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Research Paper

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Design, Fabrication and Performance Evaluation of Manually Operated Palm Oil Screw Press

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Abstract—Palm oil extraction still remains a critical bottleneck particularly at the level of small and medium scale processors in Nigeria because the procedure involved in the extraction of palm oil is tasking, drudgery and challenging. Although modern facilities which help to mechanize the palm oil extraction or expression are now available at the medium/large scale of production, their application at the small/cottage level of production is still very much limited hence the need for an innovative technology which can help address the mechanization of palm oil extraction at the small/cottage level. In this work, a manually operated palm oil screw press was designed, fabricated with locally available engineering materials and the performance evaluation of the machine was carried out. The machine which works with the rotation of the threaded rod has a capacity of extracting palm oil from 43.1kg of already digested palm fruit pulp per batch. The major components of the machine include the standing frame (550mm), the threaded rod(580mm), the perforated cylinder of volume 0.043m^3, the lock (128mm), the cross plate(250mm), the base(640mm), the supporting frame(325mm), and the oil outlet(120mm). The performance evaluation of the machine shows that the machine can extract oil from 92.40kg of digested pulp per hour. From the efficiency evaluation of the machine, 31.88% of oil was extracted with the machine. This therefore shows that indigenous technology that can solve the major drawback in the production of palm oil in Nigeria which is the use of traditional or un-mechanized method of production which makes it unattractive to young adults or young school leavers.

Keywords—Design, Fabrication, Screw press, Palm oil, performance evaluation

I. INTRODUCTION

Palm oil is an important edible vegetable oil notably for its food and not food uses. It obtained from the mesocarp of the flesh fruit of oil palm tree, (*Elaiesguineensis*)[1, 2. 3]. The palm fruit from which the oil is extracted takes almost six months to mature from pollination and it is mainly grown for its industrial production of vegetable oil [4]. Palm tree produces one of the most popular edible oil of high nutritional value. Palm oil is rich in carotenoids from which it derives its red colour and it is a major component of glycerides – a saturated fatty acid (palmitic acid) [3, 5]. According to [1], palm oil has the richest natural source of carotenoid even more than carrots. [6] reported that Palm oil contains approximately 50% saturated fatty acids, with 44% palmitic acide (C16.0), 5% stearic acid (C18:0), and trace amounts of myristic acid (C14:0). It represents the richest natural source of carotenoids (500-700 ppm), tocopheros and tocotrienols (600-1200ppm), all contributing to its stability and nutritional properties. Carotenoids, tocopherols and tocotrienol which are anti-oxidants help to improve the immune functions and fight cardiovascular diseases. Carotenoids also play an important role by acting as biological anti-oxidants, protecting cells and tissue from the damaging effect of free radicals as a result of exposure to pollutants like cigarette smoke, industrial pollution, unbalanced diets, pesticides and insecticide residues in food and water, and many other negative environmental influence [7]. Theses natural anti-oxidants found in Palm oil also act as buffer against free radicals as they play a role in cellular ageing, atherosclerosis, cancer, arthritis an Alzheimer's disease [1, 8].

Before the discovery and exportation of crude oil in Nigeria, agricultural produce especially palm oil has been Nigeria's major export product and source of national income. [9] reported that in 2012, palm oil occupied about 64% market share among the three major edible oils followed by soyabean oil with 28% market share and canola/mustard oil with 8.0% share. Over the recent years however, there has been a major drawback in the production of palm oil in Nigeria, with a major decline from being the world's largest palm oil producer with 43% share of the global market in the early 1960s to being the third largest palm oil producer behind Malaysia and Indonesia [1, 1, 9, 10, 11]

According to [11, 12] the major stages involved in the oil palm production include harvesting of the palm fruit

bunch, bunch threshing, fruit sterilization, fruit digestion, pulp pressing, oil clarification, oil drying and finally oil packaging. In Nigeria and in most developing nations, palm oil extraction is still being done using traditional methods [3, 10, 11] which among other methods involve the use of water emersion to separate the oil from the fiber, bagging out, direct manual pressing or squeezing by the hand which is done mostly by women and young men. These traditional methods are inherent with low productivity, poor product quality, time consuming, tedious and make the production very drudgery on the part of the processor.

The major drawback in the production of palm oil in Nigeria could be attributed to the traditional or un-mechanized method of production which makes it unattractive to young adults or young school leavers. Oil extraction still remains a critical bottleneck particularly at the level of small and medium scale processors in Nigeria because the procedure involved in the extraction of palm oil is tasking and challenging. Although modern facilities which help to mechanize the palm oil extraction or expression are now available at the medium/large scale of production, their application at the small/cottage level of production is still very much limited because of their inability to satisfy some local factors like availability of electricity needed to run these heavy duty screw presses. An innovative technology which can help address the mechanization of palm fruit digestion at the small/cottage level will be a welcome development and a boast to the economy of the rural dwellers that form the bulk of the palm oil processors.

II. RELATED WORK

Screw press is used in the mechanical extraction of oil from agricultural oil bear seeds.

Screw press that can be used for the extraction of palm oil at the level of small and medium scale was designed,fabricated and evaluated by [9]. The aim of the design was to mechanize the extraction process of the palm oil processing which has become drudgery with traditional methods and to increase production output thereby making it attractive for all class of people. The machine showed 17.90% as the highest oil extraction ratio(OER) while the oil extraction efficiency (OEE) was 79.56% The major components of the machine include standingframe, threaded shaft, speed reduction gear motor, driving and driven pulley and discharge outlet.

[10] developed a manually operated palm oil extraction machine with locally available engineering materials. These locally available engineering materials were cheaper as it had low purchase price compared to imported engineering materials. It offered smooth repair and maintenance. According to [10], the Designed machine had a volume of $0.033m^3$ and can extract oil from 20 kg of digested palm fruits at a time. At full capacity, the amount of extractable crude palm oil from the machine stood at 8 kg hr^{-1}.The machine works by the rotation of the handle attached to the threaded rod. The handle when rotated, manually leads a piston in a perforated cylinder to press the digested palm fruits to extract oil. [10] noted that the application force on screw can be increased by increasing the length of the handle and number of persons according to filling condition of the cylinder.

[13] in their work, design and stress analysis of screw press oil expeller, designed and simulated with ANSYS software a motorized oil expeller for small scale extraction using locally available engineering materials. The screw shaft was designed by ASME shaft design code while a 20 hp, 3-phase electric motor was used for running the machine at 140 rpm. The extraction of oil is done when a screw rotates inside the barrel of the press. This rotation creates pressure for the extraction of oil.

[14] designed and developed a motorized high torque and low rotational speed palm kernel oil expeller machine. The machine regulates the thickness and dryness of the pressed cake passing through the clearance between the barrel and the screw shaft with the introduction of an adjustable choke mechanism which allows adjustment of the back pressure. The machine components such as hopper, the expelling chamber; shaft; adjustable choke mechanism; pulleys; belts etc were designed and then fabricated using techniques such as cutting, welding, drilling, bending, and casting, etc. The machine design enables cold palm kernel seeds to be processed without pre-treatment, the breaking and cooking operation being performed by the action of the screw shaft within the barrel of the unit. The machine has a nominal input capacity of approximately 280kg/hr when driven by a10hp Electric motor.

[15], noted that the recent upsurge of interest in the demand for oils from soybeans has promoted the screw press and evaluated a continuous screw press for extraction of soybean oil that can be used in the food industry. The design comprises of three subsystems; energy unit, mechanical power transmission system and processing unit. The Energy unit controls the direction of motion of the machine through shaft connected to it. The mechanical power transmission unit is composed mainly of the system, rack and pinion gear type which is used to allow up and down movement of press. The process unit mainly consists of oil tank, cylinder used to store the oil seed, oil filter sheet which is used to differentiate oil with husks or seed coats during oil extraction process.

III. METHODOLOGY

A. Design Bases

The machine was designed and fabricated with the following considerations: simplicity in the construction of the machine; It should have simple adjustment and easy to operate; It should be made with locally available engineering materials; It should be easy to repair and maintain; The cost of machine must be affordable for small and medium scale processors.

B. Considerations for Screw Press Configuration

The screw press configuration was based on the ease of operating and maintenance of the machine, so a cylindrical shaped screw press of height 450mm and diameter 350mm was designed. The machine was perforated 114.25mm from bottom. The machine will be able to expel oil from a minimum of 15kg and a maximum of 43.1kg of digested palm oil fruit pulp per batch of operation.

C. Design Analysis

a. Design of perforated cylinder of the machine

Mass of required material, m = 43.1 kg

Density of Mesocarp, ρ = 659.40 kg m^{-3}

$$v = m/\rho \quad (1)$$

Therefore, volume, = 0.039 m^3

Considering 10% allowance

Total volume of the cylinder, Vc= (0.039 + 0.039 × 10%) m^3 = 0.043 m^3,

Now

$$Vc = \pi r2h \quad (2)$$

Where, Vc= volume of the cylinder, m3; r = radius of the cylinder, m; π = constant, 3.14; h = height of the cylinder, m

Now considering for convenience using of the machine let, the diameter of the cylinder is 304 mm.

Height of the cylinder is 450 mm.

It is perforated 228 mm from bottom to top.

A round perforated sheet of 304 mm diameter attached to the bottom of the cylinder.

According to Levinson (1970) the hoop stress in a thin walled cylinder is given as:

$$\sigma_h = P\ R\ n/t \quad (3)$$

$$t = P\ R\ n/\sigma_h \quad (4)$$

Where,

σh= hoop stress, N mm^{-2}; P = Pressure required to express oil from mesocarp, Nmm^{-2}; t = thickness of the perforated cylindrical cage, mm; n = factor of safety; R = radius of the perforated cylindrical cage, mm.

For yield strength of mild steel = 250 N mm-2 and considering a factor of safety, n= 3

The thickness of the perforated cylinder is 2 mm.

b. Design of frame of the machine

The machine is supported by an angle bar mild steel frame of length 550mm on both sides with a cross bar of length 600mm. The cross bar is made of mild steel and holds the threaded rod. The frame is attached to the base of the machine of diameter 500mm and made of mild steel.

c. Design of supporting frame of the machine

The machine has a supporting frame made of mild steel sheet and flat bars on which the machine's load is resting. The supporting frame is 150mm long and width of 225 mm.

Load on the supporting frame = Weight of the machine + Load required to express oil from mesocarp

Weight of the machine = (18.5 × 9.81) N = 181.485 N

Load required to express oil from mesocarp = Pressure required to express oil × Area of the cylinder =1.04Nmm-2×$\pi r2$ =1.04×3.1416×1522N = 75486.86 N

Therefore, load on the supporting frame,

W = (181.485+75486.86)N= 75668.35 N

Now load on each stand, L = (75668.35/ 4) N = 18917.08 N

Yield strength of mild steel, s = 250 MPa = 250 N mm-2

Now for the design, $L/A = s/N$

Where,

N = Factor of safety; A = Cross sectional area of square stand, mm2 = b2; b = breadth of the square bar, mm

Considering a factor of safety, N = 3, The breadth of each square stand, b = 15 mm

d. Design and development of threaded rod of the machine

A 25mm diameter rod is used as threaded rod. The length of the threaded rod is 600mm. the threaded rod has a mild steel iron pipe of length 500mm attached at the top of the rod. The attached pipe serves as a handle for rotating the threaded rod.

e. Design and development of piston plate of the machine

The machine has a plate called the piston plate upon which the threaded rod rest. When pressure is exerted by the threaded rod, the piston plate pushes the digested palm fruit pulp down to the bottom of the of the screw press plate to enable oil expression. For the purpose of this design and construction, the piston plate is made of mild steel of 250mm diameter.

D. Dimension of Screw Press parts:

*a. Screw Press Bucket***:** The screw press bucket which contains the digested palm fruit is a cylindrical-shaped bucket of height 228.5mm and diameter 152mm was designed and fabricated. The screw press bucket of the machine was perforated from top to bottom to improve the efficiency of the machine. The cylinder was built with mild steel.

b. Frame of the Machine: The machine is framed with mild steel angle bars that hold the piston. An opening is created at the center of the frame through which the screw is driven.

c. Supporting Frame of the Machine:

The machine has supporting frames designed and constructed with mild steel sheet and flat bar. The height of the supporting frame is 127mm and width is 344mm.

d. Threaded Rod of the Machine

A threaded rod of 35 mm diameter was used in the fabrication of the machine. The shape of the threads of the rod is v-shaped. A galvanized iron pipe was attached at the top of the rod. This galvanized pipe was used as a handle for rotating the threaded rod.

e. Piston Plate of the Machine

The piston plate of the machine was designed and fabricated with mild steel plate. The piston plate was attached at the bottom of the threaded rod.

E. Performance Evaluation of the machine

Material Preparation

Palm fruits of particular specie (Dura) was sourced from Unwana palm Plantation and processed according to the flow chart below. After sourcing, the fruit was sorted, and washed with portable water in order to remove the foreign materials. After the sorting and cleaning, the palm fruit was weighed to obtain 14.8 kg of palm fruit.14.8kg of palm fruit was therefore sterilized with portable water for half an hour. After sterilization,the boiled palm seed was separated from the water used in boiling it through filtration and sent to the digester for the breakdown of the oil bearing tissues. After the digestion, the quantity of digested palm fruit obtained is 15.7kg.The palm fruit pulp was poured into the machine (screw press) and it was pressed to extract crude palm oil. After extraction, the expressed crude oil was boiled to remove moisture and kept for few minutes so that the sludge settles down to the bottom. Theupper portion of the oil was collected and packaged as edible oil

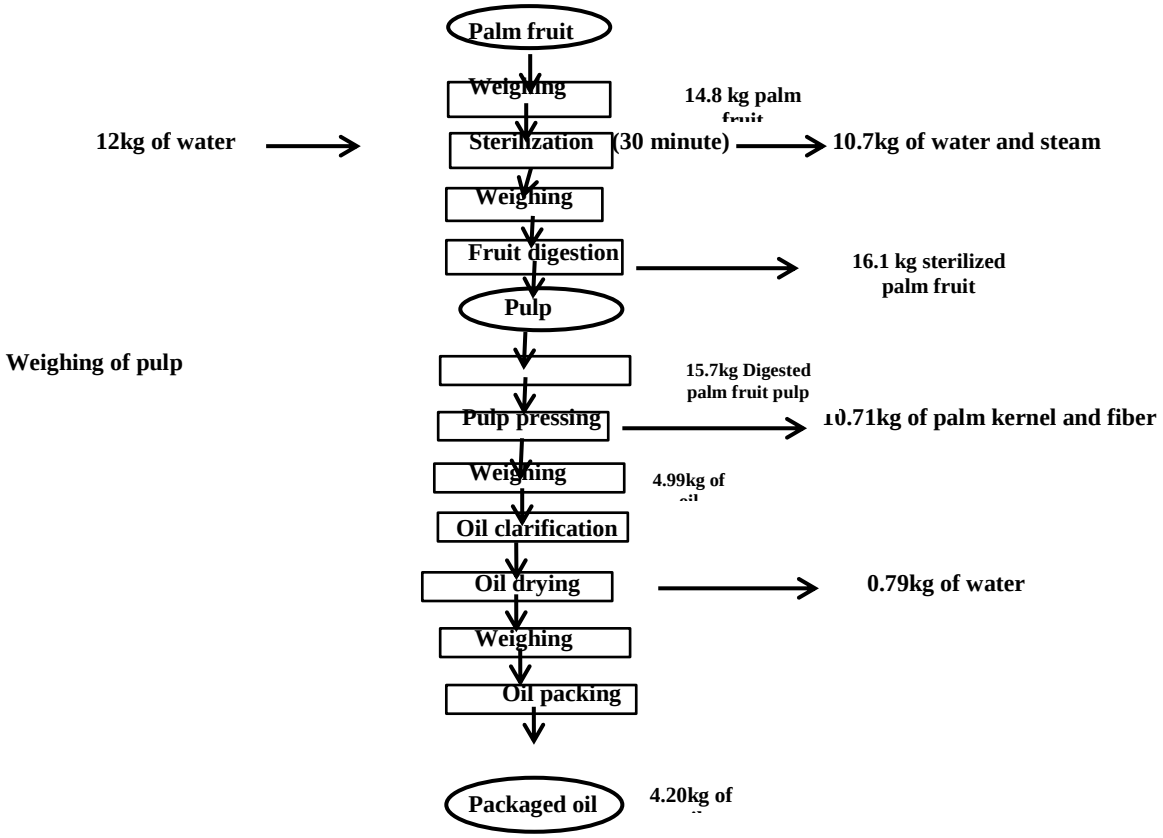


Figure 3.1: Flow chart of palm oil processing. *Sourced:*Ati (2001) modified

I. PERFORMANCE ANALYSIS OF THE MACHINE

3.7.1 Capacity of the machine:

$$C$$

Where,

C = capacity of the machine, $kghr^{-1}$; W_p= weight of mesocarp (palm fruit pulp) = 15.7kg; t_e= time required to extract the crude oil = (10minutes) 0.17hr

$$C = 92.4kg/hr$$

3.7.1Crude oil extraction efficiency of the machine

$$e \times 100$$

Where,

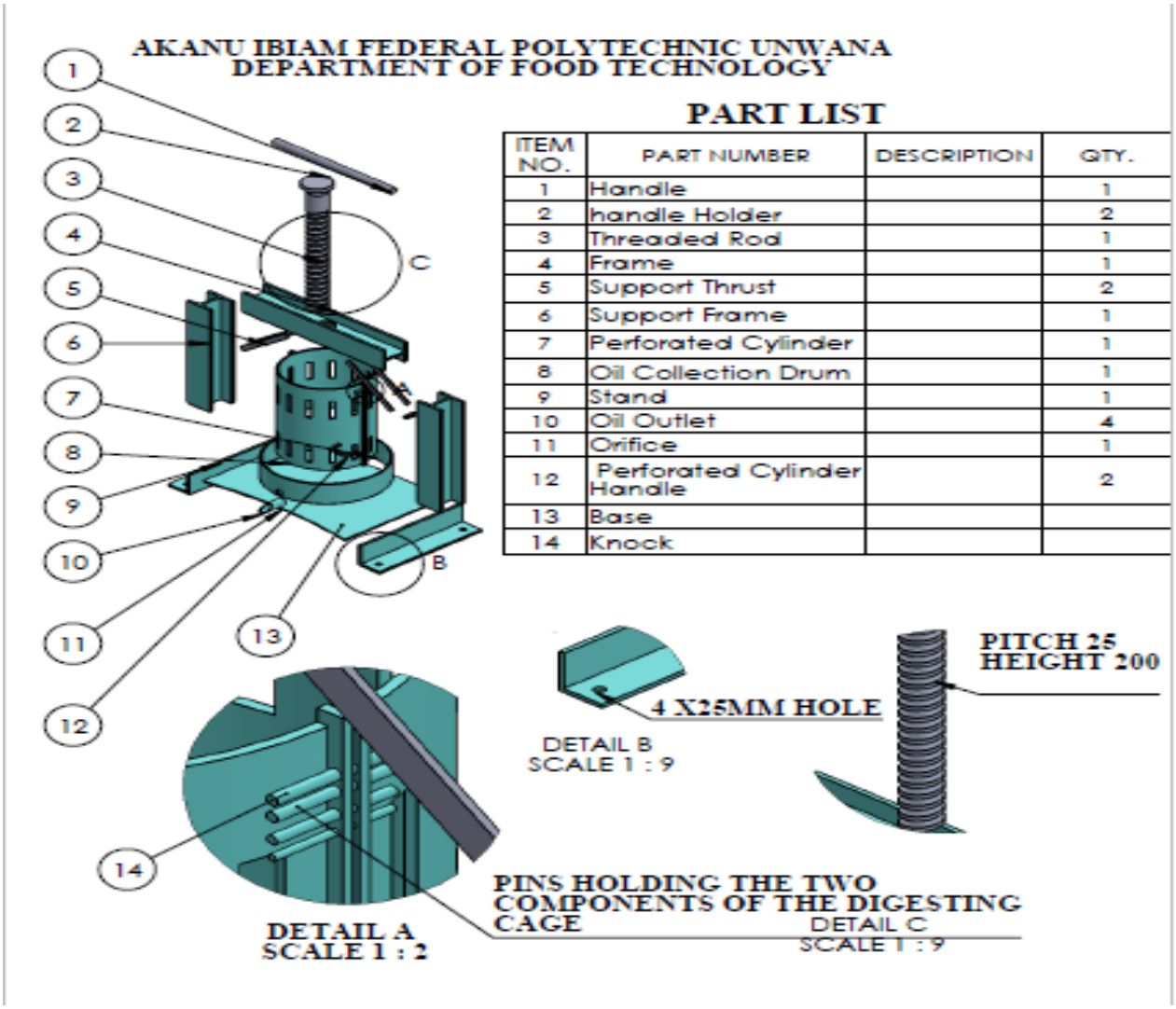
e = crude oil extraction efficiency of the machine, %; Wo = weight of crude oil, kg; Wp= weight of mesocarp (palm fruit pulp), kg

$$e \times 100 = 31.78\%$$

II. RESULTS AND DISCUSSION

3.1 Picture of new fabricated screw press

Plate 1: Part list of a palm oil screw press



3.2 PERFORMANCE EVALUATION OF THE FABRICATED SCREW PRESS

Table 4.1: Performance Evaluation of the Fabricated Screw press

Sample	Mass of Digested Pulp (kg)	Extraction time (min)	Initial mass of oil (kg)	Throughput (kg/hr)	Efficiency (%)	Final mass of oil (kg)	Oil yield (%)
PSP	15.7	10	4.99	92.40	31.78	4.20	268
WIM	15.3	50	4.4	-	18.43	3.20	20.92

Keys:
PSP: Palm oil extracted with Screw Press
WIM: Palm oil extracted with Water Immersion Method

COST ANALYSIS OF THE MACHINE

4.2. Bill of engineering material for screw press

S/N	Screw Component	Purpose	Qauntity	Unit cost (₦)	Amount (₦)
1	**mild steel sheet**	**Screw cylinder and outer container**	**3 sheets**	**19,000**	**57,000**
2	**Threaded Rod**	**For screwing**	**765mm**	**10,00**	**10,000**
3	**Galvanized iron pipe**	**Rotation of threaded rod**	**736mm**	**5,000**	**5,000**
4	**Piston Plate**	**For pressing on the fruit pulp**	**300mm**	**7000**	**7,000**
5	**Angle bars**	**The machine frame and support**	**5lengths**	**5,000**	**25,000**
6	**Labour**				**20,000**
7	**Transportation**				**10,000**
9	**Budget allowance**				**13,400**
	Total				**147,000**

Discussion

A. Mechanism of the designed machine

The local engineering materials needed for the construction of the mechaine was assembled to construct and easy to use and handle machine. It was a simple design fabricated in a workshop located at Letu in Edda Afikpo South Local Government Area of Ebonyi state.

The operating principle of the machine is by the rotation of the handle. By rotating the threaded rod clockwise, the Piston goes down and it pushes the Piston plate which presses on the digested palm fruit towards the bottom of the cylinder and oil is expressed. While an anti-clockwise rotation of the piston helps the threaded rod to loosen and releive pressure on the digested palm fruit. When compressed, oil comes out through the perforated cylinder to the oil out let. When the extraction of oil is completed, the threaded rod is rotated anti - clockwise to enable the Piston goes up. By taking the Piston to the top of cylinder, it is cleaned by removing the debris from the cylinder.

B. Performance evaluation

The volume of the cylinder of the palm oil screw press was $0.495m^3$ and can contain a minium of 15kg and maximum of 43.8kg of digested mesocarp per batch of operation. The ability of the machine to extract oil from the digested mesocarp is on the other hand. This implies that the compression force of the machine is on the handle. Therefore, so long as the handle and man power is there, the machine has an advantage to press any fruits (maximum $0.495m^3$) at a time to extract oil. The performance evaluation of the machine in table 4, shows that 31.78% of crude oil was extracted. Considering the variety of palm fruit used, the efficiency of the machine was very high. [16] reported that fresh fruit without the kernel contains about 20% to 24% oil and the first-pressing oil extraction efficiency range from 12% to 15% for the spindle - presses and repeated pressing oil extraction efficiency ranges from 20% to 24%. Therefore, the result from the experiment is very close to the standard value.

The amount of crude palm oil extraction at full capacity of the machine was found 92.4kg/hr, which is higher than the traditional or manual method of palm oil extraction.

C. Cost Analysis

Table 4.2 shows the materials used in the fabrication of the machine and their cost implication. From the table, all the engineering materials used in the fabrication of the machine are locally available engineering material. The table also showed that the machine is very affordable and cheap. The table showed that the total cost of the fabrication stood at One Hundred and Forty-Seven Thousand Naira.

Conclusion and Future Scope

In conclusion, a simple and portable screw press was designed and constructed from locally available materials for use in oil extraction. The machine which works with the rotation of threaded rod has a capacity of extracting palm oil from already digested fruit pulp. Thus machine has the capacity of extracting 31.78% of the oil. This work therefore shows that simple indigenous technology can be fabricated from available engineering material to reduce the challenges associated with the traditional method of oil extraction.

Further studies should be carried out on how to make the machine automated using solar energy. The gross contamination of the processed oil due to exposure to the open should be reduced by introducing an outer container.

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