole kernels. Breakage of kernels should therefore be kept as low as possible, given other processing considerations.

Fig.9 Manual vertical press (O.P.C., Cameroon)

Fig.10 Motorised horizontal screw press (Centre Songhai, Benin)

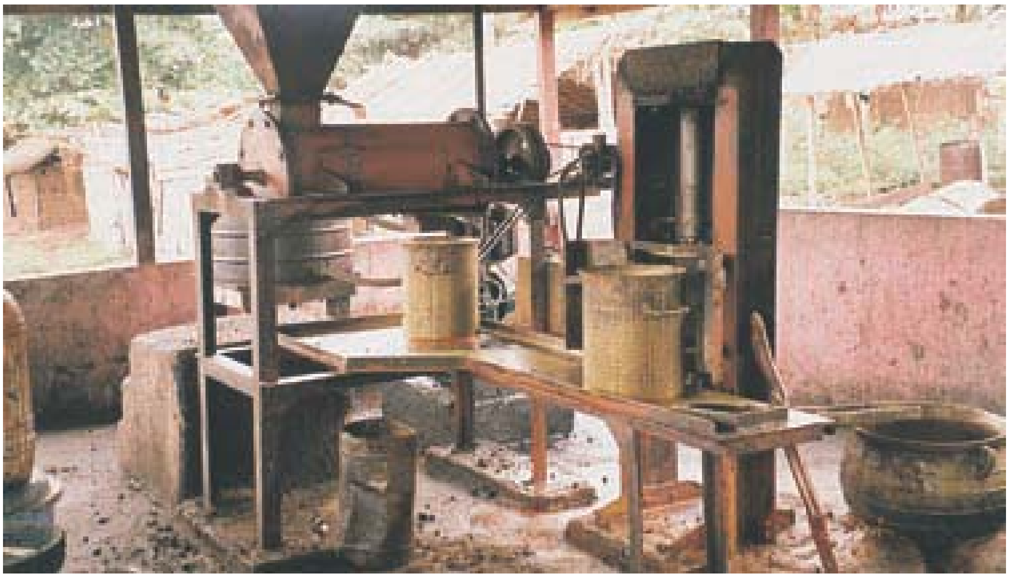


Fig. 11 Combined digester and motorised hydraulic press (Technoserve/Cort Engineering, Ghana)

Fig. 12 Flushing extractor (Cort Engineering Services, Ghana)

Summary of unit operations

Unit operation		Purpose
1.	Fruit fermentation	To loosen fruit base from spikelets and to allow ripening processes to abate
2.	Bunch chopping	To facilitate manual removal of fruit
3.	Fruit sorting	To remove and sort fruit from spikelets
4.	Fruit boiling	To sterilize and stop enzymatic spoilage, coagulate protein and expose microscopic oil cells
5	Fruit digestion	To rupture oil-bearing cells to allow oil flow during extraction while separating fibre from nuts
6	Mash pressing	To release fluid palm oil using applied pressure on ruptured cellular contents
7	Oil purification	To boil mixture of oil and water to remove water-soluble gums and resins in the oil, dry decanted oil by further heating
8	Fibre-nut separation	To separate de-oiled fibre from palm nuts.
9	Second Pressing	To recover residual oil for use as soap stock
10	Nut drying	To sun dry nuts for later cracking

Fig. 13. Clarifier tank (O.P.C., Cameroon)

Fig. 14 Clarifier tank (Nova Technologies Ltd, Nigeria)

Fig. 15 Oil filter (Faith Engineering Workshop, Nigeria)

Fig. 16 Palm nut cracker (AGRICO, Ghana)

Fig. 17 Palm nut cracker (NOVA, Technologies, Nigeria)

Fig. 18 Palm nut cracker
(Ogunoroke Steele Construction Works Ltd, Nigeria)

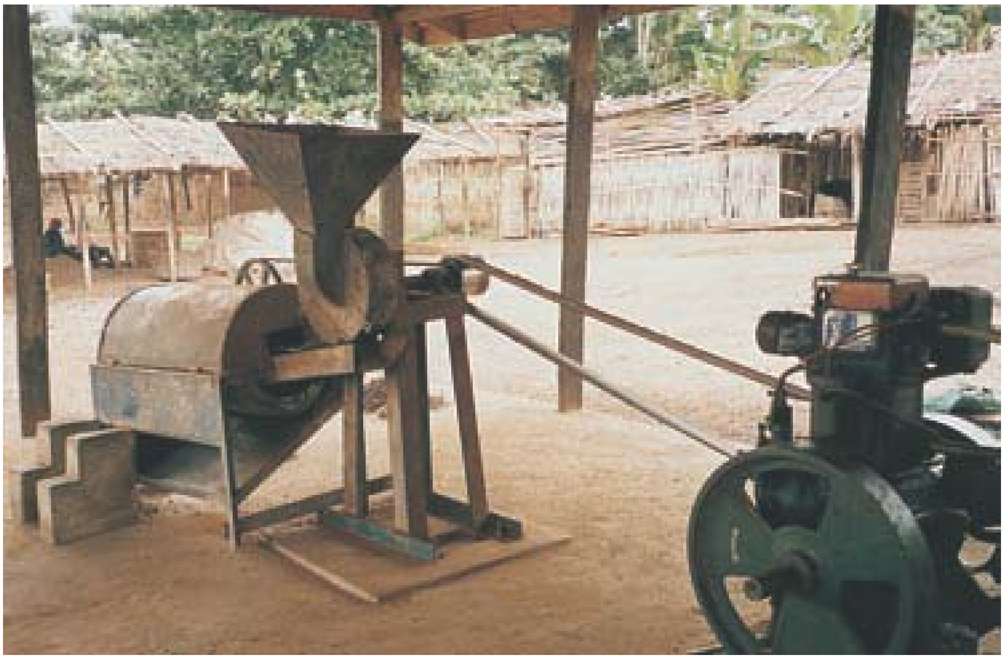


Fig. 19 Palm nut cracker combined with Kernel/Shell separator
(Hormeku Engineering works, Ghana)

3.2 Process equipment design and selection criteria

In designing equipment for small-scale oil extraction one of the key factors to consider is the quality required. 'Quality' is entirely subjective and depends on the demands of the ultimate consumer. For the edible oil refining industry the most important quality criteria for crude oil are:

- low content of free fatty acids (which are costly to remove during oil refining);
- low content of products of oxidation (which generate off-flavours);
- readily removed colour.

The most critical stages in the processing sequence for a processor seeking to satisfy these criteria are: bunch sterilization as soon as possible after harvest; and effective clarification and drying of the crude oil after extraction.

By contrast, for the domestic consumer of crude palm oil, flavour is the primary quality factor. This is boosted by the fermentation that takes place within the fruit when the bunches are allowed to rest for three or more days after harvesting. Thus sterilization immediately after harvesting is not a crucial consideration. Herbs and spices for flavour are introduced during the oil-drying phase of operations to mask off-flavours. Therefore rigid process control during oil clarification need not be prescribed or incorporated in the design.

The free fatty acids and the trace tocopherols contained in the crude palm oil after natural fermentation also have a laxative effect, which is desirable for African consumers for whom synthetic substitutes are a luxury. The acidity imparts a 'bite' to the oil which some consumers prefer. Thus the quality requirements of one market, leading to certain processing imperatives, may conflict with those of another market.

The traditional manual methods are normally referred to as 'low technology' production. The mechanised units are likewise referred to as 'intermediate technology' production.

The village traditional method of extracting palm oil involves washing pounded fruit mash in warm water and hand squeezing to separate fibre and nuts from the oil/water mixture. A colander, basket or a vessel with fine perforated holes in the bottom is used to filter out fibre and nuts. The wet mixture is then put on the fire and brought to a vigorous boil. After about one or two hours, depending on the volume of material being boiled, the firewood is taken out and the boiled mixture allowed to cool. Herbs may be added to the mixture at this point just before reducing the heat. On cooling to around blood temperature, a calabash or shallow bowl is used to skim off the palm oil. Because of the large quantities of water used in washing the pulp this is called the 'wet' method.

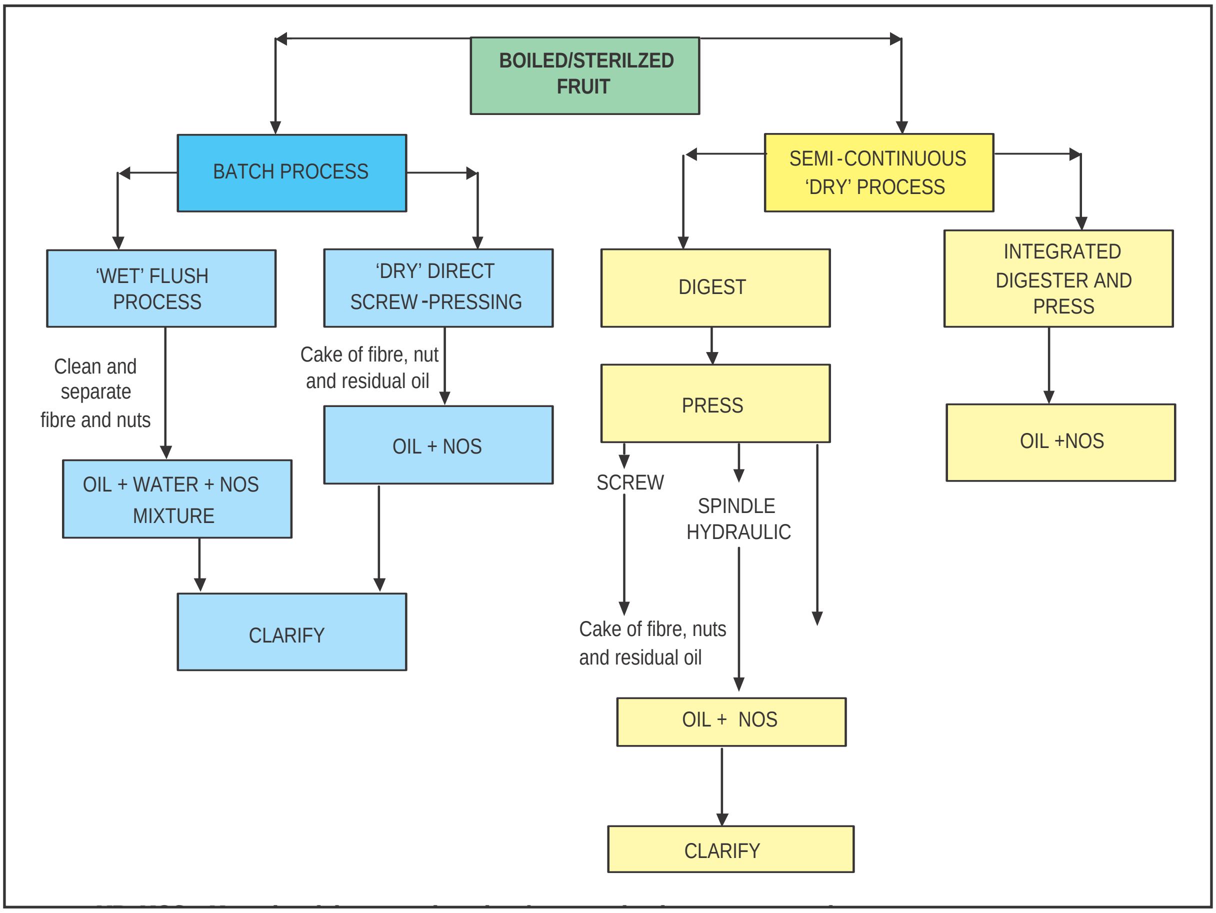
A mechanical improvement, based on the traditional wet method process, is achieved by using a vertical digester with perforated bottom plate (to discharge the aqueous phase) and a side chute for discharging the solid phase components. The arrangement combines digestion, pressing and hot water dilution into one mechanical unit operation.

The 'dry' method uses a digester to pound the boiled fruit, which is a considerable laboursaving device. The oil in the digested or pounded pulp is separated in a press that may be manual or mechanical. Motorised mechanical presses are preferred, whether hydraulic or screw type.

Most medium- and large-scale processing operations adopt the 'dry' method of oil extraction. This is because the fibre and nut shells may immediately used to fire the boiler to generate steam for sterilization and other operations, including electricity generation. If the huge volumes of fibre and shells are not used as boiler fuel, serious environmental pollution problems may result. Too much water in the fibre increases the amount and cost of steam required to dry the fibre. Hence the preference for the dry method in plants handling more than six tonnes FFB per hour.

Processing machinery manufacturers tend to make machines to fit individual processing operations. However, recent developments have been toward the manufacture of integrated machines, combining several process operations such as digestion, pressing and fibre/nut separation into one assembly. It is found that these machines fit into two key process groupings: batch and semi-continuous processes.

Schematic of processing models and associated machinery



NB: NOS = Non-oily solids entrained in oil such as coagulated protein, gums and resins, etc.

The extraction of palm oil from boiled palm fruit can be accomplished by handling successive batches of materials or continuously feeding material to the machines.

3.2.1 Batch systems

The batch systems work directly on successive loads of boiled fruit to extract oil in one operation for clarification. The ‘wet’ method uses a vertical digester (Fig. 11) with a perforated bottom plate to pound a batch of fruit and then flush out the oil and other non-oil solids from the mashed pulp with hot water. The direct screw-press is designed to pound a batch of boiled fruit in the entry section of the machine while exerting pressure on the mashed pulp in another section to expel the palm oil in one operation.

The advantage of the wet system is that it is simple and completely leaches all oil and non-oily solid substances that can be carried in the fluid stream out of the digested mash to give clean and separated nuts and fibre. The aqueous effluent from the vertical digester goes directly to the clarification stage of processing. The amount of water needed to flush the pulp is normally the same as that required for diluting the viscous oil that comes from the mechanical press in preparation for clarification. An inexperienced operator may use too much hot water to leach out the oil and thus consume unnecessary wood fuel.

The ‘wet’ method yield of palm oil is severely reduced when the wash water is cold. In the course of digesting the fruit mash, in the presence of water, there is increased tendency to form an oil/water emulsion that is difficult to separate from the fibre mass. The emulsified oil loss in the fibre can be substantial if care is not taken to ensure full loading of the digester. Vertical flushing digesters, requiring loading and discharging of a specific amount of material, can thus only be used in a batch operation.

3.2.2 Semi-continuous systems

Continuous systems work sequentially, with one operation feeding directly into another, related to the arrangement and timing of machine operations. Careful engineering of unit operations is required to minimise discontinuities in the feeding of one stage into another. Otherwise some machines have to be stopped periodically for other stations to catch up. When there are discontinuities in the flow of materials between process stations the operations are known as semi-continuous. The dry extraction systems with separate digestion and pressing stations are usually semi-continuous.

Also when digestion and pressing stations are combined into an integrated unit and there is discontinuous feeding of boiled fruit to the digester inlet the operation is termed “semi-continuous”. Once operations have been integrated to attain full continuity the capital investment capacity of small-scale operators has been surpassed, because both machinery and working capital for raw material increases greatly with the increased level of mechanisation.

The dry systems do not need much water for processing, although they have the disadvantage of leaving substantial residual oil in the press cake. The oil content of the press cake can be quite considerable (2-3 percent), depending on the type of press used and the strength of manual operators.

The efficiency with which the various presses can extract oil ranges from 60 to 70 percent for spindle presses, 80-87 percent for hydraulic presses and 75-80 percent for the Caltech screw-presses. The first-pressing oil extraction rates also range from 12 to 15 percent for the spindle-presses, 14-16 percent for hydraulic presses and 17-19 percent for the motorised screw-presses. (Rouziere, 1995)

In many instances the first press cake is then sorted to remove the nuts, and the fibre is subsequently subjected to a second pressing to obtain more oil (an additional 3 to 4 percent on FFB). The second press oil is generally of lower quality, in terms of free fatty acid content and rancidity. Such low-grade oil is used in soap-making. Some village processors undertake the traditional hot water washing of the entire press cake immediately after pressing instead of sorting fibre and second pressing.

Local manufacturers have developed a wide range of machinery and equipment for processing palm oil and palm kernel to fit any budget. All the relevant unit operational machines can be produced to various degrees of finish and quality in the Sub-Region. It is the combination of the unit operation into an affordable process chain that distinguishes the manufacturers and their supplies.

From traditional technologies that rely solely on manual labour and simple cooking utensils, raising the level of mechanization depends largely on a balance between the quantity of bunches available for processing in a given locality and the money available for investment in machines.

The first consideration should be the availability of raw materials and how to compute the processing scale. Knowing the optimum scale of operations, it is then possible to consider the type of processing techniques. The higher the technology, the more skilful operators will be required to handle the machines. These technical considerations should lead to the equipment selection and examination of the capital investments needed to acquire the necessary machines.

3.3 Plant sizing

Assume a Village Group decides to plant oil palm and establishes a program to plant a certain number of seedlings each year over a seven-year period. In the third year the first set of trees begin to bear fruit. The community wants to establish a processing mill and they call an expert. How is the estimation made of the size and type of processing unit required by the community?

Start by establishing the block of planted areas by year so the age of the trees may be determined. The oil palm tree begins to bear fruit from the third year and the yield per tree increases progressively with age until it peaks around 20 years. The yield begins to decline from year 25 through 40 when the economic life of the tree ebbs.

Table 3 describes the potential yields of palm fruit bunches (in metric tonnes) from the planted hectares per year. Estimates in Table 3 are used to calculate the expected annual yield for each annual block. For example, 8 700 seedlings planted in 1998 began to yield fruit in 2000 at the rate of 3 tonnes per hectare to give 198 tonnes for the year. By Year 7 all planted areas will be in production, at different yield rates. The estimated annual yield per planting block is calculated and then the column for the year is added to give the potential raw materials available for processing. For example, in Year 7, when all planted blocks are yielding fruit, the total is 8 919 metric tonnes (see the row designated 'TOTAL'). How the annual yield is distributed over the entire year needs to be determined in order to know which period demands the attention of processors.

The oil palm tree yield is distributed over the entire year. Most of Central and West Africa experience two rainfall seasons. The oil palm bears fruit in response to the rainfall pattern and hence there are two peak harvesting periods in these regions. Southern hemisphere tropical monsoon regions such as Malawi, Zambia and South East Asia experience only one long rainy season and therefore tend to have a single peak-harvesting season.

For Central and West Africa the annual monthly distribution pattern for produce is expected to show the following variations:

Month	**Percent yield**	**Seasonal contribution**
March	9	
April	12	
May	16	50 %
June	13	
July	8	
August	7	
September	8	34 %
October	11	
November	7	
December	5	
January	3	16
February	1	

In the peak harvesting month it is estimated that 12 to 16 percent of the annual yield is generally available for processing. The plant that is installed must be capable of processing the peak month output, which is generally estimated as 15 percent of the annual output. Conservatively, it is estimated that the plant will work two shifts during the peak season.

Table 3
Estimated annual yield per hectare (from year of planting)

Year	1	2	3	4	5	6	7	8	9	10	11	12	15	20
Estimated yield (Tonnes)	--	--	3.0	4.25	5.5	6.0	7.25	8.2	8.6	9.5	10.5	11.0	12.5	13.5

Table 4
Estimated FFB yields after planting and related plant capacity

Year/yield in metric tonnes

Hectares	1 '98	2	3	4	5	6	7	8	9	10	11	12	15	20
66	--	--	198	281	363	396	479	541	568	627	693	726	825	891
190		--	--	570	808	1 045	1 140	1 378	1 558	1 634	1 805	1 995	2 375	2 565
800			--	--	2 400	3 400	4 400	4 800	5 800	6 560	6 880	7 600	8 800	10 000
400				--	--	1 200	1 700	2 200	2 400	2 900	3 280	3 440	4 400	5 200
400					--	--	1 200	1 700	2 200	2 400	2 900	3 280	3 440	5 000
Total			198	851	3 571	6 041	8 919	10 619	12 526	14 121	15 558	17 041	19 840	23 656
Peak Month			29.7	128	536	906	1 338	1 593	1 879	2 118	2 334	2 556	2 976	3 548
Plant Capacity/hr			0.09	0.4	1.7	2.8	4.2	5.0	6.0	6.6	7.5	8.0	9.5	11.0

Source: Poku, K. Feasibility study on Malawi palm oil mill establishment

In Year 3 there is the potential of processing 198 tonnes of fresh fruit bunches. Assuming that the total quantity were to be processed in one location over a 20-day period using 8 hours in the day, we would need a processing unit that handles 186 kg per hour, or 93 kilos/hr if the choice was made to operate 16-hours per day. Table 4 shows capacity based on a 16-hour working day. For this capacity a wet type digester or the dry spindle-press operation would be recommended. By Year 5 the community would require a fully mechanised mill using motorised digesters and presses.

Before the sixth year the community would have to decide whether they want to stay in the small-scale milling category or move up to a medium-scale operation using a continuous system of machines. If the option is to stay small-scale then the community will need to place orders for additional small-scale processing modules. The new set of processing machines can be placed to run alongside the existing facility or located in another village to minimise bunch transportation costs.

The best plant size option for rural Africa is still unknown. Large-scale operations normally require high-skilled labour and management expertise. Most villages do not have such a pool of skilled labour. The villages also lack the social infrastructure such as good accommodation, schools and hospitals that would attract high-skilled labour. Thus, in order to establish a large-scale processing operation, labour needs to be imported from other parts of the country. To maintain these ‘alien’ workers and managers a provision must be made in the capital investment for housing, schools and clinics near the processing estate. Some of the schooling and medical services must be extended to the whole community or there will be resentment towards the ‘alien’ workers.

Large-scale operations also require rapid transportation of harvested bunches to the processing site, hence the need for investment in roads and civil works. The establishment of large-scale operations creates an overhead burden that is beyond the capacity of a village community.

Many of the large-scale operations established in the early 1970s have declined along with the national economies of African nations. The cost structure of these establishments has rendered the output products non-competitive on the international market.

Today decentralised small-scale processing operations are preferred in most parts of Africa.

3.4 Process technology/capital investment considerations

Once the required plant size has been determined, the next item to consider is the amount of money required to buy the necessary machinery. The more money available, the more units can be bought, to minimise the drudgery of processors.

The wide array of machinery options makes it possible for a processor to start operations with a manual spindle-press used to pound the palm fruit. Another may start with a single motorised vertical wet process digester. Further up the investment scale are those who can afford the combination horizontal digester and screw-press or combination horizontal digester and hydraulic press along with the associated sterilizers, threshers, and oil clarifiers. Another combination that is yet to be tried is the combination of a horizontal motorised screw-press in

Type of unit	Key machines	Rated capacity (kg FFB/hr)	Extraction efficiency (%)	Capital investment (US$)
Single batch unit				
Dry	Spindle	100-200	55	150-200
	Hydraulic	200-300	67-74	5 000-7 000
	Screw	250-400	77.4	1 500-6 000
Wet	Vertical digester	500-800	80-90	1 500-2 500
Dry	Motorised horizontal digester (only)	500-1000	55	2 500-3 000
Dual separate units				
Dry	Digester + Spindle presses	200-300	60-70	3 000-5 000
	Digester + hydraulic press	400-800	67-78	7 000-10 000
Semi-continuous combined units				
Dry	Motorised digester + hydraulic + spindle-press	500-850	70-87	10 000 -15 000
	Digester + screw-press	500-850	76-90	12 000-15 000

Source: Compiled from various sources

combination with a second stage vertical flushing digester for maximum palm oil extraction and fibre/nut separation.

The extraction efficiency refers to the percentage of oil that the machine can extract in relation to the total oil in the boiled fruit. The type of fruit mix (Dura/Tenera) presented for processing greatly influences the extraction efficiency of all units.

Many of the installations that use single spindle and manual hydraulic press units require manual pounding with wooden mortars and pestles, foot stomping, etc. Thus the throughput capacity of such a mill is determined by the manual pounding rate. The presses are usually not mechanised and hence the processing capacity of the press is also limited by the size of the press cage and the operator’s energy level for turning the press screw or pumping the hydraulic fluid mechanism.

Another limiting condition is the affordability of capital equipment. Where the capital equipment cost exceeds a certain value villagers will shy away from taking loans to purchase the combination of operations. The designer must bear in mind that until the rural/urban migration of village youth is reversed the villages will be mainly populated by the elderly. These elders are naturally reluctant to take up long-term loans and the local banks are reluctant to lend to a predominantly aged community group. In Ghana, for instance, capital equipment costs should be around US$10 000 to be affordable to village-based individuals or groups.

Because of the need to keep initial capital investment to a bare minimum it is imperative that unnecessary mechanised unit operations are eliminated. Work that can be done manually – without overly taxing profitability – should be, thereby taking advantage of surplus labour and creating a stream of wages and salaries in the local community. Operations that are usually associated with drudgery by processors, such as fruit digestion and oil extraction, can be mechanised. Other less strenuous tasks, such as fruit separation and fibre/nut separation, can be contracted out to elderly women and unemployed youth.

“Small-scale” does not necessarily mean a significant decrease in efficiency. It does, however, mean a reduction in working capital and operating costs. The small mills can be placed at the heart of local communities, minimising reliance on vehicular transport that is normally unavailable in rural communities, given the poor condition of road networks and other infrastructure. This increased accessibility serves to dramatically reduce fruit spoilage and consequent post-harvest losses.

Culturally, men cultivate or produce while women process and sell. Traditionally, women decide the form in which the produce is to be traded and hence determine the degree of processing they are willing to undertake. These decisions form the basis of traditional technologies upon which innovations are to be derived.

The operating philosophy for equipment innovation should therefore be an attempt to develop machinery to alleviate the drudgery of female processors while providing additional avenues for the employment of those displaced by the improved technologies, keeping some operations labour-intensive. It is therefore important to mechanise the key drudgery-alleviation equipment that can be easily handled by women.

Prime mover power is also a major consideration. Most villages do not have electricity and hence the diesel engine is the main source of power. Thus, for cost reasons there cannot be a multiplicity of these engines to drive the required unit operations. Where there is the need to drive several machines the answer could be to use diesel power to generate electricity. The cost and maintenance of this power source would eliminate most small-scale processors and communities. The power source in such instances acts as a limitation to the number of unit operations that can be mechanised and powered. Systems of pulleys and gears to drive operational machines should be actively considered when designing for village based groups.

4. TRADITIONAL TECHNIQUES AND INNOVATIONS IN SMALL-SCALE PALM OIL PROCESSING

During the course of gathering material for this publication the author visited Benin, Cameroon, Ghana and Nigeria. It was observed that a steady evolutionary development had taken place in machinery and equipment required to process palm fruit bunches to meet changing circumstances of the small-scale palm oil processing industry. These innovations have progressed from the development of individual machines to carry out particular operations to machines that combine several operations in the process.

4.1 Mechanical extraction

Pounding (digestion) and oil extraction are the most tedious and essential operations in traditional palm fruit processing; therefore early efforts concentrated on these tasks. In small-scale processing, digestion, the breaking up of the oil-bearing cells of the palm fruit's mesocarp, is the most labour intensive.

Two methods of fruit maceration common in traditional processing:

- pounding cooked/soaked fruits in large wooden or concrete mortars with a wooden pestle;
- foot trampling the cooked but cold fruits in canoes or specially constructed wooden troughs.

4.2 Direct screw-pressing

Mechanisation was introduced to Cameroon in the 1930s through the importation of Colin palm oil expellers. The Colin is a low-pressure, continuous-feed expeller made in France. It has two 6' (2 m) diameter coaxial counter-rotating screws that turn horizontally or vertically in a perforated cage. The discharge end is fitted with a backpressure cone. As the cooked palm fruit is fed into the expeller it is pushed forward by the spiral flights (worms) against the backpressure of the end cone. The oil is forced out through the perforated sides of the cage. The remaining fibre and nut are released at the end of the cage through the gap between the end cone and cage body. The ability to simultaneously de-pulp and press is a major advantage of this type of press.

Small expellers may be manually operated or motorised. These expellers have been the dominant – if not the exclusive equipment – used by small-scale palm oil processors in Cameroon.

In Ghana and Nigeria the earliest equipment introduced was the Stork manual hydraulic press. The impression was created that, for economic reasons, the only operation that needed mechanisation was oil pressing. In colonial days farm labour was cheap and easily available. Hence there was no attempt to mechanise the digestion operation. Thus, in the British colonies, early attempts at mechanisation had to focus on complementing the presses with mechanical digesters. Two types of digesters were developed: horizontal digesters based on the dry process technique; and the vertical digester, which adopts the wet process technique

In the wet system, sterilized fruits are poured into the digester. As the fruits are being macerated, hot water is continuously poured into the digester (at a regulated rate) to wash off the released oil. The resultant mixture of water and oil is filtered and then clarified.

Another attempt at mechanising the maceration process resulted in the development of the manual digester for women. This digester consists principally of a large wheel (connected to the differential system of a car axle), and a vertical shaft carrying some beater arms that rotate inside a conical shaped metal trough. The ratio of rotation of the wheel to the vertical shaft is 1:7. It takes between 12 and 15 minutes to digest a 30 kg load of fruit.

The mechanical digesters currently in use consist of a cylindrical shell and a system of beater-arms driven by a 6 hp. diesel engine through a speed reducer (where necessary). The speed reducer steps down the speed of the motor (engine) to 125 rpm - the running speed of the digester. The digester is capable of macerating over 250 kg of fruits per hour and has the singular attribute of macerating thoroughly either the Dura or Tenera fruit or a combination of both without breaking any nut.

Pressing

The traditional method of oil extraction consists of:

- steeping the pounded fruit mash in hot or cold water;
- removing fibre and nuts in small baskets and hand squeezing;
- filtering out residual fibre from the oil/water emulsion in perforated metal colanders or baskets;
- boiling and skimming palm oil from the oil/water mixture;
- drying the recovered oil.

Standing by the open fire during this operating period is not only a health hazard but is inefficient, as a lot of oil is left trapped in the mixture as an emulsion.

It was long realised that pressing is a bottleneck in small-scale palm oil processing. The process is usually conducted slowly to avoid the huge loss of oil that might result from inadequate pressing. The economic importance of this process was therefore long recognised and has received the greatest attention for mechanisation. Presses developed over the years have included models such as:

- Manual vertical screw-press
- Stork hydraulic hand press
- Motor-jack press
- Motor-jack/cantilever press
- NIFOR hydraulic hand press
- Combined screw/hydraulic hand press
- mechanical screw-press

The manual vertical screw-press, the stock hydraulic hand press and NIFOR hydraulic hand press enjoyed the highest patronage in Nigeria for a long time, even though oil loss/fibre ratio for these presses range from 18-35 percent. This should be expected as the operation of these presses depends on the strength of the operator.

In Ghana efforts to deliver a low-cost press to the smaller village processors, led the Technology Transfer Centre (of the University of Science and Technology, Kumasi) in the early seventies to come up with an inexpensive manually-operated spindle press. The presses delivered low pressures and relied on manual labour for pressure development. The throughput was about 50 kg per hour or 1.5 tonnes per day. For the really small-scale extractors in villages with small patches of oil palm farms these screw-presses gained widespread preference. Here, the traditional mortar and pestle was used to pound (digest) fruits and then the mash was taken to a press operator who extracted the oil for a fee.

The manual spindle-press was affordable and was bought by individuals and groups. In the Kusi area of the Eastern Region the use of the press was rented to the whole community. This was to signal the beginning of community-based service palm oil milling.

4.3 Hydraulic presses

AGRICO introduced the use of manually operated hydraulic presses into Ghana from India to complement the mechanical digesters. However, these presses suffered from rapid wearing of the hydraulic cylinder pressure seals, leading to poor pressure development. More importantly, the combined cost of digester and manual hydraulic press, at the time, was more than most village small-scale operators could afford. Indeed these mills were targeted at owners of medium-sized plantations who wanted to process their fruits independently rather than selling bunches to large-scale millers.

These hydraulic presses, although very popular with small-scale processors, have two major weaknesses:

- they require human strength to operate;
- because of the disproportionate nut-to-fibre ratio in Tenera or Tenera-Dura combination, oil loss to fibre is high.

4.4 Combination digester and hydraulic press systems

TechnoServe Inc. brought the digester, hydraulic press and spindle press into a rural community together with the business management training to create small-scale palm oil processing enterprises.

However there were engineering problems with plant layout and matching the throughput of machine components. For instance:

1. The press and digester stations were typically separated from each other. Extra labour was required to load the cages from material discharged from the digester. The extra labour added to production costs.

2. The digester works much faster than the press; therefore there is always digested material awaiting the press. The digested mash cools during the waiting period. The cooling process reduces oil extraction efficiency, reducing plant throughput. The digester discharge and press loading activities were performed too close to the floor from the viewpoint of hygiene.

3. The surface area of the press plates and cage diameters were too large and therefore reduced the transmitted pressure of the hydraulic presses. Reduced pressure meant reduced extraction efficiency. Operating pressure was measured at 30-40 psi in the hydraulic press cylinder.

4. The manual presses were not 'women friendly' since a great deal of muscle power was required to pump the hydraulic system all day. In the peak season the work was difficult for even two young, able-bodied men. The press cages were heavy and unyielding to manipulation by women.

5. The frequent start/stop operation was injurious to the engine and increased fuel consumption. There was idle power in the drive engine as the digester led the press in performance by about 30 minutes. The idle power could be used to drive the hydraulic system. There was, therefore, the opportunity to move to semi-continuous technology.

TechnoServe Inc. sought to address the above-mentioned defects by producing a sturdy, hygienic, mechanically semi-continuous operation that can be handled also by female processors. The aim was achieved through:

- Equipment layout design changes to link the digester and press stations through an operating table on which press cages can slide between stations so that the digested mash always remains above ground. The digester and press stations were arranged so that one operator could manipulate both units.

- Changing to a high-pressure motorised press developing about 70 tonnes (versus the current 30-40 tonnes) cylinder pressure. The higher cylinder pressure was to be transmitted to a narrower press cage with smaller (4 mm diameter) holes using a smaller diameter (270 mm-diameter) press plate. The existing cages are usually 460 mm in diameter with 10 mm drilled holes. The new cages conserve pressure better.

- The hydraulic fluid is pumped using a power take-off pulley connected to the continuously running digester shaft. Thus the prime mover engine supplies the pressing power. The press/release mechanism is a spindle-operated valve, which is held up or down. No real strength is required to hold down the valve handle to operate the press.

- The smaller press cages permit easy manipulation by women since movement is by sliding the cages on a metal table connecting the elevated digester chute and press station.

4.5 Combination mechanical digester and screw-press

The NIFOR mechanical screw-press is the latest used by the small-scale palm oil processing industry in Nigeria. This consists of a perforated tube inside which a transport screw rotates. The press outlet is more or less closed by a cone that regulates the pressing pressure. The worm transports and gradually compresses the macerated fruits. Released oil drains through the perforations in the tube.

The press is mounted directly below a feed conveyor, which is fed by gravity by the horizontal digester. The body of the feed conveyor is perforated to allow oil released in the digester to drain away.

Preliminary trials have shown that the press can handle over 1 tonne FFB per hour with an average oil loss to fibre of 10.7 percent.

The unit is sold together with the NIFOR sterilizer and continuous clarifier as a standard set of machines for palm oil processing.

There are many artesanal fabricators of machinery and equipment for small-scale palm oil processing that continue to supply individual unit operational equipment. However, most established machinery designers and manufacturers supply complete engineered sets of processing machinery comprising the cooker/sterilizer, combination digester and press, along with a continuous clarifier.

Typical process unit performance and consumption per tonne of fresh fruit bunches

Type of unit	Key machines	Rated capacity (kg FFB/hr)	Extraction efficiency (%)	Extraction rate	Consumption per tonne of fresh fruit bunches (FFB)				Capital investment (US$)
single batch unit					Water (litres)`	Elect power (kwh)	Fuel (litres)	Wood (kg)	
Dry	Spindle	100-200	55	12-14.	282	0	0	88	150-200
	Hydraulic	200-300	67--74	12-15	287	0	0	90	5 000-7 000
	Screw	250-400	77.4-	16-18	718	12	7	73	1 500-6 000
Wet	Vertical digester	500-800	80-90	19-20	750	0	2	70	1 500-2 500
Dry	Motorised horizontal digester (only)	500-1000	55	12-14	250	0	2.0-3.0	75	2 500-3 000
Dual separate units									
Dry	Digester + spindle presses	200-300	60-70	16-18	380	0	1.0-1.5	84	3 000-5 000
	Digester + hydraulic press	400-800	67-78	15-17	400-500	0	1.0-1.5	73	7 000-10 000
Semi-continuous combined units									
Dry	Motorised digester + hydraulic + spindle press	500-850	70-87	18-20	270	0	2.0-3.0	113	10 000-15 000
	Digester + screw-press	500-850	76-90	18-20	267	0	2.0-3.0	146	12 000-15 000

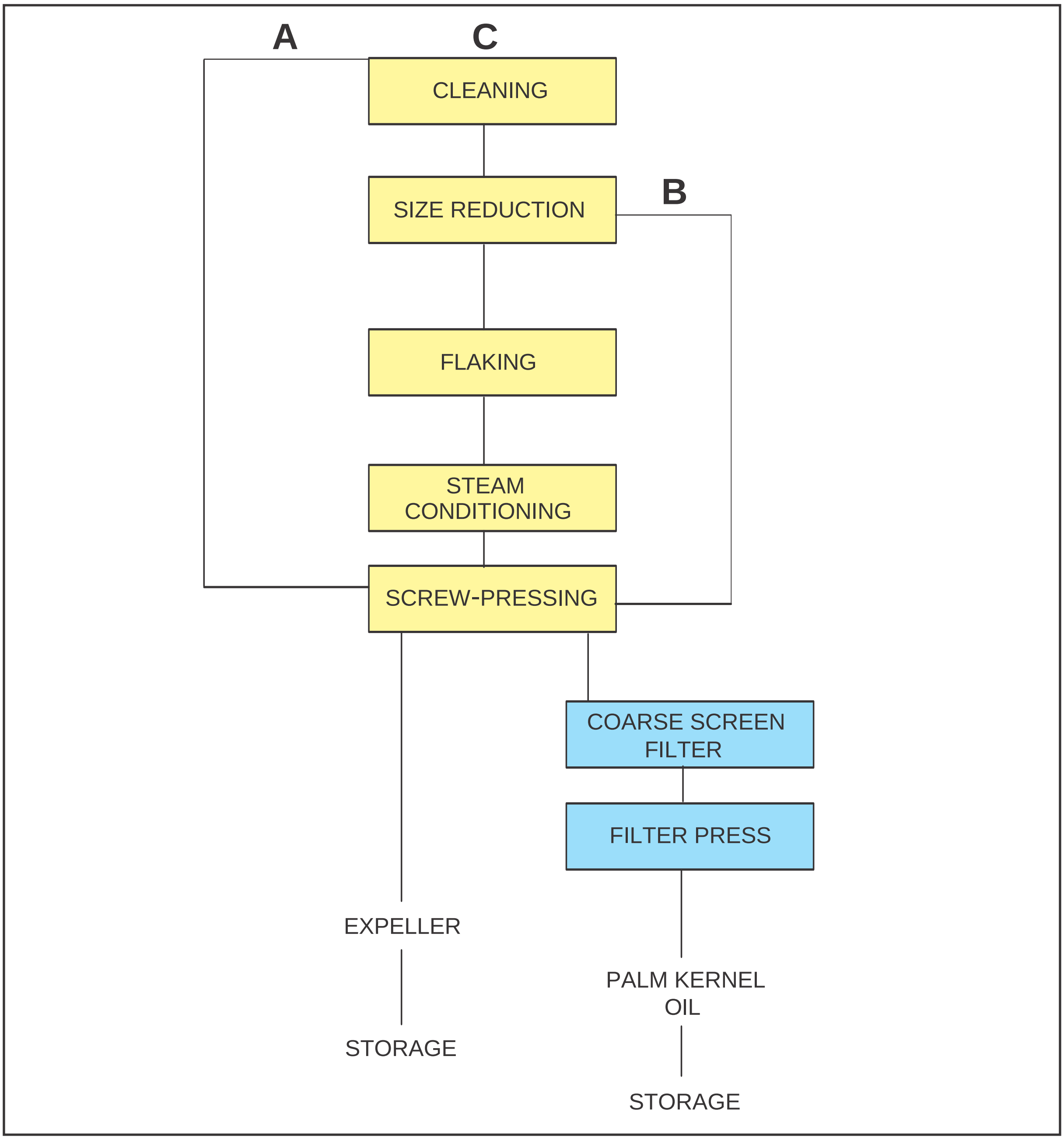
Source: Compiled from various sources.

5. PALM KERNEL OIL EXTRACTION

5.1 Mechanical extraction

Mechanical extraction processes are suitable for both small- and large- capacity operations. The three basic steps in these processes are (a) kernel pre-treatment, (b) screw-pressing, and (c) oil clarification.

Diagram 2: Mechanical extraction of palm kernel oil.



Line (A) is for direct screw-pressing without kernel pre-treatment; Line (B) is for partial kernel pre-treatment followed by screw-pressing; and Line C is for complete pre-treatment followed by screw-pressing.

Kernel pre-treatment

Proper kernel pre-treatment is necessary to efficiently extract the oil from the kernels. The feed kernels must first be cleaned of foreign materials that may cause damage to the screw-presses, increasing maintenance costs and down time, and contamination of products. Magnetic separators commonly are installed to remove metal debris, while vibrating screens are used to sieve sand, stones or other undesirable materials.

A swinging hammer grinder, breaker rolls or a combination of both then breaks the kernels into small fragments. This process increases the surface area of the kernels, thus facilitating flaking. The kernel fragments subsequently are subjected to flaking in a roller mill. A large roller mill can consist of up to five rollers mounted vertically above one another, each revolving at 200-300 rpm. The thickness of kernel cakes is progressively reduced as it travels from the top roller to the bottom. This progressive rolling initiates rupturing of cell walls. The flakes that leave the bottom nip are from 0.25 to 0.4 mm thick.

The kernel flakes are then conveyed to a stack cooker for steam conditioning, the purpose of which is to:

- adjust the moisture content of the meal to an optimum level;
- rupture cell walls (initiated by rolling);
- reduce viscosity of oil;
- coagulate the protein in the meal to facilitate separation of the oil from protein materials.

The meal flows from the top compartment down to the fifth compartment in series. At each stage a mechanical stirrer agitates the meal. Steam trays heat the cookers, and live steam may be injected into each compartment when necessary. The important variables are temperature, retention time and moisture content. In the palm kernel, the meals are normally cooked to a moisture content of 3 percent at 104-110°C.

Screw-pressing

The properly cooked meal is then fed to the screw-press, which consists of an interrupted helical thread (worm) which revolves within a stationary perforated cylinder called the cage or barrel. The meal is forced through the barrel by the action of the revolving worms. The volume axially displaced by the worm diminishes from the feeding end to the discharge end, thus compressing the meal as it passes through the barrel.

The expelled oil drains through the perforation of the lining bars of the barrel, while the de-oiled cake is discharged through an annular orifice. In order to prevent extreme temperatures that could damage the oil and cake quality, the worm-shaft is always cooled with circulating water while the barrel is cooled externally by recycling some cooled oil.

Oil clarification

The expelled oil invariably contains a certain quantity of ‘fines and foots’ that need to be removed. The oil from the presses is drained to a reservoir. It is then either pumped to a decanter or revolving coarse screen to remove a large part of the solid impurities. The oil is then pumped to a filter press to remove the remaining solids and fines in order to produce clear oil prior to storage. The cakes discharged from the presses are conveyed for bagging or bulk storage.

As can be seen from Diagram 2, not all crushers use the same procedure for mechanical extraction of kernel oil. There are three variations: direct screw-pressing, partial pre-treatment, and complete pre-treatment.

Direct screw-pressing

Some mills crush the kernels directly in the presses without any pre-treatment. Double pressing usually is required to ensure efficient oil extraction. The screw-presses used normally are less than 10 tonnes per unit per day.

Partial pre-treatment

The kernels are first broken down to smaller fragments by grinding prior to screw-pressing. In some cases, cooking is also carried out.

Complete pre-treatment

The full pre-treatment processes described earlier are carried out prior to screw-pressing. Plants with larger capacities (50-500 tonnes per day) choose complete pre-treatment and the equipment is usually imported from Europe. FATECO and Faith Engineering now offer the complete line for small-scale operators.

5.2 Solvent extraction

Solvent extraction processes can be divided into three main unit operations: kernel pre-treatment, oil extraction, and solvent recovery from the oil and meal. For the purposes of small-scale operations it is sufficient to mention the solvent extraction process is an alternative for high capacity mills. However the process is not recommended for small enterprises.

5.3 Traditional method of palm kernel extraction

Palm kernel extraction is a specialised operation undertaken by a completely different set of processors. They are usually better organized as a group and are not as dispersed as palm oil processors. The kernel processors have to go around the palm oil processors during the peak season, when prices are lowest, to purchase the nuts for drying. The nut processing and oil extraction is undertaken in the dry season when the pressure to obtain raw materials has subsided.

The traditional palm oil processing starts with the shelling of the palm nuts. The shelling used to be performed using two stones to crack each nut and separating the kernel and shell simultaneously. This manual operation has been largely superseded by the use of nut-cracking stations.

The mechanical nut-crackers deliver a mixture of kernels and shells that must be separated. The kernel/shell separation is usually performed in a clay-bath, which is a concentrated viscous mixture of clay and water. The density of the clay-bath is such that the shells sink while the lighter kernels float to the top of the mixture. The floating kernels are scooped in baskets, washed with clean water and dried. Periodically, the shells are scooped out of the bath and discarded.

The traditional oil extraction method is to fry palm kernels in old oil or simply heat the dried nuts. The fried kernels are then pounded or ground to a paste in a motorised grinder. The paste is mixed with a small quantity of water and heated to release the palm kernel oil. The released oil is periodically skimmed from the top.

Today, there are stations in villages that will accept well-dried kernels for direct extraction of the oil in mechanised, motorised expellers. (Fig. 20, 21)

Fig. 20 Whole palm kernel expeller (CAMEMEC, Benin)

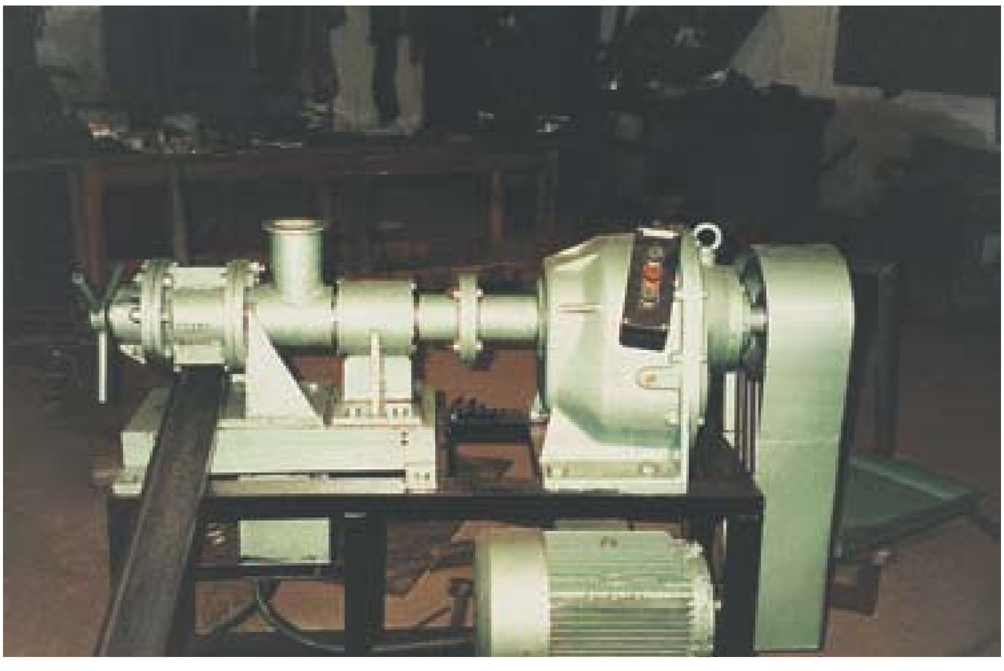


Fig. 21 Palm kernel expeller (O.P.C., Cameroon)

6. ENVIRONMENTAL CONSIDERATIONS

6.1 Treatment of solid waste products

In a well run palm oil mill, it is expected that each 100 tonnes of FFB processed yields 20 to 24 tonnes of crude palm oil and about 4 tonnes of palm kernels. Thus between 72 to 76 percent of the FFB comes out at various stages of the process as waste.

The solid wastes that result from the milling operations are:

- Empty fruit bunches,
- Palm fibre, and
- Palm kernel shell.

In the large- and medium-scale mills the above-mentioned waste products are all put to economically useful purpose. They could therefore be referred to as by-products rather than waste products.

Wet, empty bunches are partly dried in the sun and later used as fuel. Another economic use for the empty bunches is to return them to the plantation as a mulch to enhance moisture retention and organic matter in the soil.

The palm kernel shell is also used as a source of fuel for the boilers. Unfortunately the shell contains silicates that form a scale in the boilers if too much shell is fed to the furnace, thus limiting the amount of shell that can be utilised in the boilers. Residual shell is disposed of as gravel for plantation roads maintenance. Blacksmiths also buy the shells to use as fuel material in their casting and forging operations. Palm nut shell is also used in the preparation of pozzolana, a cement substitute material that has been developed by the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

The fibre recovered from the nut/fibre separation stage is a good combustible material and finds ready use as fuel to boil the fruit. (Fig. 22) The fibre constitutes the bulk of material used to fire the large boilers used to generate superheated steam to drive turbines for electrical power generation in large-scale plants.

Boiler ash is recycled as fertilizer and factory floor cleaning agent. The potash in the ashes reacts with the oil to form a weak potash soap that is washed away with water.

Small-scale mills also use the fibre and bunch waste as fuel material. Most small-scale mills do not undertake the shelling of recovered palm nuts. The nuts are sold to palm kernel processors.

Small-scale palm kernel processors use clay baths to separate kernels from shells. The shells are normally left in a pile to dry. Some of the shells are used for fuel but there are always residual amounts found around the palm kernel processing centres. Periodically the pile is removed and used as landfill.

Fig. 22 Fibre sludge

Wood consumption of small-scale operations is relatively small because of the recycling of the fibre and bunch waste as the main fuel source. The medium-scale operators tend to supplement their internally generated solid waste fuel sources with wood for firing their boilers. The impact on the local tree population is significant enough to cause factories to close while foraging for wood supplies.

6.2 Treatment of aqueous effluent

Large- and medium-scale mills produce copious volumes of liquid waste from the sterilizer, clarifying centrifuges and hydrocyclones. This effluent must be treated before discharge to avoid serious environmental pollution.

Liquid waste treatment involves anaerobic fermentation followed by aerobic fermentation in large ponds until the effluent quality is suitable for discharge. In some of the mills the treated effluent is used on the farm as manure and source of water for irrigation. The sludge accumulating in the fermentation ponds is periodically removed and fed to the land.

To manage the amount of oil entrained in the effluent, while at the same time improving the efficiency of oil recovery, the large mills use de-watering and decanting centrifuges at various locations in the process line.

When it comes to liquid waste management most traditional processors and small-scale palm oil processors do not adhere to any environmental protection practices. The environmental awareness level of the operators in this industrial area is low. Indeed much is desired of the hygiene of most facilities. Traditional processors operate so close to nature that they simply return liquids to the surrounding bushes. The discharged quantities are so small that the ground easily absorbs the waste matter and the operators have not yet seen their activities as injurious to their surroundings.

However in the more organized intermediate technology mills sludge from the clarifying tanks are carried in buckets or rudimentary gutters to sludge pits dug in the nearby bushes. When the sludge pit begins to give off a bad odour the pit is filled in and another one dug for the purpose. Charcoal from the cooking fires is dumped into the pits to absorb some of the odour.

Sometimes the oil in the sludge pit is recovered and mixed with fibre to make a fire-starting cake called ‘flint’.

It has been observed that when the small-scale mill operators empty their sludge on the surrounding bushes the bushes slowly die. Operators say they use the sludge as a herbicide to clear their surroundings. It is, however, time to develop simple inexpensive aqueous pollution control systems for small-scale operators.

Environmental pollution considerations in small-scale palm oil milling need concentrated attention as this industrial segment assumes greater importance. It is hoped that as more educated people come into the industry they will bring increased awareness and a greater commitment to adopt improved environmental management practices in their operations.

BIBLIOGRAPHY

Ataga, D.O., Ilechie, C.O., & Omoti, U. 1993. Small-scale Palm Oil Processing Technology in Nigeria. Paper presented to BUROTROP-AFOPDA Seminar on Small and Medium Scale Palm and Coconut Technologies, Accra, Ghana.

Harris, R. April 1995. A Survey of Palm Oil and Palm Kernel Extraction Equipment manufactured in Europe, Central and West Africa and Latin America. Final Technical Report on FAO Project GCP/INT/588/CFC.

Poku, K. 1983. Foya Palm Oil Mill Project Technical Evaluation of Machinery and Equipment Supply for Liberian Produce Marketing Corporation Project File

Poku, K. 1993. Innovations in Village Based Palm Oil Processing. Paper presented at the BUROTROP-AFOPDA Seminar on Small- and Medium-Scale Oil Palm and Coconut Technologies, Accra, Ghana.

Poku, K. 1998. Oil Palm Smallholder Development: Processing Technology Mission Report presented on FAO Project TCP/MLW/6612

Rouziere, A. 1995. Etude Mini et Micro Huileries de Palm en Afrique de l'Ouest et du Centre. Mission Report for Caisse Française de Développement. CIRAD-CP 793.

Tang, S.T. & Teoh, P.K. 1995. Palm Kernel Oil Extraction – The Malaysian Experience. Paper presented to the World Conference on Processing of Palm, Palm Kernel, and Coconut Oils, Kuala Lumpur, *Malaysia Journal of the American Oil Chemists' Society* Vol. 62/No.2/Feb.1985, Pg. 255.

ANNEX 1

Major manufacturers and designers of palm processing equipment in Africa

BENIN

CAMEMEC
BP 8202 Cotonou, Benin

This company is an affiliate manufacturer of crop-processing machines designed by IITA. The company produces the full range of palm oil processing machinery.

The nutcracker, kernel/shell separator and palm kernel expeller are produced to handle palm kernel. The expeller has machined flights on a single shaft with threaded backpressure cone.

Generally machines are produced having a 1 tonne/hr capacity for palm oil while the palm kernel machines have rated throughputs of 150-250 kg/hr.

Equipment includes:

Item
Caltech-type palm oil presses (both manual and motorised)
Cookers
Expeller
Fruit threshers
Horizontal digester with spindle-press combination (NIFOR-Mini type).
Nutcracker

CENTRE DE FORMATION TECHNIQUE MSGR. STEINMETZ (CFTS)

This centre is a Catholic Church institution for technical vocational training, which makes all the unit operational machines from threshing to clarification and storage. The design of machines is undertaken in-house.

Item
Caltech screw-press (manual vertical & motorised horizontal)
Clarification tanks
Cooker - 1 tonne/hr
Fibre/nut separator (under development))
Nut cracker (96% efficiency, 400 kg/hr, 5.5 hp motor)
Palm kernel press (prototype being tested 400 kg/hr)
Shell/kernel separator (manual 75-80% efficiency)
Steam cooker - 450 kg fruits for (1 hr 30 min)
Sterilizer
Storage - capacities up to 175-200 tonnes oil.
Thresher (manual) depends on operation.

SOCIETE POUR LA PROMOTION COMMERCIALE & INDUSTRIELLE (S O P C I)
BP 0247, Cotonou, Benin
Tel: 30.76.54.

The company manufactures the Caltech press for palm oil extraction but focuses mainly on producing palm kernel processing machinery:

Item
Kernel shell separator (manual & motorised)
Nut cracker
Palm kernel expeller

CENTRE SONGHAI
BP 597 Porto Novo, Rep. de Benin.
Tel.: 229-22.50.92; 22.28.81/84; E-mail: songhai@songhai.org

Songhai is a private non-governmental organization the central objective is to develop agriculture with strong links to industry. The aim is to train people to farm and then process agricultural products into food items.

The following items are manufactured for the palm oil industry:

Item
Clarification tank
Cooker
Press (manual and motorised versions of OPC screw-press)
Storage tank
Thresher

CAMEROON

AMDALE Sarl
BP 2921, Douala, Cameroon
Tel: 42.53.54

The company designs and manufactures any kind of palm oil/kernel processing machinery on demand.

Main items manufactured:

Item
Boiling vessels
Caltech screw-presses -- both manual vertical and motorised horizontal types

OUTILS POUR LES COMMUNAUTE (OPC)
BP 5946, Douala, Cameroon
Tel.37 04 32

This company continues to add to the machinery and equipment delivered to the palm oil industry, and also manufactures machinery to process other crops such as cassava, maize and rice.

OPC palm oil and palm kernel machinery production

Item
Bunch thresher
Caltech type screw-presses (manual vertical; manual horizontal and motorised horizontal versions)
Crude oil clarifier (200 litre drum type)
Expeller (whole kernel without pre-treatment)
Fibre/nut separator
Kernel/shell separator
Palm bunch sterilizer
Palm nut cracker

SERMI
BP 17123, Douala, Cameroon
Sis Rue 4 509 Bonaberi
Tel: 237-39.14.22; 93.96.85

SERMI manufactures complete palm oil and palm kernel oil mills to order. The company works with private farmers having an average holding of 1 500 ha and design custom-made medium-scale plants for the estates. Twin-screw type presses are manufactured and supplied to medium-scale processors.

The following palm oil processing equipment is manufactured:

Item
Bunch thresher
Clarifier
Screw-press
Two bunch cookers

For smallholders (200-400 ha) the company produces:

Item
Motorised screw-press
Pressure cooker (2-bar pressure with temperature and pressure regulators)

NIGERIA

FAITH ENGINEERING WORKSHOP (FEW)

c/o Nova Technologies, Ibadan

The company makes machinery for the vegetable oils and animal feed industries and collaborates with Nova Technologies in the manufacture of other machines.

Items produced for the palm kernel processing industry include:

Item	Description
Bucket elevator	
Cooker	Three or four stage indirect steam, gas or electric coil heated plates
Expeller	Sequential pre-press and high pressure worm arrangement
Filter press	300- 400 litres/hr for the 20 plate press and 500-600 litres/hr for the 24 plate press
Hammer mill	2 tonnes/hr with hopper and beater bars made from hardened mild steel or medium carbon steel depending on type of seed material to be crushed
Steam boiler	5 bar; cylindrical 48' high x 21'-23' diameter fire tube boiler

Plant equipment:

Item

Boiler
Cooker
Diesel engine (5 hp)
Elevator - 12 ft
Expeller (10 tonne/day)
Filter press with pump
Hammer mill
Nut cracker with separator
Pellet extruder (300 kg/hr)

NIGERIAN INSTITUTE FOR OIL PALM RESEARCH (NIFOR)

206 Benin - Lagos Road, Ugbowo, Benin City, Nigeria
(Tel 052-602-485; 602-486); E-mail nifor @infoweb.abs.net

NIFOR concentrates on the manufacture and supply of three models of palm oil processing machinery for the small-scale processor.

These are:

NIFOR Mini (250 kg/hr)

Item	Capacity
Clarifier one day's capacity:	
Curb press	Match digester
Fruit screen	
Manual digester	30-50 kg
Spindle press	
Sterilizer	250 kg

The throughput of the NIFOR-Mini set is nominally 250 kg/hr with an extraction rate of 12 to 13 percent on fresh fruit bunches. NIFOR supplies this unit only as a starter set for small-scale operators.

NIFOR Medium (Capacity 0.25 to 0.5 tonnes/hr).

The components for the medium capacity mills are:

Item	Capacity
Clarifier	600 litres oil
Digester/screw-press	2 tonne/hr
Fruit screen	
Sterilizer	380 – 500 kg/hr

The digester and screw-press are combined and operated using one prime mover, usually a diesel 6.5 hp engine

NIFOR-Large (0.5 to 1.5 tonnes/hr)

Item	Capacity
Clarifier	1 200 litre oil
Digester/Screw-press	2 tonne/hr
Fruit screen	
Fruit stripper	380 – 500 kg/hr
Sterilizers	0.48 to 0.5 tonnes each

NIFOR also manufactures 10 tonne metallic tanks for oil storage, which are heated with re-circulated steam or hot water around internal tubes.

NOVA TECHNOLOGIES (NIG) LTD.
U.I. PO BOX 19825, Ibadan
Tel 234-02-810-3960

Nova Technologies manufactures the 200 kg/hr vertical digester, spindle press and palm nutcracker. Bunch strippers may also be constructed for the threshing of fresh quartered fruit.

Clarifiers are manufactured but there is not much demand for the decanter attachment. Processors prefer the open kettle clarifiers.

Item
Clarifiers
Spindle press
Palm nutcracker
Vertical digester - 200 kg/hr

OGUNOROKE STEEL CONSTRUCTION WORKS LTD.

Opp. NISER Ajibode Junction, Orogun, Ibadan, Box 21542 UI Ibadan
Tel 234-02-810-7545

This is a small-scale artisanal manufacturer that works as a sub-contractor to Nova Technologies.

OSCW produces a nutcracker and expeller for palm kernel processing. The expeller works on palm kernels that have not been pre-treated. The gear reduction unit is made from adapted automobile transmission gear assemblies.

Item
Expeller – 250 kg/hr
Nutcracker
Replacement parts for expellers
Vertical digester/spindle-press

GHANA

AGRICULTURAL ENGINEERS LTD (AGRICO)

PO Box 12127, Accra North, Ghana
Tel: 233-21- 228.260; 228. 292

AGRICO product range includes farm machinery and implements, crop-handling and processing equipment for sugar, rice, maize, cassava and fruit.

The following palm oil processing machinery is produced:

Item
Boiler
Digester
Fibre/nut separator
Fruit stripper
Hydraulic press
Oil clarifier
Palm nut cracker
Sterilizer

The company imports palm kernel expellers from India for resale.

CORT ENGINEERING SERVICES COMPANY LTD.

P.O. Box AN 12982, Accra-North, Ghana
Tel: 233-21- 50.21.26. E-mail: cort@idngh.com

Cort Engineering Services developed the ‘wet’ flushing type palm oil extractor in response to a consulting assignment in Malawi. The flushing digester/press takes in boiled fruit and delivers, separated palm oil in water ready for clarification, well-washed nuts and fibre. The entire combination of processes (fruit digestion, oil extraction, fibre-nut separation) is undertaken in one machine. The company has also developed a prototype one pass digester/screw-press combination palm oil extractor that is being field-tested.

FATECO
P.O. Box 9899
Airport, Accra
Tel: 233.21.663114 / 303029

This company manufactures the full range of palm oil and palm kernel oil processing machinery.

Produces to order:

Item
Cooker (fruit thresher)
Digester
Fibre/nut separator
Hammer mill for kernel preparation
Hydraulic press (manual & motorised)
Kernel/shell separator
Manual spindle press
Motorised screw-press
Nut cracker
Oil filter press
Palm kernel expeller (screw-type with replaceable worms)
Palm oil thresher
Storage tank
Wood fired/gas fired/electric heated kernel cooker

HORMEKU ENGINEERING WORKS (HEW)
P.O. Box 20, Ashaiman, Tema
Tel: 233- 22.30.78.11

Hormeku Engineering Works manufactures a wide range of machinery and equipment including crop dryers, rice and maize processing lines as well as palm oil and palm kernel lines.

The palm oil line comprises:

Item
Clarification tank
Fruit stripper
Manual spindle press
Motorised horizontal digester
Motorised screw-press
Sterilizer

The palm kernel line comprises:

Hammer mill
Kernel grinding mill
Palm kernel expeller

Manufacturer	**Sterilizer**	**Thresher**	**Digester**	**Vertical wet digester**	**Vertical screw-press**	**Motorised horizontal press**	**Hydraulic Press**	**Spindle Press**	**Cont. Clarifier**	**Nut/fibre separator**	**Nutcracker**
Benin											
Camemec						YES					YES
CFTS	YES	YES			YES	YES			YES	YES	YES
So. Pci						YES					YES
Songhai fabrication	YES	YES			YES	YES			YES		YES
Cameroon											
Amdale	YES				YES	YES					
OPC	YES	YES			YES	YES			YES		YES
Sermi	YES	YES				YES			YES		YES
Ghana											
AGRICO	YES	YES	YES				YES	YES	YES	YES	YES
Cort Engineering			YES	YES		YES	YES	YES			
Fateco	YES	YES	YES			YES	YES	YES	YES	YES	
Hormeku Engineering	YES	YES	YES			YES		YES	YES	YES	YES
Nigeria											
Faith Engineering											YES
Nifor	YES	YES	YES			YES	YES	YES	YES	YES	YES
Nova Technologies				YES				YES			YES
Ogunoroke Steel works											YES

Manufacturer	Kernel shell separator	Hammer mill	Meal cooker	Direct whole nut expeller	Retractable worm expeller	Oil filter press	Steam boiler
Benin							
CAMEMEC	YES			YES			
CFTS	YES				YES, EXPERIMENTAL		
So. P.C.I.	YES			YES			
Cameroon							
OPC	YES			YES			
SERMI	YES	YES		YES			
Ghana							
AGRICO	YES	YES	YES		YES	YES	YES
Fateco	YES	YES	YES		YES	YES	
Hormeku Engineering		YES			YES		
Nigeria							
Faith Engineering	YES	YES	YES		YES	YES	YES
Ogun Oroke Steel Works				YES			