A Plant Design for Mechanical Extraction of Nmanu Aki (Palm Kernel Oil) Using Complete Pretreatment Process

Gbasouzor Austin Ikechukwu, *Member, IAENG*, Okeke A. C., Chima L. O., *Member, IAENG*

Abstract **– In this plant design for mechanical extraction of 200kilogram of Nmanu aki (Palm kernel oil) per day using complete pretreatment process, several researches on the palm kernel and palm kernel oil were carried out to know more about the oil extraction and how to design a pilot plant (that will extract 200kg of oil per day). This was achieved by carrying out a laboratory test (using solvent extraction method) to determine the composition of PKO in a given quantity of palm kernel cake, from which the amount of palm kernel to be fed into the pilot plant was calculated. A basis of one hour (1hr) and an efficiency of 70% was also used for the material and energy balance calculations, from which the design specifications used in the fabrication of pilot plant was determined. After the fabrication of pilot plant, it was test run. A mass of about 59.52kg of palm kernel was fed into the shaker set in vibration by an electric motor causing the separation of the palm kernel from any form of undesired material (sand, stones, palm kernel shell) and gradual movement of the clean feed into the crusher hopper from which the kernel is crushed (screw pressed) and the required oil expelled. The expelled oil drains through the perforation through annular orifice at an exit temperature of 47.3^{0}C. Lastly, 200kg of fine PKO was extracted after ten hours (per day) from which the design specification as required was met.**

Keywords**: Plant design, Nmanu aki, pretreatment process, oil extraction**

I. INTRODUCTION

Nmanu aki, (Palm kernel oil) has a great use both in edible and non-edible fields in homes and industries in Nigeria. Its extraction has been in low capacity per production run.

According to Anaekwe, 2011, it is generally believed that no part of the oil palm tree is useless. After the processing of the fresh fruit bunch to yield palm oil, the product that is left is the shelled palm nut which can be cracked to yield the palm kernel nut and the shell. While the shells can be used as fuels and road construction, though the market is not well developed in the country, the palm kernel nut can be crushed and processed to yield palm kernel oil and cake.

"Oil" is a collective term for more or less viscous, generally organic-chemical liquids. Depending on their chemical composition, a distinction may be drawn between fatty, essential, mineral and silicone oils.

Palm kernel oil is a white to yellowish oil of vegetable origin which is solid at normal temperatures and is obtained from the kernels of the oil palm (Elaeis guineensis).

Gbasouzor Austin Ikechukwu is a Lecturer in the Department of Mechanical Engineering, Anambra State University,
P. M. B. 02 Uli, Nigeria. e-mail: unconditonaldivineventure@yahoo.com
Phone: 2348034247458, 2348063896067, 2348028283035

Okeke A. C. is a Senior Technologist in the Department of Chemical Engineering, Anambra State University, P. M. B. 02 Uli, Nigeria.

Chima L. O. is a PhD researcher in the Department of Mechanical Engineering, Nnamdi Azikiwe University, Awka, Nigeria.

It is one of the best oils. Palm kernel oil is different from palm oil, which is obtained from the flesh of the fruit.

The design objective in this case is to redesign and fabricate a palm kernel oil extraction plant (mechanical) that will produce 200kg of palm kernel oil per day using palm kernel. In the extraction of palm kernel oil, many processes are involved namely: Traditional, solvent extraction and mechanical extraction methods.

In this design and fabrication, the method used is the mechanical extraction method, because it is suitable for production of small and large quantities of palm kernel oil. Its time rate is faster and much manual labour is not required; therefore, it is cheaper than traditional method which requires more manual labour.

This work which is a pilot plant for the mechanical extraction of 200kg of palm kernel oil from palm kernel arose from the need to:

- Have a functional PKO extractor so as to reduce/minimize production cost of palm kernel oil extraction locally.
- Produce high quality and quantity of palm kernel oil within a specified time interval.

The problems identified from the previous design were:

- Large mesh size.
- Low power output from electric motor.
- The crusher cannot be driven by the gear.
- The hopper is large.
- The crusher is long.

II. REVIEW OF PREVIOUS DEVELOPMENTS IN THE EXTRACTION OF NMANU AKI (PALM KERNEL OIL)

The palm fruit looks like a plum. The outer fleshy mesocarp gives the palm oil, while the kernel, which is inside the hard shell gives the palm kernel oil; and it is rather strange that the two oils from same fruit are entirely different in fatty acid composition and properties.

Palm kernel is an important by-product from oil palm mill. They constitute about 45%-48% (by weight of palm nut of the oil palm, Elaeis guineesis. On a wet basis the kernels contain about 47%-50% by weight of oil whose properties and characteristics are quite different from palm oil but rather resembles coconut oil. Palm kernel oil is also known as lauric acid ($C_{12}H_{24}O_2$), because lauric is the major fatty acid it contains. Lauric acid (C_{12}) accounts for about 48% of the fatty acid compositions. Other constituents include muriatic acid (C_{14}) about 16% and oleic acid (C_{18}) about 15%.

Methods of Palm Kernel Oil Extraction

In the earlier days all the factories used mechanical extraction for palm kernel oil recovery. However, with the installation of bigger plants, many have gone into solvent extraction. At present, there are three major types of

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extraction methods used in the extraction of palm kernel oil from palm kernels. These methods are: Traditional extraction method, Direct solvent extraction, Mechanical extraction using high pressure screw pressing.

Traditional or Thermal Extraction Method

The traditional method of palm oil processing starts with the shelling of the palm nut. The shelling is performed by using two stones to crack each nut and separating the kernel and shell simultaneously. This manual operation has been largely superseded by the use of nut cracking stations. The mechanical nut crackers deliver a mixture of kernel and shell that must be separated. The kernel/shell separation is usually performed in a clay bath which is a concentrated viscous mixture of clay and water. The density of the clay is such that the shells sink while the lighter kernels float to the top of the mixture. The floating kernel are scooped in the basket, washed with clean water and dried. Periodically the shell are scooped out from the bath and discarded. The traditional oil extraction method is to fry palm kernels or simply heat the dried kernel. The fried kernels are pounded or ground to a paste in a motorized grinder. The paste is mixed with a small quantity of water and heated to release palm kernel oil. The released oil is periodically skimmed from the top.

Solvent Extraction Method

A solvent extraction plant is designed to extract the oil either from oil seed containing about 20% oil or from the pre-pressed expeller cake. This solvent extraction method can be divided into three main unit processes thus; kernel pre treatment, oil extraction and solvent recovery from the oil and mill. For the purposes of small scale operations, it is sufficient to mention that the solvent extraction is an alternative for high capacity mills. Solvent extraction method gives a high yield of palm kernel oil when compared with the mechanical extraction method.

Extraction Unit

The cake is conveyed by a chain conveyor to the hopper from which the sample enters the extraction unit which then conveys it to sprayers that contain hexane solvent that washes the oil content of the palm kernel cake. As the cake is washed, the hexane dissolves the palm kernel oil solute and thus stripes the cake of its oil content. The effluent cake is discharged to the drying unit and the extract to the distillation unit.

Distillation Unit

Here, the extract which is a mixture of oil, hexane and traces of water are separated and this mixture is called Miscella. The separation is done by indirect heating, passing steam through coils on the wall of the vessel. During heating, hexane and water present in the oil escape as vapor through the vacuum on the vessel and condenses in the condenser. The crude oil (that is oil separated from hexane) is then sent to the separating unit. In the separation unit, hexane is separated from water, because the hexane is lighter than water, it floats while the water sinks. The hexane is sent to the storage tank for re-use.

Drying Unit

The cake sent to the drying is called de-oiled cake. This unit is simply where the hexane in the cake is removed and then dried and cooled before bagging. This is done in a vessel called Dissolventizing toaster cooler. This vessel has three compartments/layers which include the dissolventizer, the toaster and the cooler. After washing the cake with hexane, the de-oiled cake is sent to the dissolventizer where the hexane in the cake is removed with the help of heat and agitator.

During this process the hexane present in the cake escapes as vapor through the vacuum. The cake moves from the dissolventizer to the toaster layer where the cake is dried and the rest of hexane removed.

Mechanical Extraction of Palm Kernel Oil

The mechanical extraction method uses screw press as the principal means of extracting vegetable oil. However, use of the screw press for full extraction has been increased over the years in the less developed countries. Today even larger and more efficient machines are being developed for full extraction and pre-pressing of palm kernel oil.

Mechanical extraction processes are suitable for both small and large scale operations. The three basic steps in this process are;

a. Kernel pre-treatment (cleaning, size reduction, flaking and steam conditioning).
b. Screw pressing and
c. Oil clarification

Proper kernel pre-treatment is necessary to efficiently extract the oil from the kernel.

The feed kernels in the pre-treatment stage are cleaned of the foreign materials which can cause damage to the screw presses, increasing maintenance costs and downtime and also contamination of products.

Magnetic separators commonly are installed to remove metal debris, while vibration screens are used to sieve sand, stones or other undesired materials.

Breaker roll or a swinging hammer grinder or a combination of both then breaks the kernel into small fragments. This increases the surface area of the kernels, thus facilitating flaking.

In palm kernel processing industries, particles size reduction is usually carried out in order to increase the surface area and facilitate flaking process. For example, the free flow of gas may be impeded because of higher resistance to the flow of a bed of small particles. In solvent extraction not only is the rate of extraction increased by virtue of increased area of contact between the solvent (hexane) and the solid (palm kernel cake) but the distance the solvent has to penetrate into the particle in order to gain access to the more remote pocket of the solute (palm kernel oil) is reduced. The closer the jaws of the mill are to each other, the smaller the particle size resulting in the surface area, decreased compressive strength increased stickiness and reduce porosity. Thereby, leading to the extraction of more oil from the palm kernel, the quality of oil produced may however be reduced by the intensity of heat generated by the fact that heat distribution rate is higher in fine particles than in coarse particles.

Flaking

The kernel fragments are then subjected to flaking in a roller mill. The thickness of the kernel cakes are subsequently reduced as they travel from the top roller to the bottom. This progressive rolling initiates the rupturing of cell walls.

Steam Conditioning

The purpose of stem conditioning is to:

- Adjust the moisture content of the meal to an optimum level
- Rupture cell walls (initiated by roiling).
- Ensure that the action of the enzymes that increases the free fatty acids (FFA) of the oil is stopped i.e. reduces viscosity of the oil.
- Coagulate the protein in the meal to facilitate the separation of oil from protein materials.

Important variables are temperature, retention time and moisture content.

Screw Pressing

The properly cooked meal is then fed to the screw press, which consists of an interrupted helical thread (worm) which revolves within a stationary perforated cylinder called the cage or barrel. The meal is forced through the barred by the action of the revolving worms. The volume axially displaced by the worm diminishes from the feeding end to the discharge end, thus compressing the meal as it passes through the barrel. The expelled oil drains through the perforation of the lining bars of the barrel, while the de-oiled cake is discharged through an annular orifice. In order to prevent extreme temperatures that could damage the oil and cake quality, the worm-shaft is always cooled with circulating water while the barrel is cooled externally by recycling some cooled oil.

Oil Clarification

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

Uses of Palm Kernel Oil

Palm kernel oil has a great use both in edible and non-edible fields. Palm kernel oil is more saturated and so can be hydrogenated to wide range of product for the food industries. Palm kernel oil in its hydrogenated and fractionated product are widely used either alone or in blends with other oils for the manufacture of cocoa butter substances and other confectionary fats, biscuit dough's and filling cream, cake icing, limitation wiping cream, shape and table margarine etc.

Food Uses of Palm Kernel Oil in Nigeria

Food and Bakery: Palm Kernel Oil is known to confer special attractive physical features and aroma to bakers of bread. It is also used for making other baked products, hence it is suitable for making margarine, chocolate and some other related food products. Palm kernel oil is further used at home for frying and cooking different types of food like plantain chips, potatoes, stew, fried fish, akara, moi moi, etc.

Non Food Uses of Palm Kernel Oil

Fuel and Biodiesel: Local Africans use palm kernel oil to fuel native lamps for lighting in rural communities that are not connected to electricity. Palm kernel oil can also be directly combined with petro diesel or used in making biodiesel for diesel engines.

Cosmetics: Palm Kernel oil is a major ingredient for large-scale production of various types of soap, detergents, hair creams, body creams, and all sorts of body cream and pomades.

Industrial Materials: So many industrially produced common household materials are made with palm kernel oil. Some of the produce includes: candle, glue, printing inks, grease, rub, washing powder, pharmaceutical products, and rubber.

III. DESIGN ANALYSIS AND CALCULATIONS

Process Description

The process description for the mechanical extraction of 200kg of palm kernel oil per day is a follows:

Before the commencement of the extraction proper, a laboratory test was carried out to determine the composition of palm kernel oil in a given quantity of palm kernel using solvent extraction method.

LABORATORY ANALYSIS

Equipment: Mantle heater (comprising of a bottom flask), extractor flask, Leigbe condenser, Sensitive weighing balance.

Reagents: n-hexane (50ml), distilled water, raw material (palm kernel)

150ml of n-hexane was measured and poured into a round bottom flask. A known sample of palm kernel cake (P.K.C) was wrapped in a filter paper and inserted into a thimble. The thimble was placed in an adjacent position to the solution in a round bottom flask. The extractor comprises the condenser. Heat is then applied to the round bottom flask containing the n-hexane. As a result of the heat, n-hexane evaporates and condenses in the leigbe condenser. From the leigbe condenser, the liquid n-hexane comes down and passes through the wrapped palm kernel cake leaching out the oil in it.

This process is continued for about an hour. After this, the mixture of the oil and the n-hexane is weighed. The oil is then separated from n-hexane with the aid of a decanter. The amount of oil extracted is then weighed. From the experiment performed, the quantity of oil in a given quantity of palm kernel was gotten to be 48% of the palm kernel.

Having known the composition of PKO to be 48% from solvent extraction method, about 55-60kg of already cracked palm kernel at about 28°C is fed into the shaker in the pilot plant. With the aid of an electric motor, the shaker is set to vibration causing the undersize particles of the feed, to passes through the screen of sieve to an outlet and the gradual movement of the oversize particle (palm kernel) into the crusher hopper. In the hopper, an interrupted helical thread (worm) which revolves within a stationary perforated cylinder (cage or barrel) displace the volume of the feed axially which diminishes from feeding end to the discharge end thus compressing the feed as it passes through the barrel. The expelled oil drains through the perforation of the lining bars of the barrel, at about 47.3°C, while the de-oiled cake is discharged through annular orifice at an exit temperature of 47.3°C. The de-oiled cake is feed back into the crusher hopper which undergoes the same process. The expelled oil and the cake leave the extractor at a temperature of about 50.68^{0}C.

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Material Balance
Material balance takes into account the amount of material entering or leaving as well as accumulated in a giving process.
The general material balance equation is:

Input - Output + Generation - Consumption = Accumulation

However, if the system under study involves no chemical reaction, the equation above reduces to:

Input = Output + Accumulation

From the laboratory analysis carried out at Sea Master Production Company at Orlu, Nigeria, 2 grams of sample of palm kernel yielded 0.99 grams of palm kernel oil using solvent extraction method. Hence, if solvent extraction was to be employed in designing this plant, 405kilograms of the same sample of palm kernel feed would be required to produce 200 kilograms of palm kernel oil per day.

However, in the mechanical extraction unit, the same sample requires 10,000kilograms of nuts to produce 4,000kilograms of palm kernel oil. Using the above statistics, 200kilogram of kernel would be produced using 500kilograms palm kernel feed.

According to the published report of (Thin Sui Tany and Pec Kool Teeli, 1985), Palmco Holding Bepenang Malaysia, palm kernel contains about 47% - 50% by weight of oil whose properties and characteristics are quite different from palm oil.

Assuming the whole kernel oil contained in the mechanical extraction unit is expected to be extracted; 426 kilograms of palm kernel will yield 200kilograms of palm kernel oil. This would only be possible if the press is operating at an efficiency of 100%.

Comparing these three feed values (426kg, 500kg, and 405kg), relative to the production requirement of 200kg per day of palm kernel oil, it would be deduced that the mechanical extraction unit is operating at efficiency 10% less than the solvent extraction unit.

Assuming that the screw press operates efficiency of 100%, 500kg feed will yield 235kg of palm kernel oil noting that each palm kernel contains 47% oil. However, only 200kg of the palm kernel oil is extracted, showing that the mechanical press is only able to squeeze out 85.1 % of the palm kernel oil.

For the purpose of the design, in order to meet design specification of 200kg PKO, the following values were used:
1. 48% composition of PKO.
2. It was assumed that the screw press designed and fabricated is operating at an efficiency of 70%

Using the above analysis as basis, it was calculated that 286kg of oil must be contained in a feed of 595.2kg of palm kernel, in order to be able to meet up with design specification of 200kg per day. From the above analysis, it has been demonstrated that the efficiency of the mechanical press is inversely proportional to the feed rate.

The mechanical press was designed in such manner that it can only process a given quantity of palm kernel nuts at a time. Hence 10 hours operation time was made available, which run at a shift time of 5hrs. Therefore the feed rate per hour would be maintained at 59.52kg (59.52kg/hr) in order to avoid overflowing of materials during the mechanical press. Also 297.6kg of palm kernel would be processed in 5hours batch operation time.

SUMMARY OF MATERIALS BALANCE

Table 1: Material Balance around the Crusher

Symbol	Description	Qty(kg/hr)
Y	Mass of palm kernel feed	59.52
P	Mass of cake	30.95
Z	Mass of oil	28.57
X_1	Mass fraction of oil in feed	0.48
X_2	Mass fraction of cake in the feed	0.52
X_3	Mass fraction of oil in the cake	0.22
X_4	Mass fraction of bone dried cake in cake	0.78
X_5	Mass fraction of oil in palm kernel oil	0.87
X_6	Mass fraction of cake in oil	0.13

Table 2: Material Balance around the Filter

Symbol	Description	Qty(kg/hr)
A	Unclarified oil	23.095
B	Sludge	2.79
C	Fine oil	20.31

Table 3: Material Balance with Recycle

Symbol	Description	Qty(kg/hr)
R	Recycled cake	11.86
P	Cake after recycle	39.52
X_{5R}	Mass fraction of the recycle leaving the cake	0.15
X_{6R}	Mass fraction of the bone dries cake leaving the cake	0.85
X_{7R}	Mass fraction of unclarified oil after recycle	0.79
X_{8R}	Mass fraction of cake in the unclarified oil after recycle.	0.21

Energy Balance
In process design, energy balance is made to determine the energy requirements of the process, the heating, cooling and power required. In plant operation, energy balance on the plant will show the pattern of energy usage and suggest areas for conversion and savings.

Table 4: Energy balance summary in the initial run

Component	Energy in (J)	Energy generated (J)	Energy out (J)
PALM KERNEL	4.18	-	-
OIL	-	-	6659.2
CAKE	-	-	4.69
TOTAL	4.18	6662.06	-
	6670		6670

Table 5: Energy balance summary around the Crusher Considering the Recycle Run

Component	Energy in (J)	Energy generated (J)	Energy out (J)
PALM KERNEL	5.55	-	-
OIL	-	-	7982.11
CAKE	-	-	7.32
TOTAL	5.55	7989.01	-
	7995.56		7995.56

Heat Balance of Initial Run
Specific heat capacity of palm kernel = 2.508 x 10^{-3}J/kg^{0}C and that of the oil = 6.094 x 10^{-3}J/kg^{0}C

C_{pf} = Specific heat capacity of palm kernel fed, M_0 = mass of palm kernel oil, T_0 = temperature of palm kernel oil, C_{po} = Specific heat of palm kernel oil, M_c = mass of palm kernel cake, T_c = temperature of palm kernel cake, C_{pc} = specific heat capacity of palm kernel cake.

From the conservation of energy,

(Energy out) = (Energy in) + (Energy generated) – (Energy consumed) – (Energy Accumulated).

Since energy is not consumed and accumulated, we have

$Q_{out} = Q_{in} + U$ - Zero

$Q_{out} = Q_{in} + U$

Where $Q_{out} = Q_0 + Q_c$

$\therefore Q_o = Q_c + Q_{in}U$

From the third law of comminution

Total work input (Q_{input}) = $Q_{in} + Q_{generated}$

$Q_{input} = Q_{in} + U$

But $Q = mCp\ \Delta T$

Where; Q_o = quantity of heat in oil, Q_c= quantity of heat in cake, Q_{in}= Quantity of heat in the fed, U = internal generated energy as a result of workdone or comminution.

Quantity of heat in the feed (palm kernel)

$Q_f = M_f\ C_{pf}\ \Delta T_f$

Where ΔT_f = temperature of feed (P.K) (28^0C)

From material balance M_f = 59.52Kg.

Specific heat capacity (S.H.C) of feed at 3% moisture content = 2.508 x 10^{-3}J/Kg^{0}c

$\therefore$ $Q_f = 59.52 \times 2.508 \times 10^{-3} \times 28$ = 4.18J

The amount of heat in the feed (palm kernel) = 4.18J

Total (work input), work done in comminution.

From the third theory of comminution

Work input (W) = $10/\sqrt{P_i}$

Where P_i = uniform particles size or screen in micron

W = Work done per gram

W = $10/\sqrt{8000}$ where P_i = 8mm (8000 micron)

W = 0.112J/g.

W = 112J/Kg.

Total workdone in crushing 59.52Kg of palm kernel is given as work input per kg x total mass of feed in kg.

Total work input = 59.52 x 112 = 6666.2J= 6.67KJ

Quantity of heat generated (U) in the crusher considering the initial run. Assuming no heat loss,

Total work input = total work output

From the third theory calculation,

Total work input = 6666.2J

Thus total work output = 6666.2J

$Q_{generated} = Q_{out} - Q_{in}$ = 6666.2 – 4.18 = 6662.06J

$\therefore$ The heat generated in the crusher is U = 6662.06J

Estimation of the Exit Temperature

Q_{out} = Quantity of heat in oil + quantity of heat in cake

$6662.06 = M_o\ C_{po}\ T_{out}$

$6662.06 = (23.095 \times 6.094 \times T_{out}) + (39.52 \times 2.508 \times 10^{-3} \times T_{out})$

$6.662.06 = 140.74\ T_{out} + 0.099T_{out}$

$T_{out} = 6662.06/140.839 = 47.3^0$C

Initial Quantity of Heat in the Exit Oil

$Q_o = M_o\ C_{po}\ T_{out}$

= 23.095 x 6.094 x 47.3 = 6657.05J

Quantity of Heat in Cake

$Q_c = M_c\ C_{pc}\ T_{out}$

= 39.52 x 2.508 x 10^{-3} x 47.3 = 4.69J

The overall heat balance around the crusher, considering the initial run is given as

$Q_{out} = Q_{in} + Q_{generated}$

Recall $Q_{out} = Q_{oil} + Q_{cake}$

$\therefore$ $Q_{oil} + Q_{cake} = Q_{in} + Q_{generated}$

6657.05 + 4.69 = 4.18 + 6662.06

6665.0J = 6666J

6670J = 6670J

Recycle Run

From the conservation of energy,

$Q_{out} = Q_{in} + U$

But $Q_{out} = Q_{oil} + Q_{cake}$

$Q_{oil} + Q_{cake} = Q_{in} + U$

$U = Q_{out} - Q_{in}$

$U = (Q_{oil} + Q_{cake})$ -

$Q_{out} = Q_{oil} + Q_{cake}$

$Q_{in} = Q_{PK} + Q_{RC}$

Where; Q_{PK} = Quantity of heat in palm kernel

Q_{RC} = Quantity of heat in recycle palm kernel cake.

Estimation of the Uniform Inlet Temperature of Recycled Feed Mixture

$Q_{in} = Q_{PK} + Q_{RC}$

Heat loss = heat gain

$Q_{RC} + Q_{PK} = 0$

$M_{RC}\ C_P\ \Delta T + M_{PK}\ C_P\ \Delta T = 0$

Recall that

M_{PK} = 59.52Kg,T_{PK} = 28^0C, M_{RC} = 11.86Kg, T_{RC} = 47.3^0C

C_p of oil = 6.094J/Kg^{0}C

From equation above,

$11.86 \times 2.508 \times 10^{-3} \times (T – 47.3) + 59.52 \times 2.508 \times 10^{-3}$ (T-28) = 0

0.027588 (T-47.3) + 0.14927616 (T-28) = 0

0.027588T + 0.14927616T = 4.1797 + 1.3049

T = 5.4846124/0.17686416 = 31.10^0C

Quantity of Heat in the Recycled Feed Mixture

$Q_{RF} = Q_{in} = Q_{RC} + Q_{PK}$

Where; Q_{RF} = Quantity of heat in the recycled feed

Q_{RC} + Quantity of heat in the recycled cake.

$Q_{in} = (M_{PK}\ C_{PRF}\ T_{RF}) + (M_{RC}\ C_{PRF}\ T_{Rf})$

Where; T_{RF} = Temperature of recycled feed

$Q_{in} = (M_{PK} + M_{RC})\ C_{PRF}\ T_{RF}$

= (59.52 + 11.86) 2.508 x 10^{-3} x 31.01

Q_{in} = 5.5J

Thus Q_{RF} = 5.55J

Estimation of the Total Work Input in Recycle Run

From the theory of comminution, the workdone (work input) per kilogram of palm kernel was calculated to be;

W = 112J/Kg

Then, the total work input = mass of the recycled feed mixture x w (J/Kg)

$\therefore$ Work input (output) = $(M_{in} + M_{RC})$ x W (J/Kg)

= (59.52 + 11.86) x 112) = 7994.56J

Quantity of Heat Generated in the Crusher Considering Recycle

Assuming no heat loss,

$Q_{output} = Q_{input}$

From the third theory (recycle run) = 7994.56J = work output

Q_{out} = 7994.56J

$Q_{generated} = Q_{out} - Q_{in}$

= 7994.56 – 5.55 = 7989. 01J

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Estimation of the Exit Temperature of the Recycle Run

$Q_{out} = Q_{oil} + Q_{cake}$

$Q_{out} = M_o C_{po} T_E + M_C C_{PC} T_E$

Where T_E = exit temperature

$7989.01 = (25.85 \times 6.094 \times T_E) + (43.94 \times 2.508 \times 10^{-3} \times T_E)$

$7989.01 = 157.5299T_E + 0{,}1102T_E$

$T_E = 7989.01/157.5299 = 50.68^0C$

The final exit temperature of the recycle run = 50.68^0C

Quantity of Heat in the Exit Oil Recycle Run

$Q_o = M_o C_{po} T_E = 25.85 \times 6.094 \times 50.68 = 7983.62J$

Quantity of Heat in the Exit Cake of the Recycle Run

$Q_c = M_c C_{pc} T_E = 43.94 \times 2.508 \times 50.68 = 5.585J$

Total quantity out from the Crusher Considering Cycle

$Q_{out} = Q_{oil} + Q_{cake} = 7983.62 + 5.585J = 7989.21J$

So the overall energy balance in the cycle run around the crusher is

Total workinput = $Q_{in} + Q_{generated}$ = Total workoutput, Q_{out}

$Q_{in} + Q_{generated} = Q_{out} = Q_{oil} + Q_{cake}$

5.55 + 7989.01 = 7983.62 +5.59

8000J = 8000J

IV. COMPONENTS AND MATERIALS SELECTION

The components include the shaker which is driven by a belt, the hopper, the crusher which uses direct gear coupling and the expeller cage. The plant required two 3-phase AC electric motors to drive it.

Determination of hopper volume

From the material balance analysis, 59.52kg of palm kernel will be processed in 1hr. The volume of palm kernel nuts to be processed in 1hr is determined using Archimedes Principles. A known mass of palm kernel was poured into a calibrated beaker containing water and the volume rise was measured and taken as the volume of the palm kernel immersed in the fluid. A mass of 1.5kg of palm kernel gave a $0.37cm^3$ in volume of water; which gives a mass density of $405kg/m^3$.

As the shape of hopper desired is a frustum. The volume of a frustum, $V_f = (\pi h/3) \times (R^2 + Rr + r^2)$. Where R = bigger radius, r = smaller radius and h = height of hopper.

Therefore, the volume of hopper is

$$V_f = (3.14 \times 0.34/3) \times (0.46^2 + 0.46 \times 0.08 + 0.08^2) = 0.091m^3$$

Determination of shaker specifications

The shaker separates unwanted materials which are smaller than the palm kernel. Thus from the calculations, the parameters adopted are: length = 0.88m, breadth = 0.6m, height = 0.12m; thereby giving a volume of $0.0634m^3$ for the shaker.

Determination of expeller cage specifications

The expeller cage separates unwanted materials which are smaller than the palm kernel. Thus from the calculations, the parameters adopted are: length = 0.29m, internal diameter = 0.079m, external diameter = 0.115m, internal volume = $0.0003m^3$, external volume = $0.0043m^3$, void volume = $0.004m^3$.

V. TESTING AND CHARACTERIZATION

The fabricated plant was subjected to a test run with an initial input of 59.52kg of palm kernel per hour and subsequently run for 10hrs at 5hrs shift each. At the end 200.05 kg of high quality PKO was extracted.

Fig. 1: The Palm kernel oil extractor

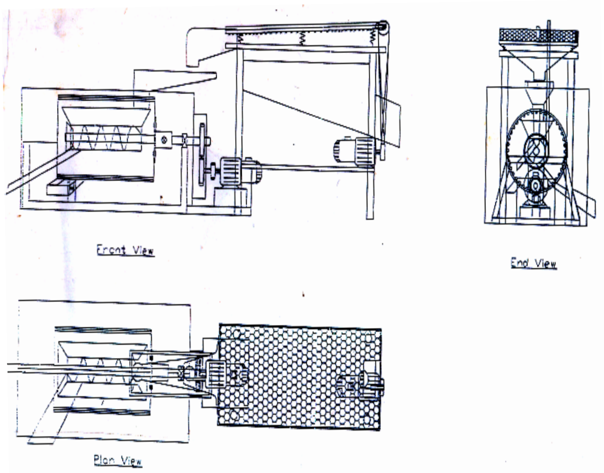

Fig. 2: Different technical views of the plant

VI. CONCLUSION

The result obtained from the design calculations and the fabrication of the pilot plant that will produce 200kg of PKO using mechanical extraction shows that this process (mechanical extraction) is the most suitable method for extracting PKO because of its high yield and high purity of PKO, both in large or small quantity.

Also, the use of an electric motor to drive the extractor produces less noise thereby reducing the cost of abating pollution. This process also generates little or no waste since the palm kernel cake will be used as animal feeds thereby reducing cost of waste disposal.

Finally, from the output of the pilot plant, it will be concluded that further design and installation of a commercial plant is viable.

REFERENCES

[1] Anaekwe E. N. 2011. Business Development Consultant http://farriconsultingng.blogspot.com/2010/04/buying-and-selling-of-palm-kernel-nuts.html.

[2] Coulson J.M and Richardson J.F, "Chemical Engineering Particle Technology and separation processes", vol. 2, 5th edition, Perganian Press International, New-York, 1980, page 56, 95 137, 506 - 510.

[3] Coulson J.M and Richardson J.F, "Chemical Engineering Design", vol. 6, 3rd edition, Perganian Press International, New-York 1980, page 1- 20, 34 - 56, 60 - 91, 129, 197 - 216, 283, 358, 398, 424, 463, 891.

[4] Coulson J.M and Richardson J.F, "Chemical Reaction Design", vol. 3, 3rd edition, Perganian Press International, New-York 1980.

[4] Max S. Peters and Klaus D. Timmerhaus, "Plant Design and Economics For Chemical Engineers", 4th edition, McGraw-Hill Book Company, New York, 1991, Page 671 - 720.

[5] Perry, R.H., and Green B. W. Perry's Chemical Engineers' Handbook", 8th edition, McGraw-Hill book Company, New York, 2007, section 21 page 56 - 65.

[6] Robert E, Treybal, "Mass Transfer Operations", 3rd edition, McGraw-Hill Book Company, New York, 1980, page 1-12, 477, -490, 544, 545, 552.

[7] Shirgley J. E. (1986), Mechanical Engineering Design. McGraw-Hill Book Company, New York.

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