

TRADITIONAL PALM KERNEL OIL PROCESSING IN GHANA :

PROCESS AND PRODUCT CHARACTERISTICS

BY



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# D E C L A R A T I O N

This thesis is my own work produced from research undertaken under the supervision of a Supervisory Board with Professor S. Sefa-Dedeh as the Chief Supervisor.



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## D E D I C A T I O N

To the memory of my late grandparents, Nana Kwadwo Tanor Debrah, and Nana Akosua Afrah Konner, who together laid the foundation of my education.



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### ABSTRACT

The process and product characteristics of the traditional palm kernel technology were studied.

The study was in two phases. Firstly, a survey on the technology in some selected areas in the Eastern and Greater Accra regions was done, to collate information on processors, processing methods, equipment used, raw materials, marketing of products and some other aspects of the technology. Then the processing methods encountered were replicated in the laboratory and investigated to assess the importance of each of their operations, in relation to production and quality characteristics of the oil. The laboratory investigation also sought to determine the optimum parameters of the factors governing the various operations for better performance and to develop modified processes based on the original processes studied, for higher yield and better quality palm kernel oil.

Two palm kernel processing methods were observed in the areas surveyed.

All the respondents used a method based on roasted kernels. This method yields the characteristically dark brown, strong scented and strong flavoured palm kernel oil commonly found on the local markets. The other method encountered, scarcely used by one processor, is that based on unroasted kernels. This yields a pale yellowish, practically odourless and mild flavoured palm kernel oil.

The roasted kernel process briefly involves roasting of kernels, milling, boiling of a slurry of the meal and

collection of oil. The unroasted kernel process rather involves soaking of the unroasted kernel, milling, boiling of meal slurry, aging, collection of oily-emulsion, and boiling of the emulsion.

The processors involved are mostly women, ranging in age from 20-80 years and are generally with no formal education. These women use simple inexpensive, mostly local equipment, in the multi-stepped processes to obtain the oil. Variations in yield per batch of processes, variations in raw materials and overhead cost lead to differences in turn over for each processor.

The laboratory investigations indicated that the process characteristics significantly influence the product characteristics. The roasting of kernels leads to the darkened colour, strong odour and strong flavour of the oil. However, it facilitates efficient milling and hence higher yield. Soaking, in the unroasted kernel process significantly reduces the yield but keeps the free fatty acid levels of the oil low. In general, the investigations indicated that the individual unit operations influence the yield, the colour, odour and free fatty acids level of the oil.

Based on the findings of the investigations, the parameters of some operations were modified in the unroasted kernel process. The soaking of kernels was limited to the first 30 minutes, milling was repeated at least 3 times, boiling and aging of meal slurry were cut down to 10 to 20 minutes and 3 hours respectively. These resulted in cutting

down the processing time of about 36 hours spread over 3 days, to about 6 hours within a day; and an improved yield and quality of the oil.

## 1.0 INTRODUCTION

### 1.1 Vegetable oil seeds processing in Ghana

Six major vegetable oil materials are largely processed into oil in Ghana. These are palm fruits, palm kernel, copra, groundnut, sheanut, and cocoa kernels. The technologies involved are mainly traditional and account for the bulk of the oils from these fruits and seeds.

Traditional oilseed processing technologies are very low yielding and give products of generally low quality characteristics. The methods are time consuming, and labour intensive. They also have high equipment demand. However, the equipment are cheaper in cost compared to the equipment in modern processes. The methods are also simple and their nature makes them convenient for small scale production.

In spite of their short-comings, the traditional processes also have numerous economic benefits which call for their continuous existence. One such benefit is employment generation. It is necessary however to improve upon them to maximise the benefits. In this work, the palm kernel processing technology was studied, to modify some of the traditional processes, for better performance.

### 1.2 Description of the palm kernel

The palm kernel is an important oilseed found in the fruit of the oil palm plant, *Elaeis guineensis*, Jacq. It

contains about 46 to 57 percent of oil on dry matter basis. A typical composition is shown in Table 1.

Structurally, it consists of an endosperm, which is white and translucent when fresh, enclosed in a light brown testa. On heating, both the endosperm and testa turn dark; (Stork 1960; Jayalekshmy and Mathew, 1991). The shape and size are related to the variety of the palm fruit. They range from spherical to oblong, and some are flattened and irregular.

**Table 1: A typical composition of the palm kernel  
(percentage by weight)**

Constituent	Concentration %
Dry matter	92.0
Crude protein (N x 6.25)	8.5
Oil (Ether extract)	49.0
Crude fibre	5.8
Carbohydrate	26.9
Ash	1.8

Source: Cornelius, (1983)

### 1.3 Economic importance of palm kernel

The processing of palm kernels yield two important products – the kernel oil, and the kernel cake or meal. These two products have many nutritional and technical values, such that their production constitutes an important economic venture in many countries. The oil is one of the two known lauric acid oils, the other being coconut oil. These two oils contain higher proportions of lauric acid and other shorter

chain fatty acids, (Table 2). They have higher proportions of saturated fatty acids.

Palm kernel oil is used in the manufacture of soap and detergent and also in formulation of margarine, shortening and cooking oils. It is particularly useful for biscuit fats, confectionery ice cream and biscuit filling cream fat, (Pantzaris, 1989). Cornelius, (1983) however noted the following two factors that limit its use for edible purposes: The product of its hydrolysis has a soapy taste which makes its rancidity readily detectable; and the oil foams badly in admixture with other oils in frying. Jones, (1989) also reported that palm kernel oil would elevate serum cholesterol levels, and hence precipitate coronary heart disease if consumed in large quantities.

**Table 2: Fatty Acid Compositions of Palm Kernel oil**

Fatty Acid Type	Percentage composition by weight of fatty acid		
	Source 1	Source 2	Source 3
Caproic	0.2	0.1	
Caprylic	2.7	4.0	3.9
Capric	7.0	3.6	3.6
Caproleic	-	-	0.1
Lauric	46.9	50.4	49.6
Myristic	14.1	17.3	16.5
Palmitic	8.8	7.9	7.6
Stearic	1.3	2.3	1.2
Arachidic	-	-	0.2
Palmitoleic	-	-	0.1
Oleic	18.5	11.8	16.0
Linoleic	0.7	2.1	1.2

Sources: 1. Bailey (1951); Weast (1987)  
 2. Cornelius (1983)  
 3. Jayalekshmy and Mathew, (1991)

Despite these limitations, the oil is considered as one of the major edible oils in the world, (Jones and Kings, 1990). The cake or meal resulting from the extraction is used in the formulation of animal feed. It has good quality protein, and favourable calcium to phosphorus ratio, (Jayalekshmy and Mathew, 1991; Cornelius, 1983). Typical compositions are presented in Table 3.

**Table 3 Composition of palm kernel cake and palm kernel meal (Percentage by Weight)**

Constituent	Cake	Meal
Moisture	11.0	10.0
Crude protein (N x 6.25)	19.0	20.4
Oil (Ether extract)	6.0	0.9
Crude fibre	13.0	15.0
Carbohydrate	46.5	49.7
Ash	3.9	4.0

Source: Cornelius (1983)

#### 1.4 Palm Kernel Processing

Palm kernel processing was done using indigenous methods in the West African region, long before the international trade of the oilseed began. The technology however developed rapidly after the industrial revolution in Europe, when the demand for palm kernel oil increased. Modern processing methods for both batch and continuous production were developed, to facilitate large scale production, (Bailey 1951; Moore, 1973; Cornelius, 1983, and Hammond and Smith, 1987); and improve product characteristics (Ata, 1976) Nevertheless,

the indigenous methods have persisted up to date and even account for the bulk of the kernel oil produced in some of the West African countries.

The traditional palm kernel processes have similar characteristics as the other traditional oil processes. Howat (1975) and Ata (undated) indicated their low extraction efficiencies and the poor sensory quality characteristics.

## 1.5. Palm Kernel Processing in Ghana

### 1.5.1 A traditional based technology.

The prevalence of traditional processes in vegetable oil production in the country, may be the reflection of the general technological development of the country; the agricultural systems practised, and other economic factors. However, certain specific factors also seem to be specific for that of palm kernel processing. These include the following:

1. About 60 percent of palm kernels produced in the country which form the amount produced by traditional palm oil millers, is processed by the traditional palm kernel processors;
2. The majority of palm kernel consumers reside in the villages where modern mill products do scarcely reach.
3. Consumer familiarity with the kernel oil characteristics of the traditional product.

4. The relatively low cost of crude palm kernel oil compared to the refined oils.

It is believed that so far as these factors continue to prevail, traditional palm kernel processing will continue to be important in the production of the bulk of palm kernel oil in the country.

#### 1.5.2 The need for improvement

In spite of the knowledge of the numerous uses, the bulk of palm kernel oil in Ghana is used in only two ways. Firstly, as cooking oil for deep frying and stews; and then in soap manufacture. This is because of the characteristics of the oils. The traditional palm kernel oils are dark brown, with sharp odour and flavour. It is indicated that they are usually very difficult, if not impossible, to refine, (Stork, 1960). The bulk of the oil is thus limited to only the two uses.

It has been demonstrated however, that the characteristics of the oil depend on the processing characteristics, (Jayalekshmy and Mathew, 1991 Howat 1975; Stork, 1960). It is thus possible that a critical review and modification of the processes involved would improve the characteristics of the oil and widen its application.

The low extraction efficiencies of the traditional processes are also of much concern. Whereas 70-90 percent of the total oil in the kernel could be extracted with the modern methods, (Aboagye, 1991; Addo consultants, 1989; Cornelius,

1983; Moore 1973); the traditional processes are estimated to extract only about 20 to 40 percent of the total, (Addo consultants, 1989; UNIFEM, 1987). Ata (1970), prior to Addo consultants, (1989), emphasized the low efficiency of the traditional processes. With the view that the traditional methods are the predominant processes in the technology, there is a need to improve for maximum utilization of the kernels produced.

Ghana is not self-sufficient in edible oil supplies. Large quantities of cooking oil are imported annually, to supplement local production. This is happening at a time when large quantities of palm kernels and some other oil seeds are wasted through poor processing technologies, and when the country is capable of producing more of these oilseeds for local processing. In this period of the country's economic development therefore, it is appropriate to have a critical look at the fats and oils industry in search for a solution to the edible oil supply problem.

Improvement in traditional palm kernel processing is one approach. This is because, the kernel is cheaply and abundantly produced; and the oil content of the kernel is high. The traditional method of processing is also very familiar to the people in the country and so when improved could be easily adopted. Above all, the oil has wide applications.

According to the Food and Agriculture Organization (FAO), (1989), 30,000 tonnes of palm kernels were produced each year

from 1987 to 1989 with a potential of producing about 14,000 tonnes of oil,(if about 80 percent of total oil in the kernel is extracted). It is predicted that the production of palm kernels will increase during this last decade of the century, (Addo consultants, 1989). The palm kernel oil technology thus has a promising future.

The traditional palm kernel processing has seen some improvement recently. With the introduction of mechanical equipment, oil extraction has been improved. The extraction rate of about 40 per cent (UNIFEM, 1987) has been achieved with the mechanical aids introduced. Prior to the introduction of milling machine, kernels were either pounded in wooden mortars (Irvine 1970) or not milled at all, but roasted till they charred, for oil to flow out, (Addo consultants, 1989). These yielded less; the oils were thus invariably poorer in quality. Addo consultants, (1989) estimated a yield of about 8 per cent of the total oil in kernels in some processes. Other equipment have also eased the processes. Examples are equipment for nut cracking which can crack 150-200 kilograms of nut per hour;(UNIFEM, 1987); winnowing, roasting and pressing. These equipment however do not solve all the technical problems.

The strong odour and the dark brown colour still persist. It is important therefore that studies are done to establish the relationships between the process and product characteristics. These could help to standardise the operations to give better results. They may also lead to

changes or modifications in some of the unit operations in the processes to facilitate better production and product quality characteristics.

#### 1.6 Objectives of Study

The following objectives were set for this thesis:

1. To survey and collate information on traditional palm kernel processing in the southern part of Ghana.
2. To assess the importance of each operation in relation to production and quality characteristics of palm kernel oil.
3. To determine the optimum parameters of the factors governing the various operations for better performance.
4. To modify the traditional methods of processing palm kernel for higher yield and better quality oil. processes studied for higher yield and better quality oil.

## 2.0 LITERATURE REVIEW

### 2.1 The oil palm – the major source of vegetable oil.

The oil palm, *Elaeis guineensis*, Jacq, is a perennial plant indigenous to tropical West Africa. It used to be in wild groves in the West African region, between latitudes 13°N and 12°S (Godin and Spensley, 1971). It is now however cultivated between 10°N and S of the equator, in Africa, Indonesia and Malaysia. (Hardon, 1984; Moore, 1973).

The plant is a member of the palm family, *Palmaeae* and the suborder *Ceroxyoideae*. It is single-stemmed and upright, growing fully to about 18–21 metres high, and carrying 20–25 pinnate leaves on its crown. The fruits which grow in bunches, vary in shape, length, weight, colour, and in physical composition, depending greatly on the variety. Generally, they are ovoid or elongated, bulging somewhat at the top; 2 to more than 5 cm in length, and 3 to over 30 grams in weight. The colours are between deep orange and reddish brown.

The fruits are the sources of two important oils, the palm oil and the palm kernel oil. A typical fruit consists of an oleaginous seed (the kernel or endosperm) which gives the kernel oil, surrounded by the following; a hard shell (endocarp), an oleaginous fleshy mass of tissue (mesocarp) which gives the palm oil, and an exocarp (skin), in that order. The shell and the kernel form the nut, whereas the exocarp, the mesocarp and the endocarp (shell) together form

the pericarp of the fruit, (Hartley, 1983). Variations in the physical compositions are seen in the thickness of the individual layers. Figure 1 shows the structure of a typical oil palm fruit.

### 2.1.1 Variety of oil palm fruit

There are many varieties of the African oil palm; (International Potash Institute, 1957; Corley *et al*, 1976; Hartley, 1983, Hardon, 1984). In Ghana, 3 varieties *dura*, *tenera* and *pisifera* are known.

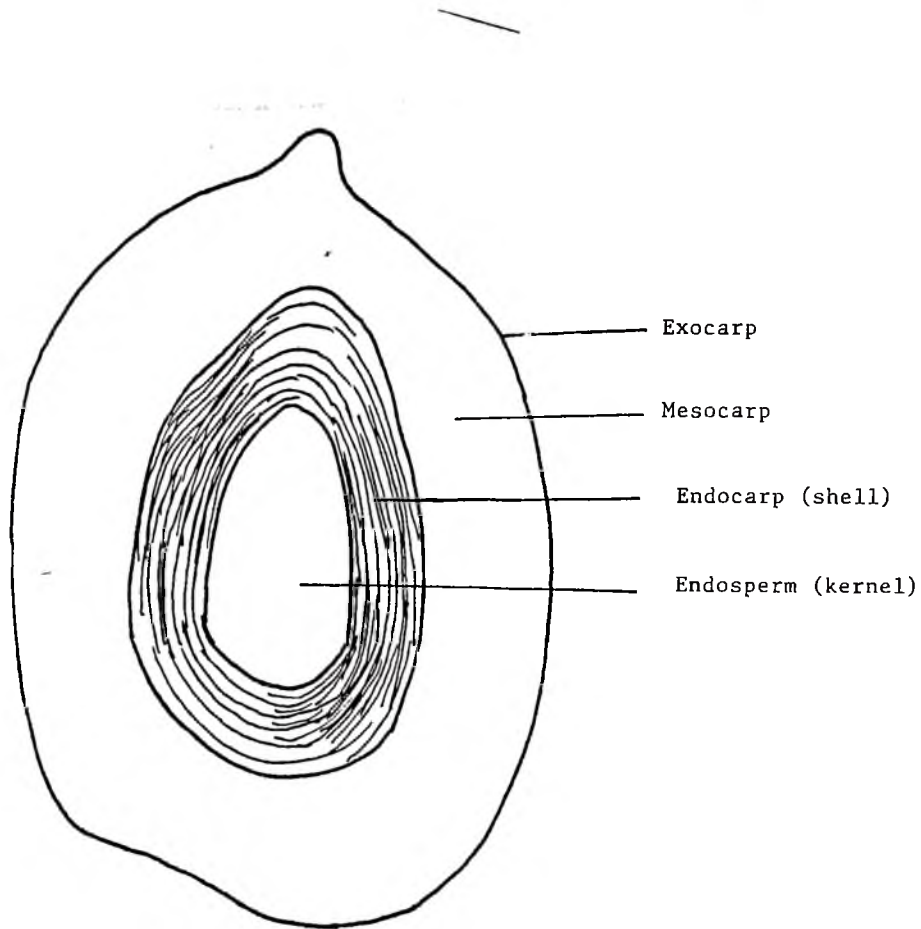
*Tenera* is a hybrid from *dura* and *pisifera*, (Hardon, 1984; Hartley, 1983).

The oil content of the different fruit varieties vary and may be related to the physical compositions of the varieties. The *dura* which has a very thick shell (about 2 - 8mm thick) and a low to medium mesocarp content, for instance has less oil than the *tenera* which has thinner shell (0.5 - 4mm) and a medium to high mesocarp content, (Hartley 1983; International Potash institute, 1957).

## 2.2 Oil palm fruit processing in Ghana

The processing of oil palm fruits constitutes a big industry in many parts of the world. This stems from the economic importance of the oils and their by-products, and the associated socio-economic values, (Addo Consultants, 1989).

**Fig. 1     The structure of a typical Dura nut**



The structure of a typical dura nut.

Two types of oil may be derived from the palm fruits, palm oil and palm kernel oil. In Ghana, the production of the palm oil, takes precedence over the kernel processing, just as in many other places; and the two processes are not necessarily carried out by the same processor or at the same premise.

#### 2.2.1 General methods for processing of oil bearing materials

The objectives in most oil extraction processes include:

1. the production of oil uninjured, which is free from undesirable impurities:
2. obtaining the oil in as high a yield as is consistent with the economy of the process, and
3. production of an oil cake or residue of the greatest possible value; (Bailey, 1951; Corley *et al*, 1976).

The various oil extraction techniques are described under three common methods:-

rendering, pressing, and solvent extraction, (Weiss, 1983; Bailey, 1951). Indigenous methods may not fall directly under any of these categories. They are described as traditional methods, (Ata, 1970; Hartley, 1983).

### 2.2.2 Traditional oil extraction processes

These are mainly water displacement and low pressure pressing techniques. They also involve pre-extraction treatment which are mechanical and requires the application of heat. Cornelius (1983), Hartley (1983), Ata (1970), UNIFEM (1987) and Irvine (1970) have described a number of traditional oil palm fruit and kernel processing techniques. Banzon and Velasco (1982) have also described a number of coconut processing methods.

### 2.2.3 Pre-extraction treatments of oil seeds

These are critical operations auxiliary to the actual extraction processes. They can be mechanical treatment or heat treatments, (Bailey 1951).

#### 2.2.3.1 Mechanical treatments

**Cleaning.** Seeds are first cleaned to separate foreign material. Manual or mechanised cleaning may be done depending on the technology.

In traditional technology manual cleaning is done.

**Dehulling and separation of husks:** Oil seeds are preferably decorticated before they are extracted wherever this is practicable. The hulls or shells are low in oil content, usually containing not more than one per cent oil. They can reduce yield if not removed by absorbing and retaining oil in the press cake. Bailey (1951) described various machinery used to remove hulls and shells of

different oil bearing seeds and nuts. Cornelius (1983) also described techniques for separating palm kernels from the nuts.

**Size reduction:** Reduction of seeds to smaller particles, facilitate extraction of oil from oilseeds by mechanical or solvent methods, (Bailey, 1951). According to Moore, (1973), breaking of seeds allows good heat penetration during subsequent cooking, and also ruptures the oil cells.

**Heat treatment:** This may be divided into two categories: Using heat treatment alone as means of extracting the oil, or to merely facilitate the subsequent expression of oil by mechanical means.

The former category, it is termed rendering, and it is used on fatty animal tissues, or other materials with a high ratio of oil to solid matter. The latter is commonly called cooking. The purposes in both categories are similar. They are to coagulate the proteins in the walls of the fat containing cells, and make the walls permeable to the flow of oil.

Heat treatment also causes the oil and moisture in the microscopic seed cells also expands to burst the cell and release the oil. In addition, the heat:

1. decreases the viscosity of the oil to make it more readily extractable;
2. reduces the harshness of the material and

3. regulates the moisture content of the material for efficient extraction, (Bailey, 1951; Moore, 1973, Cornelius, 1983).

Cooking has other important secondary effects. These include, insolubilization of phosphatides and possibly other undesirable impurities; destruction of molds and bacteria, and detoxification of gossypol, (Bailey, 1951).

#### 2.2.4. Extraction of palm oil

Processes involved are well documented. A few sources are Ay (1990), UNIFEM (1987); Ihekoroye and Ngoddy, (1985); Corneluis, (1983), Hartley, (1983), Ata (1974). There are both modern and traditional methods.

Ihekoronye and Ngoddy (1985), and Hartley (1983), specified the following unit operations in the modern technology; sterilization, stripping of fruits, digestion of fruits, pressing (extraction) and clarification. Ata (1974) described the predominant methods (both traditional and modern) used in Ghana. The traditional processes usually involve processes like boiling, pounding, fermentation, and oil separation, (Hartley 1983; Ata, 1974)

#### 2.2.5 Extraction of Palm Kernel Oil

##### 2.2.5.1 Production of palm kernel

The palm kernel is obtained by the removal of the pericarp of the fruit. This involves two main stages - removal of the mesocarp with the exocarp and cracking of

the nut to remove the endocarp (shell). The first stage is accomplished usually in processes to extract palm oil (the oil of the mesocarp).

Traditional and modern methods exist for the palm oil extraction, and these determine the detailed processes involved in the production of the nuts.

Generally, the fruits are cooked and digested. The pulp is pressed out and then the nuts separated from the fibre, (Ata, 1974; Cornelius, 1983). The nuts are dried and this may facilitate the shrinkage of the kernels from the shell. They are then cracked either manually or mechanically. The kernels are finally separated from the shells. Cornelius, 1983 described a detailed process of kernel production in a modern plant.

#### 2.2.5.2 Modern methods of extraction

Six modern palm kernel mills are presently well known in the country. These are Tema Food Complex Corporation Oil Mills, Mpohor Oil Mills, Juabeng Oil Mills, Crystal Oil Mills, St Lewis Oil Mills and Tringo Oil Mills. Ata (undated) described the operation of a mill at Atebubu Oil Mills. Gadegbeku (1969) also made mention of seven industrial mills capable of processing palm kernels.

The mills mentioned, use high pressure operated expellers. In operation, the kernels are cleaned, broken-up into a coarse meal between rollers, heated, and

then passed through the presses to squeeze out the oil. The oil squeezed out in passed through filters to remove contaminants. The extraction rate of such expellers is estimated to be about 80 per cent, (Moore 1973, Cornelius 1983; Addo consultants, 1989). Moore (1973), Cornelius (1983), and Hammond and Smith (1986) have described the detailed processes of this method of extraction.

#### 2.2.5.3 The traditional Methods of extraction

Three processes are documented. The most popular involves the roasting of the kernels and milling. The meal is then boiled in water, with frequent stirring, during which the oil floats on top of the water and it is collected, (Ata, 1970; UNIFEM 1987; Addo consultants 1989). The extraction rate is estimated to be between 20 and 40 per cent (UNIFEM, 1987; Addo consultatns, 1989).

In a second method, the kernels are roasted at very high temperatures until the oil oozes out,(Addo consultants 1989). This is less efficient than the previous method.

Irvine (1970) also described a third method which avoids the roasting operation. The kernels are soaked in water overnight. They are then pounded in a mortar, and aged with water. The oil separates out as an emulsion on the surface and is skimmed off and heated to dry. Cornelius (1983) described the traditional methods that involved water extraction as water displacement methods.

### 2.3 Quality Characteristics

Differences in the quality characteristics of the Ghanaian palm kernel oil processed using modern and traditional techniques exist. The characteristics of some industrial and traditional products have been reported, (Ata, undated).

**Table 4: Physical and Chemical Constants for Palm kernel oil**

Characteristic	Value
Specific gravity at 15°C	0.9520
Specific gravity at 40°C	0.9119
*Refractive Index at 60°C	1.4430
Melting point	23° - 26°C
Titre value	20° - 23°C
Iodine value	10 - 23.4
Saponification value	241 - 255
*Unsaponifiable matter content	0.4

Source: International Potash Institute, (1957)

\* Bailey (1951).

**Table 5: Quality characteristics of some industrially produced and traditionally produced crude palm kernel oil samples in Ghana**

Quality Criteria	Industrial Products (Atebubu Oil Mills)	Traditional Products (Asesewa area market Samples)
Colour	Bright yellowish and fairly attractive	Very dark brown and not particularly attractive
Flavour and Smell	Fairly mild flavour of palm kernel	Very strong flavour and smell of roasted palm kernel.
Taste	Very sticky on tongue and soapy feel	Sweet taste of roasted palm kernel and smooth tongue
Free fatty acid	10.0%	0.9%
Peroxide Value	10.6	2.6

Source: Ata (undated)

### 2.3.1 Effect of processing characteristics on the quality of palm kernel oil.

#### 2.3.1.1 Effect of heat treatments of kernels

Howat (1975), and Jayalekshmy and Mathew (1991) demonstrated that heating causes browning of palm kernel oil. This browning effect has been explained to result from Malliard reaction, (Jayalekshmy and Mathew, 1991; Howat 1975). The dark colour of traditionally produced palm kernel oil is due to the extensive heat treatment, (Ata, undated; Stork, 1960). The flavour and odour of the oil is also intensified during heating.

#### 2.3.1.2 Effect of storage of kernels

The characteristics of kernels and the mode of storage prior to processing have also been reported to influence the production and quality characteristics of palm kernel oil, (Bailey, 1951; Coursey 1961; Howat 1975).

When kernels are stored for long periods, they generate heat within, which also causes browning of the endosperm, (Burgoyne, 1951; Simmons, 1963).

Higher moisture levels of kernels during storage enhance decomposition of the unextracted oil, through increased mould and enzyme (lipase) activities.

According to Bailey (1951) and Howat (1975), these mould contaminate the kernels during the initial stages of drying. The lipases however accumulate in the seed during the latter part of the kernels maturation, (Bailey, 1951). Lipases are reported to resist several hours of heating at 100°C in partially dried palm kernels.

### 2.4 Improving the traditional palm kernel processing technology

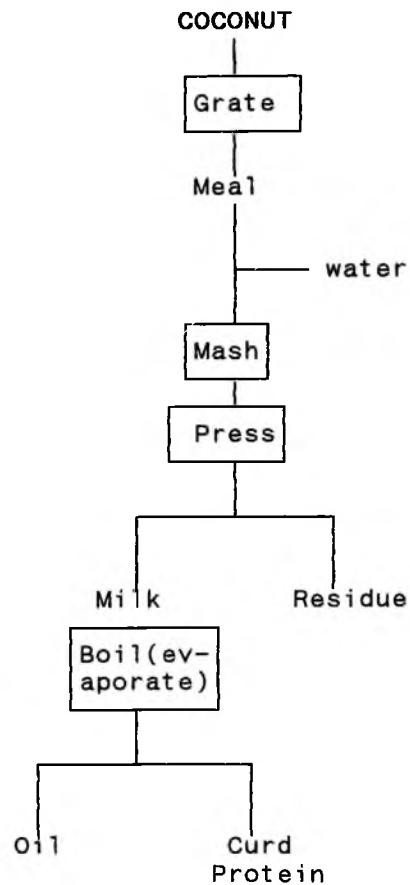
#### 2.4.1 Observations from improved Copra processing Methods

Copra has similar characteristics as palm kernel, in both structure and composition, (Bailey 1951). Their oils are therefore similar and said to be highly interchangeable, (Weiss, 1970; Cornelius 1983). It could be possible then to

compare the methods of extraction of the two oil seeds. Generally, the traditional copra processing methods have received more attention than the traditional palm kernel technology. This is assumed from the fact that the copra technology appears more developed. Many methods for processing copra have been documented, (Ata, 1970; Banzon and Velasco, 1982).

The wet processes of copra processing are worth considering in the bid to improve palm kernel processing. The basic process is shown in Figure 2 (Banzon and Velasco, 1982).

This process has some similarities with the palm kernel process described by Irvine (1970). Based on this process, many improved processes have been developed; which include the Soliven and de Leon process (Figure 3), the Yenko process, the SMS process, the Lava process, and the Villyar (Native) process (Figure 4); (Banzon and Velasco 1982). The improved methods are high yielding compared to the basic process. Perhaps, it would be possible to improve yield and quality characteristics of the palm kernel oil by developing the traditional processes along the line of development of the basic copra process.

**Fig. 2 The Basic wet press method in copra processing**

#### 2.4.2 Enzyme - Assisted Extraction

A number of oil-bearing materials similar to palm kernel have been extracted using standard extraction processes assisted by an enzyme, or combination of enzymes, (Graille *et al*, 1988). These processes have been found to be high yielding and of better quality products. Enzymes such as cellulases, hemicellulases, pectinases, proteinases, amylases,

and other enzymes which can digest plant cell walls have been used in studies, (Graille *et al* 1988). Enzyme assisted oil extraction has been reported by Fullbrook (1983), on rapeseed and soyabean, Buenrostro and Lopez-Munguia (1986), on avocado; Mcglone *et al*, (1986) on coconut oil, and Cheah *et al*, (1990), on palm oil.

Fig. 3 The Soliven and de Leon process

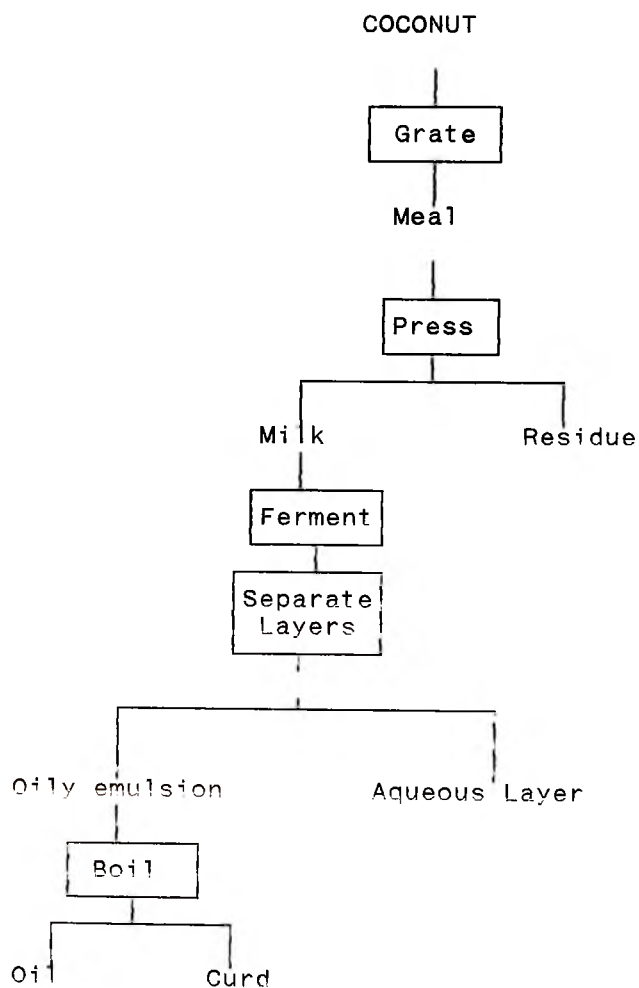
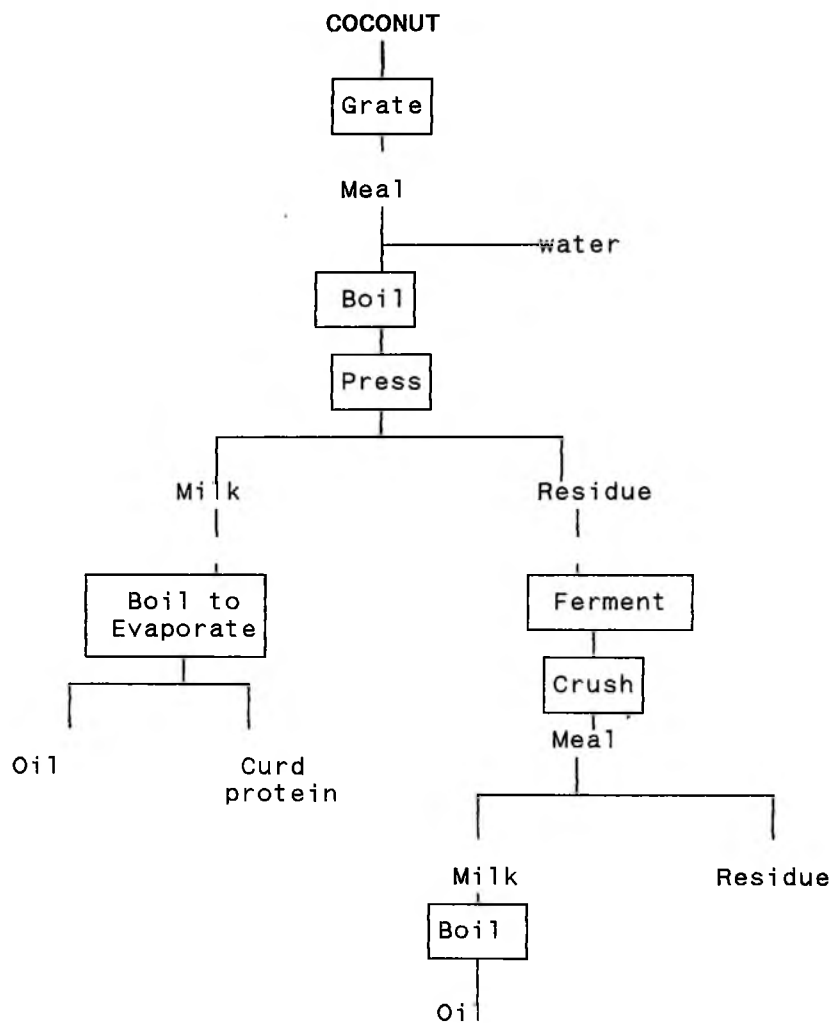


Figure 4: The Villyar Copra Method



### **3.0 MATERIALS AND METHODS**

#### **3.1 Materials**

##### **3.1.1 Palm Kernels**

A number of palm kernel samples were either produced, or acquired from a palm kernel oil mill for processing into palm kernel oil samples. Samples of palm kernels were produced from freshly harvested Dura and Tenera fruits.

Kernels from cooked and uncooked fruits of both varieties were separately produced. These were used in studies to compare the traditional roasting kernel and unroasted kernel processes, and to find the effect of pre-processing heat treatment on the production and quality characteristics of the oil.

Another sample of palm kernels (30kg) derived from Tenera, were purchased from TRINGO OIL MILLS LIMITED, Bubuashie, Accra. The sample was used in a number of process and product characteristics studies.

The third sample of palm kernels was produced from nuts purchased from individual households at the University of Ghana campus. The sample was used in a pilot study to evaluate modified processes with the unmodified traditional process.

##### **3.1.2 Palm Kernel oil Samples**

Six freshly produced palm kernel oil samples were purchased from six different processors in Accra, for evaluation of quality characteristics.

### 3.2. Methods

#### 3.2.1 Field Work

A questionnaire (Appendix 1) was used to collect data from palm kernel processors in a number of towns and villages in the greater Accra and Eastern regions. Data collected include demographic information on processors, processing methods used, equipment and raw materials, linkages of palm kernel processing with palm oil production, and marketing of product.

Thirty-one processors were interviewed. Data were analysed using dBASE III plus software (Ashton Tate, USA). Some processing parameters were also measured. These were; the specific gravity (S.G.) of the clay-bath separator, and the time-temperature relationship of the roasting operation.

The specific gravity was measured by floating a hydrometer in the clay-bath solution of five processors in Accra to measure the S.G. of the individual solution and then working out the average.

The time-temperature relationship was measured using a 360 degree Celsius mercury - in - glass thermometer. This was inserted in the kernel mass at the beginning of the operation and at specific intervals of time to determine the roasting temperatures at these times. This was done at three different places in Accra.

### 3.2.2 Kernel Production

Well cooked or uncooked fruits of **Dura** and **Tenera** varieties were pounded in wooden mortar with a pestle to remove the mesocarp. The nuts were separated from the fibre, and washed with hot water. They were then spread on aluminium trays and allowed to dry in the sun for varying number of days depending on the variety of fruit and the initial treatment, to let the kernel shrink completely from the shells. The latter facilitates cracking and separation of kernels.

The nuts were cracked with motorised cracker, and the kernels separated manually by hand picking.

The nuts purchased from households were winnowed to remove extraneous matter. They were then cracked and kernel separated.

### 3.2.3 Comparison of the Traditional Roasted and Unroasted Kernel Processes

Five kilograms of kernels were processed using the traditional roasted kernel process. Kernels were roasted in an aluminium sauce pan over an Electric stove at Medium to High heating. Roasting was done for about 40 minutes, at the end of which kernels easily disintegrated when crushed between stones. The roasting temperature at the beginning, and at specific intervals of time were recorded.

The roasted kernels were milled into a fine meal. Four hundred and fifty grams was weighed and added to 400 ml of boiling water and stirred. Additional amount of water in

smaller quantities were added and stirred until oil separated out of meal. The mass was boiled further to evaporate free water, and the oil was collected. The extraction process was repeated by boiling with additional 200 ml of water. The final meal to water ratio for the two extractions was 450 gram of meal to 800 ml of water.

A similar sample of kernels was processed using the traditional unroasted kernel process. The kernels were soaked in freshly boiled water, about 97 degree Celsius and left overnight. It was milled twice into a fine meal, using a disc attrition mill (No. 2A. Grinding Mill, Agro). The meal was boiled with water for about 30 - 45 minutes. The initial quantity of water was supplemented regularly to ensure vigorous boiling during the period. The final ratio of meal to water was 450 grams of meal to 1200 ml of water. The boiled mass was mixed with about two times its volume of cold water, and then aged overnight. An oily emulsion developed and separated out as a top layer. This was collected at the end of the aging, and boiled to obtain the palm kernel oil.

The percentage yield from each process was calculated. The specific gravities, refractive indices, free fatty acids values, iodine values, saponification values, peroxide values, (Pomeranz and Meloan, 1977, Pearson 1976, AOAC, 1975, Weiss 1970), and the photometric values, (Pomeranz and Meloan 1977) were determined. The data obtained were analysed and compared statistically.

#### 3.2.4 Effect of pre-processing heat treatment of kernels on yield and quality characteristics of oil

A kilogram of kernels each from cooked fruits of *dura* and *tenera* oil palm varieties were processed into crude oil using the roasted kernel process. A kilogram each of uncooked fruit kernels of the two palm varieties were also processed using the same roasted kernel process, under similar processing conditions. The percentage yield of oil from each treatment was calculated. The specific gravity, refractive index, Iodine value, and free fatty acid values of the oil were also determined. The values for the different oils were compared statistically.

#### 3.2.5. Effect of sorting, soaking of kernels, and meal particle size on yield and product quality characteristics

A three factorial experimental design was used in this study. Three kernel samples with different levels of sorting, (0, 50, and 100 per cent) were prepared by hand sorting. Each of the 3 samples were divided into 2 equal parts. One part each was soaked in hot water overnight. The soaked and unsoaked samples were milled into 3 different fractions; coarse, medium and fine. These were accomplished by milling one sample once, twice and three times respectively. The particle size of these fractions were determined using the microscopic method (Minifie, 1970). The meal samples were processed into oil using the unroasted kernel process. The

yield, free fatty acid values, refractive index and photometric values of the oil samples were determined.

Data obtained were analysed statistically.

#### **3.2.6 Effect of boiling of kernel meal on the yield and quality characteristics of oil.**

The boiling operation in the unroasted kernel process was examined. Five samples of unroasted palm kernel meal were extracted by boiling at different times, (0, 5, 10, 20 and 30 minutes) in duplicates. The yield in each extraction was calculated. The free fatty acid and photometric values of the oil samples were also determined. These were compared statistically.

#### **3.2.7 Effect of aging of boiled kernel slurry on the yield and quality of oil**

The aging operation in the unroasted kernel process was examined. Five samples of unroasted palm kernel meal were extracted. Each of the samples was aged for a different time (1,3,6, 12 and 24 hours) in duplicates.

The yield, free fatty acid value, and photometric value of the oil samples were determined and compared statistically.

#### **3.2.8 Effect of the mode of oily-extract separation on yield and quality characteristics**

Three unroasted palm kernel meal samples were processed into oil using the three processes presented in Figures, 4, 5,

and 6. In the first process (Figure 4), the native unroasted kernel process was systematically followed. In the second (Figure 5), the aging operation of the native process was substituted with pressing. The boiled kernel meal was tied in a cotton cloth and pressed with a juice extractor. The residue was mashed with equal volume of hot water and then pressed again. The extract was boiled to obtain the oil.

In the third process (Figure 6), the aging operation of the native process was preceded with a pressing, to have a combined operation. The unroasted kernel meal was pressed in a cotton cloth two times as in the second process to obtain the oily-extract. The residue was then aged to derive more oily-extract.

The two oily extracts were pooled together and boiled to obtain the oil. The yield of oil samples from the three processes and their photometric values were determined and compared statistically.

**Figure 5: The basic unroasted kernel process**

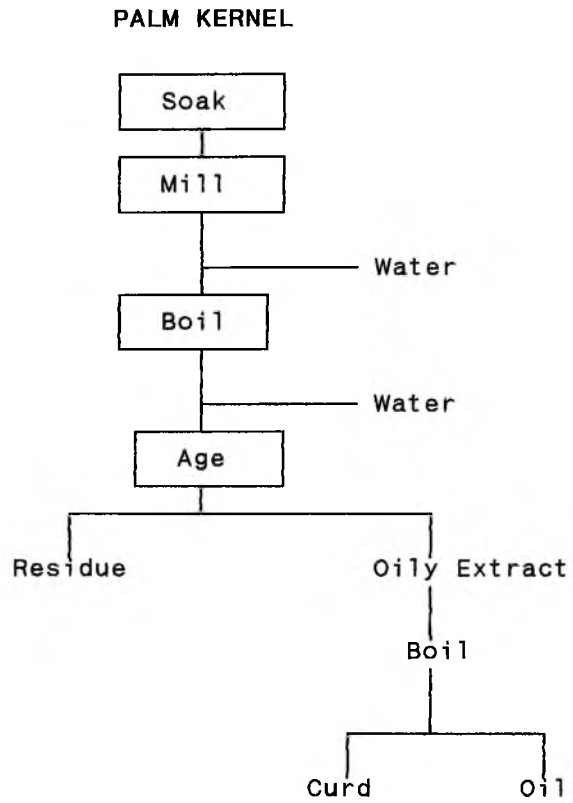
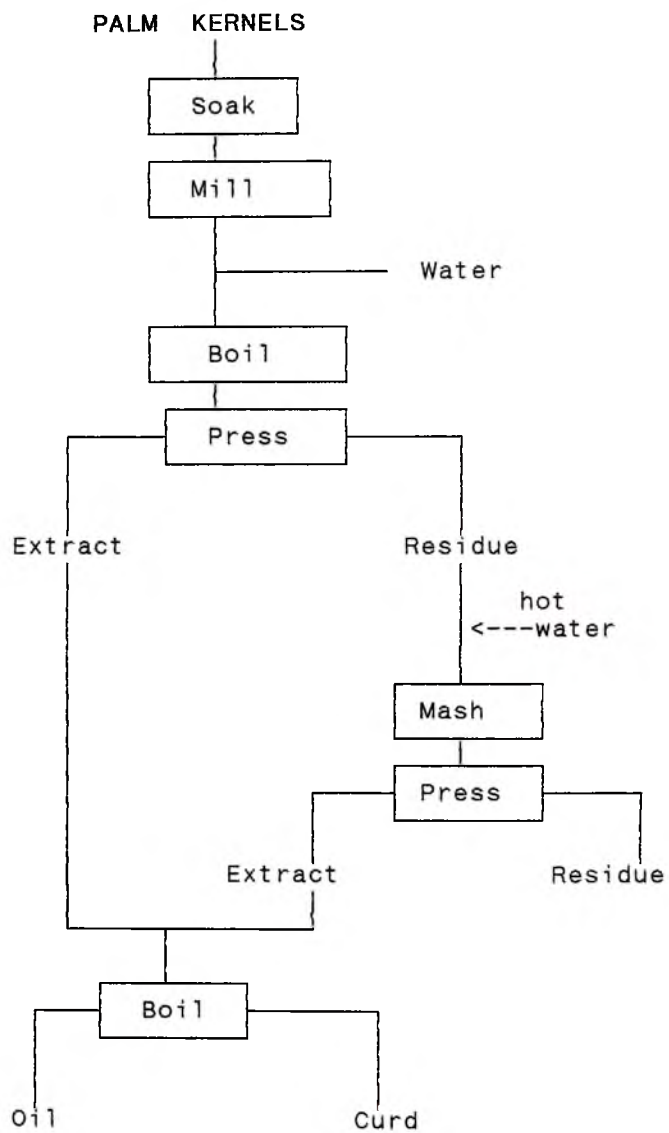
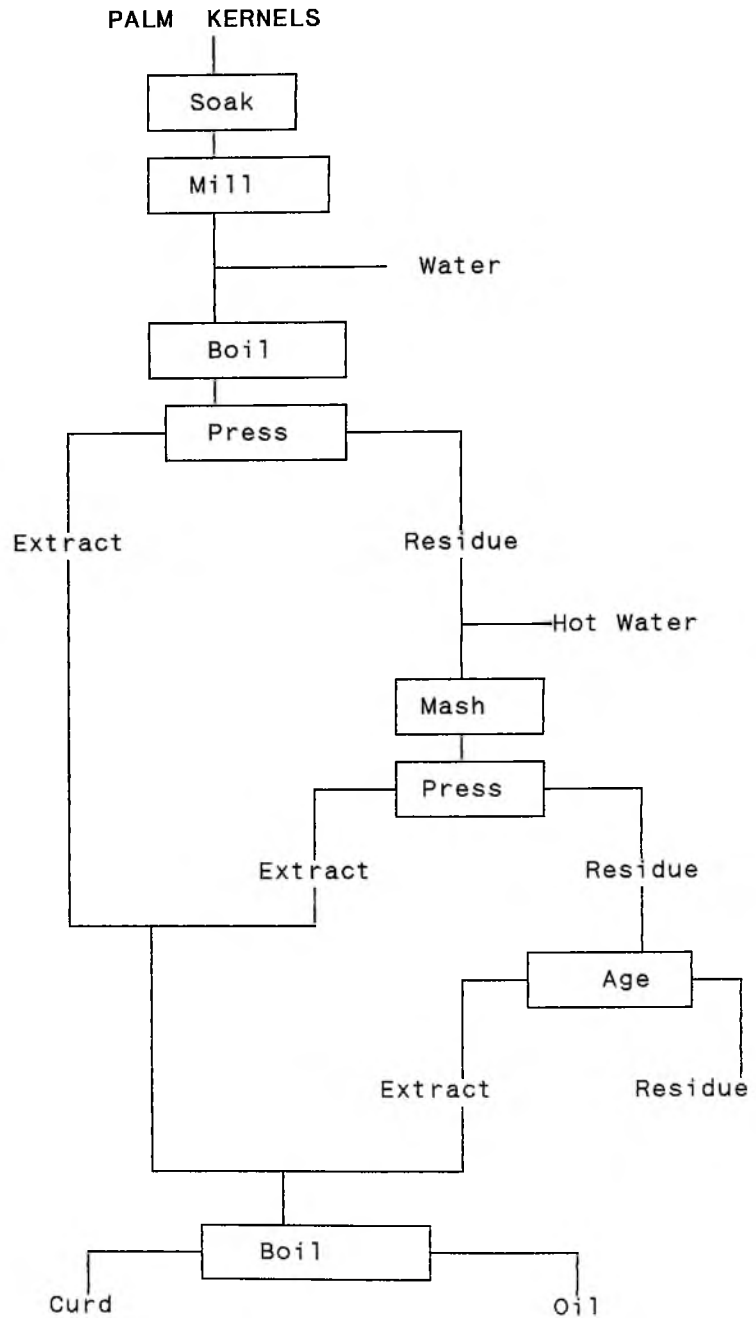


Figure 6: Modification Process 1  
(Aging Operation replaced with pressing)



**Figure 7: Modification Process 2**  
 (Aging Preceded with pressing to have combined operation)



### 3.2.9 Effect of addition of salt to meal on yield and quality of oil

Five unroasted palm kernel meal samples, about 500 gram each, were extracted using the unroasted kernel process. Salt (NaCl) was mixed into the boiled meal at the beginning of aging to find its effect on the yield and oil quality. Each of the five samples received different quantities of the salt, forming, 5, 10, 15 and 20 percent respectively, weight for weight. Similar quantities of water was used to boil and to age each; each adding up to about 2.0 litres. The boiling and aging times were also similar.

The yield, free fatty acid value, refractive index and photometric value of the oil from the different salt-treated samples were determined, and compared statistically.

### 3.2.10 Modified Processes

The parameters of the various unit operations under which yield and quality characteristics were optimum were collated to define new processing conditions for the traditional unroasted kernel process, resulting in two modified processes.

### 3.2.11 Pilot Studies

Samples of palm kernels were processed using the two modified processes and the unmodified traditional process on a pilot scale to evaluate the performance of the new processes. The yield and some quality characteristics of the products were determined and compared.

### **3.2.12 Analytical Methods**

#### **3.2.12.1 Determination of Moisture content of kernels**

Moisture content of each of the kernel samples was determined using the method described by Macfarlane *et al* (1975). Kernels were milled 3 times using laboratory disc attrition mill (Straub Model 4E Grinding Mill, Straub Co., Philadelphia, PA) and further crushed with a mortar and a pestle, to obtain fine samples. The samples were then dried to constant weight at 105 degree Celsius. The moisture content of kernel was calculated as the percentage loss in weight.

#### **3.1.12.2 Determination of Moisture content of oil samples**

AOAC (1975) method 28.002 was used. About 5 grams of oil sample was weighed and dried to constant weight in a vacuum oven at a temperature of 120°C and a pressure of 80-90 mm Hg. Percentage loss in weight of sample was reported as moisture content.

#### **3.2.12.3 Determination of Crude fat content of kernels**

AOAC (1975) Soxhlet method was used. About 2g of the kernel sample was analysed using petroleum ether (bp.40-60C) and diethyl ether as solvents.

#### **3.2.12.4 Determination of yield of oil product**

These were determined taking into consideration the moisture and fat contents of the meals, the weight of

kernel meal extracted and the weight of the oil produced from the meal.

The oil samples produced were collected into previously weighed beakers. The beakers with oils were allowed to cool and then weighed. Oil weight were then calculated. With the determined fat content, the total weight of oils in meals were calculated, and the percentage yield from a process was then calculated as follows:

$$\% \text{ yield} = \frac{\text{Wt of oil produced} \times 100}{\text{Wt of oil in meal extracted}}$$

#### 3.2.12.5 Determination of Iodine Value

AOAC (1975) method 28.029 (Wij's titration method) was used.

#### 3.2.12.6 Determination of Saponification Value

AOAC (1975) method 28.025 was used.

#### 3.2.12.7 Determination of free fatty acid value

The method described by Pearson, (1976) was used. Two grams of kernel oil was accurately weighed into a 250ml conical flask with a glass stopper. A mixture of 25 ml diethylether, 25 ml ethanol, and 1 ml 1.0 percent phenolphthalein carefully neutralised with 0.1N NaOH was added and rotated gently to dissolve the oil. The

content was titrated with aqueous 0.1N NaOH, with constant shaking until a pink colour was obtained which persisted for at least 15 seconds. The free fatty acid value was calculated as follows:

$$\% \text{ FFA} = \frac{\text{Vol. of 0.1N NaOH} \times 0.020 \times 100}{\text{Wt of oil sample used as lauric acids}}$$

#### 3.2.12.8 Determination of Peroxide Value

A method described by Tetteh (1987) was used. The procedure is outlined as follows: 1g of oil was accurately weighed into a stoppered conical flask. 20 mls of chloroform was added, and then 50 mls of a solvent mixture - acetic acid: chloroform (30:20). The flask was shaken until the oil completely dissolved. 1 ml of saturated potassium iodide solution was added.

The flask was rotated for about 20 seconds and then placed in a dark cupboard for 30 minutes. 100 mls of distilled water was added, and the mixture was titrated with 0.002M Sodium thiosulphate solution with addition of a few drops of 1% starch solution just before the end point was reached. A blank run was carried out, omitting the oil.

The peroxide value was then calculated as:

$$\text{Peroxide value (PV)} = \frac{2(S - B)}{W} \text{ mEq/kg}$$

Where S = sample titration in ml.,  
B = blank titration in ml; and  
W = weight of oil sample

#### 3.2.12.9 Determination of Specific gravity

A method described by Jacobs (1958) was used. The weight of 25 ml of distilled water, and 25 mls of oil samples were accurately determined, at the same temperature (29 degree Celsius). The specific gravity of each oil was then calculated as the ratio of the weight of the oil to the weight of the water.

#### 3.2.12.10 Determination of refractive index

AOAC (1975) method 28.007 was used. The Abbe refractometer (Olympus, Tokyo, Japan) was used to determine at 29 degree Celsius. No correction was made.

#### 3.2.12.1 Determination of photometric value

This was determined using method of Pomeranz and Meloan (1977).

The spectrophotometer model UV - 120-02 (M 101-E003C Shimadzu Corporation) was used to take the absorbance of the oil samples in a 25 mm cuvette at 460, 550, 620 and 670 nm, and with a blank of carbon tetrachloride.

The photometric value was then calculated as follows:

$$\text{Photometric Value} = 1.29A_{460} + 69.7A_{550} + 41.2A_{620} - 56.4A_{670}$$

The measure is an arbitrary number; the lightest the oil colour, the least the photometric value.

#### 3.2.12.2 Statistical Analyses

Data were analysed using the Statgraphics software (STCC Inc, Rockville, Maryland). Multiple factor analysis of variance and multiple range analyses (least significant difference) were done to compare individual values, and to determine the effects of factor on the yield and quality of oil samples produced. All analyses were tested at 95 percent confidence level.

## 4.0 RESULTS AND DISCUSSION

### 4.1 Field Work

#### 4.1.1 Respondent

The palm kernel technology is controlled by women. The oil processors interviewed ranged in age from 20 to 80 years. Most of them do not have formal education (Table 6.) The high involvement of women in the application of the technology has been reported, (UNIFEM, 1987). The involvement of men is in the operation of milling equipment. This is the only mechanized part of the process. The women therefore do the manual operations. The involvement of very old women (about 80 years) in the technology suggests that processing equipment be simple and easily operated.

Table 6: Age and Educational Status of Processors

Age	Educational Status			Total
	None	Elementary	Sec/Tech	
< 20	-	-	-	-
20-30	6	2	1	9
31-40	6	3	1	10
41-50	3	-	-	3
51-60	4	-	-	4
>60	5	-	-	5
TOTAL	24	5	2	33

#### 4.1.2 Raw Materials

##### 4.1.2.1 Predominant Raw Materials

The predominant raw material used is palm kernel. A few processors sometimes add coconut or copra. This was indicated to improve the colour and flavour of the oil. It has been reported that the addition of copra increases the yield per weight of processed material, far above an equivalent weight of palm kernel samples.

This is because coconut has a higher oil content than palm kernel, (UNIFEM, 1987, Moore, 1973). Kernels of the *dura* and *tenera* palm fruits are the varieties processed.

Sixty-one percent of processors sampled process both of the varieties.

Thirty-two percent prefer only the *tenera*, whilst 6 percent only the *dura*. Preferences are based on individual's experience with the different varieties.

Generally, the *tenera* variety is predominant since it is the variety being propagated in the oil palm plantations. The *dura* is currently obtained from the groves, which are however giving way to the plantations. *Pisifera*, the third variety is not common to farmers and so quite unavailable to processors.

The supply of nuts is seasonal and is linked to the processing of fresh palm fruits. There are therefore

periods of shortages, and periods of abundance, and this affects the price of the materials and products.

Storage of these materials is usually for a short time. Storage periods ranged from 2 days to 3 months.

#### 4.1.2.2 Minor Raw Materials

Depending on the processing method, edible oil may be used. This is purposefully used to roast the kernel to facilitate the milling. At the end however, it is mixed with the roasted kernel meal and re-extracted.

Water is also used in the actual extraction operation. Cornelius, (1983) thus described the traditional processes as water displacement methods.

#### 4.1.3 Processing methods

Two processing methods were observed. One widely known and used (by all processors visited), involves roasting of the kernels prior to oil extraction, (Figure 8a). The other does not include this roasting treatment, (Figure 8b). The two processes have some common steps.

Generally, processing starts with the acquisition of the predominant raw materials. Processors either arrange with small scale palm oil millers to purchase large quantities of nuts, or visit individual households to purchase the smaller quantities accumulated from palm soup preparations. These two sources are utilized by 93 per cent of processors interviewed. The remaining 7 percent rather obtain kernels

from markets. Processors interviewed in the Eastern region obtained their raw material mainly from the palm oil millers whereas those in Greater Accra generally make the home visits.

The nuts which may be mixed with fibre and other debris are freed by hand picking, drying and winnowing, (Plate 1 and 2). The nuts are further dried until kernels would easily separate from shells when cracked, as tested by cracking samples with stones. They are cracked, either manually on a hard surface with stones, (Plate 3a), or in motorised nut crackers, (Plate 3b).

The kernels are then separated singly by hand, (Plate 4a) or by the clay-bath method (Cornelius, 1983), (Plate 4b); in the latter, after cleaning by winnowing, and hand picking (sorting) of uncracked nuts (Plate 5). Beyond the kernel separation stage, the steps involved vary, even though there are some common unit operations.

#### 4.1.3.1 The 'roasted kernel' process

The kernels are roasted or fried in oil (Plate 6) to facilitate milling and the ultimate release of oil during the extraction. This is done in large aluminium or steel pots using palm nut shells, dried residual kernel cake (spent cake), firewood and kerosine as the predominant fuel sources. The majority of processors, (about 97 percent), actually fry the kernels, the oil used purposefully serving as a heat transfer medium to the kernels, and checking burning. The fully roasted or

fried kernels become very brittle and uniformly dark within. They also become lighter in weight as oil oozes out during the operation. Well 'roasted' kernels are removed from the pot, drained of oil and spread in containers or on the ground (Plate 7) to cool very quickly (to avoid further burning). They are then milled finely into a pasty meal which is extracted of the oil using a disc attrition mill, (Plate 8).

In the extraction operation, a thick slurry is made by dissolving the meal in boiling water. This is allowed to boil for about 30 minutes. During this time the mass is stirred frequently with a wooden stick (Plate 9), and additional water is added until a dark brown oil flows out of the boiling mass to float on the surface. Some cold water is sprinkled on the surface to wash down suspended meal particles and to clarify the oil which is collected (scooped out), (Plate 10).

The extraction is repeated two or more times by mixing the residual meal with water and boiling again. Some processors, however, after the second extraction, mix the residual meal with water into a slurry which is aged for 3 days. The remaining oil is released, and floats as an emulsion. This is collected and boiled to break the emulsion and to evaporate the water to obtain the oil.



**Plate 1 Separation of palm nuts from a press mass of fibre and nuts**



**Plate 2a** Winnowing of nuts/kernels  
The typical unaided, wind dependent system. (Nuts or cracked mass of kernels and shells are made to fall through a distance into a container along the direction of the wind. The wind blows off the lighter refuse)



**Plate 2b** Winnowing of nuts/kernels. Facilitated wind dependent system. (Air blower is used to blow air over nuts/kernels as they fall)



**Plate 2c** Winnowing of nuts/kernels using a typical manual winnower



**Plate 3a Manual cracking of nuts. A processor cracking nuts with stones.**



**Plate 3b Motorised cracking of nuts using the nut cracker**



**Plate 4a Separation of kernels using the clay-bath system**



**Plate 4b Separation of kernels by hand picking**



**Plate 5**    **Sorting of kernels of uncracked nuts before clay-bath separation**



**Plate 6**    **Roasting of palm kernels**



**Plate 7 Cooling of roasted kernels**



**Plate 8 Milling of palm kernels using the disc attrition mill**



**Plate 9 Boiling of roasted kernel meal to extract oil**



**Plate 10 Collection of oil in the traditional process**

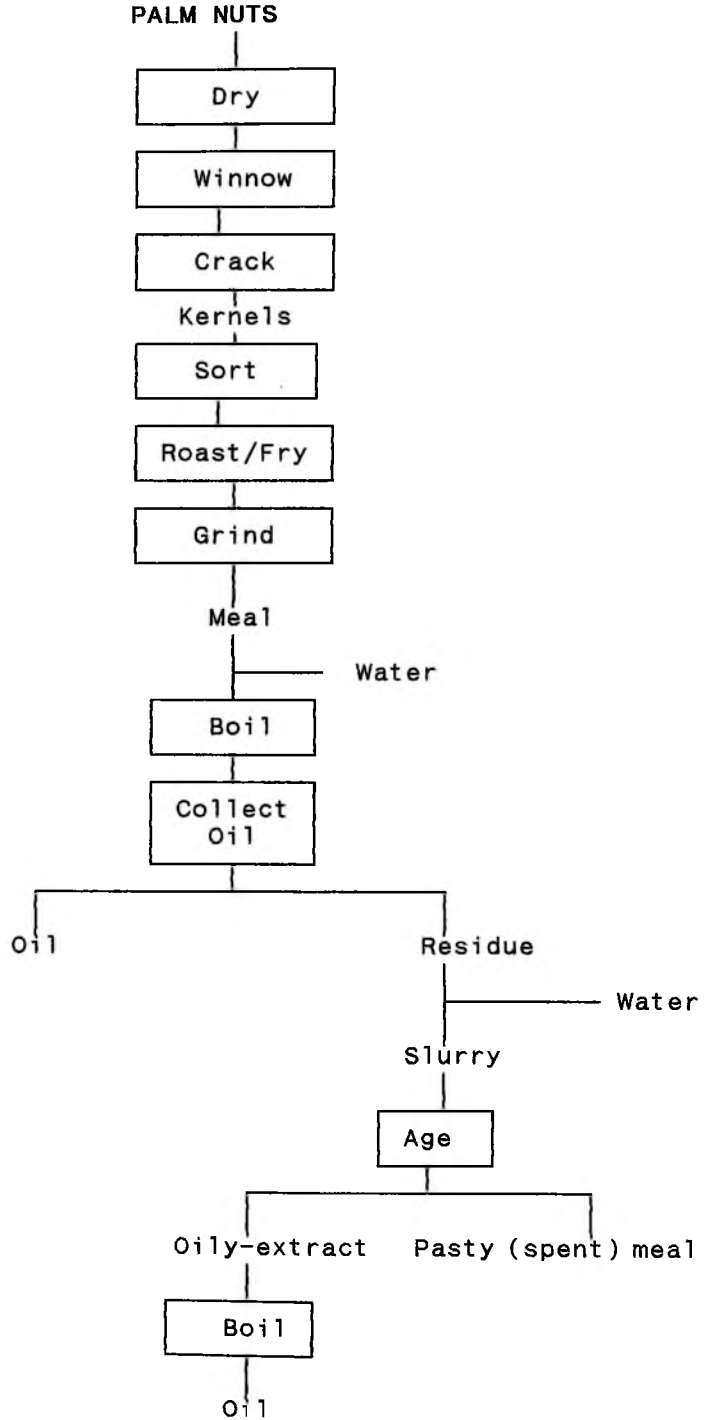
#### 4.1.3.2 The Unroasted kernel process

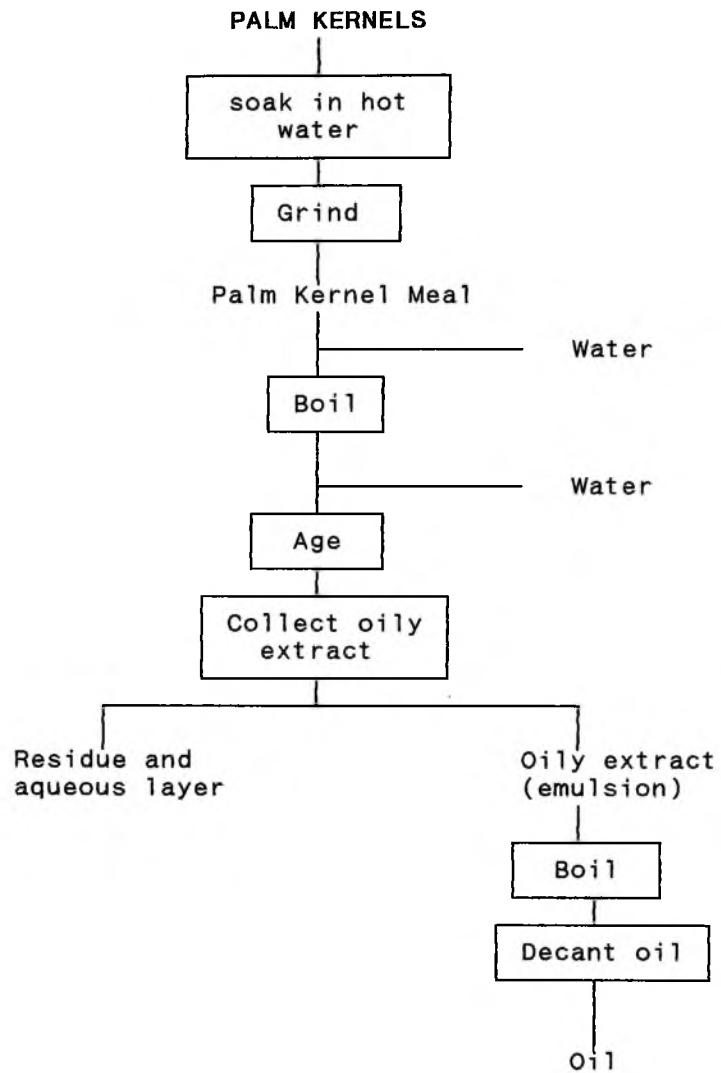
The kernels are soaked in hot freshly boiled water and left to stay in for at least 12 hours (overnight). This is purported to soften the kernels. They are drained of the water, milled 2 or 3 times to produce desirably fine particle sized meal, using the disc attrition mill (corn mill), and then extracted.

The ground unroasted kernel meal is mixed with water into a slurry and boiled for about 45 minutes, with frequent stirring. Water is added as required to enable continuous boiling. The boiled meal is transferred into many receptacles, in smaller quantities. Cold water is added, about twice the original volumes of boiled meals, and vigorously stirred. They are then left to age for about 16 hours (overnight), during which oily emulsion develops and separates to the top.

It is collected and boiled to break, and evaporate the water. A resulting clear, yellowish oil is then decanted.

Figure 8a: The traditional roasted kernel process



**Figure 8b: The traditional unroasted kernel process**

#### 4.1.3.3 Critical Operations in Processes

The critical unit operations as indicated by the processors to influence the quality characteristics and yield of the product are presented in Table 7.

**Table 7: Critical Unit operations in processes as indicated by the palm kernel processors**

Unit Operation	No. of Processors who specified (Out of 31)	% of Processors in the sample population
Roasting	29	93.55
Oil Extraction	15	48.39
Sorting	9	29.01
Milling	9	29.1

**Roasting:** This was specified to be necessary for effective milling. It determines the yield and quality characteristics of the oil produced. The colour and odour intensities of the oil for example increase with extent of roasting, becoming more darkened in over-roasting. Lighter colour oil is however more preferred, (Weiss, 1973; International Potash Institute, 1957)

**Oil Extraction:** The parameters governing this operation are, the water to meal ratio, and the boiling time. Excessive amount of water prolongs boiling time, and hence darkens the oil. It may trap some oil in the form of emulsion

with the protein of the meal, and thus lower yield. The oil may also be bloomy.

Less quantities of water however makes extraction incomplete. More oil is retained in the meal, resulting in lower yield. Oil also becomes cloudy. To ensure optimum amount of water, processors use smaller quantities, and then add a little at a time when required, until the desired thickness is achieved.

A number of processors indicated that when excessive amount of water is incidentally added, maize or cassava flour is added to the slurry to thicken. One processor however indicated the addition of some leaves (leaves of *Sida acuta*), also to thicken the slurry.

**Sorting of kernels:** The inclusion of rotten kernels was indicated to affect the taste, colour and yield of oil; shell, nuts and other extraneous matter were also indicated to lessen the efficiency of milling, and hence yield.

To avoid these problems, kernels are carefully screened and cleaned manually of all extraneous matter, shells, nuts, and rotten kernels as much as possible before they are processed. Where the proportion of rotten kernels is very high, the whole batch is discarded.

**Milling of Kernels:** Processors associate yield with fineness of meal. In general, the finer the meal, the higher the yield.

Whilst the association of high yield with fineness is universally accepted, the lowering of yield in the case of very fine meals is also worth considering. It is possible that the increased level of colloidal particles which are involved in emulsion formation, cause more oil to be retained in the residual meal, and hence the lower yield.

**Other Minor Factors:** Operations like drying and proper storage which influence the quality characteristics of the kernels were also considered by some processors to be very essential. Adequate drying, and proper storage for even short times only, were recommended for optimum yield and quality.

One processor indicated that the dark skin of the kernels also contributes to the colour of the oil. Thorough cleaning, possibly in a mortar with pestle, to scrape some of the skins was thus recommended. However, the fact that the unroasted kernel process produces lighter colour oil from the same dark skinned kernel may make this assertion invalid.

Contamination of kernels or meals with salt, or cowpea flour or peels of citrus fruits, were also indicated to lower yield. About 7 out of 31 respondents stressed this. No explanations were however given to these effects.

With the cowpea, it could be possible that the increased protein content may encourage oil-in-water

emulsion formation, making use of some extractable oil. However, the quantities of flour indicated to cause this problem are thought to be too small to cause significant loss of oil. With the salt, Ntiri (1990) observed an increase in yield in a salt-aided copra extraction.

Since copra and palm kernel have similar chemical characteristics (Bailey, 1951), it could be believed that salt contamination in the quantities indicated would rather be beneficial than detrimental to yield. Salt medium has a higher ionic strength which destabilizes oil-in-water emulsions. The assertion of these traditional processors is thus questionable.

#### 4.1.4 Processors recommendations on unit operations for improvements

About 10 percent of processors interviewed recommended all the operations for improvement (Table 8) They suggested total mechanization of the technology. Seventy seven (77) percent specified complete mechanization of the kernel production (separation) operations, (from cleaning of nuts of fibre, to removal of shells and extraneous matter). Currently, mechanised cracking and winnowing equipment are in use at some places. The clay-bath system facilitates fast kernel separation, and is even used in automated systems (Cornelius, 1983).

**Table 8: Operations suggested by processors for improvement**

Operation	No. of respondents (per cent of sampled population)	Suggested improvement method
All unit operations	3(9.68)	Total mechanization
Kernel Extraction	24(77.42)	Total mechanization
Roasting	15(48.39)	Mechanization
Oil Extraction	5(16.13)	Mechanization

Fifteen (15) out of 31 processors (48.39 per cent) wanted the roasting operation to be mechanised. Mechanised palm kernel roasters are in existence, (UNIFEM); they have however not yet reached the majority of the traditional processors. Sixteen per cent also recommended mechanization of the oil extraction operation. Many processors specified more than one operation. Generally, the operation specified are those that are highly labour intensive. They tend to make the processes very tedious and time consuming, eventually determining the rate of production. Also, there are a lot of hazards associated with them, for example the long exposures to high roasting temperature, and the inhalation of shell particles and dust. It is generally thought that the mechanization will reduce the labour intensity and the risks involved.

#### 4.1.5 Processing equipment

The equipment used in the technology are mostly local and very simple (Table 9) ranging from stones and wooden sticks to motorised disc attrition mill. They are similar for the two processing methods.

**Table 9: Processing equipment in traditional palm kernel processing with current prices.**

Equipment	Uses	Made (Local/ Foreign)	Price (Cedis) (Nov. 1991)
Stones	Cracking of nuts	Local (L)	0-120.00
Wooden stick	Stirring	L	0-120.00
Aluminium/ Steel pot	Roasting/Boiling	L	20,500 (largest size)
Basket	Sieve, Container	L	150-500 (depending on size)
Clay-Bath System	Separation of Kernels	L	-
Various receptacles	Containers	L/F	5,000 (Max.)
Ladle	Collection of oil	L	500
Calabash	Collection of oil	L	500
Nut cracker	Cracking of nuts	L/F	N/A
Winnower	Winnowing	L/F	N/A
Airblower	winnowing	L/F	N/A
Disc attrition mill	grinding	L/F	420,000 450,000

L/F - Local with foreign component  
N/A - Not available.

The basic of these are the metal pot (aluminium or steel), wooden stick, laddle or calabash, various receptacles (baskets, trays, and basins). With these, any of the two processes could be carried out, provided there is a commercial grinding mill.

Ninety percent of processors use the clay-bath system to separate kernel and also a commercial motorised nut cracker. Forty-two percent also use a commercial winnower or an air-blower to winnow nuts and kernels. A few of the equipment would be described here.

**The clay-bath separator:** This consists of a mixture of water and a fine clay (clay which does not contain appreciable quantity of sand or organic matter) with a density range of 1.05 to 1.2, in a large receptacle. In operation, the kernel/shell mixture is poured in and thoroughly stirred to release the kernels from the shells. The kernels have different density from that of the shells, (S.G. for kernel is about 1.06 - 1.07, and S.G. for shells, about 1.3 - 1.5, Cornelius 1983). By the differences in densities, the kernels float or become suspended and is sieved out, whilst the shell sink and settle at the bottom of the system. The kernels are then washed with ample of clean water.

The International Potash Institute (1957) reported of the use of common salt (NaCl) to separate kernels based on a similar principle.

**The Winnower:** There are two main types, motorised and manually operated systems. In each, the nuts with fibre and other debris or a cracked mixture of kernels and shells, are either passed through a rotating screen drum or fed on to a vibrating screened platform. As the material is rotated or shaken, the fibre, lighter shells and other contaminants which can pass through the screen fall through, leaving clean nuts, or kernels with highly reduced shell content. A typical manually operated winnower observed was shown in Plate 2c. This equipment is usually owned by the same people who own nut crackers and corn mills (disc attrition mill).

**Nut crackers:** Shown in Plate 3b was a mill operator operating a motorised palm nut cracker.

In principle, nuts are fed through a receptacle into an action zone where they are cracked. The kernels, and shells come out together. UNIFEM (1987) described some different types.

#### 4.1.5.1 Ownership of equipment

Generally, with the exception of the motorised equipment, (nut cracker, winnower, and attrition mill), all equipment (the simple inexpensive pieces) are owned by the individual processors. The nut cracker and the attrition mill are equipment for which the processors pay for service.

Service charges per batch of operation for each equipment vary from place to place. Averagely however,

at the time of the survey, nuts were cracked at ₵200.00 per maxi bag, and kernels ground at ₵300.00 per tray full of roasted kernel meal, and ₵400.00 of soaked unroasted kernel meal.

#### **4.1.6 Linkage of palm kernel and palm fruit processing**

Palm kernel processing is generally linked to the processing of fresh palm fruits into palm oil. Fifty eight percent of processors visited depend on palm fruit processors for the supply of nuts. These are mostly the kernel processors in Eastern Region where palm fruit processing is widely done. The remaining 42 percent obtain their material from either individual households or the market, thus not directly from the palm oil producers. They are mostly processors in the Greater Accra Region, where palm oil production is less extensively done.

The kernel processors who deal with the fruit processors appreciate the role of the fruit processors in their operations, and recognise a vital link between the two processes. On the other, hand the kernel processors who obtain nuts from the other sources, do not see any link between palm kernel and palm fruit processes. They think that palm kernel processing could survive without the palm fruit processors.

## 4.1.7 Product Quality and Marketing

### 4.1.7.1. Grading

Colour and taste are important quality criteria for palm kernel oil. No grading system exists for marketing palm kernel oil. Processors however aim at producing oils of lightest colour, and with no off-taste. These are judged as best quality oil by consumers.

### 4.1.7.2 Marketing

The oil is sold to middlemen, food processors, and soap manufacturers, in different units of measure. The units used are bottles (0.65 litres), gallons (4.5 litres) and tins (18 litres). Table 10 shows the average prices associated with these measures.

Table 10

Average price of palm kernel oil in cedis (¢)  
(December 1990 - January 1991)

Unit of Measure	P r i c e   R a n g e (¢)	
	(a)	(b)
0.65 litre (beer bottle)	200 - 280	80 - 140
4.5 litre (gallon)	1,200 - 1,600	600 - 900
18 litres (tin)	3,000 - 7,000	2,400 - 3,000

(a) Off-season price (at time of survey)

(b) In-season price

Conversions: 1 gallon = 7 beer bottles

1 tin = 4 gallons = 28 beer bottles

The price varies with the time of processing. Generally, they were higher during the oil palm lean seasons, and when fish is in season, (majority of fish processors prefer palm kernel for deep frying to other edible oils.

The Unroasted palm kernel oil is priced higher. Palm kernel oil appears to be less preferred to other crude vegetable oil for general cooking purposes due to the strong odour and darkened colour of the popularly known palm kernel oil (roasted kernel oil). Its usage is therefore limited to only a few people who usually use it for deep frying. In the rural communities where it is often used as stewing oil. At peak palm oil production seasons marketing of the palm oil sometimes becomes a problem.

#### **4.1.8 By-Products**

The majority of processors interviewed do not make use of the by-products, the cake and the shell. Some of the processors use the dried residual meal as fuel, or sell to meat and fish smokers to be used as such. The palm kernel cake is however, known to contain protein of good amino acid balance and calcium to phosphorus ratio (Cornelius, 1983); which makes it very good for livestock feeding. Only a smaller proportion of this traditional by-product is sold to livestock farmers for this purpose. The rest is thrown away.

#### **4.1.9 Production cost and sales of products in Traditional Palm Kernel processing**

The cost of production, the total earning and cost per litre of oil in the traditional palm kernel processing, vary

from processor to processor (Table 11). Variations are generally based on the cost of raw materials, overhead costs, price per litre of product, and yield of product.

Table 11: Inputs and Outputs of the traditional palm kernel process per batch of process

INPUT				OUTPUT		
RAW MATERIAL			OVERHEAD (Processing) COST (¢)	PRODUCT		
No:	Quantity (in maxi bag of nut)	Cost (¢)		Quantity of oil in (litre)	Value per litre (¢)	Total value of product
1	2	3,000	1,900	18.0	361.1	6,500
2	2	2,000	800	18.0	333.3	6,000
3	2	2,000	700	12.0	359.4	3,600
4	3	6,000	3,350	32.0	375.0	11,500
5	4	6,000	3,300	32.0	370.4	12,000
6	8	14,400	3,200	54.0	300.0	20,000
7	14	17,900	4,360	108.0	222.2	24,000
8	8	8,000	2,840	54.0	222.2	12,000
9	4	3,600	1,640	27.0	277.8	7,500
10	5	8,000	2,050	54.0	222.2	12,000
11	4	7,800	1,650	36.0	333.3	12,000
12	5	6,000	2,340	31.5	317.5	10,000
13	3.5	4,000	1,300	36.0	250	9,000
14	2	6,000	1,500	18.0	466.7	8,400
15	3	4,500	1,750	27.0	333.3	9,000
16	15	15,000	10,000	108.0	166.7	30,000
17	10	4,000	3,000	67.5	162.96	11,000
18	3	4,000	3,450	36.0	333.3	12,000
19	3.0	3,000	5,100	36.0	333.3	12,000
20	1.0	1,000	1,000	9.0	355.6	3,200
21	3.0	3,800	3,650	31.5	349.2	11,000
22	8.0	7,500	6,500	54.0	333.3	18,000
23	15.0	15,000	6,900	108.0	311.1	33,600
24	15.0	15,000	4,900	108.0	305.6	33,000
25	15.0	15,000	11,500	108.0	311.1	33,600
26	2.0	2,500	2,500	26.0	307.7	8,000
27	1.0	700	400	11.0	363.6	4,000
28	2.0	3,000	1,500	18.0	333.3	6,000
29	1.0	250	750	13.5	296.3	4,000
30	1.0	400	700	9.0	266.7	2,400
31	12.0	6,000	4,200	9.0	200.0	18,000

\* (1) All values and quantities are estimates from the processors studied.

Generally, between 1 and 15 maxi-bags of nuts are processed in a batch. These nuts are either bulk purchased, especially in the area where palm oil extraction is extensively done, or accumulated over a period of time, as it normally happens in Accra. The cost of the nuts varied from ₵250 to ₵2,000 at the different places. It is cheaper in the Eastern region where palm oil extraction is extensively done. It is also cheaper when purchased in bulk, (i.e. in bags or barrels in some areas).

The processing cost also varies from processor to processor, per bag of nuts processed. It ranged between ₵300 to ₵1700. The variations result mostly from the differences in charges of equipment paid for service, cost of fuel, quantities of oil used to fry kernels and transportation. Whereas some processors for instance used the shells and dried spent kernel cake to fuel processes in order to cut down cost, others also purchase fire wood. Some processors purchase water for processing whilst others do not. With the exception of hired labour, the estimated cost of the processors personal labour input was not considered when computing total cost of input.

Similarly, the yield of oil from a bag of nuts and the price per litre of oil vary from processor to processor. The yield sometimes depend on the processor's personal experience and the state of the kernels. Where there are a lot of rotten kernels for instance, it is thought that the yield is lower.

Coarse milling and poor extraction procedure will also lower the yield. On the other hand, the wide variations

observed is a reflection of the empirical nature of the traditional process. However instead of seeking methods to maintain higher yield however, many processors are of the view that luck plays a role in the process, as expressed in a statement like: "there are times when if one is lucky, would obtain very high yield from even a small quantity of materials". It is believed though that a careful study of the technology could help standardise the yield to increase the profit margins.

#### **4.1.10 Quality evaluation of field,traditionally processed palm kernel oil samples**

The quality characteristics of palm kernel oil produced vary from processor to processor, and even a batch to batch.

Evaluation of the samples collected from the different processors, showed significant variations in moisture content, free fatty acid levels, photometric colour, and the peroxide values. The Iodine values, specific gravities, and refractive indices were however, statistically similar.

Presented in Table 12 are the mean values observed for the different characteristics from the samples analysed.

The free fatty acid values, moisture content and colour intensity (photometric value) were very high. The mean peroxide and free fatty acid values were higher than values reported earlier (Ata, undated). The reported

**Table 12: Quality characteristics of some traditionally produced palm kernel oil from different processors**

% Moisture	Specific gravity (30°C)	Photometric value	% FFA	Peroxide value	Iodine value	Refractive Index
0.11	0.955	88.71	3.01	6.02	18.81	1.4555
0.09	0.956	45.68	2.87	5.44	20.07	1.4554
0.23	0.956	66.48	4.30	5.86	17.86	1.4550
0.24	0.954	85.74	7.90	6.34	19.16	1.4450
0.07	0.956	58.84	2.95	4.84	18.88	1.4450
0.15	0.956	60.49	1.64	5.46	17.82	1.4450
Mean 0.15	0.955	67.66	3.78	5.66	18.75	1.4552

values were 2.6 and 0.9 respectively . This confirms the variability in the quality characteristics. The peroxide values were however within the codex Alimentarius standards of 10 mEq/kg (max.) The free fatty acid values, even though around levels specified for international trade (Sudin and Lin, 1990), were expected to show up in a rancid flavour, (Pearson, 1976); which was the case in two of the samples. The moisture levels were above specified maximum values of 0.05 (max) (Sudin and Lin, 1990).

#### 4.1.11 Field measurement of some processing parameters

##### 4.1.11.1 Specific gravity of clay-bath solution

A specific gravity range of 1.05 to 1.08 was observed, with a mean of 1.06. In the low density system, the kernels do not completely float on the

surface but are suspended within the solution. They are thus scooped out with baskets.

#### 4.1.11.2 Roasting temperatures

The temperature of operation varies almost throughout the period of roasting. It increases quickly to a point and then begin to level up.

Generally, the kernels stay above the boiling point of water for over one hour of operation. Table 13 shows some values recorded during the survey. The time of roasting depended on the quantity of kernels in the pot, the quantity of oil used for the operation, and the intensity of the heat energy for the operation.

**Table 13: Temperature variation with time for three palm kernel processors**

Time of Roasting (Minutes)	Temperature of Medium (0 degree cesius)		
	1	2	3
0	38	37	38
15	70	68	63
30	90	90	87
45	97	96	95
60	102	101	102
75	105	106	105
90	135	134	133
100	148	148	147
110	160	163	160
120	170	175	173
130	176	180	178
140	178	183	180
145	182	-	-

## 4.2. STUDIES ON PROCESS AND PRODUCT CHARACTERISTICS

### 4.2.1. Kernel Production

Boiling of the fresh palm fruit prior to nut separation is an important operation. It was found that the production of nuts from the uncooked fruits is very difficult and takes a longer time than from the cooked fruits. Processing of the *dura* fruits was easier than the *tenera* fruits. This was probably due to the comparatively thinner fibrous layer, and the thicker and harder shell, which facilitate attrition forces for fibre separation. At the end of the operation, more damaged nuts were observed in the latter than the former, and also in the uncooked samples.

Cooking of fruits loosens the tissue of the sarcocarp, to make stripping easier with the least application of force. The harder, thick shells of the *dura* nuts seem to aid in nut separation.

Nut characteristics were quite different for each of the two fruit varieties. These have been reported by Hartley (1983), and International Potash Institute (1957). The mean shell thickness estimated ranged from 1.5 to 5 mm, and 0.5 to 2 mm for the *dura* and *tenera* nuts respectively. The *dura* nuts weighed more than the *tenera* nuts, however the proportion of kernels in the nuts was higher in the latter than the former.

For instance, a typical weight of 1000 nuts, freshly produced, was 4.1 kg and 1.9kg for *dura* and *tenera* respectively. On the other hand, the proportion of kernels per nut weight as estimated was 26.7 and 35.7 per cent

respectively. These mean that the *tenera* nuts would yield more kernels than a similar weight of *dura* nuts.

#### 4.2.2. Comparison of the roasted and unroasted kernel extraction process

The observation made in comparison of the two kernel extraction processes observed in the field in terms of process characteristics, yield, and quality of products are described.

Oil extraction from unroasted kernels took a longer time than the roasted kernels. Extraction from unroasted kernels required about 36 hours including soaking time (16 hours), milling time, cooking of kernel meal slurry (45 mins.), aging (12 - 16 hours), collection of oily extract, and boiling of extract. These activities are spread over 3 days. Extraction of oil from roasted kernels rather required about 6 hours, all within a day.

The different pre-extraction treatment had varying effects on the kernels and their oils. The roasting of kernels involved temperatures above 120°C, (Table 14), and was high enough to cause the kernels to brown.

Table 14: Temperature Variation with time in kernel roasting process

	TEMPERATURE
0	29
5	45
10	93
15	120
20	149
25	176
30	188
35	198
40	203

It made the kernels very brittle to be ground finely and easily in a single run. The hot water used to soak the unroasted kernels had an initial (maximum) temperature of about 95°C. This quickly fell to 58°C when it was added to the kernels. It stayed above 50°C for about 25 minutes and then fell. The final temperature was 26 degree at the end of the soaking period; (Table 15).

**Table 15: Temperature Variation with time in Soaking of Kernels**

Time (Mins)	Temperature (°C)
Initial of Water	95
1	58
5	57
10	56
15	52
20	50
25	48
30	46
35	42
40	38
45	26

The initial high soaking temperature could have some fungistatic effect (Weiser *et al*, 1971). The unroasted, soaked kernels were very difficult to be grind, and required several grindings. Cleaning of equipment after grinding the roasted kernel was also more involving.

The fat content of kernel is reduced moderately during roasting, and slightly during soaking in hot water. The moisture content also falls during roasting and rises during soaking, (Table 16).

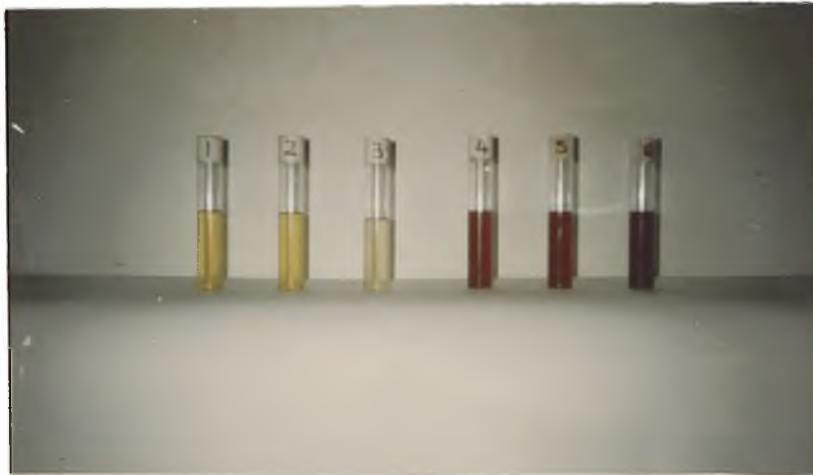
**Table 16: Crude fat and Moisture Contents of Pre-extraction treated kernels**

COMPONENT	UNTREATED KERNELS	ROASTED KERNELS	SOAKED KERNELS
Moisture	14.38	4.53	19.6
Fat	54.68	43.56	53

Roasting of kernels produces strong irritating odour. The processors are also exposed to smoke, fumes, and high temperatures (Plate 11a) more than those who use unroasted kernels. The roasted kernels process, may thus be more risky to health than the unroasted kernel process. The fumes and smoke from roasting kernels are alleged to cause sneezing and itching eye.



**Plate 11a Risks in the roasted kernel process. Elaborate exposure to fumes**



**Plate 11b Oil samples from the roasted kernel and unroasted kernel processes**

1-3 Unroasted kernel samples  
4-6 Roasted kernel samples

The yield of oil from the two processes vary. The roasted kernels yield more oil than the unroasted kernels. Table 17 shows some processing indices.

**Table 17: Yield of oil in roasted and unroasted kernel extraction processes**

PROCESS	WEIGHT OF MEAL USED (g)	FAT CONTENT (% d.m.b)	YIELD (ml)	YIELD (g)	YIELD (%)
Roasted 1	435	43.56	80	76.4	40.47
Kernel 2	435	43.56	78	74.41	39.42
Unroasted 1	375	53.45	55	52.07	26.07
Kernel 2	375	53.45	52	49.71	24.75

The values fall within reported ranges, (Addo Consultant, 1989; UNIFEM, 1987). The mean percentage yield was 39.94 and 25.41 for the roasted kernels and unroasted kernel processes respectively. These are significantly different at the 5 percent level ( $P < 0.05$ ) when tested in an analyses of variance, (Table 18).

**Table 18: Anova Summary table on yield of oil from roasted and unroasted kernel processes.**

SOURCE OF VARIATION	SS	DF	M.S.	F. RATIO	SIG. LEVEL
Main Effect	425.3409	4	106.3352	1000.0	0.0000
Process	422.5324	1	422.5324	1000.00	0.0000
Replicate	2.8084	3	0.9362	77.00	0.0025
Residual	0.036	3	0.0122		
Total	425.3774	7			

The data suggest that when palm kernels are roasted before oil extraction the yield of oil is higher. The traditional processor's reasons for roasting is thus valid. Roasting assists size reduction which results in higher yield.

The colour of the roasted kernel oil was dark brown, (Plate 11b) compared to the golden yellowish colour of the unroasted kernels oil. The former was also strong scented whereas the latter was practically odourless, with very mild fresh kernel flavour.

**Table 19: Quality characteristics of oil samples from the roasted and unroasted kernel processes**

PROCESS	SPECIFIC GRAVITY	REFRACTIVE INDEX	PHOTOMETRIC VALUE	FREE FATTY VALUE	IODINE VALUE	PEROXIDE VALUE
Roasted kernel	0.955	1.4545	39.87	1.02	16.96	9.41
Unroasted kernel	0.955	1.4541	8.80	1.44	16.94	1.2

The specific gravities and iodine values were similar for all the samples. Both oil groups had a mean specific gravity of 0.955; but iodine value of 16.96 and 16.94 for the roasted and unroasted kernel oil samples respectively. These values were statistically not significantly different ( $P < 0.65$ ). Hartly (1983), International Potash Institute, (1957), and Bailey, (1951) reported similar iodine values for palm kernel oil. Iodine value is a measure of the degree of unsaturation of oils. The number is characteristically constant for

individual oils, unless the fatty acid composition is probably significantly changed. In a similar way the specific gravity is constant at specific temperatures, unless the chemical nature of the oil is changed. The observations made thus suggested that the processes do not have significant varying effects on the chemical nature of the oil, and hence the statistically similar iodine values and specific gravities.

The photometric values, refractive indices, and peroxide values were relatively higher for the roasted kernel samples. The free fatty acid values however were higher for the unroasted kernel oil samples. Variations in these data are statistically significant ( $P < 0.05$ ) (Table 20).

**Table 20: Anova Summary table on free fatty acid values (Comparison of roasted and unroasted kernel oil samples)**

SOURCE OF VARIATION	SS	DF	M.S.	F. RATIO	SIG LEVEL
Main Effect	0.3536	4	0.0884	606.086	0.0001
Process	0.3486	1	0.3486	1000.00	0.0000
Replication	0.0049	3	0.0016	11.286	0.0384
Residual	0.0004375	3	0.00014		
Total	0.3540	7	6		

These suggest that the roasting of the kernels actually increased the colour intensity and oxidative properties of the oil, but kept the free fatty oil values lower, than in the soaked samples. Howat (1975), and Jayalekshmy and Mathew (1991) reported the darkening effect, and increased peroxide values in roasted kernels. The darkening effect reflected in

the changes in the refractive properties of the oil, and hence the photometric values and the refractive indices.

The observed variations in the free fatty acid levels could be due to the differences in treatments, in the two processes. The production of free fatty acid could be caused by thermal degradation and lipase activity. The latter is more pronounced. Whilst it is possible that the high roasting temperature caused increases in the free fatty acids in the roasted samples it is more likely that the soaking, subsequent cooking, and aging operations of the unroasted kernel process provided highly favourable conditions for both lipase activity and thermal degradation, to cause the significantly higher values in the unroasted samples.

The observations made indicate that the roasted kernel process yields more oil with lower free fatty acid values, but has strong odour and flavour. The unroasted kernel oil however has pleasant odour, more acceptable colour, but high free fatty acid value. However whilst the latter could be refined to improve upon the free fatty acid value which is even within internationally acceptable levels, (Sudin and Lin, 1990), the former could not be bleached and completely deodorized (Stork, 1960). This means the unroasted kernel oil could be conveniently improved if desired, (traditional palm kernel oil is usually used unrefined). The unroasted kernel process is thus more appropriate.

#### 4.2.3. Effects of pre-processing heat treatment of kernels on yield and gravity characteristics of palm kernel oil

Palm kernels processed into oil are usually produced as by-products of the palm oil process. As a result the kernels are subjected to invariably prolonged heat treatment, before entering the kernel processing line. The effect of this pre-processing treatment as observed in the study is described.

The values of oil yield from the different samples of kernels are presented in Table 21.

**Table 21: Yield and quality characteristics of oil obtained from processing kernels of cooked and uncooked fruits.**

KERNEL PROCESSED	YIELD (%)	SPECIFIC GRAVITY	REFRACTIVE INDEX	FREE FATTY ACID VALUE (%)	IODINE VALUE	SAPONIFICATION VALUE
Cooked Dura	54.82	0.9504	1.4547	0.50	18.98	257.81
Cooked tenera	45.01	0.9505	1.4542	0.60	18.08	249.70
Uncooked Dura	64.27	0.9504	1.4545	0.85	20.17	249.85
Uncooked Tenera	52.71	0.9505	1.4545	0.67	20.28	244.46

Apparently higher yield were observed for the uncooked samples of both fruit varieties. Analyses of variance of these values indicate however that the differences are not significant, ( $P > 0.05$ ). Differences were also observed in the yield between

the fruits varieties, but were not statistically significant. Generally, the yields were high compared to that reported by Addo Consultants, (1989) and UNIFEM (1987).

The data and analyses suggest that the pre-processing cooking does not significantly affect the yield of oil. The oil content of the pre-cooked and uncooked kernels were very similar, 53.68 and 54.62 percent respectively. The minor differences observed between the treatment might then be typical of the extraction process itself.

The oils were dark brown in colour and with strong odour. The odour was more intense for the uncooked kernel samples. The colour intensity was rather high for the oils from the cooked- fruit kernels. Howat (1975), Jones and King (1990), White, (1991) and Jayalekshmy and Mathew, (1991) described the darkened colour, intense odour, and cloudiness of the oil samples as deteriorative effects of prolonged heat treatment.

The deteriorative effects of prolonged heating are brought about by the formation and decomposition of browning and odorous compounds during thermal break down of triglycerides. The more prolonged the heat treatment, the higher the extent of deterioration. The observed differences in the colour intensities between the samples may thus be attributed to the additional heat effect when the fruits were cooked before kernel production. The stronger odour of the uncooked kernel oil samples rather suggests that the additional heating decreased the odour. It may be by decomposing some volatile compounds, or forming new compounds to influence the existing ones, (White, 1991).

Values for quality indices measured are also presented in Table 21. The specific gravities, refractive indices and iodine values were very similar for all the samples. The others apparently varied – free fatty acid values being higher for the uncooked kernel oil samples and saponification values higher for samples from the cooked fruits kernels. Apparently, variations for saponification values also seemed to occur within samples of the different kernel varieties.

Statistical analyses of the data however show that only the variation in the free fatty acids are significant. ( $P < 0.05$ ). This suggest that the cooking of fruits minimized the free fatty acid production. Oilseeds contain appreciable amount of lipases at the time of harvest, which could contribute to lipolysis (Bailey, 1951). The level of enzyme increases after harvest and during storage except when the oilseeds are cooked or "sterilized" (Howat, 1975). The "sterilization inactivates the enzymes and stops the lipolysis. Lipolysis may thus account for the significant differences in the free fatty acid values between the oil samples from the uncooked and cooked fruits kernels.

The objective of every oil extraction process is to maximize yield and produce oil less injured in quality, (Bailey, 1951; Corley *et al* 1976). The data and the analyses of the study show that the cooking of palm fruits makes nut and kernel separation easier and faster, and more effective; minimized the free fatty acid values of the kernel oil, and reduces the strong odour of the oil. These, thus support the traditional way of nuts and kernel production.

None of the variation in the characteristics was statistically significant between the different varieties of the kernels. This seems to confirm the uniformity of the kernel characteristics, as reported by Weiss, (1983).

#### **4.2.4. Effect of sorting, soaking and meal particle size on yield and quality characteristics**

The traditional processors spend several hours or days to hand-pick (sort) kernels with large pieces of shells attached, rotten kernels, the few uncracked nuts, pieces of shells and other extraneous matter from each batch of kernels before processing. These kernels are usually those purchased from large scale oil mills, or markets, or those separated in a clay-bath after motorized cracking. The sorted kernels in the unroasted kernel process are soaked for 12 to 16 hours and then milled two times before the extraction is done. The effects of the sorting, soaking and meal particle size observed in the study are described in this section.

The kernel used was purchased from the TRINGO OIL MILLS LTD; Bubuashie, Accra. It was from a batch produced by a large scale oil mill, the Ghana Oil Palm Development Corporation (GOPDC) Oil Mills, Kwae. Thirteen percent of the kernels weight was estimated to be of shells, nuts and other extraneous matter., The moisture content on dry matter basis were 5.21 and 54.62 per cent respectively.

## 4.2.4.1. The Meal Particle Size

The mean particle size of meal were 855, 552 and 327 microns respectively for samples ground one, two and three times. The estimated value for the individual subsamples are presented in Table 22.

**Table 22: Meal Particle size of sorted, soaked and differently milled meals**

## (a) Soaked Samples

LEVEL OF CONTAMINATION	MILLING FREQUENCY	MEAN PARTICLE SIZE OF MEAL (Microns)
0	1	930
	2	550
	3	290
50	1	900
	2	500
	3	430
100	1	830
	2	520
	3	330

## (b) Unsoaked Samples

LEVEL OF CONTAMINATION	MILLING FREQUENCY	MEAN PARTICLE SIZE OF MEAL (Microns)
0	1	820
	2	640
	3	350
50	1	820
	2	590
	3	300
100	1	830
	2	510
	3	260

Analysis of these data indicate that milling significantly reduces the particle size of the meal. It also suggests that the contaminant do not have any significant influence on the milling efficiency. Soaking did not increase the milling efficiency of the kernel; (Table 23). Again the data and analyses suggest that sorting, and soaking operations in the traditional processes may not be essential in achieving meal fineness contrary to the views of the traditional processes.

**TABLE 23: Anova Summary tables for mean particle size of meals**

SOURCE OF VARIATION	SS	DF	M.S.	F. RATIO	SIG. LEVEL
MAIN EFFECT	853811.11	5	170762.22	64.036	0.0000
Sorting	8444.44	2	4422.22	1.658	0.2671
Soaking	1422.22	1	1422.22	0.533	0.5002
Milling	843544.44	2	421772.22	158.165	0.0000
Sort x mill	4822.22	4	1205.56	0.452	0.7689
Soak x mill	12677.78	2	6338.89	2.377	0.1737
RESIDUAL	16000.00	6	2666.67		
TOTAL	887311.11	17			

#### 4.2.4.2 Oil Yield from the Differently Treated Meals

Percentage yield of oil are presented in Appendix 2.1. There were higher oil yield from the unsoaked kernel meals. The yield also increased with increasing fineness of meal. Sorting did not seem to affect the yield of oil. Analysis of variance of the data (Appendix 3) show that variations in yield due to soaking and meal particle size were significant ( $P < 0.05$ ). These suggest that soaking of the kernels in hot water overnight affects the yield. They also suggest that the finer the meal the higher the yield of oil.

#### 4.2.4.3. Quality Characteristics of oils.

Generally, the oil samples were pale to golden yellow, with mild odour of fresh kernel. The oil from unsoaked kernel had higher free fatty acid values which increased with increasing fineness of meal. The values were also slightly higher in samples from the completely sorted kernels. Analyses of variance of the data (Appendix 2) shows that the variations in free fatty acid of the oil due to soaking and meal particle size are significant ( $P < 0.05$ ); (Appendix 4). It is possible that the initial high temperatures of water during soaking reduced the microflora of the kernel (Weiser, *et al*, 1971) and hence lipolysis.

Differences in oil colour were observed. Generally, the oil samples from the soaked kernels were slightly more intense in colour. They therefore had higher photometric values. Statistical analyses of the data show that the variations in the colour intensity, as measured by the photometric values, are significant, ( $P < 0.05$ ), (Appendix 4). Cornelius, (1983), Hammond and Smith, (1986), and Jayalekshmy and Mathew, (1991) described the relationship between heating and darkening colour of the kernel oil. The initial high temperature of the soaking water could have thus caused the slight darkening.

The observations seem to imply that yield depends mainly on the fineness of the meal. The finer the meal,

the higher the yield. Kernels should thus be milled several times as possible to obtain the finest meal. Soaking limited the fineness of the meal (Appendix 3), and hence the lower yield from the soaked samples. They also seem to suggest that sorting is not crucial for higher yield, yield could be optimum without sorting. The low free fatty acid values for the oil samples from the soaked kernels rather suggest that the soaking is very important in keeping free fatty acids low. It is possible that the initial higher temperatures of the soaking water, (Table 15), reduced the mould population on the kernel and hence the subsequent lipolytic effect; and was thus the cause of the differences in the free fatty acid values. If this was actually the reason, then since this effect was the only benefit from soaking, (within the limitations of the experiment), the soaking time could be reduced to the first 30 minutes to both allow the effect and save time. It may also reduce the impact of the soaking operation on yield.

#### **4.2.5. Effect of boiling of palm kernel slurry on the yield and quality characteristics**

The kernel meal obtained by grinding the soaked kernels was mixed with water into a slurry and boiled for about 45 minutes before aging to separate the oil. This boiling was supposed to facilitate the oil separation. Its effect on the

yield and product quality characteristics as observed are described.

The kernel slurry, when additional water was added (about 2 times, the volume of each slurry) and aged, separated into layers; the bottom layer of residue, the middle aqueous layer, and a top oily layer. Separation between aqueous and oily layers in slurry boiled for 30 minutes was more effective than in the unboiled and less-boiled slurries. Thus the longer the boiling time the more effective the separation. Other than that, the oil remained in emulsion with the water which diffused into both the aqueous and oily phases. This could increase the volume of the supposed oily extracts collected (more water would be collected as emulsion), hence the time required to boil to break the emulsion and evaporate water; or could leave more oil with the aqueous phase uncollected.

The yield of oil from each of the boiled kernel meal was higher than from the unboiled meal (Table 24, Fig. 9). Analysis of variance of the data and a multiple range analysis indicate that the variations in yield of oil between the unboiled and differently boiled samples are significant,  $P < 0.05$ .

The free fatty acid values appeared to increase as boiling exceeds 10 minutes. The variations observed in these free fatty acid values are also statistically significant ( $P < 0.05$ ). In a similar way, the colour intensity increased with the boiling time. This reflected in the photometric values, (being lower for the less intense coloured oil from

the unboiled meal samples). These variations are also statistically significant, ( $P < 0.05$ ).

The observations suggest that boiling increases yield up to a point. It may also increase the free fatty acid levels and darken the colour of the oil significantly.

The effect of boiling of kernel meal on yield is well documented (Bailey, 1951), and is reviewed in section 2.2.1.3. In a similar way, the colour darkening and lipolytic effect that accompany heat treatment have also been reviewed, (Section 2.3.3.)

**TABLE 24: Yield of oil from the differently boiled kernel mashes and some of their quality characteristics**

Boiling time (Mins)	Yield (Percent)	Free Fatty Acid (Percent)	Photometric Value
0	37.97	1.05	23.01
5	50.61	1.05	25.10
10	53.51	1.05	25.42
20	53.51	1.09	26.74
30	52.17	1.13	26.83

**4.2.6. Effect of aging of boiled kernel slurry on the yield and quality characteristics**

The boiled kernel slurry of the meal is mixed with water, about twice the volume of the boiled mash. This is allowed to age for overnight (12 - 16hr). During the aging the oil separate out of the meal and settles on top as both free oil and oil-water emulsion.

The effects of the aging on the yield and quality characteristics as investigated are presented below.

The percentage yield of oil and some of the quality characteristics of the oil samples are presented in Table 28.

**TABLE 25 Effect of aging on yield and quality characteristics of oil**

AGING TIME (HR)	YIELD (%)	FREE FATTY ACIDS (%)	PHOTOMETRIC VALUE
1	43.75	1.36	33.46
3	46.99	1.39	21.65
6	45.59	1.42	23.61
12	45.91	1.45	14.40
24	43.62	1.53	14.36

The yield was fairly constant in all the samples. The least variations observed are not statistically significant ( $P > 0.05$ ). A very low correlation coefficient of 0.1142 between aging time and yield also suggest the poor association between the two.

The percentage free fatty acid values (FFA) showed consistent increases with increasing aging times. The analyses of variance of these data indicate that the variations are statistically significant ( $P < 0.55$ ). There is also a very high correlation, 0.9124, between the FFA values and the aging time, which suggests a strong association.

The photometric values also reflected the colour intensities of the oil samples, which apparently decreased with aging time. That is, the oil samples from the 24 hour aged meals were lighter in colour than the less aged samples, and hence had lower photometric values. The variations were statistically significant, ( $P < 0.05$ ). The correlation coefficient between the values and the aging time was also negatively high,  $-0.8955$ , suggesting a strong association.

The aging is necessary to effect a separation of the oily emulsion from the aqueous phase. The observation seem to suggest that the operation is at its optimum around the period of 3 hours. The increases in free fatty acid values with aging time suggest shorter aging periods. It is possible that spontaneous fermentation occurs as the aging period lengthened. This could cause lipolysis, to produce the free fatty acids (Bailey, 1951).

The differences in colour may be due to an effective separation of colouring dirt particles from the oil phase into the aqueous phase with increased aging time. The causes are however not very clear.

The observations suggest that aging for 3 hours is adequate for optimum performance. The traditional way of overnight aging is thus not justified.

#### 4.2.7 Effect of the mode of oil extract separation on yield and quality characteristics

The aging operation is the only mode for separating the oily extract from the boiled kernel slurry. It was thought however that introducing pressing in the separation operation could increase the yield. This was therefore investigated. The effects of the aging, pressing, and a combination of pressing and aging as observed are described in this section.

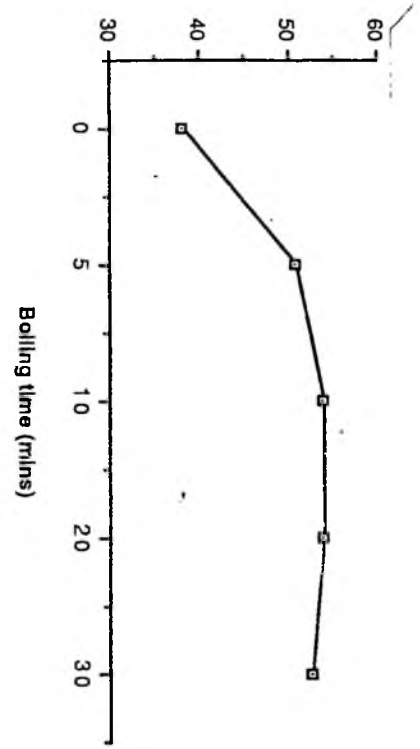
The yield and colour intensities (Photometric values) of oils with the different modes of separation are presented in Table 26.

TABLE 26 Yield and Photometric Values of oil samples obtained with different modes of extract separation

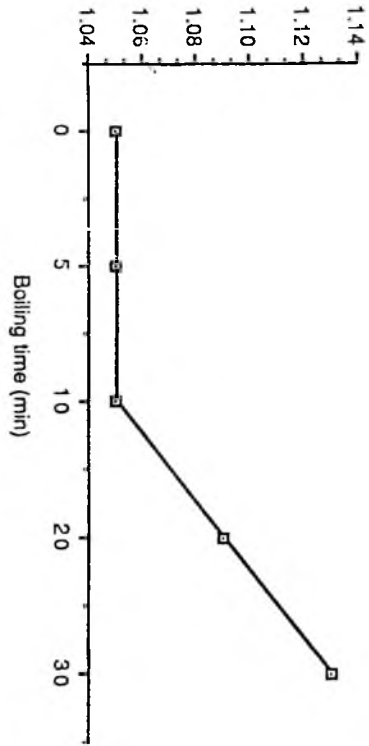
MODE OF SEPARATION	YIELD (PERCENT)	PHOTOMETRIC VALUE
Aging	44.63	6.87
Pressing	20.64	7.44
Pressing + Aging	8.39	18.38

**Fig. 9**      **Effect of boiling on yield and quality characteristics of palm kernel oil**

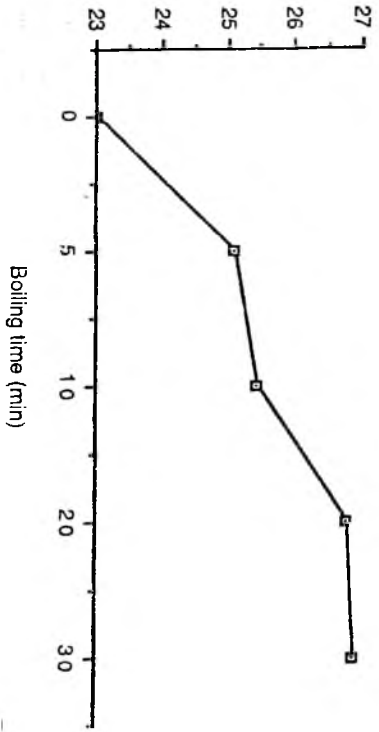
Yield (%)



Free fatty acids level (%)



Photometric Value



The combination of pressing and aging (Pressing + aging) yielded the highest amount of oil. This operation and the aging operation yielded over two times as much as the pressing operation.

Statistical analyses (Multiple range analyses) show that the yield from the pressing operation is significantly different from the others. The values from the aging and the combination of pressing and aging were however similar, (Appendix 6).

The photometric values were comparatively higher for the aging separated sample, but similar for the other two. The former and latter are statistically, significantly different ( $P < 0.05$ ), (Appendix 6).

These observations suggest that combining pressing and aging would be favourable for achieving high yield in the traditional unroasted kernel process. Based on the observations one could have suggested that the combination of pressing and aging is a better strategy to increase the performance of the traditional process. A similar practice is used to increase yield in some modern mills, where pressing and solvent extraction are combined in one process, (Cornelius, 1983). However, factors like the convenience of the combination, the availability of the pressing equipment and the extra cost to processors, compared to the significance of the additional benefit may not justify this combination. In this case, the aging operation is justified.

#### 4.2.8 Effect of the addition of salt to boiled kernel slurry in the aging operation on the yield and quality characteristics of the oil

Common salt (NaCl) has been demonstrated to increase the yield of oil in copra processing, (Nitri, 1990). With the similarity of palm kernel with the copra, it is thought that similar effect would result when salt is added in the processing of kernels. However, traditional palm kernel processors indicate that even the slightest contamination of kernels or their meal with salt lowers the yield significantly (Section 4.1.3.3.)

This section describes the effect of salt on the yield and quality characteristics of the oil in the unroasted kernel process. Table 27 (Fig. 10) shows the yield, free fatty acid values, refractive indices and photometric values of the oil samples produced from the different salt treated kernel slurry samples.

Addition of 5 to 10 percent salt gave a slight higher oil yield than all the others. A fall in value from the 10 percent level was also observed. Statistical analyses (anova) show that the effect of addition of salt on yield is not significant ( $P > 0.05$ ). It may therefore not be necessary to add to the slurry as done in copra processing.

TABLE 27 Yield and quality characteristics of oil samples from the different salt-treated kernel slurry samples

SALT LEVEL (%)	YIELD (%)	FREE FATTY ACID (%)	REFRACTIVE INDEX	PHOTOMETRIC VALUE
0	48.97	1.47	1.4565	15.775
5	52.43	1.56	1.4560	10.82
10	52.22	1.45	1.4560	12.705
15	47.88	1.53	1.4560	11.00
20	46.82	1.67	1.4557	12.44

The percentage free fatty acid (FFA) values were also not affected by the addition of salt: (not statistically significant,  $P \leq 0.05$ ). The colour intensities of the oil samples were also quite similar. Here too no definite pattern was observed with the different concentrations of salt. The refractive indices were very similar, with no statistically significant variations at 95 percent confident level.

The photometric values were also similar, though slightly higher for the 0 percent salt level sample. These seem to suggest that the salt lightened the colour to some extent. The variations in the photometric values were statistically significant ( $P \leq 0.05$ ), and multiple range analyses indicate the 0 percent samples as the cause of the variation, (Appendix 8). It is possible that the high ionic strength created by the salt caused better precipitation of pigment and other coloring matter, making the oil sample more clearer.

In general, the observations suggest that salt (NaCl) could be added up to about 5 percent of the weight of the meal without limiting the extraction efficiency and damaging the

quality of the oil. This observation is contrary to the assertion of the traditional processors revealed during the survey. One could thus consider the use of a 'salt-bath' system for the separation of kernels from shells, in place of the clay-bath. The salt-bath could be more convenient particularly in this country where salt abounds. Some of the advantages of the salt-bath system may include the cleanness of the operation which may demand less water; the higher feasibility of using it in large scale processing, the less bulkiness of salt compared to the clay, and the possibility in improving the oil colour and clarity.

#### 4.2.9. The Modified Unroasted Kernel Processes

Presented in Figures 11 and 12 are flow diagrams of two palm kernel processes based on the traditional unroasted kernel process. The processing conditions have been modified with the optimum parameters observed in the laboratory investigations. Both modified processes have some advantages over the original process. These include:

- (1) **Reduction in processing time.** The processing time is very substantially reduced from over 36 hours to less than 12 hours. This is achieved with cuts in times for the different unit operations, including cuts in times for soaking of kernels, from 12 - 16 hours to 30 minutes, boiling of kernel slurry from 45 minutes, to 10 - 20 minutes, and aging of boiled kernel slurry, from 12 - 16 hours to 3 hours.

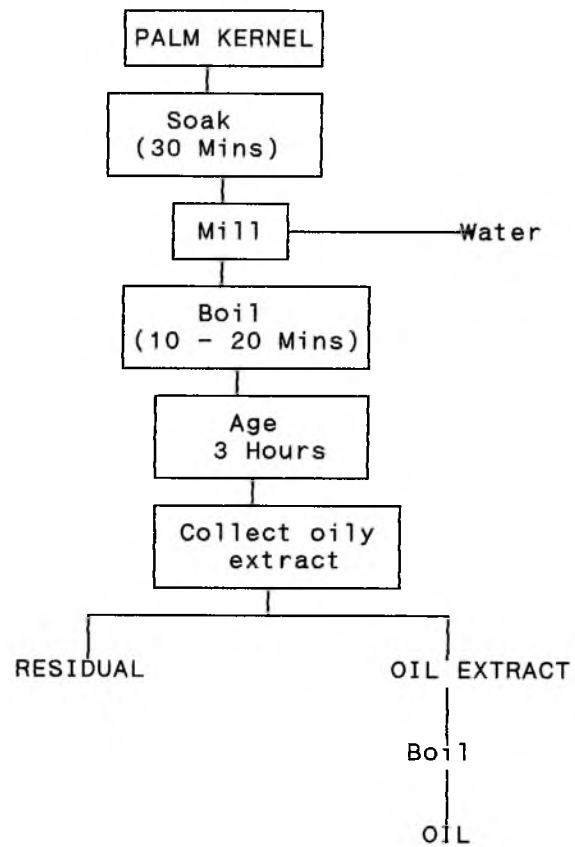
**Figure 11** The Modified aging-operated oil separation method

Fig. 10 Effect of salt on yield and quality characteristics of palm kernel oil

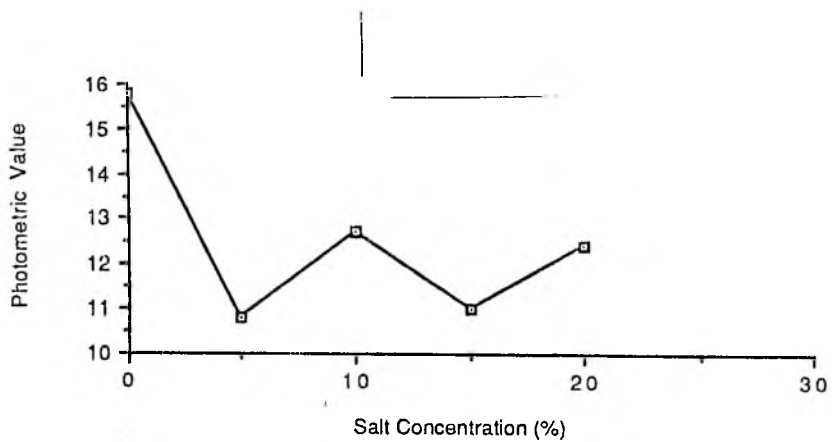
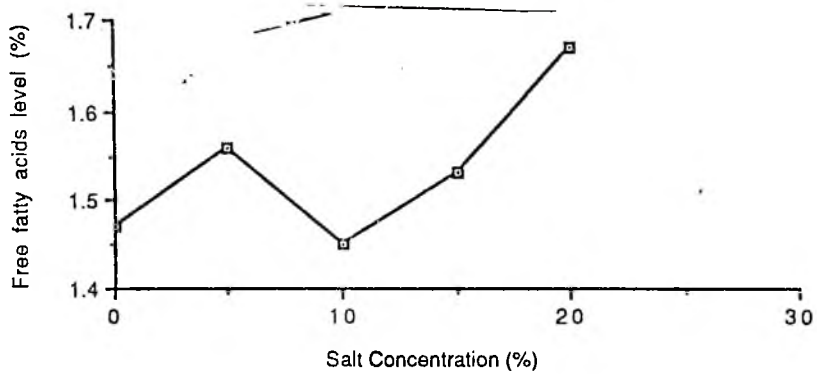
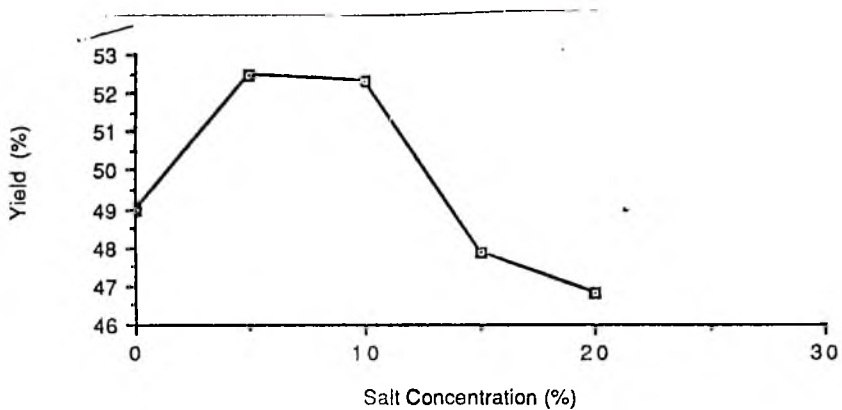
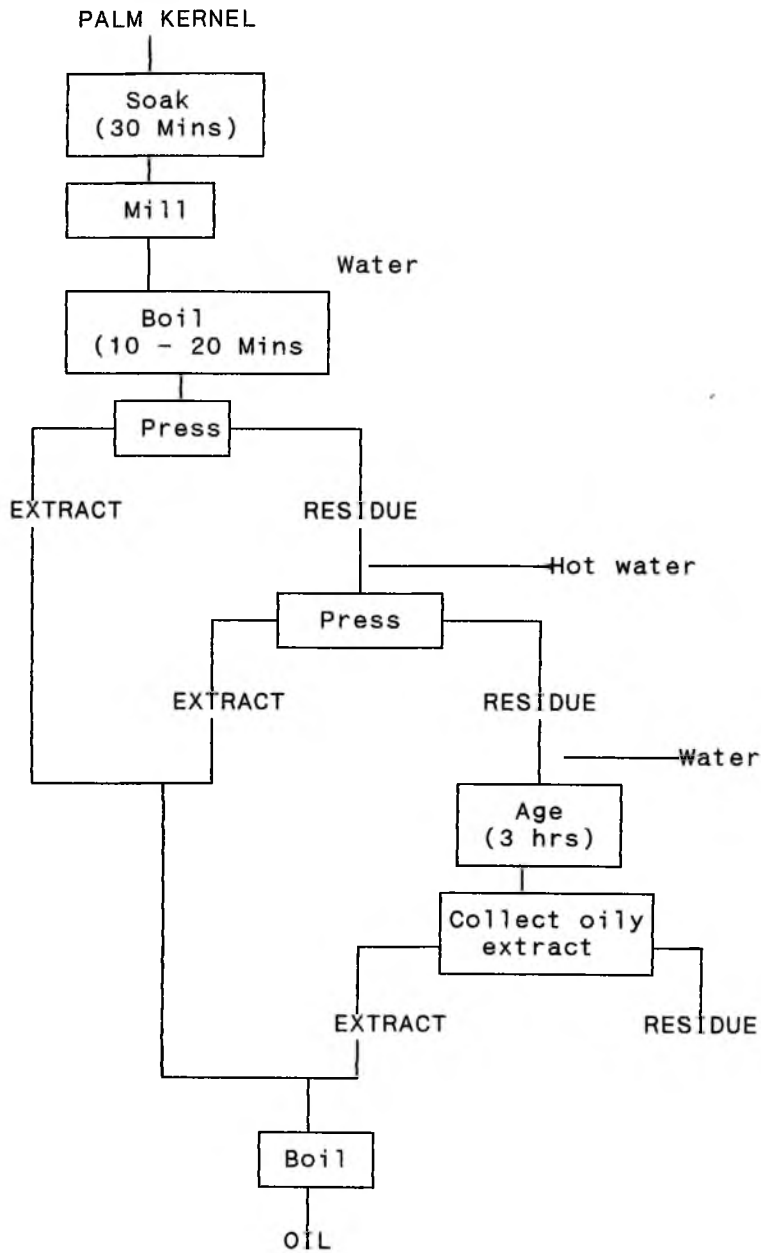


Fig. 12 The Combined Pressing and Aging oil Separation Operation methods.



- (2) **Increase in yield.** The yield is significantly increased from less than 40 percent to about 50 percent of the total fat content of kernel.
- (3) **Improvement in the general quality characteristics of the oil, particularly colour and free fatty acid levels.** Colour is improved with the minimization of heat treatments. Free fatty acid level is also reduced with the cuts in soaking, and aging times and the heat treatments. These improvements would likely reflect in better flavour, odour and taste of the oils from the processes. The processes are described below.

**Modified Process 1: The modified aging oil separation operated method (See Fig. 11)**

The palm kernels are soaked with hot water and allowed in for about 30 minutes. This is to give the fungistatic effect and hence reduce lipolysis. It is thought that this effect could also be achieved by holding the kernels in roasters below 100°C for up to 30 minutes; or boiling the kernels for about 15 minutes. The heat treated kernels are milled at least 3 times into a fine meal.

The meal is mixed in boiling water into a slurry, and boiled for 10 to 20 minutes. This is mixed further with cold water to about twice the volume of the boiled slurry and then aged for 3 hours.

The slurry separates into a bottom residual meal layer, a middle aqueous layer and a top oily - layer.

The top layer is collected then boiled to break the emulsion and evaporate. The left over residual meal and aqueous layer is discarded.

**Modified Process 2: The Combined Pressing and Aging oil separation operated method**  
(See Fig. 12)

The process is similar to the modified process 1 except that the aging operation is preceded with pressing. The boiled kernel slurry is pressed in a clean cloth to get the oil extract. The residual meal is mixed and mashed with hot water, of similar volume and pressed again. Cold water, about two times the volume of pressed meal is mixed with the pressed meal, mashed, and then aged for 3 hours. The oily layer is collected as in modified process 1. All the extracts are pooled together and boiled to obtain the oil.

#### 4.2.10 Pilot Studies on Modified Processes

The observation on the yield, free fatty acids and photometric values of products from the original traditional unroasted process and the modified processes are presented in Table 28.

The yield from the modified processes were higher than that from the unmodified process. Values for the two modified processes were however similar. Analyses of variance and a multiple range analyses of the data show that the variations are significant ( $P < 0.05$ ), and it is the value for the unmodified process which is different from the cites (Appendix 9).

**Table 28 Yield, Free Fatty Acids and Photometric Value of products from unroasted palm kernel process**

PROCESS	YIELD (%)	FREE FATTY ACID (%)	PHOTOMETRIC VALUE
Unmodified process	29.65	3.56	21.46
Modified process 1	43.86	3.55	21.06
Modified process 2	43.94	3.46	22.75

The free fatty acid values were quite similar. The values were generally higher for all the samples from this batch of kernels. Analyses of variances of the data showed no significant difference at 95 percent confidence level; suggesting that the modification may not have significant effect on the free fatty acid values on higher scale of production.

The photometric values were also similar for all the samples. Analyses of variance indicated no significant variation, ( $P \geq 0.05$ ). This also suggests that the modification may not significantly improve the colour on a larger scale processing.

In general the observations suggest that yield is significantly improved, and processing time significantly shortened in the modified processes. Improvement in quality characteristics may however not be significant on a large scale. They also suggest that the efficiencies of the two modified processes are similar and for the cost-effectiveness

and convenience of processing, the aging process is more justified.

## 5. CONCLUSION

Data collated from the field survey revealed two traditional methods of palm kernel processing, the roasted kernel method and the unroasted kernel method. The roasted kernel method involves roasting and milling of the kernels and a water displacement extraction. It is the predominant method used by all the traditional kernel processors. It yields dark brown, strong scented, strong burnt flavoured oil, the type of traditional palm kernel oil found on the Ghanaian markets. The unroasted kernel method involves soaking and milling of the kernels and another form of water displacement extraction involving aging of the meal in a slurry form. It yields pale yellowish, practically odourless, mild fresh kernel flavoured oil. The method is scarcely used by the traditional processors, yet its oil product is considered superior in quality, compared to the roasted kernel product.

The technology of palm kernel processing involves predominantly women, ranging in ages from 20 to 80 years. Majority of them have had no formal education. The processors make use of simple, inexpensive equipment to process the kernels. The palm kernel is the predominant raw material.

However, some processors sometimes add copra to increase the yield, and to improve the colour in the roasted kernel process. The kernels which are of the *dura* and *tenera* oil palm varieties are seasonal in supply and the supply is linked

very well with the processing of the fresh palm fruits. They are generally purchased from traditional palm fruit processors or from individual households in the nut form and cracked to separate the kernels.

The processes are labour intensive and many of the processors wished that most of the unit operations, which are currently manual, are mechanised.

Marketing of the oil is similarly done in most places. There are no grading systems, except that lighter coloured oils are more preferred. The oil is sold in different measures at varying prices. Generally bottles (predominantly beer bottle, 0.65 litres), gallons (4.5 litres) and tins (18 litres) are the measures used. The prices vary from place to place, and from season to season; being highest in the palm kernel off-seasons. The net output from a batch of process may vary from processor to processor. This may be due to variations in cost of raw materials from one place to another, the variations in overhead cost for processing, variations in yield from similar quantities of kernels, and the variations in price per litre of product. By-products, the spent meal or cake, and the shells, are generally discarded. Some processors in Accra dry a small quantity and use as fuel for heat processes.

The quality characteristics of the oils vary from one market sample to another. Significant variations in moisture content, free fatty acid values, photometric values, and peroxide values for instance occur. This may partly be due to lack of standardisation in the processes, differences in the

raw material quality, and the inherent characteristics of the processes.

The laboratory investigations have indicated that the process characteristics of the methods influence the yield and the quality characteristics of the oil.

The roasting operation which many processors today see to be indispensable in palm kernel processing, is responsible for the darkened colour and strong odour of the roasted palm kernel oil. These characteristics make the oil less preferred to other edible oils, thus lowering the economic value of the oil. The operation however is seen to be imperative for higher yield. It destroys the tissues and cells of the oily material to release the oil; and also makes the oil less viscous. Other heat applications such as boiling, to the kernel or its meal, have similar effects on yield, but with a milder effect on the oil quality.

Milling of the kernels into a finely comminuted meal is a very crucial operation in the process. The finer the meal, the higher the yield of oil. The roasting operation, facilitates fine milling; kernels roasted could be milled only once to obtain a very fine meal, as compared to unroasted kernels which ought to be milled several times in the disc attrition mill. On the contrary, soaking of kernels limits the comminution and hence the yield. Soaking with freshly boiled water however keeps the free fatty acid level of the oil low, probably due to a possible fungistatic effect.

The aging operation used to separate out oil from kernel slurry in the unroasted kernel process was found to be

adequate by the third hour of operation. Beyond this, no significant increase in yield occur, and the free fatty acid level of the oil may even increase; and before it also, the yield may not be optimised.

Considering acceptability of the palm kernel oil and the process characteristics, it is suggested that the unroasted kernel process is more appropriate for the traditional technology. However, the operating conditions should be improved to optimise the yield and quality characteristics and to shorten processing time. In this wise, the modifications suggested are worth considering. These should however be further tested using other experimental designs, such as the response surface methodology, to further optimise the process conditions. The modifications are:

1. Soaking of kernels should not exceed 30 minutes. It should be done in freshly boiled water (about 95 -100°C). Soaking could better still be avoided by holding kernels in a roaster below 100°C for 10 - 30 minutes, or boiling the kernels for 10 - 20 minutes. The rationale is to give the kernels a mild pre-processing heat treatment to cause the possible fungistatic effects.
2. Kernels should be very finely comminuted; to obtain particle size of about of about 300 $\mu$  (at least 3 times milling).
3. Cooking of kernel slurry should not exceed 20 minutes of boiling at 100°C.

4. Aging of kernel slurry should be done for averagely three hours, not far below or beyond.

It is thought that these would also help to standardised the process to reduce the variations in the yield and product characteristics from batch to batch and from processor to processor. This is provided palm kernels of good quality characteristics would be processed.

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## APPENDICES

### Appendix 1

#### QUESTIONNAIRE FOR PALM-KERNEL OIL TECHNOLOGICAL SURVEY

Date.....

1. Region..... 2. Town/Village.....

#### RESPONDENT

3. Sex.....M/F 4. Age .....

5. Educational Status (formal)

- |         |          |                    |
|---------|----------|--------------------|
| a) None | b) Elem. | c) Sec/Tech/Comm   |
| d) Voc. | e) Univ. | f) Other (specify) |

#### TECHNOLOGY

6. Local name of product.....  
 7. Local name(s) of process (if any).....  
 8. Predominant ingredient(s).....  
 9. Other ingredients .....

10. What steps do you follow in the preparation of the food?

- |          |          |
|----------|----------|
| a) ..... | f) ..... |
| b) ..... | g) ..... |
| c) ..... | h) ..... |
| d) ..... | i) ..... |
| e) ..... | j) ..... |

11. Please describe what you do at each step (include objective) equipment and how these affect the yield and quality of the product. Then also, the proportions of raw materials, pre-treatment and conditions of operations such as heating temperatures and pressures (if known). (Indicate the time spent in each step).

.....  
 .....  
 .....  
 .....  
 .....

12. a) Which of these steps do you consider important in achieving the desired quality in the products? Give reasons.

Step	Reason
a) .....	.....
b) .....	.....
c) .....	.....
d) .....	.....
e) .....	.....

- b) How do you control these steps?

.....  
 .....  
 .....  
 .....

13. In which of these steps do you think improvement is necessary to make processing more profitable and/or more easy?.....

.....  
 .....  
 .....

14. Suggest any improvement you will want to see in the steps listed in 13.

Step	Improvement
.....	.....
.....	....
.....	.....
.....	....
.....	.....
.....	....
.....	.....
.....	.....

15. Describe any other palm kernel extraction process you know, as in 11. Indicate the variation with the previously described process and your reason for a preference.

.....  
 .....  
 .....  
 .....  
 .....

**EQUIPMENT**

16. List the equipment and implements used for processing

Equipment Local/Foreign	Uses
.....	.....
.....	.....
.....	.....
.....	.....
.....	.....
.....	.....
.....	.....

17. Which of the equipment to you own? Please indicate cost and when purchased.

Equipment	Cost	Date of Purchase
.....	.....	.....
.....	.....	.....
.....	.....	.....
.....	.....	.....

18. Which of the equipment do you rent?  
 .....  
 .....  
 .....

19. Which of the equipment do you pay for services?

Equipment	Charges per batch of process
.....	.....
.....	.....
.....	.....

**RAW MATERIALS SUPPLY**

20. Where do you obtain you major raw materials? (Indicate all sources)

- a) Oil palm mills (directly).....
- b) Market ..... c) Home .....
- d) Other (specify).....

21. In what form is the material obtained?  
 a) ..... b) Kernels  
 .....

22. Oil palm fruits are generally grouped as 'Agric' and 'Local' in the country. The 'Agric' type represent what

oil palm breeders call Tenera and Piscifera, and the local type, Dura. Do you use kernels of a specific type for your process? If yes, specify the type and give the reason.

.....  
.....  
.....

23. How do you store your raw materials (indicate the form in which they are stored, the storage condition and pre-storage treatments).

.....  
.....  
.....  
.....

24. Are the raw materials easily available? Explain, indicating the general supply conditions and your personal constraints in obtaining them.

.....  
.....  
.....  
.....

**LINKAGES AND HUMAN RELATION FACTORS WITH PALM OIL PROCESSORS**

25. Do you often come into contact with palm oil processors in the course of your work? ..... Y/N For what?

.....  
.....  
.....

26. Do you find any linkage between palm kernel oil processing and palm oil processing? ... Y/N

27. Describe the linkage, if yes.

.....  
.....  
.....  
.....

28. Do you recognize any relationship between palm oil processors and palm kernel oil processors, generally? ..... Y/N

29. Describe this relationship. If yes, outlining the factors that underlie the relationship.

.....  
.....  
.....

30. How does the relationship influence palm kernel oil processing?

.....  
 .....  
 .....  
 .....

**PRODUCT QUALITY AND MARKETING**

31. Are there any grading systems for marketing? ..... Y/N

32. If yes, what criteria is used for grading?

a) Intended uses

.....

b) Colour

.....

c) Other (specify)

.....

33. How many grades are there and what are their characteristics.

Grade	Characteristics
.....	.....
.....	.....
.....	.....
.....	.....

34. What grade(s) of products do you produce and why?

.....  
 .....  
 .....  
 .....

35. How do you market your products?

.....  
 .....  
 .....

36. What are your units of measures and the prices that could be obtained for them.

Unit	Price
.....	.....
.....	.....
.....	.....

37. Do you receive complaints from customers? .... Y/N

38. If yes, are there complaints recorded? .... Y/N
39. Is any action taken about customers complaints? Describe the action taken with the kinds of complaints?

**Complaints**

**Action**

.....

.....

.....

.....

40. Do you find it a problem to market your produce? ..Y/N

41. Describe the problem(s).....
- .....
- .....
- .....

**BY-PRODUCTS**

42. What kinds of by-products do you produce?

.....

.....

43. What do you do with them?

.....

.....

.....

**FINANCIAL ANALYSIS**

44. **INPUT**

a.	<u>Materials</u>	<u>Quantities</u>	<u>Cost</u>
		<u>Per Batch</u>	
	.....	.....	.....
	.....	.....	.....
	.....	.....	.....

- b. Total cost of fixed assets and other equipment

Building.....

Equipment owned.....

Equipment rented.....

Equipment paid for service .....

Other .....

c. Labour charges for a batch

<u>Type of work</u>	<u>Labour requirement</u>	<u>Cost</u>
.....	.....	.....
.....	.....	.....
.....	.....	.....

d. Overhead costs.....  
 Total inputs.....

45. OUTPUTS

- a. Quantities of products produced in a batch  
 .....
- b. Average stable prices per unit quantity  
 .....
- c. Total sales from a batch  
 .....

46. Taxespaid.....

## APPENDIX 2

Yield and Quality characteristics of Oil Extracted from Soaked and Unsoaked Samples with Different Levels of Contamination and Different Frequency of Milling

## (a) Soaked Samples

Meal Sample		Yield (%)	Refractive Index	Photo-metric Value	Free Fatty Acid
Level of Cont'n	Freq. Milling				
0	1	39.07	1.4560	21.85	0.91
	2	43.47	1.4560	25.85	0.87
	3	60.73	1.4560	23.81	0.91
50	1	36.40	1.4555	22.94	0.83
	2	45.19	1.4560	24.86	0.93
	3	51.40	1.4560	27.22	0.92
100	1	33.39	1.4560	25.66	0.89
	2	48.39	1.4555	27.87	0.86
	3	57.58	1.4560	26.37	0.96

## (b) Unsoaked Samples

Meal Sample		Yield (%)	Refractive Index	Photo-metric Value	Free Fatty Acid
Level of Cont'n	Freq. Milling				
0	1	33.65	1.4555	16.35	1.25
	2	51.15	1.4555	14.58	1.47
	3	74.79	1.4560	15.84	1.72
50	1	34.82	1.4555	17.93	1.07
	2	52.40	1.4560	15.58	1.46
	3	75.52	1.4560	19.79	1.72
100	1	41.58	1.4550	17.13	1.13
	2	58.33	1.4550	16.82	1.13
	3	79.06	1.4560	18.86	1.48

Appendix 3: Anova Summary Table on Yield for the Effect of Sorting, Soaking and Milling on Yield and Quality

SOURCE OF VARIATION	SS	DF	M.S.	F.RATIO	SIG. LEVEL
MAIN EFFECT	3176.4727	5	635.2945	48.79	0.0001
Sorting	45.7744	2	22.8872	1.758	0.2507
Soaking	404.9738	1	404.9858	31.103	0.0004
Milling	2725.7124	2	1362.8562	104.667	0.0000
2 FACTOR INTERACTION					
Sort x Mill	26.9488	4	6.7372	0.517	0.7273
Soak x Mill	285.2733	2	142.6366	10.954	0.0099
RESIDUAL	78.1256	6	13.0209		
TOTAL	3566.8204	17			

Appendix 4 Anova Summary Table on Free Fatty Acids Effect of sorting, soaking and milling on Quality of Kernel Oil

SOURCE OF VARIATION	SS	DF	MS	F. RATIO	SIG. LEVEL
MAIN EFFECT	1.3167	5	0.26335	26.046	0.0005
Sorting	0.0407	2	0.02036	2.013	0.2143
Soaking	1.05125	1	1.05125	103.970	0.0001
Milling	0.2248	2	0.1124	11.117	0.0096
2 FACTOR INTERACTION	0.180056	6	0.0300	2.068	0.1057
Sort x Mill	0.03642	4	0.0091	0.901	0.5185
Soak X Mill	0.14363	2	0.0718	7.103	0.0262
RESIDUAL	0.0607	6	0.01011		
TOTAL	1.5575	17			

**Appendix 5: Anova Summary Table On Photometric Values Effect of Sorting Soaking and Milling on Quality of Kernel Oil**

SOURCE OF VARIATION	SS	DF	M.S.	F. RATIO	SIG. LEVEL
MAIN EFFECT	327.3478	5	65.4696	29.582	0.0000
Sorting	18.2388	2	9.1194	4.121	0.0434
Soaking	300.5335	1	300.5335	135.795	0.0000
Milling	8.5755	2	4.2878	1.937	0.1866
RESIDUAL	26.5577	12	2.2131		
TOTAL	353.9056	17			

**Appendix 6: Multiple Range Analyses On Yield By Separation Process (95 per cent LSD Intervals)**

LEVEL	COUNT YIELD	AVERAGE GROUP	HOMOGENOUS
2	2	20.64	*
1	2	47.63	*
3	2	48.39	*

**Appendix 7: Multiple Range Analyses on Photometric Value By Separation Process, (95 Percent LDS Intervals)**

LEVEL	COUNT	AVERAGE PHOTOMETRIC VALUE	HOMOGENOUS GROUP
2	2	6.87	*
3	2	7.44	*
1	2	18.38	*

Appendix 8 Multiple Range Analyses On Effect of Salt Addition on Photometric Values, 95 percent LSD Intervals

LEVEL	COUNT	AVERAGE PHOTOMETRIC	HOMOGENOUS GROUP
2	2	10.82	*
4	2	11.00	*
5	2	12.445	*
3	2	12.70	*
1	2	15.775	*

Appendix 9: Anova Summary Table On Yield Comparison of Modified and Unmodified Processes

SOURCE VARIATION	SS	DF	M.S.	F. RATIO	SIG. LEVEL
MAIN EFFECT	274.6338	3	91.5446	62.34	0.0158
Process	274.5697	2	137.2849	93.489	0.0106
Replicate	0.0641	1	0.0641	0.044	0.8559
RESIDUAL	2.9369	2	1.4685		
TOTAL	277.5707	5			