Czech University of Life Sciences Prague

Faculty of Engineering

Technique and Technological Aspects of Palm Oil (*Elaeis guineensis*) Processing in Ghana

Supervisor: Ing. Ludmila Skarkova CSc.
Made by: Hero Toseafa

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Dedication

Whoso findeth a wife findeth a good thing, and obtaineth favour of the Lord (Prov. 18:22).

I dedicate this piece of work to my lovely and sweet wife Mrs. Evelyn Korkoi Toseafa.

Acknowledgement

My two years stay in Czech republic has been one of a kind. I hare have been enriched in different cultural diversity. But it would not have been so if it weren't for some people. I think it is only natural that I thank them.

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Declaration

I hereby declare that this work submission is my own work and that, to the best of my knowledge, it contains no materials previously published or written by another person or material which to a substantial extent has been accepted for the award of any other degree of the University or other Institute of higher learning, except due acknowledgement has been in the text.

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Hero Toseafa

Abstract

The importance of oils and fats in human nutrition is well known. They give us a lot of energy and vitamins in our diet. About 71% of edible oils are derived from plant Sources. Palm oil is one of the best plant oils in the world. Its uses have now moved from just edible oil to industrial uses like biodiesel. The production of oil palm has expanded rapidly in respond to the growing world population and the rising living standards. In addition, technological improvement have lead to higher production levels and improvement in product quality. This has also pared a way for the development of technologies for the processing of non food products using palm oil as the raw material

Palm oil originated from tropical Africa and Ghana was one time a leading producer of this crop. The Malaysians therefor came to Ghana to learn the technics of' growing this crop and behold they are one of the leading producers of it today. in the world whiles Ghana, from whom they leant the technic still marks time.

The researcher is therefore interested in how best the production of Palm oil can be maximized. Taking .into consideration the local way of production, the modern factory way of production and how to blend and improve on it.

The researcher is of the view that, to increase production. One must not only increase the production of the raw material but waste must also be minimized. He therefore looked at postharvest operations.

Finally, oils produced locally and that produced from a factory were compared and recommendations made.
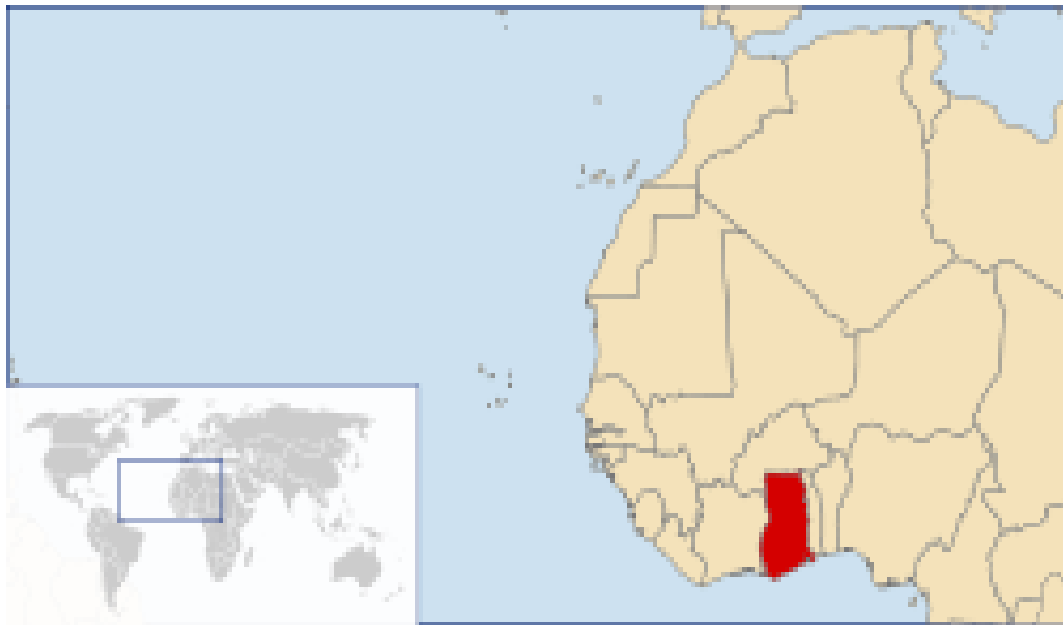
CONTENT

1   INTRODUCTION

Oil palm is considered to be native to tropical Africa. There is an archeological evidence for the production of oil palm as early as 5000 years ago and even of the trade in that commodity in the civilizations of the Upper Sudan (Shaw 1976).

Figure 1 Map of Ghana in West Africa

Source (Wikipedia.org)

The Republic of Ghana is a country located in West Africa borders Côte d'Ivoire (Ivory Coast) to the west, Burkina Faso to the north, Togo to the east and the Gulf of Guinea to the south. The word *Ghana* means "Warrior King" and derives from the Ghana Empire.

Ghana was inhabited in pre-colonial times by a number of ancient predominantly Akan Kingdoms, including the Akwamu on the eastern coast, the inland Ashanti Empire and various Fante and non-Akan states, like the Ga and Ewe, along the coast and inland. Trade with European states flourished after contact with the Portuguese in the 15th century, and the British established a Crown colony, Gold Coast, in 1874.(Fedepalma.org.)

The Gold Coast achieved independence from the United Kingdom in 1957, becoming the first sub-Saharan African nation to do so and the name Ghana was chosen for the new nation to reflect the ancient Empire of Ghana, which once extended throughout much of west Africa. Ghana is a member of many international organizations including the

Commonwealth of Nations, the Economic Community of West African States, the African Union, La Francophonie (Associate Member) and the United Nations. Ghana is the second largest producer of coci in the world and is also home to Lake Volta, the largest artificial lake in the world. (Fedepalma.org).

HISTORY

Figure 2 Oil palm tree (*Elaeis guineensis*)

Source (Wikipedia.org)

Palm oil (from the African oil palm, *Elaeis guineensis*) is long recognized in West African countries, and is widely use as cooking oil. European merchants trading with West Africa occasionally purchased palm oil for use in Europe, but as the oil was bulky and cheap, palm oil remained rare outside West Africa. In the Asante Confederacy, state-owned slaves built large plantations of oil palm trees, while in the neighbouring Kingdom of Dahomey, King Ghezo passed a law in 1856 forbidding his subjects from cutting down oil palms.

Palm oil became a highly sought-after commodity by British traders, for use as an industrial lubricant for the machines of Britain's Industrial Revolution. Palm oil formed the basis of soap products, such as Lever Brothers' (now Unilever) "Sunlight Soap", and the American Palmolive brand. By c. 1870, palm oil constituted the primary export of some West African countries such as Ghana and Nigeria, although this was overtaken by cocoa in the 1880s. (Wikipedia .org)

Oil palms were introduced to Java by the Dutch in 1848 and Malaysia (then the British colony of Malaya) in 1910 by Scotsman William Sime and English banker Henry Darby. The first few plantations were established and operated by British plantation owners, such as Sime Darby and Boustead. The large plantation companies remained listed in London until the Malaysian government engineered the "Malaysianisation" policy throughout the 1960s and 1970s. (Wikipedia .org)

Federal Land Development Authority (Felda) was formed on 1 July 1956 when the Land Development Act came into force with the main aim of eradicating poverty. Settlers were each allocated 10 acres of land (about 4 hectares) planted either with oil palm or rubber, and given 20 years to pay off the debt for the land. After Malaysia achieve independence in 1957, the government focused on value adding of rubber planting, boosting exports, and alleviating poverty through land schemes. In the 1960s and 1970s, the government encouraged planting of other crops, to cushion the economy when world prices of tin and rubber plunged. Rubber estates gave way to oil palm plantations. In 1961, Felda's first oil palm settlement opened, measuring only 375 hectares of land. As of 2000, 685,520 hectares of the land under Felda's programmes were devoted to oil palms. By 2008, Felda's resettlement broadened to 112,635 families and they work on 853,313 hectares of agriculture land throughout Malaysia. Oil palm planting took up 84% of Felda's plantation land bank. (Wikipedia .org)

In December 2006, the Malaysian government initiated merger of Sime Darby Berhad, Golden Hope Plantations Berhad and Kumpulan Guthrie Berhad to create the world's largest listed oil palm plantation player. In a landmark deal valued at RM31 billion, the merger involved the businesses of eight listed companies controlled by Permodalan Nasional Berhad (PNB) and the Employees Provident Fund (EPF). A special purpose vehicle, Synergy Drive Sdn Bhd, offered to acquire all the businesses including assets and liabilities of the eight listed companies. With 543,000 hectares of plantation landbank, the merger resulted in the new oil palm plantation entity that could produce 2.5 million tonnes of palm oil or 5% of global production in 2006. A year later, the merger completed and the entity was renamed Sime Darby Berhad. (Wikipedia .org)

1.1 OIL PALM FARM SYSTEMS IN GHANA

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

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

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

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

Figure 3 Oil palm farm in Mpoho in Ghana

Source (Hero Toseafa, 2010)

1.2 PRINCIPLES OF PRESERVATION AND PROCESSING METHODS

The general principles of preservation include:

destruction of enzymes (a complex organic substance which in solution produces fermentation and chemical changes in other substances apparently without undergoing any change itself) in the raw material and contaminating micro-organisms by heat (sterilization) during processing;

elimination of as much water as possible from the oil to prevent microbial growth (bacterial activity, or disease-causing germs) during storage. The oil therefore has a long shelf life due to its low moisture content.

proper packaging and storage of the extracted oil to slow down chemical deterioration (rancidity).(Kwasi Opoku fao.org.)

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

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

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

2 THEORETICAL REVIEW

2.1 PRODUCTION

The production of palm oil and palm kernel oil during 2008 is given in Table 6-1. The production of these oils is restricted to the developing countries of the world, mostly in Asia and Africa. Malaysia is the world's largest producer of palm oil and palm kernel oil. Indonesia and Nigeria are next to Malaysia in the production of palm oil. Indonesia is rapidly increasing its palm oil production (Hatje, 1989). Other countries like have also realized the importance of palm oil and have launched oil palm plantation programs. (Salunkhe 1992)

2.1.1 ORIGIN

Oil palm is considered to be native to tropical Africa. There is an archeological evidence for the production of oil palm as early as 500 years ago and even of the trade in that commodity in the civilizations of the Upper Sudan (Shaw, 1976).

Figure 4 World production of palm oil and palm kernels

Country/region	Production (1000 MT)	
	Palm oil	Palm kernels
World	8227	2687
Africa	1527	702
Cote Divoire	215	41
Nigeria	730	360
Ghana	680	300

Source: FAO (1987)

2.1.2 BOTANICAL DESCRIPTION

Oil palm (*Elaeis guineensis* Jacq.) is a monocotyledon and belong to the family Palmae, subfamily or tribe Cocoinae and order Spadiciflorae. The genus *Elaeis* is derived from the Greek word "elaion" meaning oil. The specific name *guineensis* indicates its origin in the Guinea Coast. The chromosome number (2n) of *E. guineensis* is 32. The genus *Elaeis* includes two other species of American origin: *E. oleifera* (H.B.K) Cortes and *E. odora* Trail (Gascon et al., 1989).

There are no specific varieties of oil palms. They are, however, classified according to the thickness of the shell and the color of the fruits. Depending upon the presence of thickness of the shell, oil palms are distinguished into three forms: thick-shelled, thin-shelled and shell-less oil palms (Godin & Spensley, 1971; Purseglove, 1975). Thick-shelled *E. guineensis* var. *dura* fruits contain 20-40 % or even higher proportions of shell. The thickness of the shell is 2-8 mm. The kernels are large and account for 7-20 % of the fruit. The proportion of mesocarp is obviously low. Thin-shelled *E. guineensis* var. *tenera* fruits contain about 5-20 % shell. The shell is thin (0.5-3.0 mm). The kernels are smaller than in *dura* and account for about 3-12 % of the fruit weight. The mesocarp content is more than in *dura*. The fruits of *E. guineensis* var. *pisifera* are shell-less and the kernels, when present, are small. The oil palms are also classified according to the color of the fruit (exocarp) (Purseglove, 1975):

1. *Nigrescens*. The unripe fruits are deep violet to black at the apex and ivory-colored towards the base. This is the most common type of palm.
2. *Virescens*. The unripe fruits are green, ripening to a light reddish orange with a small greenish tip. This type of palm is relatively uncommon.
3. *Albescens*. The fruits lack a reddish color at maturity as they contain little or no carotene. This type is extremely rare.

The oil palm fruits are oval-shaped sessile drupes. The shape and size of the fruits vary considerably. The fruits are about 2.5-5 cm in lenght and 2.5 cm in diameter and weigh about 3-30 g (Godin & Spensley, 1971; Gascon et al., 1989). The epicarp of the fruit is thin and reddish orange in color but shows variation in color through yellow, orange, red, brown and black according to the variety (Cobley, 1956). The mesocarp or pulp is orange or reddish brown in color. It is oily and fibrous (Vaughan, 1970). Oil palm seed is the nut which reamins after the removal of soft oily mesocarp during palm oil extraction. It consists of shell or endocarp and one or more (mostly one) kernels. The endocarp consists black schlerenchyma and has three pores as in coconut (Hartley, 1967). The thickness of the shell varies considerably depending upon the variety. The kernel consists of layers of hard oily endosperm and embryo. The endosperm is greyish white in color, with a slight cavity in the center and is surrounded by a dark brown testa. The embryo is embedded in the endosperm, opposite to one of the pores. (Salunkhe 1992)

2.2 PALM OIL

2.2.1 CHEMICAL COMPOSITION

Three commercial products are obtained from oil palm fruit. These are palm oil, palm kernel and palm kernel cake or meal.

Palm oil is held in the cells of fibrous mesocarp of the fruits and represents about 20-24 % of the harvested palm fruit bunch (Hutagalung et al., 1983; Gascon et al., 1989). The mesocarp or pulp of the palm fruit has an average oil content of about 56 % (Godin & Spensley, 1971). Purseglove (1975) reported a range of 45-55 % oil in the mesocarp of palm fruit. On dry-weight basis, the mesocarp of harvested fruit containts 70-75 % oil. There is very little fat in the mesocarp of the fruit just after anthesis. The oil content increases during fruit ripening up to the start of the fruit detachment (Crombie & Hardman, 1958; Thomas et al., 1971; Wuidart, 1973; Eschie, 1978).

LIPID CLASSES AND GLYCERIDE COMPOSITION

The bulk of the commercial palm oil is made up of neutral lipids and contains very low levels of phospholipids and glycolipids (Jacobsberg, 1974). Kohr et al. (1980) reported 96.2 % neutral lipids, 2.4 % phospholipids and 1.4 % glycolipids in palm oil. During fruit development, shortly after anthesis, the mesocarp of palm fruits contained only small amounts of lipids, most of which were phospholipids and glycolipids. The content of nonpolar lipids increased and reached 60 % of the mesocarp fresh weight at peak maturity (Bafor & Osagie, 1986, 1988).

Most natural triglycerides contain a saturated fatty acid in the 1 and/or 3 positions and an unsaturated fatty acid in the 2 position. Palm oil, however, contains some triglycerides species which are completely saturated. Palm oil consists of mostly mono glycerides (48-55 %) and diunsaturated glycerides (30-43 %) with small quantities of saturated (6-8 %) and unsaturated glycerides (6-8 %) (Hartley, 1967; Maiti et al., 1988).

2.2.2 FATTY ACID COMPOSITION

Palm oil contains almost equal proportions of saturated and unsaturated fatty acids. Palmitic and oleic acids are the major fatty acids with small quantities of linoleic and stearic acids (USDA, 1979; Pantzaris, 1987). Its fatt acid composititon is comparable to that of human milk (Patton & Jense, 1975), lard, tallow and hydrogenated whale oil (Cornelius, 1971).

Bafor and Osagie (1986) studied changes in the fatty acid composition of palm mesocarp oil during fruit ripening. The lipids synthesized shortly after anthesis contained more unsaturated fatty acids. There was a significant increase in the proportion of palmitic acid, while linolenic acid decreased to nondetectable levels after 16 weeks from anthesis. The proportion of unsaturated fatty acids decreased to 44 % at maturity.

The fractionation of palm oil into olein and stearin fractions has significant influence on its fatty acid composition. The olein fraction resembles other edible vegetable oils and contains a high proportion of unsaturated fatty acids, particularly oleic acid (Table 6-4). The stearin fraction contains more saturated fatty acids, particularly palmitic acid, and resembles other saturated fats.

2.3 FATTY ACID COMPOSITION OF PALM OIL

Figure 5 Fatty acid composition of palm oil

Fatty acid	Godin & Spensley (1971)	Purseglove (1975)	Weiss (1983)	Murthi et al. (1987)	Maiti et al. (1988)
Myristic	1.0-2.5	1-6	2	1.2	0.5-6.0
Palmitic	32-47	32-45	42	47	35-40
Stearic	1-9	2-6	4	4	2-8
Oleic	40-53	39-52	42	39	40-50
Linoleic	2-11	5-11	10	9	5-11

Source: Clegg (1988)

FATTY ACID COMPOSITION OF PROCESSED PALM OIL AND PALM OIL FRACTIONS

Figure 6 Percentages of fatty acids in palm oil

	Fatty acid (%)								
Palm oil or fraction	14:0	16:0	18:0	20:0	Total saturated	18:1	18:2	18:3	Total unsaturated
Neutralized	0.8	41.0	5.1	0.1	47.0	39.0	13.8	0.2	53.0
Interesterifid	0.7	41.2	5.0	0.1	47.0	38.6	13.8	0.6	53.0
Olein	0.5	9.9	1.4	0.0	11.8	63.1	23.9	0.2	87.2
Stearin	1.0	66.0	8.4	0.5	75.9	18.6	5.4	0.1	24.1

Source: Lago & Hartman (1986)

2.4 POLAR LIPIDS

Palm oil contains very small quantities of phospholipids and glycolipids. The major components of palm oil phospholipids are phosphatidylcholine, phosphatidylethnolamine, phosphatidylinositol and phosphatidylglycerol (Goh et al., 1982). Phosphatidic acid, diphosphatidylglycerol and lysophosphatidylethnolamine are the minor components. A study of the glycolipids of Malaysian palm oil showed the presence of esterified stearyl glycosides, monoglycosyl diglycerides (MGDG), cerebrosides, stearyl glycosydes and diglycosyl diglycerides (DGDG). MGDG and DGDG are the major components and contain more unsaturated fatty acids. The other glycolipids contain a higher proportion of saturated fatty acids (Khor et al., 1980).

UNSAPONIFIABLE MATTERS

The unsaponifiable fraction of palm oil is rich in carotenoids and tocopheols (Jacobsberg et al., 1978). The oil also contains some sterols, waxes and hydrocarbons. Palm oil contains upto 2000 ppm carotenes (Patterson, 1989). The carotenoid content varies with the degree of ripeness and the genotype of the fruit. The Malaysian genotypes of *E. guineensis* have been reported to contain carotenoids as follows - *dura nigrescens*: 700-1000 ppm, *dura virescens*: 200-300 ppm, *tenera nigrescens*: 500-800 ppm and *tenera virescens*: 400-600 ppm (Clegg, 1973). Tan et al. (1986) reported 700-800 ppm carotenoids while Goh & Gee (1986) reported 500-700 ppm carotenes in crude palm oil. The variation in carotenoid content from 800-1520 ppm has been reported in palm oils of Nigeria, Ivory Coast, Togo and Dahomey (Clegg, 1973). The oil from palm plantations contained relatively less

carotenoids that that from palm groves. Purvis (1957) reported that the oil from red palm fruits contained more carotenes (2560 ppm) than the oil from orange fruits (1100 ppm). The carotenoids in palm oil include mainly α- and β-carotenes with lesser amounts of γ-carotene, lycopene and xanthophylls (Goh & Gee, 1986). Ng & Tan (1988) detected 12 carotenoids in palm oil. The α- and β-carotenes were predominant and were present in a ratio of 1:2.

The provitamin A activity of β-carotene (1.66 IU/μg) is almost double that of α-carotene (0.9 IU/μg). Other carotenoids have very low provitamin A activity. Palm oil contains a high proportion of β-carotene and, therefore, is a rich source of vitamin A. The proportion of β-carotene was more in red palm fruits than in orange fruits. Therefore, the red fruits have more vitamin A potential than the yellow fruits (Purvis, 1957). Purseglove (1975) reported the vitamin A potency of red palm oil as 1000-100,000 IU with an average value of 20,000 IU in unrefined oil.

Palm oil contains large amounts of vitamin E - the tocopherols and tocotrienols (Jacobsberg et al., 1978). It may contain up to 800 ppm of total tocopherols (Hartley, 1967). Cpursey et al. (1984) reported a rnage of 30-560 ppm tocopherols in tradicionally prepared palm oil. The vitamin E group includes tocopherols, tocotrienols, isomers and derivatives that differ in their biological activity. They are usually present in low concentrations in most vegetable oils (Appleqvist, 1989). The vitamin E activities of α, β, γ and δ-tocopherols and tocotrienols are in the ratio of 100, 40, 10, 1, and 30, respectively (McLaughlan & Weihraugh, 1979). The α and γ-tocopherols predominante in palm oil. Bernardini (1984) reported 300, 500 and 860 ppm α, γ and total tocopherols, respectively in palm oil.

Some loss of tocopherols occurs during the processing of palm oil. Wong et al. (1988) reported the total tocopherols in unprocessed palm oil as follows - crude palm oil: 794 ppm; refined, bleached, deodorized (RBD) palm oil: 563 ppm; RBD palm olein:643 ppm; RBD palm stearin: 261 ppm and palm fatty acid distillate (PFAD): 704 ppm.

The sterol content of palm oil is relatively low, i.e. 300 ppm of oil (Loncin & Jacobsberg, 1965). The major sterols present are β-sitosterol (74 %), stigmasterol (8 %) and

campesterol (14 %) while cholesterol comprises about 1 % of the total sterols (Itoh et al., 1973). The sterol content of palm oil is reduced during refining. Goh and Gee (1986) reported the presence of a wide range of n-alkanes ($C_{12}H_{26}$ to $C_{36}H_{74}$), n-alkanes and squalene in crude palm oil.

2.5 CHARACTERISTICS OF PALM OIL

Palm oil has a pleasant odor and taste. It is stable and resistant to rancidity. The color of palm oil ranges from pale yellow to deep orange. The depth of the color depends upon several factors such as carotenoid content, the extent of oxidation by lipoxygenase, storage period, iron content, etc. The color of crude palm oil is primarily due to the presence of carotenoids while that of the processed oil may be due to the presence of some other high molecular weight compounds (Fraser & Frankl, 1981). Berger (1986) suggested that there is an interaction between hydroxybenzoic acid and other phenols in palm oil and traces of iron from the mill process. The interaction product eventually causes color formation. The use of stainless for those parts of the equipment which are in contact with oli would reduce the iron content and color formation in palm oil (Maclellan, 1983).

Palm oil is solid at ambient temperatures in temperate climates and fluid in tropical and subtropical climates with certain fractions held in crystalline form. When cooled to 5-7ºC, the separation of the liquid and solid fractions can be clearly seen. This phenomenon is called clouding. The palm oil melts over a range of 25-55ºC (Cornelius, 1971; Purseglove, 1975). Interesterification of palm oil produces two fractions, one with a very low melting point (olein) and the other with a high melting point (stearin). The iodine value of palm oil is lower (44-58) than other vegetable oils because of a high proportion of saturated fatty acids. Fractionation of palm oil results in an olein fraction with a high iodine value and a stearin fraction with a lower iodine value. The saponification value of palm oil is higher (195-205) than other edible vegetable oils.

The crude palm oil contains relatively high amounts of free fatty acids. The method of oil extraction has a significant influence on the content of free fatty acids. The oil extracted by traditional methods contains more free fatty acids. The oil obtained by the "soft oil" process has a lower (7-12 %) free fatty acid content than that obtained by the "hard oil"

process (30-50 %) (Hartley, 1967). The oil from over-ripe fruits contains high levels of free fatty acids. Special prime bleach (SPB) palm oil have been developed in the Congo by harvesting unripe fruits (Hartley, 1967). Processing of fruits without delay or fermentation yielded a good-quality oil with a low free fatty acid content of 2.3 % (Babatunde et al., 1988). Free fatty acids may be formed by the action of lipase in fruit or microbial lipase or by autocatalytic action (Purseglove, 1975). The oil from freshly harvested fruits contains very little free fatty acids. In bruised and crushed fruits, the free fatty acid content may increase up to 50 % in a few hours. This may be due to the action of lipase present in the fruit. Oo (1981), however, could not detect the presence of lipase activity in aqueous buffered extracts of the mesocarp of palm fruits. The hatvested fruits when kept for several days before processing allow the occurence of microbial growth and lipolysis. Heating palm fruits before pulping inactivates the lipase enzyme and prevents formation of free fatty acids. Even if lipase is destroyed, palm oil can deteriorate during storage through autocatalytic hydrolysis in the presence of small amounts of moisture (Loncin & Jacobsberg, 1965). The free fatty acids already present act as catalysts in the presence of water. The rate of autolysis increases with time and temperature of storage. Refined or neutralized palm oil contains very little free fatty acids (Lago & Hartman, 1986). There is a slight increase in the content of free fatty acids in palm oil after interesterification and fractionation.

NUTRITIONAL SIGNIFICANCE

Palm oil is a rich source of vitamins A and E. The carotenes in palm oil may be important to correct the vitamin A deficiency in children in certain part of the world. This may be achieved by incorporation of palm oil in the diets in the form of edible fat blends, margarines, etc. (Anderson & Williams, 1965). Crude palm oil contains high levels of β-carotene which is lost significantly during bleaching. Therefore, processing treatments and conditions of palm oil should be optimized to retain and stabilize carotenoids and other nutrients. Tocopherols and tocotrienols act as powerful nutritionla antioxidants and help to reduce cellular damage due to free radicals arising from the body's normal oxidative energy metabolism. Tocopherols help in retardation of oxidative rancidity in palm oil and palm oil-containing products. Tocopherols are especially important in palm oil because of the long shipment and storage time it undergoes. Palm oil contains 5 to 11 % linoleic acid which is known to be essencial for growth and health in animals and humans. Deficiency

symptoms in humans include skin disease, loss of weigh and increased metabolic rate (Vles & Gottenbos, 1989).

Like other edible oils and fats, palm oil is easily digested, absorbed and utilized for the support of healthy growth (Calloway & Kurtz, 1956). Feeding experiments with young growing rats showed that palm oil and refined oil were at par with other common edible oils and fats with respect to digestibility, absorption and growth (Gottenbos & Vles, 1983). Fractionated randomized palm oil and interesterified palmolein products showed a higher coefficient of digestibility than *vanaspati* (hydrogenated fat) (Majumdar et al., 1986; Majumdar & Bhattacharyya, 1988).

Palmitic and oleic acids have been reported to be less hypercholesterolemic than the saturated fatty acids in the range of C_6 to C_{14} (Horlick & Craig, 1957). Oleic acid has been reported to be just as effective as the unsaturated acids in lowering blood cholesterol (Mattson & Grundy, 1986). Monoenes were shown not to contribute significantly to the effect of dietary lipids on the plasma cholesterol content (Keys et al., 1965). Epidemiological (Keys et al., 1986) and experimental (Mattson & Grundy, 1986) studies indicated that dietary monoenes may lower the plasma cholesterol content.

In animal feeding experiments, palm oil diests were found to be no different in their effects on total cholesterol compared to highly unsaturated vegetable oils (Kris-Etherton et al., 1984; Querishi, et al., 1987). As apposed to saturated fats like tallow, lard, dairy fat, palm kernel oil and coconut oil, a plam oil diet lowered the levels of blood cholesterol and LDL-cholesterol in experimental animals (Kris-Etherton et al., 1984; Sugano, 1987; Lee et al., 1988). Human feeding sudies using formula diets revealed that a palm oil diet lowered the plasma cholesterol levels (by 7 to 38 %) as compared to the initial periods during which the subjects were taking their normal western diets (Mattson & Grundy, 1986; Hornstra, 1987; Bonanome & Grundy, 1988). Hypocholesterolemic effects of palm oil in human subjects have been demonstrated in Malaysia (Lim et al., 1988) and Pakistan (Khan et al., 1988). It has been demonstrated that *d*-tocotrienol inhibits the liver HMG-CoA reductase activity anf causes reduction of serum cholesterol and LDL-cholesterol in broilers (Quereshi et al., 1986). The tocotrienols present in palm oil (Jacobsberg et al., 1978) may be responsible for the effect of palm oil on the plasma cholesterol levels in humans.

Although palm oil contains relatively more saturated fatty acids than most common edible oils, it does not promote but, in fact, inhibits arterial thrombosis (Hornstra & Lussenburg, 1975). The antithrombotic effect of pal oil has been confirmed in animal (rat) models (Hornstra et al., 1987). Animals fed on a palm oil rich diet have shown a reduced tendency for the blood to clot (Rand et al., 1988). The antithrombotic effect of palm oil was associated with a reduced production of the prothrombotic prostanoid, thromboxane (TXA_2) and an increased production of the antithrombotic prostanoid, prostacyclin (PGI_2) (Hornstra et al., 1987). The blood-coagulating property of palm oil is thought to be due to its total tocopherol content (Hornstra et al., 1987). Machlin (1980) suggested that tocopherols help in the prevention of platelet aggregation and increase in the peripheral blood flow.

There is some epidemiological evidence that β-carotene may protect against certain forms of cancer (Wald et al., 1980; Menkes et al., 1986). β-carotene is widely regarded as an anticancer agent of great promise (Temple & Basu, 1988). β-carotene stimulates the body's immune defence mechanism by way of an increased capacity of the macrophases to kill the tumor cells and increases the production of the tumor necrosis factor. Unrefined palm oil is the richest source of β-carotene.

Palm oil contains high levels of tocopherols and tocotrienols. Tocopherols help in protection against chemically induced buccal pouch tumors both by systemic administration and topical application (Shklar, 1982). This could be related to vitamin E's well-established role as an antioxidant. It protects body cells from oxidative destruction which could weaken the cell membrane and suppress immunity. Tocotrienols are known to cause inhibition of liver HMG-CoA reductase activity (Quereshi et al., 1986) and thereby reduce the levels of mevalonate which is required for the growth of neoplastic tissue.

2.6 PALM KERNEL OIL

Palm kernel oil is obtained as a minor product during processing of oil palm fruit. It is obtained from palm kernels after separation, drying and cracking of the shell or nut. Palm kernel oil represents about 2-4 % of the harvested palm fruit bunch (Hutagalung et al.,

1983; Gascon et al., 1989). Palm kernels contain 46-54 % oil with an average of 50 % (Godin & Spensley, 1971).

The chemical composition of palm kernels is given in Table 7 below.

Figure 7 Chemical composition of palm kernel oil

	Content (%)		
Constituent	*Cornelius (1965)[a]*	*Gohl (1975)[b]*	*Vohra (1989)[b]*
Moisture	6-8	-	-
Oil	47-52	54	52
Protein	7.5-9.0	7.9	8.8
Nitrogen-free extract	23-24	32.5	23.6
Crude fiber	5	3.9	5.2
Ash	2	1.7	2.0
Calcium	-	0.09	-
Phosphorus	-	0.31	-

Source: Godin & Spensley (1989)

On fresh-weight basis.

On dry-weight basis.

Palm kernels contain less proteins than most oilseeds. There is very little fat in the endosperm of the palm fruit until 10-12 weeks after anthesis. Maximum oil accumulation occurs during 14-16 weeks after anthesis (Bafor & Osagie, 1986). Palm kernel oil is characterized by its high proportion of saturated fatty acids. Lauric acid is the predominant fatty acid in palm kernel oil, which also contains some low molecular weigth fatty acids commonly found in other vegetable oils. The fatty acid composition of palm kernel oil is closer to that of coconut oil with which it is also readily interchangeable (Gascon et al., 1989).

Offem & Dart (1985) did not find significant differences in the fatty acid composition of 41 samples of palm kernel oil (obtained from 41 individual trees) from two oil palm estates in Eastern Nigeria. Fungal infection and discoloration of the stored palm kernels was found to have a significant influence on the fatty acid composition [Table] The oil from the discolored and fungal-damaged kernels contained less saturated and more unsaturated fatty acids than the oil from good-quality kernels.

FATTY ACID COMPOSITION OF OIL FROM GOOD QUALITY, DISCOLORED AND FUNGAL-DAMAGED PALM KERNELS

Figure 8 Fatty acid content of palm oil and palm kernel oil

Palm kernels	Fatty acid (%)									
	8:0	10:0	12:0	14:0	16:0	18:0	Total saturated	18:1	18:2	Total unsaturated
Good quality	4.1	4.2	49.3	16.5	8.8	2.4	85.3	13.6	1.1	14.7
Discolored	3.3	2.6	49.5	16.2	9.1	2.9	83.6	14.9	1.5	16.4
Fungal-damaged	2.7	2.5	42.0	18.1	10.5	3.6	79.8	18.1	2.5	20.6

Source: Dart et al. (1985)

Saturated triglycerides are the major triglycerides of palm kernel oil and constitute over 60 % of the total triglycerides. Monounsaturated (monooleic) triglycerides constitute more than 25 % of the total triglycerides (Hartley, 1967). Bezard (1971) found a total of 87 glycerides in palm kernel oil. Of these the trilaurin (19.8 %) and dilauromyristin (14.1 %) were the major ones. There were many similarities between palm kernel oil and coconut oil in the glyceride content.

Palm kernel oil is characterized as hard oil and closely resembles coconut oil with which it is readily interchangeable. It is nearly colorless. It is solid at ambient temperatures in temperate regions (Purseglove, 1975). Its melting point is 25-30ºC (Dart etal., 1985). Oil from discolored and fungal-damaged kernels exhibits a lower melting point than the oil from good quality kernels. Free fatty acid content of good quality palm kernel oil is low (about 4.75 %) (Cornelius, 1965). Fungal infection of kernels has been reported to increase the free fatty acid content (Idem, 1973; Oso, 1979; Airede & Esuruoso, 1987). Dart et al. (1985) reported 3.6, 11.5 and 29.2 % free fatty acids in the oil from good-quality, discolored and fungal-damaged kernels, respectively. The iodine value of palm kernel oil is low, i.e. in the range of 14-33 (Hartley, 1967; Itoh et al., 1973; Bernardini, 1984). The saponification value of palm kernel oil (245-255) is comparable to that of coconut oil (250-264) (Itoh et al., 1973; Bernardini, 1984).

The sterol composition of palm kernel oil is similar to that of palm oil. β-sitosterol (70 %) is the major sterol component with small proportions of stigmasterol (11 %), campesterol (9 %) and Δ^5-avenasterol. The proportion of cholesterol is very low (3 %) (Itoh et al., 1973).

2.7 PALM KERNEL CAKE AND MEAL

Palm kernel cake is the major byproduct of palm kernel oil extraction. Palm kernel cake, when powdered, gives meal or flour. As such there is no significant alteration in the content of nutrients when the cake is converted to meal or flour. Palm kernel meal contains about 20 % protein (Table 6-10), which is the lowest among the oilseed meals (Hartley, 1967).

Figure 9 Proximate composition of palm kernel cake abd meal (%)

	Palm kernel cake	Palm kernel meal		Soybean meal
Component	*Hartley (1989)*	*Bell (1989)*	*Morrison (1949)*	*Bell (1989)*
Moisture	11	9.7	8.6	10.9
Carbohydrates	48	42.5	49.7	30.3
Crude fiber	13	14.5	11.9	3.0
Crude protein	19	21.4	19.2	48.5
Ether	5	7.3	6.7	1.0
Ash	4	4.6	3.9	5.9

Source: Hartley (1989)

The protein content of palm kernel meal depends upon the method of oil extraction (Table). Palm kernel proteins have a poor amino acid balance (Table), with lysine as their first limiting amino acid. Methionine content in palm kernel proteins is higher than in soybean proteins.

Carbohydrates are the major constituents of palm kernel meal. Palm kernel meal contains more carbohydrates than most other oilseed meals. It is characterized by a higher fiber content (Table). The contents of nitrogen-free extract (NFE) and crude fiber depend on the method of oil extraction from palm kernels. The NFE contains variable quantities of sucrose, reducing sugars and starch (Cornelius, 1965; Hartley, 1967). Because of the high fiber content the metabolizable energy content of palm kernels is very low.

Palm kernel meal contains some residual oil. Solvent-extracted meal contains very little (<1 %) oil while screw-pressed cake contains 6-9 % oil (Gohl, 1975). Palm kernel meal contains a good amount of minerals, particularly calcium, phosphorus and iron (Cornelius, 1977). Morrison (1949) reported 0.69 % phosphorus, 0.42 % potassium and 0.017 % iron in palm kernel meal. The ratio of calcium to phosphorus in palm kernel meal is reported to be more favorable than in other oilseed meals (McDonald et al., 1982).

2.8 PRODUCT SEPARATION

2.8.1 PALM OIL FACTORY PROCESSES

PRODUCTS: Crude palm oil (CPO) and crude palm kernel oil (CPKO).

ORIGIN: CPO-(Mesocarp oil-cells of a ripe oil-palm fruit); CPKO-(Endosperm (kernel) oil-cells a ripe oil-palm fruit).

PRODUCT SEPERATION Above products are isolated through a series of processes as presented in the block diagram (Figure 1)

BUNCH RECEPTION

Weighed fresh fruit bunches (FFB) are stored temporarily then packaged into 2.5ton bunches per cage-boogie (transferred) into production process chain.

BUNCH STERILISATION

Packaged bunches are subjected to two staged direct 3bar.a. steam heating (at 0.27 ton steam per ton FFB) for 50 minutes followed by 40 minutes cycle with a brief inter-stage heat relief in a tubular pressure vessel. Process results in; hydrolysis (breakdown) of gums on fruit stalk to facilitate detachment (bunch-threshing), deactivation of lipolytic enzymes in the pericarp to prevent free fatty acid (FFA) formation through enzymatic hydrolysis, breakdown of fibrous mesocarp to facilitate depulping (fruit-digestion),initiate oil-cell wall rupturing to facilitate oil appellation(oil-pressing),coagulation of albuminous proteins to prevent downstream process emulsifications, hydrolysis of starches/celluloses to enhance downstream preclariffication by settling, rendering detachment of kernels from shell walls (by relative shell-kernel expansion due heating/cooling) to facilitate downstream kernel recovery.

BUNCH THRESHING

Sterilized bunches are subjected to repetitive mechanical impulses due their repetitive impacts onto walls of a rotary cylindrical drum driven at 20rpm to which they are fed. Fruits on well sterilized bunches are detached.

FRUIT DIGESTION

Detached fruits are deputed by subjection to stirring at 5-8rpm and 90-100°C(through direct 3bar.a.steam heating) in a lagged mechanical-stirrer-fitted cylindrical vessel for 30minute residence. Fibrous mesocarp structures of sterilized fruits are detached/broken up from the adhering nut to result in thorough completion of oil-cell wall rupturing initiated in sterilization.

OIL PRESSING

Digested fruits (mash) are subjected to mechanical pressures ranging 50-70bar by combined propulsion (transport-effect) of a screw-worm versus an obstruction of a hydraulic powered cone-headed piston in an integrated digester-screw press. Free oil together with water/non-oil solids (cell debris, fibres, carbohydrates, celluloses and proteins) ie crude palm oil is pressed out of the mash which is further diluted with 90-100 ^{o}C water at volume flow of 3.0m^3/hr ≡20% water weight to processed FFB weight (as a precondition for settling) to reduce crude oil viscosity aptly necessary for apt design settling rate of non-oil solids/water from crude-bulk in downstream separation (settling) processes.

2.8.2 CRUDE OIL CLARRIFICATION

SCREENING

Diluted crude oil is passed through mechanically vibrated 30-40 micron mesh-size sieves. Suspending non-oil larger than specified sieve sizes are separated out of the diluted crude oil.

STABILIZATION

Screened diluted crude oil is passed through baffled tanks for a residence of 15-30minutes. Considerable massive celluloses/coagulated albuminous proteins settle out to enhance immediate downstream processes.

EBULITION

Stabilized screened diluted crude oil is passed through a direct 3bar.a. steam injected vessel to heat to 90-95°C (as further precondition).Massive reduction of crude oil viscosity

versus sharp reduction of oil media density (which increases differential density between settling particles and crude oil media) summarily result in an apt increased settling rate as shown in stokes law.

CONTINOUS SETTLING (PRECLARIFIER)

Emulated stabilized screened diluted crude oil is resided for one hour in lagged steam-coil-heated cylindrical vessel. Water, non-oil solids and some oil(bottom-sludge) of density 0.997kg/litre containing about 12% oil by weight settles at the bottom and its separated by hydrostatic pressure pumping whiles oil of density about 0.860kg/litre(surface-oil) floats for separation by skimming.

BOTTOM-SLUDGE OIL RECOVERY (Sludge centrifuge)

Bottom-sludge preheated to 100^oC by in a direct 3bar.a. Steam injected stirrer-fitted storage vessel is fed to a three-phase nozzle-decanting centrifuge speeding at 3500rpm.Free oil in the bottom-sludge is recovered together with surface-oil whiles solid-sludge (carbohydrates, proteins, cell-debris, moisture and bounded oil) and liquid-sludge (excess-free waters, carbohydrates, proteins, cell-debris, free/bounded oil) discharged as effluents.

SURFACE-OIL PURIFICATION/DRYING

Recovered surface-oil preheated to 80-85^oC in a steam-coil-fitted jacketed storage/holding-vessel is fed to a closed-bowl centrifuge revving at 4500rpm, thence to a

-0.9bar.g. hydro-steam ejector powered vacuum-dryer . Surface-oil is further de-silted/dewatered, then dried, thence to storage finally as crude palm oil (CPO).

NUT/FIBRE SEPERATION

Compact mixture of de-oiled fiber and nuts exiting a screw press (press-cake) is fed to a (6-16m/s, 5900ft^{3}air/ minute) pneumatic separation system via a 3bar.a. steam jacket-heated pedal conveyor. The beating action of rotary-pedal arms result in thorough split-up of the press cake-into loose fairly demoistured fiber and nuts from which fiber and light-weight nuts/broken nuts/kernels are pneumatically extracted by air separator to fuel boiler whiles nuts drop off to storage.

NUT STORAGE

Recovered nuts are subjected to hot air at 50-60 $^{\circ}$C for 12-14 hours in a pyramidal baffled vessel. The moisture content of the nuts is reduced rendering shells brittle with complete kernel detachment from shell-wall already initiated in sterilization altogether to facilitate efficient nut cracking; fungal growth(responsible for accelerated FFA by enzymatic hydrolysis) is also stemmed.

NUT GRADING

Aptly dried nuts from storage are charged into varying-hole size riddled cylindrical rotary cages revving at 14rpm.Nuts are separated into small,medium,large sizes through passage of apt hole size as well as freed from kernel/shell/fiber dust and solids(stone, bunch-pieces etc) altogether to facilitate efficient nut-cracking/kernel separation.

METAL SEPERATION

A graded nut prior into crackers passes a powerful magnetic surface. All metal pieces accompanied/originating from machine wear/tear and bunch sources are isolated to secure downstream products (kernel/kernel oil) and equipments.

NUT CRACKING

Graded nuts are charged unto surface of alternately arranged rod-assembled rotary rotor revving between 1500-2500rpm within tungsten carbide metal surface. By virtue of centrifugal force imparted by rotor rods unto charged nuts as they collide they are hurled against the tungsten carbide surface to result in split cracking of shells to release loose kernels.

KERNEL SEPERATION

Kernel/shell mixture (cracked mix) exiting crackers are sequentially subjected to air separation (6-16m/s, 5900ft^3 air/minute winnower system), screening (14rpm) and dual-stage hydrocycloning.Shells from the small nut cracked mix are pneumatically extracted to fuel boilers with the resulting kernels passed by screen to storage whilst partially/untracked nuts recycled back to crackers. A portion of most light shells from medium-large nuts are pneumatically extracted to fuel boilers with the resulting kernel-medium weight shells

passed by screen to hydrocycloning where mostly pure kernel fraction are floated off to storage via a hydro baskets and shells slinked off to fuel boiler with partially/untracked nuts screen-isolated to crackers.

KERNEL DRY-STORAGE

Recovered kernels are subjected to hot air at 50-60°C for 12-14 hours in a pyramidal baffle vessel. Kernel moisture levels is reduced to preserving limits/render oil cells flaccid (due dehydration) to facilitate maximized oil recovery.

KERNEL-SIZE REDUCTION

Kernels from dry storage are passed through a rotary hammer crusher. Kernel surface area increase results (pulverization) from the shearing impact of the crusher to enhance intimate screw-surface contact with kernel oil cells to maximize oil recovery in the oil expellers.

OIL EXPELLATION

Pulverised kernels are subjected to high shearing pressures by combined propulsive/compaction features screws in oil expellers (kernel crushers).Further pulverization of kernel occurs with the rupturing/pressing of oil cells to release crude palm kernel oil finally (CPKO) to storage after filtration.

2.9 STERILIZATION

This is the first mechanical treatment the fruit is exposed to. This is done with sterilizers. The fruit stays in for 90 mins at 126 degrees Celsius. The following are the reasons for sterilizing.

Inactivation of oil-splitting enzyme

Coagulation of the albuminous substances

Hydrolysis of the mucilagenous matter

Loosening the fruit in the bunch

Preparation of the fruit for further treatment in the extraction plant

Preliminary treatment of the nuts

FFB
10 000 kg

1, 840 kg

Exhaust steam

Process steam
2, 240 kg
Condensate

Sterilization
126°C for 90.0 mins

1, 600 kg

8, 800 kg

Sterilized bunches
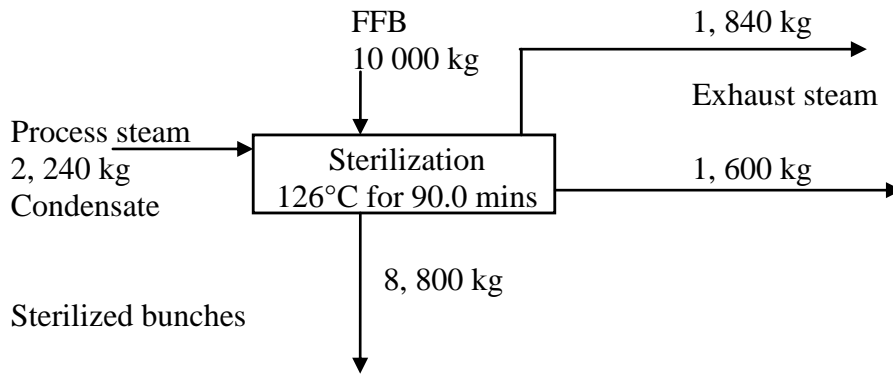
THRESHING

This is the process wherby the sterilized fruits are stripped off the buches

8, 800 kg sterilized bunches

Threshing

2, 150 kg   Empty bunches

6, 650 kg

Sterilized fruits
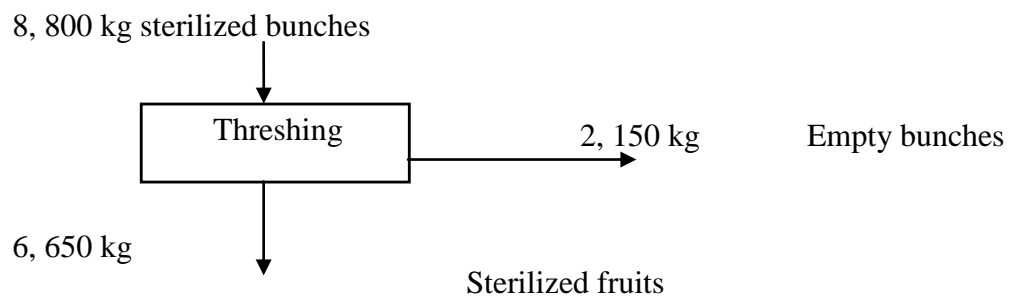
DIGESTION AND PRESSING

This is the process by which the oil bearing cells in the fruits are ruptured by the stirring action of the digester forcing the oil to be released. This process produces the digested mash which is fed to the press. The press functions to squeeze out the crude oil from the digested mash. This process is aided by the addition of hot water.

6, 650 kg   Sterilized fruits

Digestion 95°C for 15
mins and pressing at
50 – 70 bar

, 525 kg

2, 475 kg

Hot watter addiction

Press cake

6, 700 kg crude oil
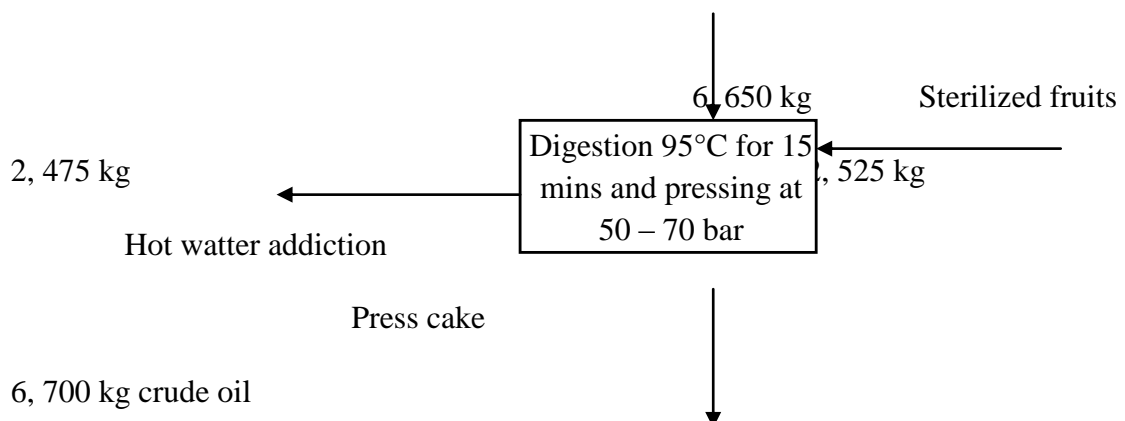
CLARIFICATION

This is the process of getting moisture and dirt out of the crude oil. The crude oil from the pressis made to pass through a vibrationg screen of mesh size of about 40 micron. This filters off the debris of pulverised fibre and nuts contained in the crude oil ffrom the press. Next, the oil goes to a crude oil tank en-route where there is addition of steam to reduce the viscosity of the oil to improve seperatability in the continuou settling tank. In this tank, the crude oil which is made up of oil and sludge - the sludge being water and impurities which are so small they escaped screening is made to stay for a short time without agitation. Separation of the sludge from the oil in the c/s tank is based on differences in densities between the two components. The sludge being denseer than the oil settles by gravity to the bottom of the c/s tank. The quantity of oil recovered here is determined by the viscosity of the crude oil and the retention time.

6, 700 kg
crude oil

Oil from centrifuge

900 kg

Clarification involving screening on vibrating green of mesh size 30-40 micron and separation in a continuous petting tank at 85-95°C

5, 400 kg

Sludge

2, 200 kg   Oil
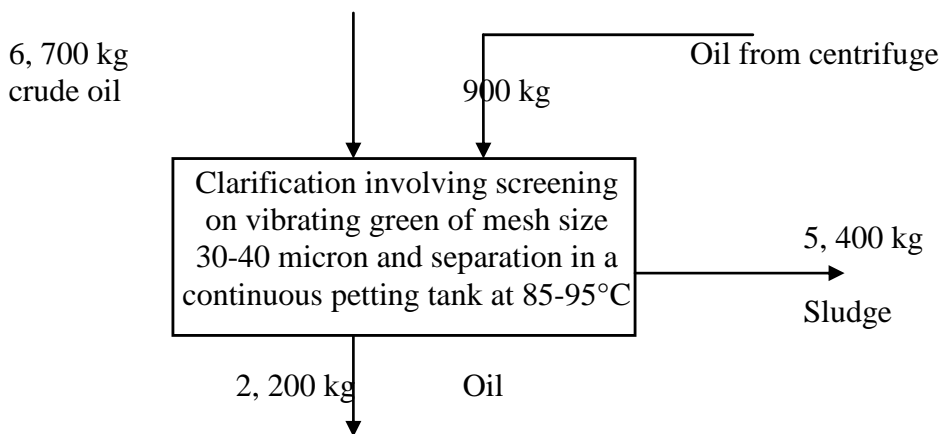
CENTRIFUGING

The recovered oil in the continuous settling tank is pumped into a clean oil tank. The sludge at the bottom of the tank contains some oil as oil recovery cannot be 100% efficient. The quantity of oil remaining in the sludge depends on the efficiency of recovery. The oil content could be as much as 8 - 10%. In order to recover this oil, the sludge is pumped to a sludge tank where there is adequate supply of steam. This tank is equipped with stirrers the action of which create a homogeneous mixture - a condition necessary for centrifugation. The sludge from here is sent to tricanters. These are centrifuges which separate the sludge into its constituent oil, water and solids. The recovered oil is sent to the clean oil tank.

5, 400 kg sludge

```
                              ┌─────────────────┐
                              │                 │
4, 209 kg liquid  ◄───────────│  centrifuging   │───────────►  290,7 kg solids
                              │                 │
                              └─────────────────┘
                                      │
                                      ▼
                              900 kg oil
```
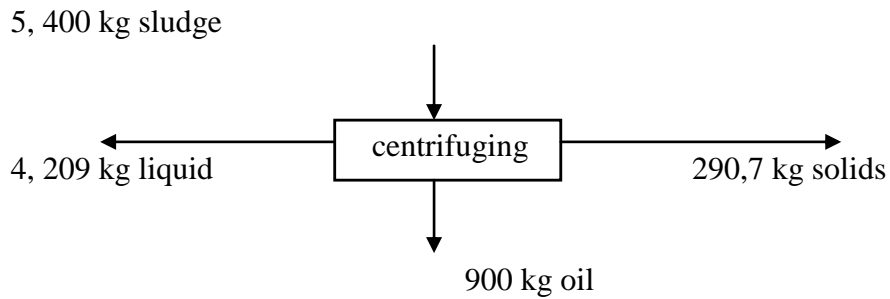
PURIFICATION AND DRYING

The oil from the clean oil tank is sent to the purifiers for the final traces of impurities to be removed and then sent through a vacuum drier at pressure -0.9 bar. Drying is done in a vacuum to prevent hydrolysis of the oil which leads to an increase in free fatty acids content due to absorption of moisture. After drying, the oil is sent for storage.

```
 200 kg          Oil from clarification
                              │
                              ▼
              ┌──────────────────────────────┐
              │   Purification and drying at  │─────────────►
 20 kg        │   vacuum pressure of -0.9 bar │
              └──────────────────────────────┘         Water and dirt
                              │
                              │          2, 180 kg
                              │          Crude palm oil to storage
                              ▼
```
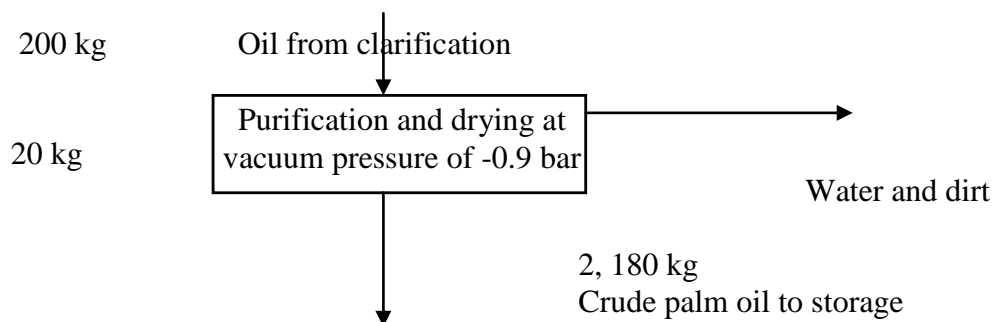
DEPERICARPING

In the presses, the crude oil is pressed out of the digested mash leaving the presscake. This is made up of nuts and fibre. As the kernel in the nut is needed to make palm kernel oil, there is need to separate the nuts from the fibre as the first step in kernel recovery. Depericarping then becomes the first unit of operation in the kernel recovery plant. From the press, the presscake empties into a cake-breaker conveyor. This meechanical machine is made up of a long horizontal rotary shaft having short blades projecting from it alternately along its wholelength.The cake breakor conveyor is supplied with steam.

It functions to break up the presscake by means of its blades as it rotates and conveys the cake along its length to the depericarper. Breaking up the cake creates a wide surface area and exposes the cake to steam which dries up the fibre and prevents it from sticking to the

nuts. The depericarper is a long, hollow vertical structure reaching up from the ground towards the roof of the plant and bending towards the boiler house. As the presscake falls into the depericarper by gravity, a current of air is made to blow upwards from the bottom. The current is enough to blow away the fibre but not the nuts. By so doing, the nuts are separated from the fibre
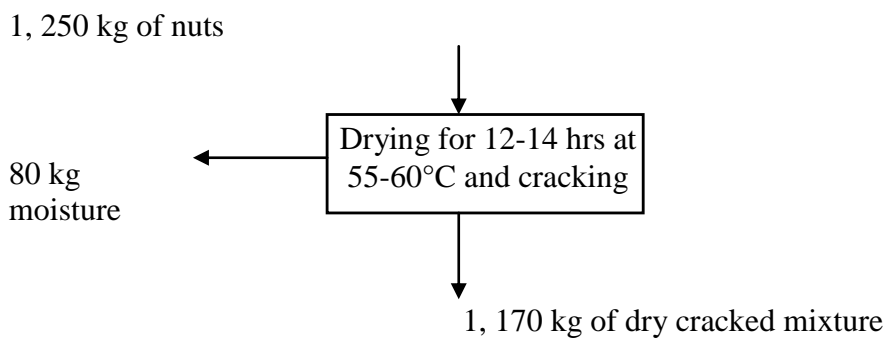
2, 475 kg of presscake from press

1, 225 kg

Wet Fibre

Description (nut/fibre separation

1, 250 kg
Nuts
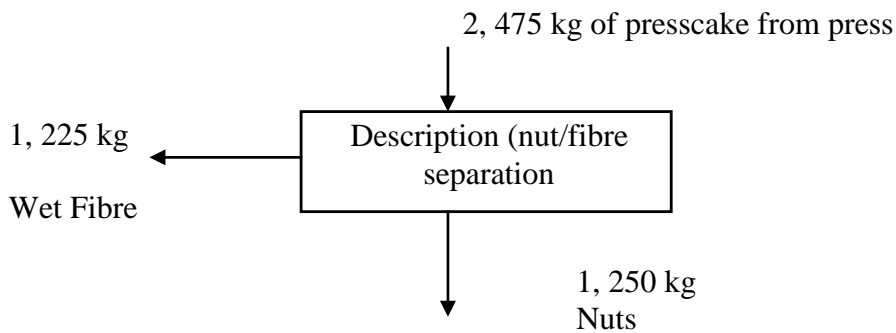
DRYING AND CRACKING

The nuts from the depericarper fall into a polishing drum where they are polished to get rid of the little pieces of fibre on them and then sent for drying in the nut silos. Drying is done at 55 – 60 degrees Celsius for 12 - 14 hrs. Drying is done as a pre-treatment for efficient nut cracking. In the wet state, the kernel in the nut is attached to the internal shell wall. If the nuts are cracked in this state, The mechanical shock will cause a lot of broken kernel in the process. This exposes subsstrates in the kernel for bacteria to grow on. The result is increase in the free fatty acid content of the kernel which leads to rancidity in the palm kernel oil. After drying, nuts are sent to the crackers to be cracked.

1, 250 kg of nuts

80 kg
moisture

Drying for 12-14 hrs at 55-60°C and cracking

1, 170 kg of dry cracked mixture

WINNOWING

This is done to separate light weight cracked mixture made up of kernel and shell. An air cyclone is employed to blow away shells to the boiler house leaving behind the heavire weight kernel and shell.

1, 170 kg
cracked dry mixture

Winnowing

510 kg

dry shells

660 kg of kernel and shell
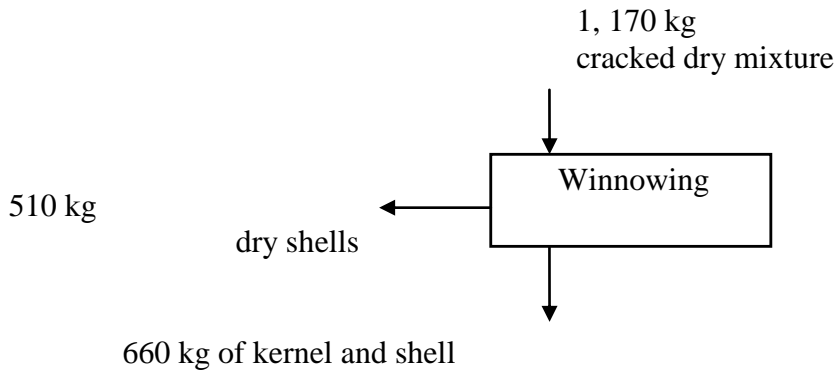
HYDROCLONE

The hydroclone is employed to separate heavy weight kernel and shell. Seperation here is based on differences in the buoyant densities of kernel and shell in water.

660 kg kernel and shell

1, 100 kg

water

60 kg
Wet shells

Hydrocyclone

1, 100 kg

water

600 kg wet kernel
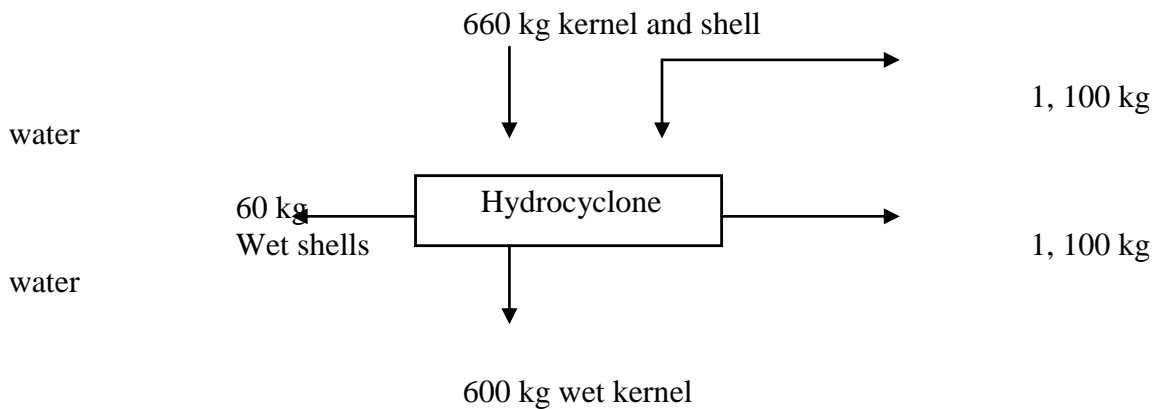
STORAGE AND DRYING

The kernels are sent to kernel silos where they are dried at 55 - 60 degrees Celsius prior to crushing .

600 kg wet kernel

| Storage and drying at 55-60°C |

40 kg moisture

560 kg kernel
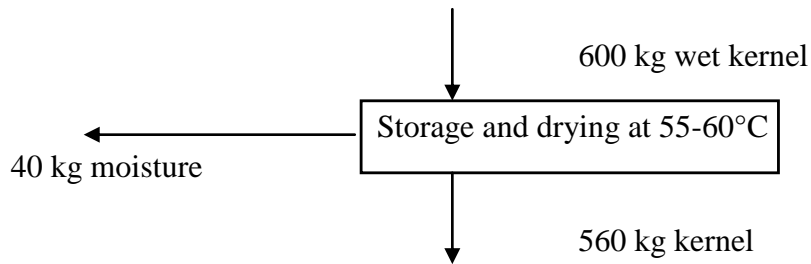
CRUSHING AND FILTRATION

From the silos, the dried kernels are sent to the kernel crushers for oil extraction and then for filtration and finally to storage.

560 kg kernel

| Crushing and filtration |

296 kg pkc

palm kernel oil to storage
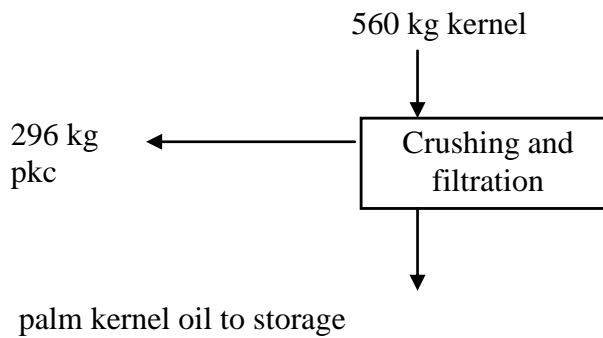
2.10 CPO/CPKO SEPERATION PROCESS BLOCK DIAGRAM

Figure 10 CPO/CPKO seperation process block diagram
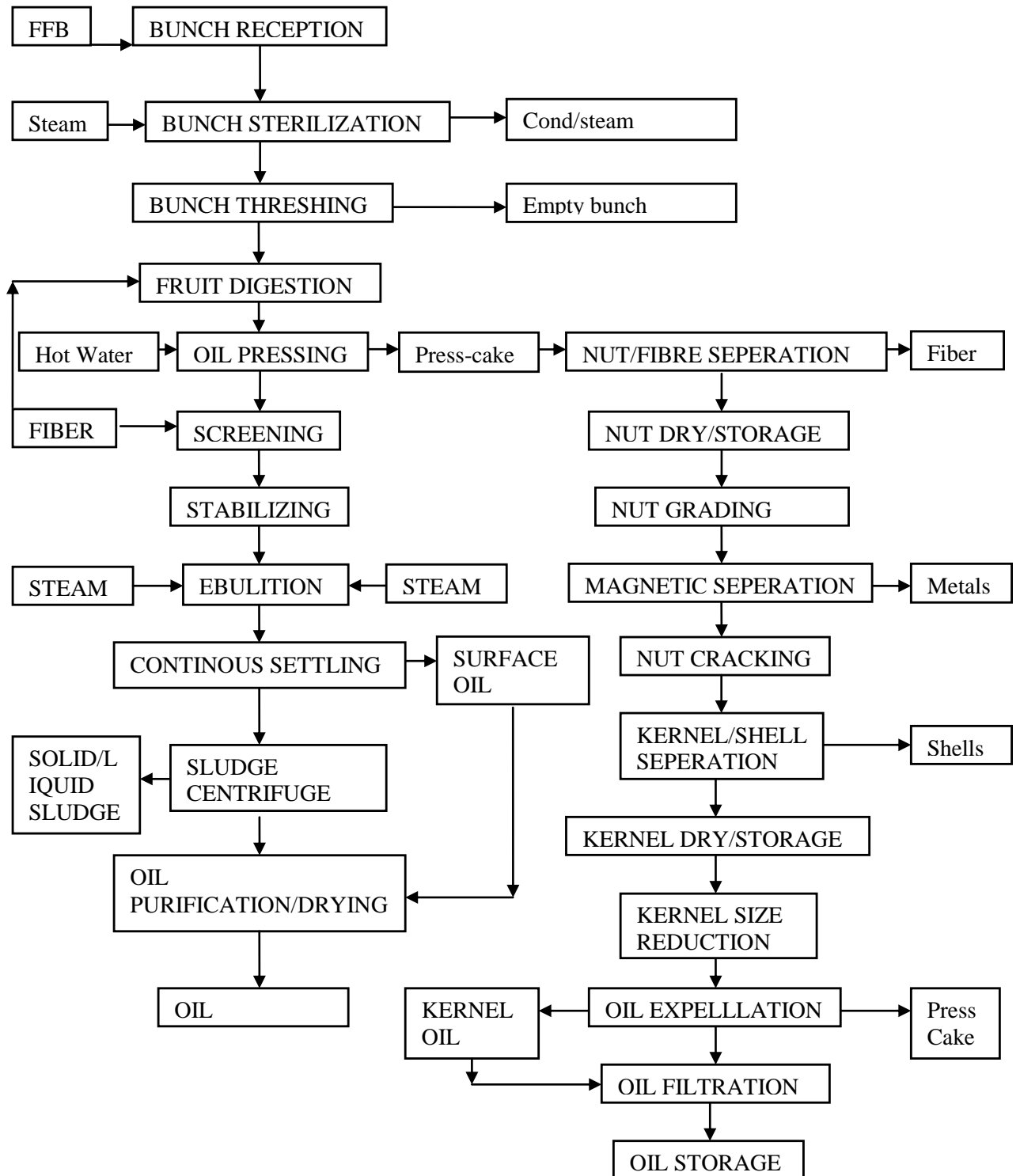
Source (Dolev, 1998)

2.11 LOCAL PROCESSING OF PALM OIL

BUNCH RECEPTION

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

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

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

THRESHING (REMOVAL OF FRUIT FROM THE BUNCHES)

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

In a mechanised system a rotating drum or fixed drum equipped with rotary beater bars detach the fruit from the bunch, leaving the spikelet on the stem.

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

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

STERILIZATION OF BUNCHES

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

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

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

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

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

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

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

- Hydraulic system but care should be taken to ensure that poisonous hydraulic fluid does not contact the oil or raw material. Hydraulic fluid can absorb moisture from the air and lose its effectiveness and the plungers wear out and need frequent replacement. Spindle press screw threads are made from hard steel and held by softer steel nuts so that the nuts wear out faster than the screw. These are easier and cheaper to replace than the screw.

The size of the cage varies from 5 kg to 30 kg with an average size of 15 kg. The pressure should be · However, during sterilization it is important to ensure evacuation of air from the sterilizer. Air not only acts as a barrier to heat transfer, but oil oxidation increases considerably at high temperatures; hence oxidation risks are high during sterilization. Over-sterilization can also lead to poor bleach ability of the resultant oil. Sterilization is also the chief factor responsible for the discolouration of palm kernels, leading to poor bleach ability of the extracted oil and reduction of the protein value of the press cake.

DIGESTION

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

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

PRESSING (EXTRACTING THE PALM OIL)

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

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

BATCH PRESSES

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

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

Different designs use either a screw thread (spindle press) (Fig. 4, 5, 6) or a hydraulic system (hydraulic press) (Fig. 7, 8, 9) to move the plunger. Higher pressures may be attained using the increased gradually to allow time for the oil to escape. If the depth of material is too great, oil will be trapped in the centre. To prevent this, heavy plates' can be inserted into the raw material. The production rate of batch presses depends on the size of the cage and the time needed to fill, press and empty each batch.

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

CONTINUOUS SYSTEMS

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

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

CLARIFICATION AND DRYING OF OIL

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

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

OIL STORAGE

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

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

KERNEL RECOVERY

The residue from the press consists of a mixture of fibre and palm nuts. The nuts are separated from the fibre by hand in the small-scale operations. The sorted fibre is covered

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

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

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

2.12 USES OF PALM OIL AND PALM KENNEL OIL

A healthy, versatile crop

Due to its physical characteristics, palm oil can be used and prepared in a number of processes without the need to hydrogenise it. This has advantages as hydrogenation can produce undesirable trans fatty acids which may lead to diseases, including cardiovascular problems and diabetes. (Sundram,J.,1996)

The composition of palm oil, together with its natural consistency, appearance, pleasant smell and its resistant nature makes it an ideal ingredient in the development and production of a variety of edible oils, in particular margarines and fats. Palm oil is also ideal when making the following products: dry cake mix used for baking biscuits, cakes and sponge cakes, soaps, sauces, fat substitutes used when making condensed milk, powdered milk, non lacteous cream used in coffee and ice-cream. (Sundram,J.,1996)

Palm oil is also considered one of the best oils for frying. This is because it can resist high temperatures and does not produce unpleasant smells. Palm oil as such is used in the home, in restaurants and during the mass production of fried potatoes, French fries, puffy hor'dourves, pies, ring-shaped pastries and doughnuts.

Also, palm kernel meal, a byproduct of palm oil, is used in the production of concentrated foods and as a supplement in animal food. (Sundram,J.,1996)

In comparison palm kernel oil, even though it comes from the same fruit, is very different from the oil obtained from the rest of the fruit. In fact, palm kernel oil resembles coco oil and is semi-solid or solid at room temperature. When it is eaten it produces a soft sensation in the mouth, similar to cacao. This makes palm kernel oil popular among chocolate lovers. Due to its neutral taste and long life, palm kernel oil can also be used as a substitute for cacao and fats found in milk.

Palm kernel oil is used in cream made from sugar, condensed milk and doughnut fillings. It is also found in biscuits and cakes giving them a softer texture and sweeter taste which lingers in the mouth. Palm kernel oil is also used to make special kinds of margarines and is found in ingredients used when baking cakes, croissants and bread, giving these products added volume, a soft texture and making them last longer. Palm kernel oil is also favoured when making sweets, cream for coffees and peanut butter.

2.13 OTHER USES OF PALM OIL

African palm oils have non-edible uses which are of great economic value and can be used as a substitute for petroleum.

Palm and kernel oils are used in the production of oleo chemical products such as fatty acids, fatty esters, fatty alcohols, which all contain glycerol and fatty nitrogen. Recently, palm and kernel oils have been increasingly used as biodiesel fuel.

In 1900, Rudolf Diesel used vegetable oil as fuel for his car, from which the motor engine subsequently took its name. Years later, palm oil was successfully developed as a biofuel for cars. Using palm oil as a biofuel is more environmentally friendly and its more advantageous than other combustible fuels such as petro diesel and standard petrol.

Colombia has pledged to produce biodiesel using palm oil mixed with diesel. This will eventually play an important role in providing energy fuels which can power thousands of cars and machines with motor engines across Colombia. Using palm oil as a biodiesel brings benefits and is environmentally friendly. It also generates employment and contributes to the demand for renewable energy sources.

Non-edible uses of palm oil include:

• Soaps and detergents

• Candles

• Cosmetics

• Lubricating greases for machinery used in the production of edible foods

• Grease for bread moulds and bread making equipment

• Grease used to protect tanks, pipelines and similar instruments which remain uncovered and in the open air

• Drilling mud for the petroleum industry

• Epoxidated palm oil used to plastify and sterilize products in the plastics industry, in particular during the production of PVC

• Glue

• Printing inks

• Biodiesel

• Metallic soaps for the manufacture of lubricating grease and metallic dryers

• Steel cold rolling processes

• Tinplate rolling

• Acids to lubricate fibres in the textile industry

In addition to oils extracted from the oil palm fruit, other parts of the tree can be used in industry. For example, leaf fibres and empty fruit bunches are used to produce chipboard and plywood. After plantations are cleared out, the trunks of old palms can be used to make furniture. (Fedepalma.org).

2.14 OIL SUBSTITUTE

A variety of alternate ingredients that can be used instead of oil or butter in the preparation of foods. Substitute products exist with reduced fat and no fat and in different forms such as spreadable and liquid. Fruit purees or applesauce can be used as oil substitutes for baking purposes. Add skim milk to applesauce or fruit-based purees for liquid cooking oil substitutes. Butter buds mixed to form a liquid, corn syrup, and cooking sprays may also be used as good oil substitutions. Non-sticking cooking pans can be used in order to reduce or eliminate oil required for cooking. For specific food oils used in cooking, consult the "Food Substitutions" guide for suggested alternatives. (Sundram,J.,1996)

3 AIMS OF THE THESIS

Optimization of post- harvest operations,

General principles of palm oil processing in Ghana,

Focused on nutritive, organoleptic and technological aspects of palm oil products.

4 MATERIAL AND METHODOLOGY

4.1 FACTORY

In Ghana, the researcher chose a factory in the western Regan where he observed the processing of palm oil. I therefor give a brief history of this factory.

Ayiem Oil Mills Ltd was established in 1977. The company began the production of palm oil in 1980 with an initial capacity of 36 tons of fresh fruits bunches (FFB) per day (3 shifts) and a staff strength of 50. In 1982, installation of additional sterilizer doubled the capacity of the plant. In 1986, Mpohor Oil Company was established to process kernel oil and cake. The initial capacity was 15 tons of palm kernel milled per day with a labour force of 20. The two companies merged in 1993, to create two distinct sections, palm oil and palm kernel oil divisions. Over the years, the company gradually expanded its production facilities to 144 tons of FFB per day and 30 tons of palm kernel milled per day. The old plant is labour intensive; however the new plant under construction is semi-automated and therefore would require less labour. The increased capacity of the palm fruit processing plant is demanding complementary capacities of auxiliary equipment to optimize capacity utilization of the installed plant.

Name	Estimated quantity	Installed capacity
Palm oil (organic)	5600 tons p.a	7500 tons pa
Palm kernel oil	2600 tons p.a	3500 tons pa
Kernel Cake	4200 tons p.a	7500 tons pa

The company has about 200 employees some of whom are not technically trained.

4.2 USE OF MATERIAL

For purposes of this thesis have used a total of 8 samples of palm oil and 1 sample palmojádrového oil imported into the Czech republic in tropical, the 2 samples palmstearinu.

These are samples:

1 unrefined palm oil, domestic production, Guinea, West Africa

2 unrefined palm oil, industrial processing, Nigeria, West Africa

3 unrefined palm oil, industrial processing, Ivory Coast, West Africa

4 refined palm oil, SETUZA, Usti nad Labem

5 kernel oil, domestic production, Guinea, West Africa.

4.3 PRODUCT SAMPLES

Samples of palm oil and palm kernel oil were taken from the factory according to international standards. A liter each of palm oil and palm kernel oil was taking from the factors for analysis in Czech republic. The same quantity was also taken from the local market (Makola) and finally from African market in London. These samples were analyzed in laboratories in Czech republic and the results compared with other known results.

4.4 CHEMICAL ANALYSIS

All samples were determined following chemical analysis:

1: free fatty acids

2: fatty acids

2: iodine value

3: fat content

4: acid number

5: saponification value

6: iodine number

7: water activity

Analyses were performed in the laboratory of Research Institute of Food Science (VÚPP) in Prague, Czech University of Life Science (FAPPZ) and Czech Institute of Chemical Technology (VŠCHT) in Prague.

4.5 FREE FATTY ACIDS

Free fatty acid content is determined by Weigh 10 g oil, dilute with alcohol to a height of 1.5 to 2 cm, the boiled leaves. After cooling, titrate with potassium hydroxide (KOH) before becoming pink oil. According to the scale of consumption, find the number of free fatty acids.

4.6 FATTY ACIDS

Preparation of fatty acid methyl

To a sample of oil (weighed 100-200 mg) with 10 ml of methanol and 0.2 ml methan potassium hydroxide solution (KHO). The solution is heated until clear (5-10 minutes) and transfer to dividers. Add 20 ml petroleum ether and 5 ml of distilled water. Shake, esters of fatty acids pass into the light petroleum layer. Light petroleum fraction wash 2x 10 ml of distilled water. Washed extract is dried anhydrous sodium sulfate, filter, and thus is ready to nátřiku (1 ml) into the chromatograph.

4.7 IODINE VALUE

Melt a sample with is dry and free from solid impurities up to a temp ~80°C.

Take a sample weight depending of the iodine value.

Add 20ml of Cyclohexane (AOCS Cd 1b-87) or cyclohexane and glacial acetic acid 1:1 v/v (for AOCS Cd 1d-92). Swirl until the sample is completely dissolved. Prepare also a blank

Dispense 25ml wijs solution into the flask containing the sample (or blank) and swirl to ensure an intimate mixture. Set the timer for 1.0 or 2.0hr, depending on the iodine value of the sample: IV<150,1.0.hr $\geq$150, 2hr

Store the flasks in the dark at room temperature.

Remove the flasks from storage and add 15ml of KI solution, followed by 80ml of distilled water.

Titrate with 0.1 M $Na_2S_2O_3$ solution, adding it gradually and with constant and vigorous shaking.

Continue the titration until the yellow color has almost disappeared.

Add 1-2ml of starch indicator solution and continue the titration until the blue color has just disappeared.

With the automatic titration no indicator is necessary. The electrode measure the IV.

Figure 11 Standard iodine value table

Iodine value expected	Weight, g,0.001
>5	3.0000
10	2.0000
20	1.0000
30	0.8000
40	0.6000
50	0.4000
60	0.3500
70	0.3000
80	0.2500
90-100	0.2000

Source (eur-lex.europa.eu, 2010)

Calculations (see Notes 2)

$$IV = \frac{(B - S) \times M \times 12.69}{wt \ of \ sample}$$

B= titration of blank

S = titration of sample

M = molarity of $Na_2S_2O_3$ solution

Notes

1.Hoffman and White showed that the addition of 10 ml of 2.5% mercuric acetate in glacial acetic acid resulted in a reduction of the absorption time of the wijs method from

1hr to 6 min. The accelerator is added immediately after the addition of the reagent, the procedure being carried out otherwise as usual.

2. Range of accepted results = IV $\pm$ 0.8

Weigh 5 g of the sample in a 250 ml Erlenmeyer flask.

Add 30 ml of the acetic/chloroform mixture and 1 ml of saturated KI-solution.

Allow the solution to stand for 1 minute with occasional shaking.

After exactly 1 minute, add 30 ml of distilled water and 1 ml of the starch solution

Titrate with the standard $Na_2S_2O_3$ 0.01N solution until discoloration.

Conduct a blank in the same conditions.

Calculation:

$$PV = \frac{(B-S) \times N \times 1000}{wt\ of\ sample} meq\ peroxide\ 100\ g\ of\ sample$$

B = titration of the blank

S = titration of the sample

N = normality of the $Na_2S_2O_3$ solution

4.8 STANDARD OPERATING PROCEDURE

4.8.1 CRUDE PALM OIL AND PALM KERNEL OIL

CPO and PKO samples should be bulked in a suitable, clean, dry container with a stopper or screw cap. The sample must be taken from the pipeline leading from drier to storage.

250 ml samples must be taken at half-hourly intervals during the whole time that oil is being centrifuged or in the case of oil being dispatched from the mill during the whole time that the road tanker or vessel is being filled.

The stopper or screw cap of the sample containers should be replaced immediately to prevent the oil from picking up moisture from the atmosphere.

4.8.2 PRODUCTION, HOPPER AND HYDROKERNELS

Both production kernel with hopper kernel and hydro kernel should be sampled.

500g each of production, hopper and hydro kernel should be drawn from the kernel hopper containing kernel ready for crushing, and outlet of the kernel side of the hydroclone respectively at hourly intervals during processing.

Each of these samples should be bulked in their respective clean, dry containers and closed.

SLUDGE (CLARIFICATION EFFLUENT)

During processing 100 ml of liquid sludge and 120g of solid sludge should be taken from the outlet of each centrifuge, put in their separate clean, dry containers and covered.

Samples taken each hour throughout the whole processing period should be bulked in a clean, dry container and covered after each time.

EMPTY BUNCH

The sample should be taken from the empty bunch conveyor after the unstrapped bunch check-point.

An empty bunch should be collected at random at hourly intervals.

Each empty bunch collected should be divided longitudinally into four parts; one of which should bulked in a clean, dry container, covered and the rest discarded.

UNSTRIPPED BUNCH

Every hour an unstrapped bunch should be collected, if any (after observing for 10 minutes), from the unstrapped bunch checkpoint on the empty bunch conveyor.

Such unstrapped bunches should be bulked in a clean, dry container and covered.

PALM KERNEL CAKE

1 kg of kernel cake is taken from the outlet of each kernel press every hour throughout the process of crushing.

Each sample should be bulked in a clean, dry container and covered.

CRACKED MIXTURE

1 kg samples of the cracked mixture is taken from each cracker outlet just before the shell separation and emptied into their different containers (one for each cracker to help us determine the cracking efficiencies of each cracker separately). This is done every hour over the whole of the cracking period and each sample bulked.

DRYSHELLS AND HYDROSHELLS

A sample of 1 kg each of shells should be drawn from the outlets of the dry shell separators and hydroclone every hour over the whole period of processing.

Each sample should be bulked in its clean, dry container and covered.

CRUDE OIL AND SLUDGE (FOR DILUTION)

A sample of 250 ml each of crude oil and sludge is taken from the pipeline leading from the vibrating screen and from the continuous settling tank respectively and covered. Prior to this, the sample containers should be rinsed three times with their respective samples. These samples are taken to the laboratory immediately for analysis.

4.9 SAMPLE PREPARATION AND ANALYSIS

MOISTURE

The method involves heating a known weight of oil at 104 ℃ to constant weight.

The bulk sample of oil is thoroughly mixed to homogenize and a sub-sample of 250 ml taken.

This sample is gently heated to soften at 50 °C – 60 °C (do not melt) and thoroughly homogenized prior to taking a test portion.

A clean glass crystallizing dish is dried in the oven at 104 °C for 15 minutes and allowed to cool in a desiccator and weighed to the nearest 0.001 g and the weight recorded.

20 g of the molten oil is introduced into the dish.

The dish plus the oil is weighed to the nearest 0.001 g and recorded.

The dish is placed in the middle shelf of the oven and heated at 104 °C for two and half hours, cooled in a desiccator and weighed. The dish is put back in the oven and heated for 30 minutes, cooled in desiccator and weighed. Heating is continued intermittently until the

oil has attained a constant weight and the weight is recorded. (In this case the difference in weight should not exceed 0.002 g) The remaining kernels are further quartered down to a sample size of about 30.0 g and sliced or pulverized.

A Petri dish is weighed and its weight recorded.

The sliced or pulverized kernels is introduced into the dish, weighed and the weight of the kernel and dish recorded.

The kernel and dish is dried in the oven at 104 ℃ to constant weight and the weight of dish plus dry kernel recorded.

The moisture content of the kernels can then be calculated

FREE FATTY ACID

This method involves dissolving a known mass of the sample of oil in neutralized isopropanol or ethanol and neutralizing the free fatty acid with standard alkali.

The bulk sample of oil is thoroughly mixed to homogenize and a sub-sample of 250 ml taken.

A conical flask is weighed to the nearest 0.001 g and the weight recorded.

2.0 g of the oil is poured into it and the weight of oil plus flask recorded to the nearest 0.001 g.

The sample must be well mixed and entirely liquid before weighing

50 ml of neutralized isopropanol or ethanol is poured into the oil to dissolve and heated to 40 °C – 50 °C using a hot plate. A magnetic stirrer is introduced into the mixture to stir.

Three drops of phenolphthalein indicator is added and titrated with standard alkali (normally 0.1N NaOH)

Titration is continued until there is a faint but noticeable change in colour of the indicator. This colour must persist for 30 seconds. The volume of alkali used is recorded.

IMPURITIES

The method involves dissolving the oil in solvent (hexane), filtering off the solvent and further extracting the residue with solvent.

A glass filter paper is placed in a gooch crucible, washed with approximately 10 ml petroleum ether, dried at 104 °C for 30 min., cooled in a desiccator and weighed to the nearest 0.001 g.

A flask is weighed to the nearest 0.001 g and its weight recorded.

2.0 g of the sample is poured into the flask, and the weight of the flask plus sample taken and recorded.

100 ml of solvent (hexane) is added, and heated while swirling to achieve complete melting and homogenization.

The mixture is left for about 5 minutes for the insoluble matter to settle.

The solution is then poured off with caution through the pooch crucible of known weight into another flask

The flask is rinsed with 10 ml solvent once again and the content is poured through the gooch crucible into the second flask. This step is repeated two more times to ensure the totality of oil has been removed.

The crucible is removed and the outside wiped with clean tissue and dried in the oven at 104 °C for 30 minutes, cooled in the desiccator to room temperature, weighed and its weight recorded. All weighing are done to the nearest 0.001 g.

4.10 DIRT

In the case of hydro kernels, the sample is spread out and left to dry till the next morning before analyzing.

The bulk sample is quartered down to a final sub-sample of about 1 kg.

All the free shells in the sample are collected, weighed and the weight recorded.

The entire half - cracked nuts in the sample are collected, cracked and all the shells from such nuts weighed and their weight recorded.

The whole nuts in the sample are also collected, weighed and their weights recorded.

From this. the percentage dirt or admixture in the kernels is deducted.

All broken kernels in the sample are picked out and weighed.

4.11 PRESSCAKE

The bulk sample from each press is well mixed and divided into two parts. This is done individually for each press sample.

The first half is weighed and its weight recorded.

The whole nuts are separated out, weighed and the weight recorded.

Next, all the broken nuts are picked out, weighed and the weight recorded.

Following this, the broken kernel and the free shells are picked out, weighed together and their weight recorded.

From this, the total nuts in the press cake can be calculated as well as the broken nuts to nuts ratio. The wet fibre to press cake can also be calculated.

The second half of the press cake is quartered down to a sub-sample size of about 200 g and sent to the laboratory for analysis in a closed container.

In the nuts are carefully picked out of the 200 g sample.

The fibre is well mixed by teasing out and quartering down to a final size of 20 g (the quartering down should be done on a smooth, clean surface. It should also be ensured that any dust that may tend to separate out is mixed with the fibre again).

A dish is weighed to the nearest 0.01 g and its weight recorded.

The fibre sample is put in it and weighed again. The weight of the dish plus the fibre is recorded.

The fibre is then put in the oven at 104 ℃ to dry for four hours.

After this, the sample is cooled in a dessicator and weighed.

Drying is continued for a further two hours in the oven and the weight redetermined. After a further two hours the weight should be consistent but if this is not so drying must be repeated and the final consistent weight recorded.

The percentage moisture can then be calculated

The dried fibre is transferred into a filter paper and placed in an extraction thimble.

A flask is weighed to the nearest 0.001 g and its weight recorded.

About 250 ml of hexane is poured into the flask.

The soxhlet extraction apparatus is set up and extraction is started.

Extraction is made to continue for about four hours after which the solvent is removed from the flask by distillation.

The flask is then heated over the hot plate to get rid of the final trace traces of solvent.

The flask and oil is cooled in a dessicator and weighed and its weight recorded.

The % oil to wet fibre, non-oil solids to wet fibre, oil to non-oil solids etc can also be deduced from calculation.

4.12 CYCLONE FIBRE

The bulk sample of cyclone fibre is well mixed to homogenize and quartered down to a final sample size of about 1 kg.

The entire broken kernel from this is picked out, weighed and its weight recorded.

All the half-cracked nuts and whole nuts are also picked out, cracked to separate out the kernels and the kernels weighed.

The whole kernels in the sample are also all picked out, weighed and the weight recorded.

The kernel losses to the cyclone fibre can then be calculated.

The fibre is quartered down to about 20.0 g sample size.

A dish is weighed to the nearest 0.01 g and its weight recorded.

The fibre sample is put in it and weighed again. The weight of the dish plus the fibre is recorded.

The fibre is then put in the oven at 104 ºC to dry for four hours.

After this, the sample is cooled in a dessicator and weighed.

Drying is continued for a further two hours in the oven and the weight redetermined. After a further two hours the weight should be consistent but if this is not so drying must be repeated and the final consistent weight recorded.

The percentage moisture can then be calculated

The dried fibre is transferred into a filter paper and placed in an extraction thimble.

A flask is weighed to the nearest 0.001 g and its weight recorded.

About 250 ml of hexane is poured into the flask.

The soxhlet extraction apparatus is set up and extraction is started.

Extraction is made to continue for about four hours after which the solvent is removed from the flask by distillation.

The flask is then heated over the hot plate to get rid of the final trace traces of solvent.

The flask and oil is cooled in a dessicator and weighed and its weight recorded.

The % oil to wet fibre, non-oil solids to wet fibre, oil to non-oil solids etc can also be deduced from calculation.

SLUDGE

A dish is weighed to the nearest 0.01 g and recorded

The bulk sample is thoroughly mixed to homogenize and a sub-sample of about 20 g is taken and introduced into the dish.

This is weighed and the weight if dish plus sample recorded.

The sample is put in the oven to dry at 104 °C for six hours after this; the sample is put in a desiccator to cool.

Drying is continued for a further two hours in the oven and the weight redetermined. After a further two hours the weight should be consistent but if this is not so drying must be repeated and the final consistent weight recorded. From these measurements, the percentage moisture can be calculated.

A flask is weighed to the nearest 0.001 g and its weight recorded.

About 250 ml of hexane is poured into the flask.

The soxhlet extraction apparatus is set up and extraction is started.

Extraction is made to continue for about four hours after which the solvent is removed from the flask by distillation.

The flask is then heated over the hot plate to get rid of the final trace traces of solvent.

The flask and oil is cooled in a dessicator and weighed and its weight recorded.

The % oil to wet sludge, non-oil solids to wet sludge, oil to non-oil solids etc can also be deduced from calculation.

EMPTY BUNCH

The empty bunch samples are chopped into pieces with a matchet well mixed and quartered down to a sample size of about 20 g.

A dish is weighed to the nearest 0.01 g and its weight recorded.

The sample is introduced into the dish and the weight of the dish and sample taken and recorded.

The sample is put in the oven to dry at 104 °C for four hours; after this the sample is put in a desiccator to cool.

Drying is continued for a further two hours in the oven and the weight redetermined. After a further two hours the weight should be consistent but if this is not so drying must be repeated and the final consistent weight recorded. From these measurements, the percentage moisture can be calculated.

A flask is weighed to the nearest 0.001 g and its weight recorded.

About 250 ml of hexane is poured into the flask.

The sox let extraction apparatus is set up and extraction is started.

Extraction is made to continue for about four hours after which the solvent is removed from the flask by distillation.

The flask is then heated over the hot plate to get rid of the final trace traces of solvent.

The flask and oil is cooled in a desiccator and weighed and its weight recorded. From these, the oil loss to the empty bunch can be calculated.

UNSTRIPPED BUNCH

The unstrapped bunches are counted and number recorded.

The unstrapped bunches are weighed and their weight recorded.

The bunches are stripped of all fruit, the fruits are weighed and their weight recorded.

4.13 PALM KERNEL CAKE

The palm kernel cake sample is well mixed to homogenize.

A dish is weighed to the nearest 0.01 g.

About 20 g sub-sample of the palm kernel cake is introduced into the dish and weighed. The weight of the dish plus the cake is recorded.

The sample is put in the oven to dry at 104 °C for four hours; after this the sample is put in a desiccator to cool.

Drying is continued for a further two hours in the oven and the weight redetermined. After a further two hours the weight should be consistent but if this is not so drying must be repeated and the final consistent weight recorded. From these measurements, the percentage moisture can be calculated.

A flask is weighed to the nearest 0.001 g and its weight recorded.

About 250 ml of hexane is poured into the flask.

The sox let extraction apparatus is set up and extraction is started.

Extraction is made to continue for about four hours after which the solvent is removed from the flask by distillation.

The flask is then heated over the hot plate to get rid of the final trace traces of solvent.

The flask and oil is cooled in a desiccator and weighed and its weight recorded.

The % oil loss to the palm kernel cake can be deduced from calculation.

4.14 CRACKED MIXTURE

The sample of cracked mixture is quartered down to a sample size of about 1 kg.

All the broken kernel in it is picked out, weighed and recorded.

Likewise, all the half-cracked nuts and whole nuts are picked out separately, weighed and their weights recorded.

From these weighing, the cracking efficiency can be calculated.

DRY SHELLS AND HYDROSHELLS

The hydro shell sample must be left to dry overnight before analysis.

Each sample is quartered down to a size of about 1 kg.

The broken kernels in each sample are picked out, weighed and the weight recorded.

The half – cracked nuts are also picked out, cracked to remove the kernels and the kernels weighed and the weight recorded.

The same is done for the whole nuts. The kernel loss to dry shells and hydroshells can be calculated.

CRUDE OIL AND SLUDGE (FOR DILUTION

These samples each are thoroughly mixed to homogenize and 15 ml of each poured into test tubes. This should be done in duplicate in order to balance the centrifuge.

The samples are placed in the centrifuge and separated at 2000 rpm for 3 minutes.

Using a ruler, the height of oil and sludge in each test tube is measured and recorded. From this, the ratios of oil and sludge can be calculated.

5 RESULTS AND DISCUSSIONS

Palm oil and palm kernel oil samples were taken from a factory and local market in Ghana and analysed in laboratories in Czech republic. The analysis were done according to the methods discoursed in chapter four above and the results compared with other known results.

Figure 12 Analysis of fatty acids (FA) content

Analysis of methylesters of fatty acids: (ISO 5509:2000, ISO 15304:2002)

	Palm kernel oil	Palm oil local quality	Palm oil export quality
fatty acids (FA)	content of FA % w/w	content of FA % w/w	content of FA % w/w
C4	0,00	0,00	0,00
C6	*0,02*	*0,15*	*0,00*
C8	*0,00*	*2,37*	*0,01*
C10	0,01	2,72	0,01
C12	0,07	42,00	0,03
C14	1,02	17,84	0,57
C14.1	0,00	0,00	0,00
C15	0,05	0,01	0,04
C16	42,49	10,27	37,89
C16:1	0,16	0,02	0,14
C17	0,10	0,02	0,10
C18	5,45	3,72	5,79
C18:1 9cis	37,80	17,31	41,06
C18:1 11cis	0,72	0,16	0,80
C18:1 >11cis	0,00	0,13	0,00
C18:1trans	0,10	0,15	0,08
C18:2cis,cis	10,99	2,85	11,93
C18:2trans,trans	0,00	0,00	0,00
C18:2cis,trans	0,00	0,00	0,02
C18:2trans,cis	0,00	0,00	0,00
C18:2 conjug.	0,00	0,00	0,00
C18:3	0,00	0,00	0,00
C20	0,49	0,16	0,53
C20:1	0,45	0,11	0,78
C22	0,09	0,00	0,12
C22:1	0,00	0,00	0,00
C24:0	0,00	0,00	0,10
C24:1	0,00	0,00	0,00

Source (Hero Toseafa, 2010)

Figure 13 Fatty acid composition of fats from the seeds of palm trees (% of total fatty acids)

Fatty acid		Coconut oil	Palm kernel oil	Palm oil	Palmstearin	Palmolein
caproic	6:0	0,0-0,6	0,0-0,8	0,0-0,2	0,1-0,4	0,1-0,5
caprylic	8:0	4,6-9,4	2,1-4,7	0,7-1,3	1,1-1,8	0,9-1,4
capric	10:0	5,5-7,8	2,6-4,5	40,1-46,3	48,4-73,8	38,2-42,9
lauric	12:0	45,1-50,3	43,6-53,2	0,0-0,3	0,1-0,2	0,1-0,3
myristic	14:0	16,8-20,6	15,3-17,2	4,0-6,5	3,9-5,6	3,7-4,8
palm	16:0	7,7-10,2	7,1-10,0	36,7-40,9	15,6-36,0	39,8-43,9
stearic	18:0	2,3-3,5	1,3-3,0	9,4-12,1	3,2-9,8	0,4-13,4
oil	18:1	5,4-8,1	11,9-19,3	0,1-0,4	0,1-0,6	0,1-0,6
linoleic	18:2	1,0-2,1	1,4-3,3	0,1-0,7	0,3-0,6	0,2-0,6

Source (Reissová, 2002)

Palm oil contains large amounts of vitamin E - tocopherols and tocotrienols (800 ppm total tocopherols). A certain amount of tocopherol is lost during the processing of palm oil. Crude palm oil - 754 ppm, refined, bleached, palm oil dezodorizovaný - 563 ppm, refined, bleached dezodorizovaný palmolein - 642 ppm, refined, bleached dezodorizovaný palmstearin - 261 ppm (Corley, 1976).

Content of sterols in palm oil is relatively low (300 ppm). The main sterols are β-sitosterol (74 %), stigmasterol (of 8 %) and kampasterol (14 %), cholesterol (1 %). Content of sterols is reduced during refining (SALUNKHE, 1992).

5.1 ANALYTICAL RESULTS

Figure 14 Analytical results of palm oil and palm kernel oil sample from Ghana

Analytical results	Palm kernel oil	Palm oil local quality	Palm oil export quality	Norms
Acidity value [mg KOH/g]	6,36	8,38	25,48	ČSN 58 8756
Saponification value [mg KOH/g]	268,69	219,47	206,97	ČSN 58 8763
Esterification value [mg KOH/g]	262,33	211,09	181,49	
Iodine value [g of iodine/100g]	11,87	43,10	45,72	ISO 3961:1996
Peroxide value [mequivalents of act. oxygen/kg]	11,19	6,67	12,84	ISO 3960
content of carotenoids [μg/g]	8,83	228,79	225,32	
content of feofytins [μg/g]	0,00	1,14	0,00	
sensory evaluation of colour [number of colour scale]	16,00	18,50	18,50	ČSN 58 0101
water content [% w/w]	0,46	0,40	0,27	by Mettler, HR73 halogen moisture analyzer
fat content [% w/w]	99,54	99,60	99,73	

Source (Reissová, 2002)

Figure 15 Analytical results of palm oil and palm kernel oil sample from Reissova

Analytical results	Palm Oil Guinea	Palm Oil Nigeria	Palm Oil Côte d'Ivoire	Palm Oil SETUZA	Palm kernel oil Guinea
Acidity value [mg KOH/g]	7,965	3,228	9,660	1,961	2,087
Saponification value [mg KOH/g]	218,683	93,295	22,647	241,482	171,918
Iodine value [g of iodine/100g]	49,491	63,873	43,992	31,302	14,805
water content [% w/w]	0,770	0,330	0,330	0,390	0,430
fat content [% w/w]	99,13	99,56	99,58	99,57	99,53

Source (Reissová, 2002)

The researcher compared his laboratory result with a similar result from Riessova (2002) above. When l compares Fat content in percentages, one can tell that, the sample of palm oils from Ghana has the highest percent of fat, especially palm oil export quality (99,73 % fats). That makes it better the others from Nigeria, Guinea and Côte d'Ivoire. The same goes for moisture content. Nigeria, Guinea and Côte d'Ivoire has high moisture content. Palm kernel oil from Ghana is 99,54 %, while Guinea has 99,53 %. Acidity value of palm kernel oil from Ghana is 6,36 mg KOH/g, whiles that of Guinea has 2,09 mg KOH/g. Acidity value of palm oil from Ghana is 25,78 mg KOH/g, whiles that from Guniea has 7,569 mg KOH/g.

The samples from Ghana have very high acidity value 6,36 mg KOH/g and palm kernel oil is 25,48 mg KOH/g. This is not too good as compared to those from Nigeria, Guinea and Côte d'Ivoire.

Ghana Samples has high Saponification value 219.47, 206.97 and 268.69 as compared to 218.683, 93.295, 241.482 and 171.918 KOH/g.

They have similar iodine value as the differences are not too big. On the whole, the values had by Riessova (2002) on her Samples and the values from this research are not too different however, the result from this research suggest that the oil samples from Ghana are of a better quality than that from Nigeria, Guinea and Côte d'Ivoire.

SALUNKHE (1992) mentions, that unrefined palm oil contains relatively high amounts of free fatty acids. Method of oil extraction has a significant effect on free fatty acid content in oil. Oil obtained by traditional methods of extraction contains more free fatty acids (softening of the oil 7-12 %, solid oil 30-50 %). These activities can be a result of the activity of lipase in foetus or lipase activity of microorganisms. Refined or unrefined palm oil contains very little amount of free fatty acids.

Chemical analysis showed a higher content of free fatty acids of unrefined oils (5.09 % to 18.54 %) and very low contant in raffinades and kernel oil (0.06 % to 0.20 %).

The content of fatty acids corresponds to the values for a given oil sample, which VELISEK (1999).

The water content is below 1% in the range from 0.25 % to 0.77%. A higher percentage of water is a negative effect, allows the activity of microorganisms, especially pathogens.

For all samples analyzed, the content of fats was above 99 %.

Acid number carried out according to chemical analysis is very various, ranging between 2.6 mg KOH/1 kg of fat up to 36.34 mg KOH/1 g fat. BOCKISCH (1993) mentions that the chemical characteristics of the acid number is the most variable, depending on the time of harvest, seed maturity, health state and way of storage.

PARDUN (1976) indicates the number of saponification of palm oil 195-205 mg KOH/1 g of fat. According to chemical analysis of the saponification number varies significantly below those values especially for samples no. 2 (93 mg KOH/1 g of fat), sample no. 3 (22 mg KOH/1 g of fat) and sample no. 6 (73 mg KOH/1 g of fat). Other samples are more or less correspond to the mentioned range. Literature indicates 240-270 mg KOH/1 g of fat a saponation value of kernel oil, in sample no. 15 sampling number became 171 mg/1 g of fat.

HALL (1970) indicates the iodine number of palm oil 44-49 g of iod/100 g of fat, of kernel oil 14-24 g of iod/100 g of fat. Iodine number is only for samples no. 1 and 3 varies in the mentioned range. Other samples of palm oil from this range are significantly different, for samples no. 2 was determined iodine number 63 g of iod/100 g of fat, for samples no. 6 was determined iodine number 22 g/100 g of fat. Iodine number of kernel oil (14 g of iod/100 g of fat) respondes to the range, mentioned by MICHL (1988).

Figure 16 Solid fat content

Solid fat content (SFC)	ČSN ISO 8292				
	temperature [°C] 5	10	15	25	45
SFC [% w/w]	Palm kernel oil 67,78	60,29	55,57	17,77	0
	Palm oil local q. 53,41	50,09	43,48	8,85	0
	Palm oil export q. 39,71	38,4	33,97	9,14	0

Source (Hero Toseafa, 2010)

Figure 17 Graph of solid fats in palm oil and palm kernel oil
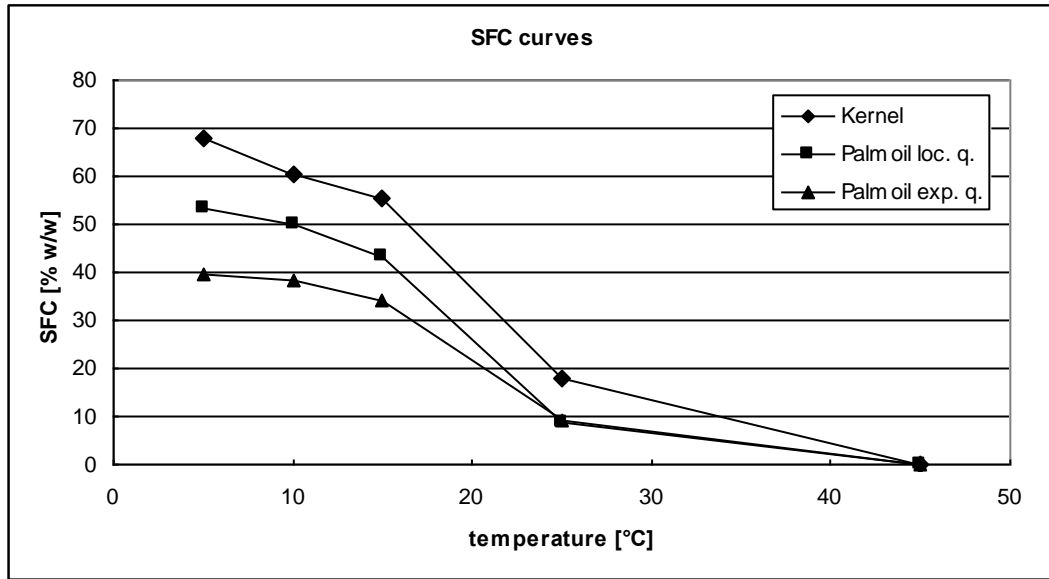
Source (Hero Toseafa, 2010)

I. $100 - 94, 39 = 5, 61$
   $100 - 92, 28 = 7, 72$

Nitrogen= $100 - (5, 61 + 2, 8 + 13, 82 + 14, 22 + 21,05) = 100 - 57,5 = 42,5 => $ **42,5%**
Free extract

Figure 18 Nitrogen free extract of palm kernel chaff and whole kernel seed

	Dry matter %	**Ash %**	**Protein %**	**Fats %**	**Fibre %**
Palm kernel chaff	94,39	2,80	13,82	14,22	21,05
Palm oil seeds	92,28	0,91	8,88	41,36	15,92

Source (Hero Toseafa, 2010)

II. $100 - 92, 28 = 7, 72$

Nitrogen= $100 - (7, 72 + 0,91 + 8,88 + 41,36 + 15,92) = 100 - 74,79 = 25,21 => $ **25,21%**
Free extract

Figure 19 Nitrogen free extract of palm kernel chaff and whole kernel seed

	Dry matter %	**Ash %**	**Protein %**	**Fats %**	**Fibre %**	**Nitrogen free extract %**
Palm kernel chaff	94,39	2,80	13,82	14,22	21,05	42,5
Palm oil seeds	92,28	0,91	8,88	41,36	15,92	25,21

Source (Hero Toseafa, 2010)

Palm oil contains very small amounts of phospholipids and glycolipids. The main components of phospholipids are fosfatidycholin, phosphatidylethanolamine, and fosfatidylinositol fosfatidyglycerol.

Palm oil is rich in tocopherols and carotenoids. It also contains sterols, waxes and hydrocarbons. Palm oil owes its dark orange color was carotenoids. Those containing up to 2000 ppm. Duri nigrescens contains 700-1000 ppm, 200-300 ppm virescens dura, the thin nigrescens 500-800 ppm and 400-600 pm thin virescens carotenoids. Carotenoids consist mainly of α-and β-carotene, lycopene and xanthophylls. Provitamin A activity of β-carotene (1.66 IU / mg) is twice that of α-carotene (0.9 IU / mg (SALUNKHE, 1992).

Figure 20 Characteristics of palm oil

Oil	Palm	Flaxen	Soybean	Rape
Specific gravity	0,921-0,925	0,927-0,934	0,920-0,924	0,913-0,920
Melting Point (° C)	27-50	-20	-16 to -20	-9
Unsaponifiable content (%)	0,2-0,8	1,5	1,0	1,0
Iodine value gJ/100g	44-58	170-204	125-141	100-125
Saponification value mg of KOH / g	195-205	185-195	109-195	175-190
Acid number mg KOH / g max		0,8	1,0	1,0

Source (Reissova, 2002)

Palm oil contains relatively high amounts of free fatty acids. Method of oil extraction has a significant effect on free fatty acids. The oil obtained by traditional methods of extraction of more free fatty acid (7-12 % softening of the oil, solid oil, 30-50 %) (Hartley, 1972). Free fatty acids generated activity of the enzyme lipase (contained in fruits, or microbial origin), or autocatalytic reaction (PURSEGLOVE, 1975). Oil from freshly harvested fruits contain very little free fatty acids. The battered and otherwise damaged fruit increases free fatty acid content to 50% in just a few hours (SALUNKHE, 1992).

Figure 21 Chemical Composition of palm kernel

Component	Content (%)
Humidity	6-8
Oil	46-54
Proteins	7,5-9,0
Nitrogen free extract	23-24
Crude fiber	3,9-5,0
Ash	1,7-2,0
Calcium	0,09
Phosphorus	0,31

Source (Salunkhe, 1992)

Kernel oil is characterized by a high proportion of saturated fatty acids, among which dominates Lauric acid. Fatty acid composition palm kernel oil is close to coconut oil, with whom he often confuses (GLASCON, 1989).

Figure 22 Composition of fatty acids palm kernel oil (% of total fatty acids)

Fatty acid		% (Salunkhe, 1992)	% (Velisek, 1999)
caprylic	8:0	3-4	2,1-4,7
capric	10:0	3-7	2,6-4,5
lauric	12:0	46-52	43,6-53,2
myristic	14:0	15-17	15,3-17,2
palm	16:0	6-9	7,1-10,0
stearic	18:0	1-3	1,3-3,0
oil	18:1	13-19	11,9-19,3
linoleic	18:2	0,5-2,0	1,4-3,3

Source (Salunkhe, 1992)

Kernel oil is a tough, talking about it as fat. Melting point is 25-30 °C. Oil from the kernels damaged by fungi has a lower melting point than the oil of good quality cores. Free fatty acids in oil from the kernels of quality is lower (0, 4.25 %). It has been shown to increase free fatty acids due to fungal infection palm kernels, rape (SALUNKHE, 1992). DART et al. (1985) indicates 3.6 %, 11.5 % and 29.2 % free fatty acids in oil from the kernels of quality, color-altered nuclei and fungi infected kernels. iodine value palm kernel oil is low, ranging from 1914 to 1933, a saponification number (245-255) is comparable with coconut fat (250-260) (Hartley, 1972).

Sterol composition palm kernel oil is consistent with palm oil. B-sitosterol (70 % of) is a major component of sterols, further stigmasterol (11 % of), campesterol (9 % of). Cholesterol content is very low (3 % of) (SALUNKHE 1992).

Figure 23 Composition palm kernel cake and grits (%)

Component	Palm kernel cake	Palm kernel meal	Soybean meal
Humidity	11	9,7	10,9
Carbohydrates	48	42,5	30,3
Dietary fiber	13	14,5	3,0
Protein	19	21,4	48,5
Ash	4	4,6	5,9

Source (Salunkhe, 1992)

Palm kernel meal contains mainly carbohydrate, it is due to high fiber. Fiber content depends on the method of extraction. Palm kernel meal contains a residual oil, its amount depends on the method of extraction. The ash contains mainly calcium (0.69 %), phosphorus (0.42 %) and iron (0.017 %) (SALUNKHE, 1992).

Figure 24 Composition of the essential amino acids in proteins palm kernel meal (g/16 GN)

Amino acid	Protein palm kernel scrap	Reference protein (FAO, 1973)
Isoleucine	4,0	4,7
Leucine	6,4	7,0
Lysine	3,4	5,5
Methionine	2,1	3,5
Phenylalanine	4,3	6,0
Treonin	3,1	4,0
Tryptophan	1,0	1,0
Valine	5,4	5,0

Source (Salunkhe, 1992)

5.2 STORAGE OF OIL AND FACTORS AFFECTING THE QUALITY OF OIL

Storage must be sufficiently dried oilseeds, but should not be unnecessarily interrupted. Critical moisture content of oilseeds is a limit of moisture, which decreases the intensity of respiration at a value that can jeopardize stored seeds. The critical moisture content is related to fat (Michl, 1988). Critical humidity can be calculated by the formula:

$V = (14 * Z) / 100$ where:

V = critical moisture content in%

14 = constant

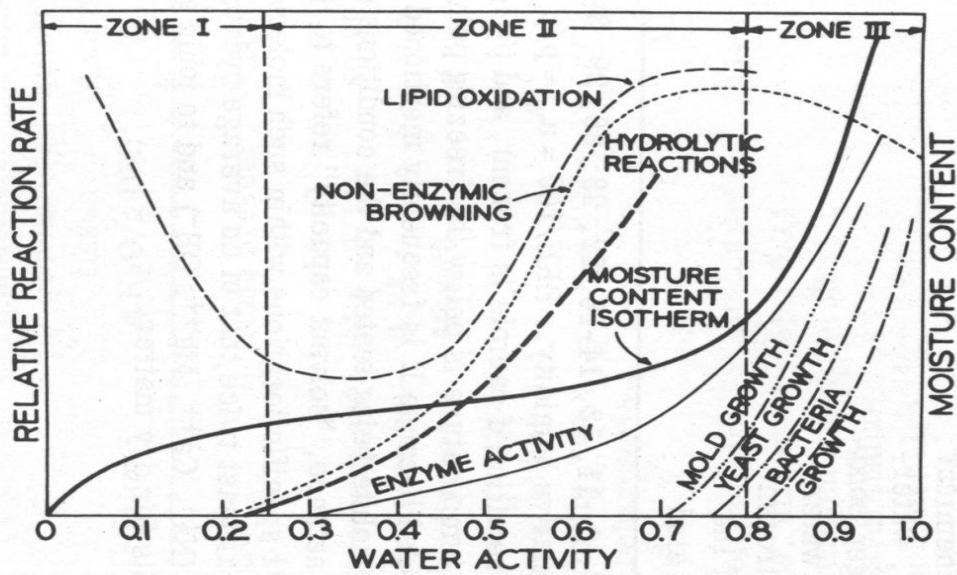$Z = 100$ -% fat content (Dudas et al., 1981).

Figure 25 Critical humidity for storage of oilseeds

Product	Critical moisture storage in%
Groundnut	7
Copra	7
Palm kernel	5
Cotton seeds	10
Soybeans	13

Source (Hayma, 1990)

Figure 26 Standard diagram of water activity

Source (novasina.ch, 2003)

Figure 27 Water activity of palm oil and palm kernel oil

	Water activity
Palm oil (local quality)	0,256
Palm oil (export quality)	0,422
Palm kernel oil (local quality)	0,298
Palm kernel oil (export quality)	0,250

Source (Hero Toseafa, 2010)

Water activity or a_w is a measurement of the energy status of the water in a system. It is defined as the vapour pressure of water divided by that of pure water at the same temperature; therefore, pure distilled water has a water activity of exactly one.

There are several factors that control water activity in a system. Colligative effects of dissolved species (e.g. salt).

In comparison palm kernel oil, even though it comes from the same fruit, is very different from the oil obtained from the rest of the fruit. In fact, palm kernel oil resembles coco oil and is semi-solid or solid at room temperature. When it is eaten it produces a soft sensation in the mouth, similar to cacao. This makes palm kernel oil popular among chocolate lovers. Due to its neutral taste and long life, palm kernel oil can also be used as a substitute for cacao and fats found in milk.

Palm kernel oil is used in cream made from sugar, condensed milk and doughnut fillings. It is also found in biscuits and cakes giving them a softer texture and sweeter taste which lingers in the mouth. Palm kernel oil is also used to make special kinds of margarines and is found in ingredients used when baking cakes, croissants and bread, giving these products added volume, a soft texture and making them last longer. Palm kernel oil is also favoured when making sweets, cream for coffees and peanut butter.

Distribution of food by water activity values

1,00-0,90   high moisture foods

0,90-0,60   intermediate moisture foods

<0,60   Low moisture foods.

When waterway activity of less than the specified limit, the microorganisms grow.

Aw	TYPE
0,99	Moraxella
	Acinetobacter
0,97	Clostriduim botulinum type
	Clostridium perfringens
0.96	Shigella
	Klebsiella
	Lactobacillus helveticus
0,95	Pseudomonas fluorescens
	Salmonella
	Eschericha coli
	Clostridium botulinum type A &B
0,94	Clostridium sporogenes
	Streptococcus thermophiles
	Vibrio parahaemolyticus
	Lactobacillus plantarum
	Enterobacter aerogenes
	Bacillus megatherium
	Microbacterium
	Pediococcus
	Streptococcus
0,92	Bacillus cereus
	Listeria monocytogenes
0,91 rust	Staphylococcus aureus-anaerobni
0,90	Bacillus subtilis
0,86	Staphylococcus aureus aerobni rust
0,83	Micrococcus
0,75	Halobacterium

6 CONCLUSION AND RECOMMENDATIONS

The researcher went on an inspection into the small factory (AYIEM OIL PROCESSING MILLS) which produces crude palm oil and palm kernel oil for export and for sale locally. Taking the locality and the conditions of the area into consideration they have done very well. The company runs two shifts. The morning and night shifts. This means that, the machines are well utilized. They are also using semi-modern machines. His are used machines from Malaysia. The company also utilizes some of the waste from the factory. They use the dry fiber from the palm fruit to power their boilers. Meaning, they produce their own steamwinch is the core past of the production process. They have a laboratory for testing the quality of their products. The company has as own farms but it is not enough to feed the factory so they rely on other nearby farms They also rely on electricity company of Ghana for electric supply Their centrifuging machine is not working so they are producing without it. They also do not have a refinery and therefor produces only crude oil.

The oil from this factory and oils produced locally at home without the use of sophisticated machines were taken and compared in laboratories in Czech Republic. From the results in tables 62 above, it shows that the oil produced locally are of a better quality. This sound ridiculous because one would have thought that a factory production should be better than a locally produced product. Upon a careful analysis the researcher noticed that the factory product has a higher water content. This is because they are not using the centrifuge machine to lower the water content whiles the locally produced oils are heated above too to evaporate water in it. I will therefor like to suggest the following.

The factory should consider the method used in producing palm on and palm kennel oils locally and improve on it by using machines instead of tools.

The centrifuge machine should be repaired and put back an the production line as soon as possible.

The factory laboratory should be equipped with modern equipment to determine the quality of their product. This will make them improve on the quality.

The factory should have their own generator to ensure constant supply of electricity. As all the machines uses electricity. Or get a cogeneration unit so they can utilize most at the factory waste by using it to produce electricity.

The management of the factory should use modern agricultural practices so they can maximize yield for a constant supply to feed the factory.

Finally the factory must minimize past harvest loses by getting modern machines so that all the on can be execrated from the fibre and kernel cake. . The laboratory experiment done on the kernel cake shows there are stole a lot of oil in the cake. This makes it not too good for animal feeding.

7 REFFERENCES

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APPENDIX

SOME USEFUL DEFINITIONS

A.1 Free Fatty Acid Content (AOCS Ca 5a-40)

Definition. This method determines the free fatty acids existing in the sample

A.2 Moisture Content

Scope. This method determines the moisture and any other material volatile under test

Conditions.

A.3 Insoluble Impurities†

Definition. Insoluble impurities are those materials insoluble in n-hexane or light

petroleum

Peroxide Value (AOCS Cd 8-53)

Definition. This method determines all substances, in terms of mill equivalents of peroxide

per 1000g of sample, that oxidize potassium iodide (KI) under the conditions of the

test. The substances are generally assumed to be peroxides or other similar products of

fat oxidation.

A.5 Colour (AOCS Cc 13e-92)

Definition. This method determines colour by matching the colour of the light transmitted

Through a specific depth of liquid fat or oil to the colour of the light originating from the

same source, transmitted through glass colour standards

A.6 Iodine Value (AOCS Cd 1b-87)

Definition. The iodine value is a measure of the unsaturation of fats and oils and is

expressed in terms of the number of centigrams of iodine absorbed per gram of sample (%

iodine absorbed

A.7 Cloud Point (AOCS Cc 6-25)†, §

Definition. The cloud point is that temperature at which, under the conditions of this

test, a cloud is induced in the sample caused by the first stage of crystallization

A.8 Dropping Point (AOCS Cc 18-80)†, §

Definition. The dropping point of a fat or oil is the temperature at which the sample

will become fluid under the conditions of the test.

A.9 Deterioration of Bleach ability Index§

Definition. The deterioration of the bleach ability index (DOBI) is the numerical value

of the ratio of the spectrophotometric absorbance at 446nm to the absorbance at 268nm.

The determination is only valid for crude palm oil.

DEFINITIONS

Identifying any abbreviations or specialized terms used.

1. FFA = Free Fatty Acid

2. CPO = Crude Palm Oil

3. PKO = Palm Kernel Oil

4. RBDO = Refined Bleached Deodorized Oil

5. RBD PKO = Refined Bleached Deodorized Palm Kernel Oil

6. IV = Iodine Value

7. DOBI = Deterioration of Bleach ability Index

A

B

C

A. Drum for separating palm fruits from bunches
B. Screw conveyor transporting sterilized fruits#
C. Pressing machine breaking the fruit to release oil

A.

B.

C.

D.

A. Front of factory where fresh fruit bunches are received
B. Front of Palm kernel oil factory
C. Screw press machine for palm oil pressing
D. Loading FFB into sterilizer

A. Palm chaff for boiler

B. Kernel cake for animal feed

C. Empty bunch for fertilizer

A. A bunch of fresh palm fruits
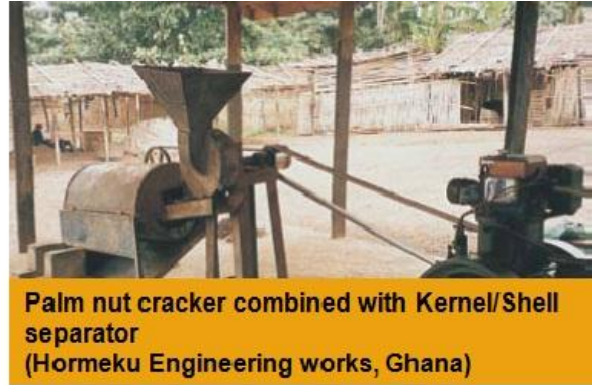

B. Single fruits

C. Cross section of high breed palm fruit

D. Cross section of local breed palm fruit
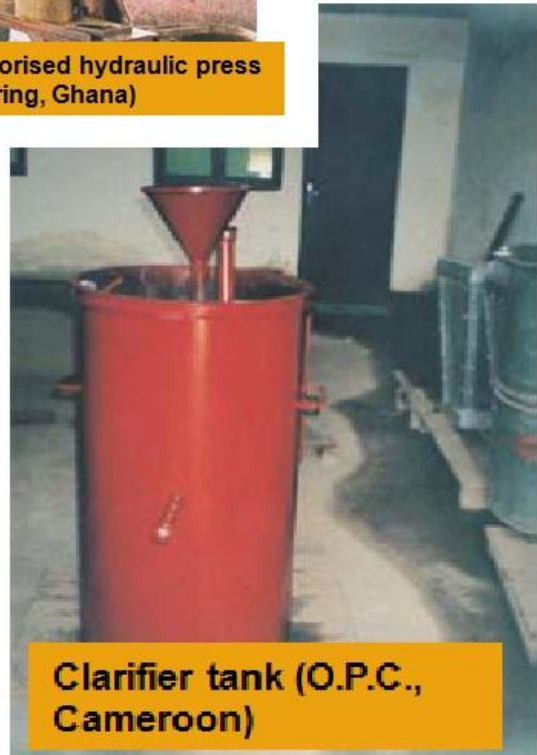
Motorised horizontal screw press
(Centre Songhai, Benin)

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

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

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

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