Fast Tracking Third World Countries Economic Development through Improved Mechanized Processing of Palm Oil in Farm Settlements

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Abstract: **This aimed at evolving a cheap, simple, and compact technology to keep the local farmers in Farm Settlements, in the third world countries abreast with modern methods of oil palm processing which will translate to increase in production output, cleaner technique; and eventually increased output for the farmers and fast track economic development. Mechanized equipment adaptable to the local communities for palm oil processing was designed and developed for the rural farmers based on the considerations of functionability, cost, serviceability, durability, machinability and availability which is capable of achieving a remarkable increase in palm oil production in third world country's farm settlements for economic development. From test results, it is possible for the farmer(s) to produce close to 1000 litres of palm oil within a period of one week which is not realizable using the local methods of extraction.**

Keywords: design, mechanized processing, Palm oil, farm settlements.

I. INTRODUCTION

Although palm oil has been identified as a major source of revenue to the local farmers, lack of modern industrial processing equipment to ensure clean and adequate supply of the commodity has hampered their dream of becoming major producers/suppliers in spite of its abundance. The current methods of processing the fruits as adopted by the local farmers are not only crude, but also laborious and unhygienic.

In the local processing of oil palm the farmer(s), having gathered the harvested bunches, allow them for a period of 4-5 days to enable the fruits to loosen up from the bunches. Thereafter, bunches are beaten lightly, making the ripe fruits to fall off. Subsequently they are gathered and sieved to remove the chaff. When this has been done, the ripe fruits are then covered for a further 5- 7 days to allow for fermentation. Thereafter they are matched and crushed into pulp with the aid of the feet. Having properly crushed them, water is added to the pulp and the mixture stilled to allow the oil to float and is collected in drums for further processing.

A visit to some small farm settlements in the third world countries indicate that the farmers are in dire need of new technologies for processing palm fruits which will in effect increase palm oil output in the area and subsequently result to better income for the local farmers and fast track the economic development.

The aim here is to evolve a cheap, simple and compact technology to keep the local farmers abreast with modern methods of oil palm processing which will translate to increase in production output, cleaner technique; and eventually increased output for the farmers and fast track economic development in third world countries.

II. EXTRACTION OF PALM OIL

Palm oil is extracted from the ripe fruits through various processes ranging from the harvesting of bunches, extraction of the fruits from the bunches, to processing of the fruits to obtain palm oil and finally the extraction of the fibrous mass of processed fruits.

III. PROCESSING OF PALM FRUITS

The processing of palm fruits extends through local methods to advanced methods of technological sophistication.

All the methods have the same principle but in the local method, because of the high free fatty acid content and the level of bacteria, the quality of oil produced is not good for industrial purposes. This is because the local farmers allow the fruit to over ripe and this is high in carotene which gives the oil a deep red colour and as such the oil produced is only good for consumption. It is not used industrially because it is not easily bleached. Good oil produced industrially has a slightly yellow colour and this can be bleached easily and used for the production of soap and margarine.

Industrial processing of palm oil requires the following steps: a. Sterilization b. Stripping c. Maceration d. Pressing e. Clarification

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A. Sterilization

This is carried out in a boiler at a given temperature. Bunches must be steamed or parboiled for about an hour or so. This is done to destroy bacteria, fungi and enzymes in the fruit which otherwise will cause a rise in the free-fatty acid content. It is expected that sterilization begins within 12 hours after harvest. Sterilization is done under a pressure of about 2280mmHg for 40 - 60 minutes.

B. Stripping

In the traditional method stripping is done by mulching bunches under shade for 3-5 days. This loosens the fruits which are then removed by light beating.

Industrially nuts are separated from bunches in rotating threshing drums, the loose fruits falling through openings in the drum and bunches are discarded at the end.

C. Maceration

This is a process of soaking or steeping the fruits in water and subsequent heating to make the extraction of oil easier. This is carried out in heating towers in which steel beaters rotate. As the process continues the fruits are squeezed into pulp which is discharged into the press.

D. Pressing

The macerated fruits are then pressed in the press to extract oil from the pulp under a pressure of about 50 bars, for efficient extraction to be done.

E. Clarification

This is a process which involves the removal of any material which constitutes impurities in the oil.

The process entails cooking the oil (mixed with water) for about 15 to 30 minutes, followed by settling in a tank for 1 or 2 hours, during which pure oil separates from impurities. The oil is scooped into another drum where it is later heated to reduce moisture content.

IV. RELATED LITERATURES

The exact origin of the palm oil milling machine is not known but it is traceable to the early 1920s when Indonesia and Malaysia began large scale production of palm oil for the international market. Hartley (1967).

Hartley observed that the palm oil produced in Malaysia and Indonesia was being put upon European market at a lower price than the Nigerian oil. This was due to the fact that there was abundant supply of trained manpower and modem equipment for the processing of palm oil which Nigeria lacked.

V. MODERN METHODS OF PALM OIL EXTRACTION

There are two distinct methods of extracting oil from the digested material using the milling machine. One method uses mechanical process and is called dry method, while the other which is called wet method uses hot water to leach out the oil.

Ellis et a1 (1923) recommended that mechanical extraction of palm oil can be embarked upon immediately having discovered palm produce in the West African sub-region. Nigeria started producing and this is due to the remarkable improvement in the quality of both exported and locally consumed palm oil.

It is noteworthy to say that the oil palm milling machine has undergone remarkable improvement over time.

Having analyzed the local method adopted by the farmers in this locality which is labour intensive, unhygienic, and of low yield, and the comparative advantages associated with use of the mechanized oil mill in terms of cost, high yield, and quality of the oil produced, the farmers in this locality have seen the need for the introduction of the oil milling machine in their area.

VI. VERTICAL PALM OIL MILLING MACHINE

The vertical palm oil mining machine consists of a mild steel drum, a shaft with eight (8) vanes or blades, base or support, drive shaft carrying pulley, and an axle with a gear and pinion assembly. It is powered by an external generator which drives the shafts through a system of belt and pulley. The power from the generator is transmitted through the belt to the pulley mounted on the drive shaft which is connected to an axle. The rotation of the axle drives the pinion mounted on the shaft with blades, and by this the crushing of palm fruits is achieved.

VII. METHODOLOGY

A. Design Considerations/Materials Selection

In selecting materials suitable for each component part of our design, the following factors were considered: Functionability, Cost, Serviceability, Durability, Machinability, Availability.

Mild steel has been chosen as the engineering material for this project due to its desirable properties of which the mechanical properties are of major interest to us.

B. Mechanical Properties of Mild Steel

The mechanical properties of mild steel of concern to this project are those associated with its ability to resist mechanical force and load. These include strength, malleability, stiffness, elasticity, toughness, and machinability.

Mild steel is an excellent structural material, cheap, and easy to form. It has good mechanical properties and is used in the design of shafts, gears, and other machine components subjected to mechanical stress under load. It is made up of 0.15-0.3% carbon, 0.5% phosphorus, 0.05-0.2% copper and the remaining being iron by composition.

The materials requirement for the construction of the palm oil milling machine is outlined below:

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C. The Drum

The drum is made with a mild steel plate measuring 1920 mm x 610 mm, rolled on a rolling mill and welded to a diameter of 610 mm and a height of 610 mm. The volume of the drum is calculated thus:

Volume, $V = \pi r^2$

$$V = 3.142 \times 305^2 \times 610$$

$$V = 178293575.5 mm^3$$

$$= 1.783 m^3$$

Note: $C = 2\pi R$

$$D = C/\pi$$

But $C = 1920mm$

Therefore D = 610mm

Note that at this point in time the two ends of the drum are still open.

The part labeled B is to be welded to the drum to cover the base and to form a top cover which can be opened during feeding. A Hole measuring 35.5mm in diameter is to be bored at the centre of the base to accommodate the shaft bearing. The part labeled C is to be cut out to form the discharge port. The discharge port has a lid that covers it when the machine is in operation.

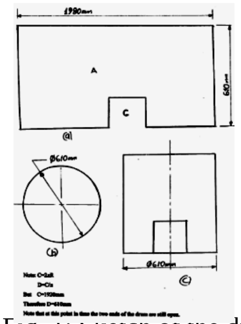

Fig. 1: Sketch of the drum

C. The Shaft

There are two shafts – the vertical shaft which is to be 750mm long and 35mm diameter, located inside the drum and carrying eight (8) blades, with each blade measuring 300mm in length, 50mm wide and 5mm thick, and made from mild steel flat bar. The second shaft measuring 450mm long and 30mm in diameter drives the first and has a pulley mounted at one end by means of which power from the drives operates the system. The other end fits into an axle which engages the pinion in the blade carrying shaft. Each blade of the crushing shaft is to be inclined at an angle of 65^0 and is arranged along the length of the shaft. When in operation the blades are responsible for the crushing of the fruits into pulp.

D. The Stand or Support

The base or support frame is to be formed from mild steel angle bars, each cut to length of 590mm, using hacksaw or power saw. Welded to a dimension of 390 x 390 x 590mm, they are to form the support that carries the drum and its content.

At a height of 70mm from the bottom is a base upon which is mounted the axle (axle sitting), centrally located under the drum.

E. The Crankwheel, Pinion and Pulley

This consists of all the rotary members of the machine that assist in the transmission of power, including the axle and pulley.

The axle is made of cast iron and consists of some set of bevel gears inside with openings at two ends for shaft attachment, which help to transmit motion over an angle of 90^0. This is achieved through the help of the horizontal shaft connected to it from the pulley. The pulley is double grooved; therefore, it will carry two belts. It is also made of cast iron and helps to transmit power from the generator.

F. The Blades

The blades are to be from mild steel flat bar and each is 300mm long, 50 mm wide and 5 mm thick, and are to be arranged along the length of the 750mm shaft inside the drum at angle of 65^0. When this shaft rotates, the blades carry the fruits, squeezing them against themselves and against the wall of the drum and in the process reduce them mass to a pulp.

VIII. DESIGN SPECIFICATION

A. Determination of the Palm Fruits Volume

The palm fruits, being irregularly shaped, cannot be measured directly by a ruler. However, using Archimedes principle which states that 'the volume of liquid displaced by a body immersed in a liquid is equal to its own weight', one is able to determine the weight of the fruits.

Experimental results of weighing the fruits will include the following:

Table I: Volume of water displaced by fruit

Fruits	Volume of water displaced (ml)
1	15.0
2	15.5
3	15.0
4	10.5
5	15.0
6	10.0
7	8.3
8	10.0

Average ml of water displaced by eight (8) palm fruits

=

$$\frac{15 + 15.5 + 15 + 10.5 + 15 + 10 + 8.3 + 10}{8}$$

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= 99.3/8

=12.41m1

Converting to litres, we have;

$$\frac{12.41}{1000} = 0.01241 \text{ litres}$$

i.e. Volume (litres) = Volume (ml) x 10^{-3}

But $10^9 mm^3$ = 1 litre

Therefore, Volume (mm^3) = 0.01241 x $10^9 mm^3$

0.01241 x 109 mm^3

Volume = 12410mm^3

B. Determination of the Mass of Palm Fruits

The fruits are to be weighed directly on a digital weighing machine and possible experimental results of weighing 8 fruits are as follows:

Mass of 8 fruits = 155.0 g = 0.155 kg

1 fruit = 0.115/8

= 0.0144 kg

Weight of 1 fruit = 0.0144 x 9.81

= 0.141264N = 0.1413N

C. Determination of Total Weight on Machine

Assuming one palm bunch has an average of 150 nuts and that 50 bunches = 1 drum,

Total number of fruits in drum = 50 x 150

Total mass of fruits = 7500

= 0.115 x 7500

= 862.5 kg

Given that volume of 8 fruits = 12410 mm^3

1 fruit = 12410/8

= 1551.3mm^3

And 7500 fruits = 1551.3 x 7500

$$Density = \frac{Mass}{Volume}$$

$$\frac{M_1}{V_1} = \frac{M_2}{V_2}$$

$$M_2 = \frac{(M_1.V_1)}{V_2}$$

$$\frac{0.0144}{1551.3} = \frac{M_2}{11634750}$$

$$M_2 = 0.\frac{0144x11634750}{1551}.3$$

= 108kg

Total weight = 9.81 x 108

= 1059.5N

D. Determination of Crushing Force

This is done by the use of several hammers of known masses to crush the fruits. The mass of the hammer that crushes the epicarp of the fruit successfully without causing any damage to the endocarp is to be recorded. Sample results are as shown in the table below.

Table II: Determination of crushing force

Seed #	Mass of Hammer (g)	Force (N)
1	15.0	141.2
2	14.2	139.3
3	14.4	141.3
4	15.6	153.0
5	15.2	149.1
6	14.9	146.2
7	15.0	147.2
8	15.0	147.2

Average force P =

$$\frac{(147.2 + 139.3 + 141.3 + 153.0 + 149.1 + 146.2 + 141.2 + 147.2)}{8}$$

$$= \frac{1170.5}{8}$$

= 146.3N

Design force, FD = Average Force x Factor of Safety

= 146.3 x 1.6

= 2234.08 N

We know that crushing force is given by

$P = m\omega^2 r$

Where P = crushing force

M = Mass of blade

ω = Angular velocity

r = Length of blade = 0.30

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E. Calculation of Angular Speed (ω)

$$\omega = \sqrt{P/mr}$$

$$= \sqrt{146.3/(0.5x0.30)}$$

$$\sqrt{975.33}$$

$$\omega = 31.23$$

To convert to r.p.m.

$$= \frac{31.23 \times 60}{2\pi}$$

= 298.22 r.p.m.

F. Power Determination

Torque = F x r

Where r = R = length of blade

T = 146.3 x 0.30

= 43.89N-m

From the relation,

T = F x 60/2πN

43.89= Px60/1873.77

F = 1370.66

The generator's efficiency is about 75%; therefore the actual power required is:

=1370.66/0.75

= 1442.8W

Converting to Horse Power,

1 h.p = 746W

=1442.8/746

= 1.93h.p

G. Shaft Design

The length of the shaft corresponds to the length of the drum. The shaft is loaded only in torsion.

H. Shaft Analysis

Shear strain, $\phi = MM_1/L$ (1)

Also $\phi = \tau_{max}/C$ (2)

Equating 1 & 2,

$MM_1/L = \tau_{max}/C$

But, $MM_1 = R\theta$ where R = radius of shaft

$R\theta/L = \tau_{max}/C$

$\tau_{max}/R = C\theta/L$ (3)

Note: For a solid shaft, the maximum permissible angle of twist is 0.0046 rad of length (Motto, 1970)

i.e. θ = 0.0046 rad

C = 80GPa = 80 x 10^3MPa (C = Modulus of rigidity)

For solid shaft, $I=\pi D^4/32$

Where D =35mm = 0.035m

$I = \pi(0.035)^4/32$

$I = 1.473x 10^{-7}$

But $\tau = IC\theta/L$ (Agholor R.O., 2006)

$\tau = (1.473x10^{-7} \text{ x } 0.0046x80x10^9)/0.117$

τ = 463.30 N-m

For a round shaft,

$\tau_{max} = TR/I$

= (463.30 x 0.0175)/1.473x10.7

$\tau_{max} = 8.10775 \text{ x } 10^7/1.473$

= 55042430.41 Pa

= 55.04MPa

Hence maximum torsional shear stress the shaft can withstand is 55.04MPa

Table III: Criteria for Shaft Selection

	For Stationary Shaft	K_M	K_T
1	Gradually applied load	1.0	1.0
2	Suddenly applied load	1.5-2.0	1.5-2.0
	For Rotary Shaft	K_M	K_T
1	Gradually applied load	1.5	1.0
2	Load suddenly applied(minor shock)	1.5-2.0	1.0-1.5
3	Suddenly applied load(major shock)	2.0-3.0	1.5-3.0

(Khurmi and Gupta, 2008)

K_M = Combined shock and fatigue factor applied

K_T = Combined shock and fatigue factor for torsion

ACME codes for commercial steel shafting are:

Shear stress (allowable) -55MPa for shaft without keyway.

Shear stress (allowable) -40MPa for shaft with keyway.

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I. Bearing Selection

The bearing chosen for the design of the milling machine is rolling contact bearing because of its advantages over sliding contact bearing.

The advantages include the following;

1. Low starting and running friction

2. It generates lesser heat while in operation

3. Easy mounting

4. Low maintenance cost

5. Accuracy of shaft alignment

6. Reliability in service

7. Small overall cross sectional area.

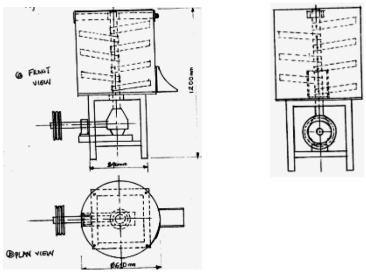

Fig. 2: Sketch of the Palm Oil processing machine

IX. CONCLUSION

In a time like this when government is preaching about green revolution, there is need for the government to provide a necessary and conducive environment for the local farmers to thrive well. This can only be done by way of providing the basic farm inputs for them through the introduction of simple technology that will impact on their output.

Based on the above, there is no better time for the local communities with vast palm trees to ask for the oil palm milling machine.

It is hoped that when the design is carried out and is eventually put to use, there will be a remarkable increase in palm oil production for economic development in the areas of third world countries.

From test results, it is possible for the farmer(s) to produce close to 1000 litres of palm oil within a period of one (1) week which is not realizable using the local method extraction earlier discussed.

X. RECOMMENDATIONS

Everyone, no doubt, believes that some of the third world countries like Nigeria has the potential to be a major producer of palm oil and can reduce over dependency on crude oil as the economy's main means of survival.

This is only achievable by the government(s) giving the necessary encouragement to the farmers through the provision of soft loans to enable them acquire these moderm farm technology.

It is hoped that, through commitment the nation’s dream of becoming Africa’s economic hub will be achieved.

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