

MODIFICATION OF SEQUENCE OF UNIT OPERATIONS IN MECHANIZED PALM FRUIT PROCESSING

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Abstract

Induced free space among nuts in the press cake as the palm oil is expelled during pressing was identified as the basic cause of excessive nut breakage/crushing when screw press is used for palm oil extraction. This is the cause of unpleasant odour/taste and congealing associated with palm oil processed by mechanical method unlike the one processed using traditional technique. Palm nut-pulp separation was also revealed as the only unit operation of the traditional palm fruit processing method that has not been mechanized. The various nut-fibre separators in the present day mechanized palm fruit processing of all scales was in addition identified as an error and shouldn't have been if the appropriate nut-pulp separating step of the traditional palm fruits processing technique was not misinterpreted at the beginning by the pioneer European authors of the native oil palm fruits processing technology. Thus, palm nut-pulp separating machines should be designed, developed and installed between the digester and press in all the existing and future palm oil production mills to ensure mass production and effective recovery of high quality palm oil and kernel. Also recommended is the phasing out of nut-fibre separation step and all machineries/equipment associated with it in all mechanized palm fruit processing.

Keywords: nut-pulp separation, screw press, nut breakage, palm oil, fibre

1. Introduction

The oil palm (*Elaeis guineensis*) originated from the tropical rain forest region of Africa, but due to its economic important as the world highest yielding source of edible and technical oils, it is now grown as a plantation crop in most countries with high rainfall in tropical climates within 23°N to 23°S of the equator and longitude 17°W to 102°E [1]. The oil palm tree bears its fruits in bunch which contains many individual fruits similar in size

(15-30mm) to a small plum [1, 2]. The individual palm fruit shown in Figure 1 is a drupe comprising the pulp and nut.

The pulp is made up of the exocarp and mesocarp which contains the palm oil in its cell debris, while the central nut is made up of the shell (endocarp) and edible kernel which contains the palm kernel oil [2, 3]. These two distinct non-toxic edible oils from the oil palm fruits are both very important in the world trade [4].

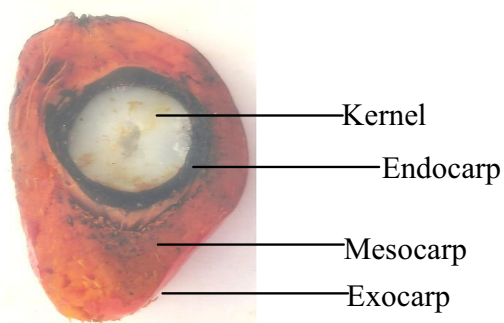


Figure 1: Structure of an Oil Palm fruit.

The three main varieties of the oil palm distinguished by their fruits characteristics are *dura*, *pisifera* and *tenera* [5]. However, successful processing of the palm fruits into the two edible oils is only possible with *dura* and *tenera* fruits due to shellless nature of *pisifera* [6]. The *dura* fruits pulp content is generally low to medium (35-55%), though *deli dura* may have as much as 65% mesocarp. When cut transversely, relatively no ring of fibre is noticed in the mesocarp close to the shell. The *dura* nut has a relatively thick shell (between 2 and 8mm thick) with kernel comprising about 7-20% of the fruit weight. *Pisifera* is a shellless fruit comprising of almost entirely fleshy oil bearing mesocarp material. As result of this and their high tendency of female sterility, *pisifera* is not used for commercial purpose. The *tenera* fruits pulp content varies from 60 to 96% but may occasionally be as low as 55%. When cut transversely a prominent ring of fibre is seen close to the shell and this provides a way of identifying *tenera* fruits. Its shell thickness varies from 0.5 to 4mm with kernel comprising about 3-15% of the fruit weight. *Tenera* is widely adopted by farmers at all levels since its advent as a result of relatively high palm oil content of its fruits, thus making its cultivation and processing the most economical for both industrial and commercial purposes [3]. Modern processing of the oil palm fruits bunches into palm oil and kernel products is mostly practiced

using mechanical methods due to the tedious and drudgery nature of the traditional techniques. The sequence of unit operations involved in the processing of the harvested oil palm fresh fruit bunches (FFB) into palm oil and kernel by mechanical methods is; sterilization-stripping-digestion-palm oil extraction-clarification-nut/fibre separation-drying of nuts-nut cracking-kernel/shell separation-drying-storage of the extracted oil and kernel [7, 8].

Screw press is generally adopted in all modern palm oil mills for the extraction of palm oil from digested palm fruits cake since its advent because optimum deoiling of the pressed fibre is independent of sterilization and digestion processes with this press unlike other oil extraction methods. In addition, the press brought full continuous process in the palm fruits processing sector, and requires less power and capital cost for a given pressing capacity. However, the problem of using screw press for palm oil extraction is excessive nut breakage/crushing, and attempts to reduce this cause undesired palm oil loss to pressed fibre [9]. In practice under suitable operating conditions of palm oil production mills with screw presses, an optimum pressed fibre contains about 9-11% of palm oil with over 10% nut breakage [1, 5, 9]. Although, FAO [1], reported 2-3% oil content of a pressed fibre in some small scale palm oil production, the bleachability and oxidation conservation of the palm oil extracted were severely affected negatively because some kernels crushed during pressing released their palm kernel oil into the extracted palm oil and the two oils could not be separated by simple methods. These traces of the palm kernel oil in the palm oil extracted cause congealing and unpleasant odour/taste of the palm oil processed by mechanical methods especially when stored, thus the preference for palm oil processed using traditional methods by consumers [10]. Another consequence of this menace is poor quality palm kernel oil extracted from mechanically processed kernels because free fatty acid

(FFA) content increases much faster in the broken or defective kernels on storage. But according to FAO [1] and Hartley [2], all the machineries/equipment used for the processing of oil palm fruits were all designed based on the observation of the traditional system practiced in West Africa where the fruit and its processing technologies originated. For this reason it makes economic sense to reexamine and compare thoroughly, all activities involved in each unit operation of both the traditional and mechanized palm fruit processing methods, in order to ascertain the problems of the native technique that have not been or/ not properly addressed by the existing mechanical methods, hence this study. This will help to find out the basic causes of the nut breakage during pressing and specific design modifications required for effective recovery of high quality palm oil and kernel in all mechanized palm fruit processing.

2. Materials and Methods

This study was carried out by analytical procedures which include;

1. Paying visits to farmers/villages in the eastern Nigeria where absolute traditional palm fruit processing is still in practice to thoroughly study the steps involved in each unit operation of this technique.
2. Paying visit to places where various scales of mechanical systems are used for palm fruit processing to observe the operation and functioning of their machines/equipment to be acquainted with the problems the operators encounter in the course of using the machines.
3. Relevant pioneer and other available records on oil palm fruit processing were also analyzed and compared with practical observations.
4. The matching activities of each unit operation of both the traditional and mechanical methods were thoroughly compared in order to make certain the problems of the native techniques that have not been or/

properly addressed by the present day mechanical methods in order to come out with modifications that will appropriately address the problem of nut breakage during pressing.

2.1. Traditional palm fruit processing technique

According to Hartley [2], Stephen and Emmanuel [5], Kenneth and Kriemhild [7], and RMRDC [8], all traditional palm fruit processing methods involve the following sequence of unit operational stages;

1. Stripping process of cutting FFB into sections and picking off of loosed fruits from the sections by hand after allowing it to ferment.
2. Sterilization stage (boiling or fermentation) where the fruits are softened up usually by heat treatment.
3. Digestion process where the pulp is loosened from the nuts (de-pulping) and prepared (broken up) for palm oil extraction. This is usually done by pounding of the cooked/soaked fruits in a mortar with pestle or foot trampling of the fruits in a trough.
4. Palm oil and kernel extraction processes. The traditional palm oil extraction process consists of the following sequential steps; (a) Steeping the pounded fruit mash (digested cake) in a hot or cold water to enable the flotation of the less dense digested fibrous pulp while the dense nuts sink to the bottom of the container - nut-pulp separation. (b) Hand squeezing of the pulp to release the crude palm oil and skimming of the oil from the water surface. (c) Filtration of the residual pressed fibre out of the sludge using a nest made from palm frond or small baskets. (d) Barring of the nuts from the bottom of the container using small baskets and disposal of the sludge. (e) Boiling and drying of the extracted palm oil.

Although, the pioneer authors such as Laurent [11], Faulkner and Lewis [12], that wrote

on the native oil palm fruit processing reported the first activity in the traditional palm oil extraction process (i.e. separation of digested nut and pulp) as “removing of fibre and nuts with small baskets and hand squeezing of the fibre to release oil” and others after them followed suit, it should not be mistaken as nut-fibre separation step in the present day mechanized processes. This is because by the context of their statement the fibrous material referred to by these authors is the non-pressed (unde-oiled) digested fibrous oil matrix exo-mesocarp (pulp) material and that is why the follow up phrase “hand squeezing of the fibre to release oil” in their respective reports. Again, the agreement of various reports of these pioneer authors with those written by Hartley [2], Kenneth and Kriemhild [7] and RMRDC [8] on soft and hard oil production indicated that the nut-fibre separating process does not exist in the exclusive native palm fruit processing methods as we observed during our study visits to local palm fruit farmers/processors. Kenneth and Kriemhild [7], nearly captured this well in their description of the native process as “the pounded palm fruit mash is diluted with water, and the oil is skimmed off after its expulsion from the floating fibrous content of the mash by hand squeezing”. The traditional palm kernel extraction process involves drying of nuts under the sun for days and cracking of the nuts using stones or any other hard objects. This is followed by separation of the kernels from their shells by hand picking and drying of the extracted kernels under the sun for about two to four days before storage or sale [13].

2.2. Mechanized Oil Palm fruits processing technique

Modern processing of oil palm fruits by mechanical methods is grouped into three as small-scale, medium-scale and large-scale processing according to their throughput and degree of complexity of unit operations involved. Small-scale processing is a semi-mechanized process which makes use of simple stand-

alone unit operational machines/equipment and semi-continuous/integrated systems. It retains some manual nature of traditional techniques and is generally suitable for processing FFB from wild oil palm groves or from small plantation holdings. Medium- and large-scale operations involve the use of automated palm oil production mills (sophisticated industrial factory mills) for the extraction of palm oil and kernel from FFB. The factory mill is a fully mechanized (non-labour and capital intensive) continuous process with over 90% rated efficiency and 23-24% oil extraction rate. Generally, factory mills that process less than 10 tonnes of FFB per hour are considered medium scale units [7, 8]. Figure 2 is a flow diagram of the sequence of unit operations involved in the processing of FFB into palm oil and kernel by mechanical method. Although level of mechanization and the interconnecting materials transfer mechanisms may differ, all mechanized palm fruit processing involve these sequential unit operations irrespective of their scale. Further processing of the extracted kernel to palm kernel oil and palm kernel cake is done in another separate process using mills that process other oil seeds [1, 8].

Centrifuging and pressing are the most mechanical means of extracting crude palm oil from digested palm fruit. Even though both are “dry” processes, centrifugals are no more used in modern factories because of the high pulp contents of tenera and deli dura fruits [9]. Unless precautions are taken during centrifuging, the pulp causes “blocking” in the centrifugal cake, thereby preventing easy expulsion of oil from the cake. Due to this impermeability, a visible layer of oil (sometimes referred to “wall of oil”) builds up inside the cake resulting to huge loss of oil to fiber. Muthurajah [9], further said that this “wall of oil” can be avoided by adding nuts to the digested fruit before centrifuging, but it is not easy to do this satisfactorily in practice. For this reason the efficiency of centrifuges are not as high as that of the press, thus the sys-

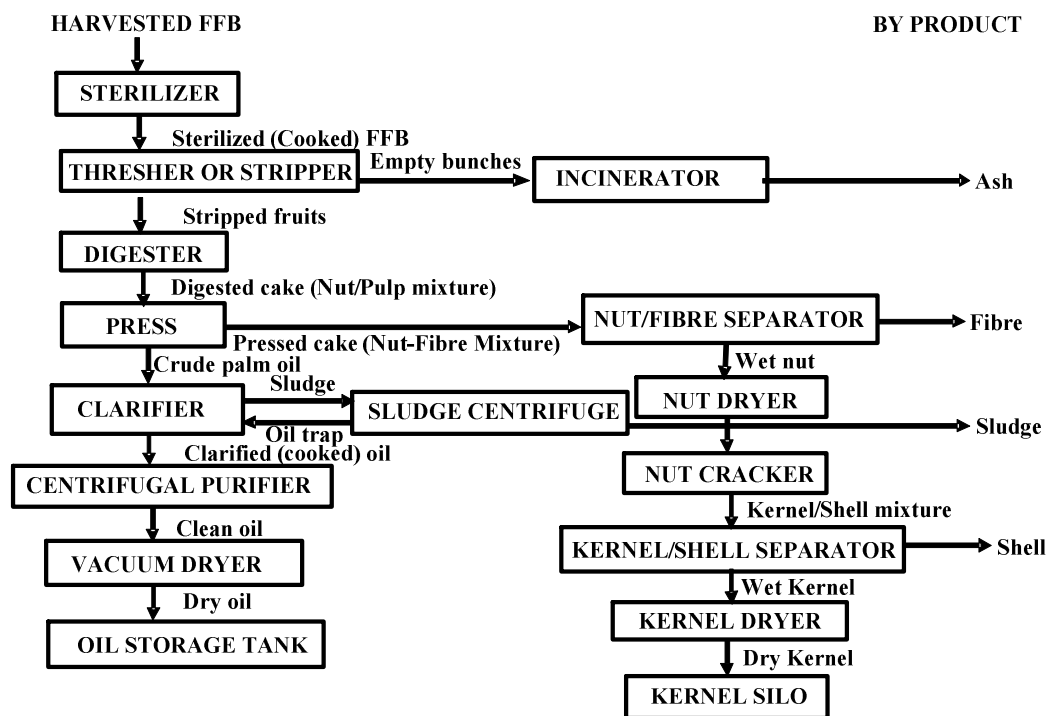


Figure 2: Flow diagram of the extraction process of palm oil and kernel by mechanical methods.

tem is obsolete. The economic importance of pressing was long recognized and has received the greatest attention for mechanization. Stephen and Emmanuel [5], said that the process is usually conducted slowly in small-scale palm oil processing to avoid huge loss of palm oil that might result from inadequate pressing. Presses developed over the years in search of the most effective means of extracting palm oil from the digested fruits includes stork hydraulic hand press, motor-jack press, cantilever press, NIFOR hydraulic hand press and mechanical screw press. Screw press is the latest and mostly used in most palm fruit processing industries due to its merits over others. Its typical design consists of a perforated tube inside which a transport screw rotates. The press outlet is more or less closed by cone that regulates the pressing pressure. The worm transports and gradually compresses the macerated fruits. The oil released drains through the perforations in the tube. This press is usually mounted below the digester in all continuous and semi-continuous systems to form digester-screw press assembly as shown in Fig-

ure 3. The digester consists of a shaft to which stirring arms were attached and these stir and rub the fruits so loosening the pulp from the nuts and at the same time breaking open the oil cells of the pulp.

2.3. Analysis of existing experimental records on nut breakage during pressing

Muthurajah [9], determined experimentally that the free space among palm nuts in a unit mass (1kg) of de-oiled palm fruit cake is approximately 0.563dm^3 for dura and 0.832dm^3 for tenera and that the bulk density of digested palm fruit pulp is approximately $925\text{g}/\text{dm}^3$. It follows that the mass of the digested pulp required to fill the free space among 1kg of dura nuts which are touching one another is approximately 521g. The corresponding figure for tenera is 770g. Muthurajah [9], also determined experimentally that the ratio of pulp to nuts needed, if the nuts in the digested fruit are to be all just touching one another without breakage/crushing is 0.5 for dura fruits and 0.8 for tenera. According to FAO [1], NIFOR [6] and RMRDC [8],

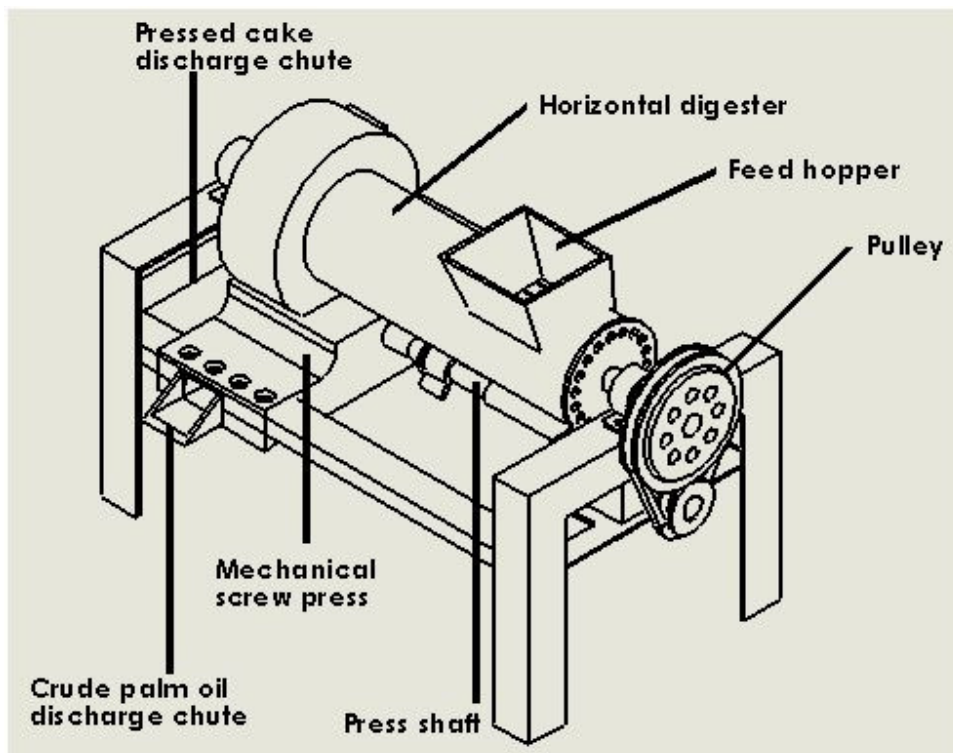


Figure 3: NIFOR horizontal digester- screw press assembly.

the average ratio of pulp to nuts is relatively 0.55 and 0.75 for dura and tenera respectively. Thus, there is always sufficient pulp to separate all the nuts immediately before pressing operation for each fruit variety. However during pressing as the crude palm oil is gradually expelled from the pulp the remaining fibre-pulp mixture become insufficient to prevent the nuts content of the cake from touching one another, thereby subjecting the nuts to great pressure while shielding the partially deoiled pulp of the cake from the applied pressure. But the pressure is solely meant for the pulp which contains the palm oil. Another experimental record by Muthurajah [9], shown in Table 1 revealed that as the press pressure applied increases, the nuts break and its crushed pieces fill the empty spaces between the remaining nuts until the whole empty spaces are filled up to permit a reasonable deoiling of the cake. The breakage/crushing of the nuts continues until the nuts will no longer touch one another on average as sufficient nut debris that filled the free spaces has kept them

Table 1: Variation of nut breakage and oil content of pressed fibre with applied press pressure.

Approximate Pressure (kg/cm ²)	Oil Loss to Pressed Fibre (%)	Nut Breakage (%)
17.00	35.80	1.00
33.00	22.40	13.80
50.00	20.20	21.50
67.00	16.90	20.60
83.00	14.40	19.90
100.00	13.90	18.40

slightly apart, at this stage further pressure increase results to relatively little extra nut breakage.

Table 1 also confirmed the general concept that effective deoiling of the fibre will not be achieved if the applied pressure is set such as to avoid nut breakage. Therefore the induced free space among nuts in the press cake constitutes the major source of nut breakage during pressing in the mechanized palm fruit processing.

2.4. Efforts on effective recovery of quality palm oil and kernel

The early search at improving the efficiency of oil recovery and reducing nut breakage by

the early village processors led them to widely adopt the use of experienced persons for careful digestion and pressing operations to avoid huge loss of products. They prefer digestion method of treading the cooked/soaked fruits with human foot to pounding with pestles. This is because pounding method attracts high nut breakage and undesired loss of oil in attempts to prevent breaking/crushing of the nuts especially when inexperienced persons pound [7]. Furthermore, it is only the digested pulp that is been subjected to pressure by hand squeezing for oil extraction in exclusive traditional palm fruit processing methods to avoid breaking/crushing of small nuts and enhance effective deoiling of the pressed fibre within the capacity of this manual process. This is done after the separation of digested pulp and nuts in a wet process by sifting using palm front sieves/small baskets or sorting by hand picking of the nuts from the digested pulp in the dry process [5, 7].

Second digestion (re-digestion) of pressed fibre to recover residual oil of high FFA content was practiced and still exists in some small scale mechanized units [1, 7]. Elimination of nut breakage in digestion process has been achieved in both small and large scale operations with the recent models of mechanical digester which is capable of macerating thoroughly either dura or tenera fruits or a combination of both without breaking any nut [1]. Second pressing of pressed fibre is another measure which exists in small-scale processing to increase oil recovery and reduce nuts breakage especially when screw press is in use [5]. As an imitation of the traditional technique, manual separation of the digested pulp and nuts immediately after mechanical digestion by hand picking/sorting before pressing of the digested pulp is practiced by small scale processor in some rural communities of Nigeria, Ghana and other West African nations [1]. Although, this measures eliminate practically all nut breakage associated with pressing and enhances effective deoiling of pressed fibre as desired, the practice yields palm oil of high

FFA due to undesired delay in the process which exposes the digested cake to microbial attack. However neither companies nor individuals desire oil with high FFA [1, 8, 14].

3. Discussion of Results

Analysis of experimental records of Muthurajah [9], FAO [1], NIFOR [6] and RMRDC [8], revealed that induced free space among nuts in the press cake as the palm oil is expelled from it is the basic cause of nut breakage during pressing. Also revealed in this investigation is the omission of palm nut-pulp separating unit operation (contained in the traditional method) in the mechanical method. The various nut-fibre separators in the present day mechanized palm fruit processing of all scales was in addition identified as an error in design and shouldnt have been if the appropriate palm nut-pulp separating operation was not misinterpreted at the beginning by the pioneer European authors of the native technology. The comprehensive records of the world designers and manufacturers of oil palm fruits processing machineries/equipment as contained in the Survey of Selected Agricultural Raw Materials in Nigeria on Oil Palm by Raw Materials Research and Development Council of Nigeria, Abuja and FAO Agricultural Service Bulletin 148 of Food and Agricultural Organization indicates palm nut-pulp separation as the only unit operation of the traditional processing technique that has not received any attention for mechanization[1, 8]. Therefore to circumvent tedium and drudgery as well as palm oil with high FFA associated with this manual process, a palm nut-pulp separating machine should be designed, developed and installed between the digester and press in all the existing and future palm oil production mills as shown in Figure 4.

4. Conclusions and Recommendations

Nut-fibre separation is not a unit operation of the traditional palm fruit processing techniques and the operation does not add any

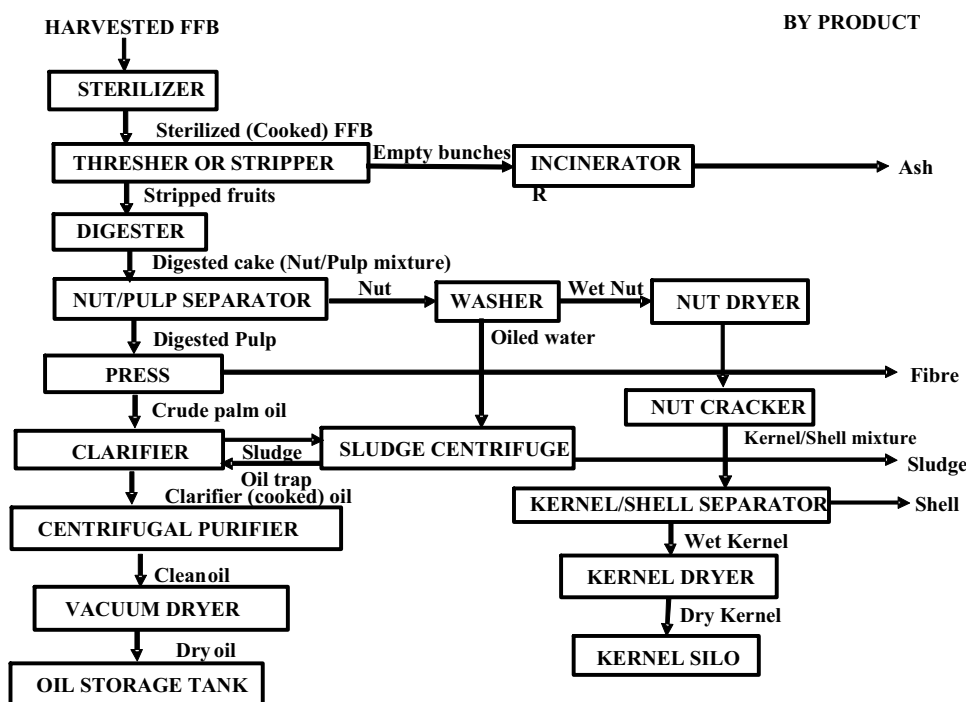


Figure 4: Flow diagram of palm oil and kernel extraction by mechanical methods with a palm nut-pulp separator.

value, hence all machineries/equipment associated this operation should be phased out in all mechanized palm fruit processing. Thus, nut-pulp separating machine should be designed and installed in all the mechanical palm fruit processing systems in between the digestion and pressing operations as contained in the native techniques. Furthermore, manufacturers should take up the novelty of nut pulp separation and implement in both the existing and future mill design and manufacture to boost mass production and effective recovery (0% loss) of high quality palm oil and kernel. This recommendation is in accordance with the campaign of Akor[14], which directed that we should modify some palm fruit processing machines produced by Stork Amsterdam and other foreign companies to suit our condition as we know them.

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