International Journal of Scientific & Engineering Research, Volume 5, Issue 7, July-2014
ISSN 2229-5518

Development of a Screw Press for Palm Oil Extraction

O. A. Adetola, J. O. Olajide and A. P. Olalusi

Abstract- A palm oil screw press was designed, fabricated and evaluated for small and medium scale palm fruit processors in order to mechanize the extraction process and increase production output. The major components of the machine are standing frame, threaded shaft, speed reduction gear motor, driving & driven pulley and discharge outlet. The highest oil extraction ratio (OER) of 17.90% and oil extraction efficiency (OEE) of 79.56% were obtained at the sterilization time of 60 min, digestion time of 10 min and screw speed of 10 rpm. The production cost of the press is $650 and it is powered by a three- phase 5hp electric motor.

Index Terms: Design, extraction, fabrication, palm oil, screw press, fruit processors, efficiency

1. INTRODUCTION

The oil palm (*Elaeis guineensis*) is an important economic tree that is grown in Asia, Africa and South America [1]. It is the principal source of palm oil which is an edible vegetable oil. About 90 percent of the palm oil produced ends in food products, while the remaining 10 percent is used for industrial production [2].Because of its many uses demand is growing fast as the world's population increases and standards of living rise. Palm oil accounts for 34 percent of the world's annual production of vegetable oil and 63 percent of the global exports of vegetable oils. It is produced in tropical climates and in 42 countries across the world [3]. Nigeria is currently the third largest producer of palm oil in the world after Indonesia and Malaysia; however it remains a net importer. Palm oil and palm oil manufacturing represents one of the most effective methods of raising Nigerians from poverty and ensuring food security. It provides employment for millions of unskilled and semi-skilled workers [4-5]. The traditional method of palm oil processing is time consuming, laborious, hazardous and inefficient resulting in the production of low quality oil. Oil extraction still remains a critical bottleneck particularly the level of small and medium scale processors in Nigeria [5]. Nigeria has lost its premier position on the list of world major palm oil producers for the past few decades [6]. This has been traced to lack of improved variety of palm fruit, land tenure system, and lack of appropriate processing technologies. Lack of appropriate processing technologies constitutes the major obstacle to palm oil production in Nigeria [5].

• *Adetola Olufemi Adeyemi is currently pursuing his PhD* in Agricultural and Environmental Engineering Department, Federal University of Technology Akure, Nigeria. *Email: olufemi.adetola@gmail.com*
• Olajide *O. J. is currently working as a Professor* in Food Engineering Department, Ladoke Akintola University of Technology, Ogbomoso, Nigeria. Email: folarant95@yahoo.com
•Olalusi A.P. is currently working as a Senior Lecturer in Agricultural and Environmental Engineering Department, Federal University of Technology, Akure, Nigeria. Email: ayoolalusi@yahoo.co.uk

Over the years attempts have been made to mechanize the various operations involved in palm oil processing. Extraction (pressing) has received the greatest attention for mechanization. Presses developed over the years have included models such as: Manual vertical screw-press, Stork hydraulic hand press, Motor-jack press, Motor-jack/cantilever press, NIFOR hydraulic hand press, combined screw/hydraulic hand press, mechanical screw-press [6]. Existing imported screw press machines for oil palm are very expensive and not readily affordable by small and medium scale processors who form the majority of the processors. Industries established with imported technology do not function for a long period of time because of lack of spare parts, inadequate maintenance and inability to satisfy some local factors [7]. It is essential to evolve indigenous technology to address the issue of food processing in Nigeria. Many authors have reported on the need to develop indigenous technology in the various aspect of agricultural and food processing operations [8-10]. Several African nations including Nigeria are currently developing oil palm plantations so as to produce palm oil on a commercial scale in order to eradicate poverty and diversify the economy. Production of indigenous machinery to process the expected boom in palm fruits to palm oil is imperative. The objective of this work therefore is to design, construct an indigenous palm oil screw press to effectively extract crude oil from oil palm.

2. MATERIALS AND METHODS

2.1.1. Machine Description and Working Principle

The screw press consists of the following components: worm shaft, cylindrical barrel, feeding hopper, electric motor, pulley, cake outlet, oil outlet and main frame. The cylindrical barrel was made from a mild steel pipe of length 650 mm, inside diameter of 166 mm and thickness of 10 mm. The worm shaft was made from a mild steel solid rod of diameter 80 mm and length 900 mm, which was machine on their lathe at a decreasing screw pitch and decreasing screw depth. The worm shaft is housed in the cylindrical barrel at a clearance of 1.5 mm between the screw diameter and inside diameter of the barrel. In operation, the digested palm fruit is introduced into the machine through the feeding hopper; the machine convey sand presses the digested palm fruit inside the cylindrical barrel with the aid of the worm shaft until crude oil is pressed out of the mash. The crude oil extracted is drained through the oil channel into the oil tray where it is collected, the residual cake is discharged at the cake outlet and collected at the cake tray. The machine is powered by a 5hp three – phase electric motor and has production cost of $650 with the construction materials being locally available at affordable costs.

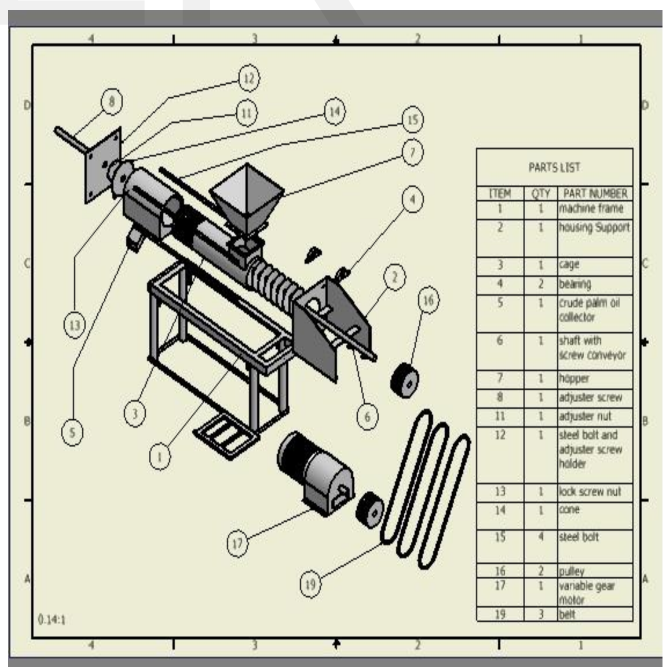


Figure 1: Exploded view of the palm oil screw press showing the component parts

Figure 2: Palm oil screw press developed

2.2. Design Considerations and Calculation Procedures

2.2.1. Design considerations

While designing the machine consideration included: high oil yield, high oil extraction efficiency and ratio, low extraction loss, quality of oil, availability and cost of construction materials. Other considerations included the desire to design the cylindrical barrel to accommodate the require quantity of raw material (digested palm fruit). Also considered is to design the worm shaft to ensure maximum conveyance and pressing of the crude oil. Other considerations included the simplicity in design and easy to fabricate the machine, be usable by anybody even without any previous technical training and a strong main frame to ensure structural stability and strong support for the machine.

2.3. Design Calculations

2.3.1. Design of worm shaft of the expeller

The worm shaft is the main component of the screw press and is acted upon by weights of material being processed, pulley and screw thread. In operation, the worm shaft conveys, presses and squeezes the material (digested palm fruit) for oil extraction. Therefore, in other to safeguard against bending and tensional stresses, the diameter of the shaft was determined from the equation given by [11-12] as:

$$d_s = \frac{16T}{0.27\pi\delta_O} \quad (1)$$

Where, d_s is diameter of the screw shaft, T is the torque transmitted by the shaft and δ_O is the yield stress for mild steel. Given that T = 628.471Nm and δ_O = 432.33N/mm^2; hence, d_s = 28.00 mm. Therefore, a mild steel rod of diameter 30 mm was used for the worm shaft.

2.3.2. Design of the screw thread

The worm shaft is essentially a tapered screw conveyor with the volumetric displacement being decreased from the feed end of the barrel to the discharge end. The screw treading system was design as a step up shaft diameter and decreasing screw depth using the expression in the equation below as:

$$U_n = a+(n-1)d \quad (2)$$

Where, U_n is the screw depth at the discharge end, a is the screw depth at the feed end, n is the number of screw turns, and d is the common difference between next successive screw depths. Given that U_n=5 mm, a = 25 mm, and n = 9; hence d= -2.5mm. Therefore, the screw depth would be decreased consistently by 2.5 mm from the feed end to the discharge end of the barrel.

2.3.3. Design of the load that can be lifted by the screw

The load that can be lifted by the screw was determined from the equations given by [13]

as; $$W_e = T\frac{\frac{D_m}{2}\tan\theta+\frac{\mu}{\cos\alpha}}{(1-\mu\tan\theta\cos\alpha)} \quad (3)$$

$$\alpha = \tan^{-1}(\tan\theta_n\cos\theta) \quad (4)$$

Where, W_e is the load that can be lifted by the screw, T is the Torque transmitted by the screw shaft, D_m is the mean thread diameter, μ is the coefficient of friction, θ_n is the thread (lift) angle, and θ is the tapering angle. Substituting T = 628.471 Nm, D_m = 55 mm, θ = 3, μ = 0.15 and ϴn = $15^{o,}$ hence, α = 14.98^o and we = 52.88KN. Therefore, 5.40kg of mash can be processed at a time.

2.3.4. Design of the pressure to be developed by the screw thread

The pressing area [13] and the pressure developed by the screw thread were determined by equations 5 & 6 respectively as:

$$A_p = \pi D_m n h \qquad (5)$$

$$P_r = \frac{W_e}{A_p} \qquad (6)$$

Where, P_r is the pressure developed by the screw thread, A_p is the pressing area and h is the screw depth maximum pressure (discharge end). Substituting $\pi = 3.142$, D_m = 55mm, n = 9, h = 5 mm, and W_e = 52.88 KN, hence A_p =7776.45mm^2 and P_r = 6.80 N/mm$^{2.}$ Therefore, a pressure of 6.80Mpa would be available for pressing and squeezing oil from the mash during operation.

2.3.5. Design for the pressure of the barrel

The pressure that can be withstood by the barrel was determined by the equation given by [12, 14] as;

$$P_b = \frac{2t\delta_a}{D_i} \qquad (7)$$

Where P_b is the pressure to be withstood by the barrel, t is thickness of the barrel, δ_a is allowed stress = 0.27 δ_0 , δ_0 is the yield stress of mild steel, and D_i is the inside diameter of the barrel. Substituting t= 10 mm, δo = 423.33N/mm^2 , and D_i = 166 mm, hence δ_a = 114.30N/mm^2 and P_b = 13.77N/mm^2 or 13.77Mpa. This means that the pressure that the barrel can withstand (13.77Mpa) is greater than the pressure developed by the screw thread for oil extraction (6.80Mpa). Therefore, the barrel will withstand the extraction pressure without bursting.

2.3.6 Designed for the capacity of the expeller

The theoretical capacity of the expeller was determined using a modified form of the equation given by [15] as:

$$Q_e = 60\frac{\pi}{4}(D_s^2 - d_s^2)P_s N_s \varphi\rho \qquad (8)$$

Where, Q_e is the theoretical capacity of the expeller, D_s is the diameter of the screw thread, d_s is the base diameter of the screw shaft, P_s is the screw pitch, N_s is the rotational speed of the screw (worm) shaft, $\varphi$is filling factor, and ρ is the bulk density of palm fruit. Substituting D_s = 60mm, d_s = 30mm, P_s = 50mm, Ns = 150 rpm, φ = 0.8 and ρ = 913kg/m^3 into Equation 8; hence Q_e= 697.081Kg/h.

2.3.7 Design for the power requirement of the screw press

The power required to drive the screw press was calculated using a modified from [15] as:

$$P_e = 4.5 Q_v I_s \rho g F \qquad (9)$$

Where, P_e is the power required to drive the screw press, Q_v is the volumetric capacity of the worm shaft, I_s is length of worm shaft, g is the acceleration due to gravity, and F is the material factor. Substituting Q_v = 0.3965m^3/h, I_s = 440mm, g=9.81m/s^2, ρ = 913kg/m3, and F =0.4 into equation 9, hence P_e=2.8125kw.

The power of the electric motor to drive the screw press was estimated using the equation given by [15] below as:

$$P_m = \frac{P_e}{\eta} \quad (10)$$

where, P_m is the power of the electric motor and η is the drive efficiency. Given that η=75% or 0.75, hence, P_m=3.75kw or 5hp. Therefore, a 5hp three-phase electric motor was selected was to drive the screw press.

2.4. Material Selection and Fabrication of the Machines Components

The hopper was fabricated from a standard length of 1.5 mm thick mild steel sheet. Four piece of dimension 340x330x350mm were cut from the mild and welded together to form hopper. The worm shaft was fabricated from a mild steel rod of diameter 50 mm and length 900 mm which was machine on the lathe to 30mm base (shaft)diameter. Thereafter, the screw thread was machined at a decreasing screw depth from 25 mm to 5 mm thereby forming a tapered screw conveyor of nine screw turns. The barrel was fabricated from a mild steel pipe of 166 mm internal diameter, 10 mm thickness and 850 mm long which was cut and machined to 650 mm length. Using oxyacetylene flame, a slot of 50x50 mm was made on the upper side of the barrel for the hopper base. Holes were made on the lower portion of the barrel to serve as drainage channels for the expelled oil. The main frame was made from an angle iron of dimension 50x50x40 mm which was cut to the required dimensions and welded together. Fabrication process included: marking out, machining, cutting, joining, drilling and fitting. The workshop tools and machines used included: scriber, steel rule, and compass, Centre punch, grinding machine, lathe machine, oxy-acetylene gas, saw frame and blade for cutting and welding machine for joining. The specification of construction materials is in table 1.

TABLE 1: Materials for construction of the screw press and their specifications

Materials	Specifications	Quantity
Mild steel sheet	1.5 mm thickness, standard size	2
Mild steel rod	Φ 100mm, length 900mm	1
Mild steel pipe	ϕ 166m, thickness 10 mm, length 650 mm	1
Screw bolt	45 mm x 320 mm	1
Mild steel angle iron	38 mm x 4 mm standard length	1
Roller bearing	ϕ 30 mm	2
Cast iron pulley	ϕ 50 mm,125 mm	2
Cast iron pulley	ϕ 200 mm	2
V-belt	B 65	3
Bolts & nuts	24 mm x 50 mm	4
	30 mm x 50 mm	4
	19 mm x 30 mm	12
Welding electrode	Guage 12 mild steel	2 packets

2.5. Materials and Methods Used for Testing

Palm fruit bunches of tenera variety were obtained from teaching and research farm, FUTA. The fresh palm fruit were cleaned, weighed and prepared for oil extraction. The screw press was set into operation and known weights of each were fed into the machine through the feeding hopper. The worm shaft conveyed, squeezed and pressed the mash in order to extract the oil. The fresh fruit bundles, the oil extracted and the residual cake (kernel and fiber mixture) were collected and weighed separately. From the values obtained, oil extracted ratio (oil yield), oil extracted efficiency, material discharge efficiency and machines capacity were calculated according [1] as :

$$OER = \frac{W_{OE}}{W_{FFB}} X \frac{100}{1} \% \quad (11)$$

$$OEE = \frac{OER}{AEO} X \frac{100}{1} \% \quad (12)$$

$$MDE = \frac{W_{CO}+W_{RC}}{W_{FFB}} X \frac{100}{1} \% \qquad (13)$$

$$MCP = \frac{W_{FFB}}{T} \qquad (14)$$

Where, OER, OEE, MDE AND MCP are oil extraction ratio (oil yield),oil extraction efficiency, material discharge efficiency in % and machine capacity in tons of bunches/hr, W_{OE}, W_{FFB}, AEO, W_{CO}, W_{RC} and T are weights of oil extracted, fresh fruit bunches, amount of oil expected, crude oil, residual cake and time in hours. Each test was carried out in triplicates.

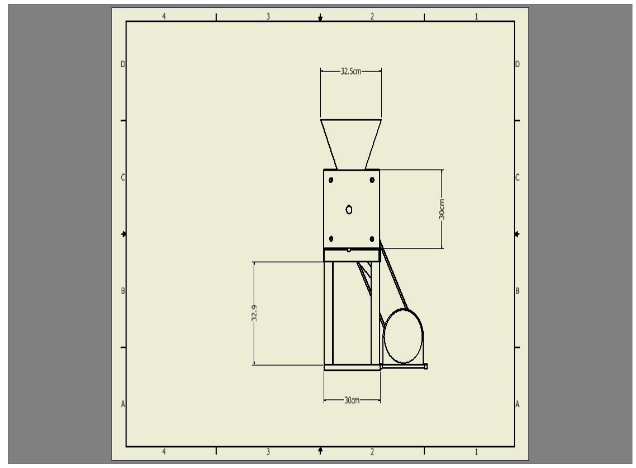
3. RESULTS AND DISCUSSION OF TESTING

The average oil extraction ratio, oil extraction efficiency, material discharge efficiency and machine capacity were17.90, 79.56, 96.92% and 0.532 tons of bunches/hr respectively. The machine operates smoothly during testing without frequent jamming. The result obtained from the tests shows that the oil palm screw press effectively extract the crude oil from the digested palm fruit (mash).

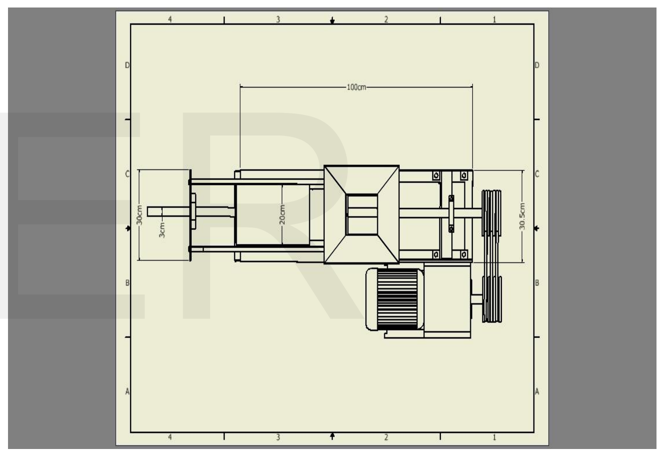
4. CONCLUSION

An oil palm screw press was designed, constructed and tested for palm fruit extraction. The screw press was simple enough for local fabrication, operation, repair and maintenance. Powered by a 5hp three-phase electric motor, the screw press has average oil extraction ratio and oil extraction efficiency of 17.90 and 79.56% respectively from palm fruit with a production cost of USD650. The screw press can be used for small scale palm fruit oil extraction in the rural and urban communities. A palm fruit oil processing plant based on this technology can provide employment for at least two persons at the same time provide palm oil at affordable costs for rural and urban communities.

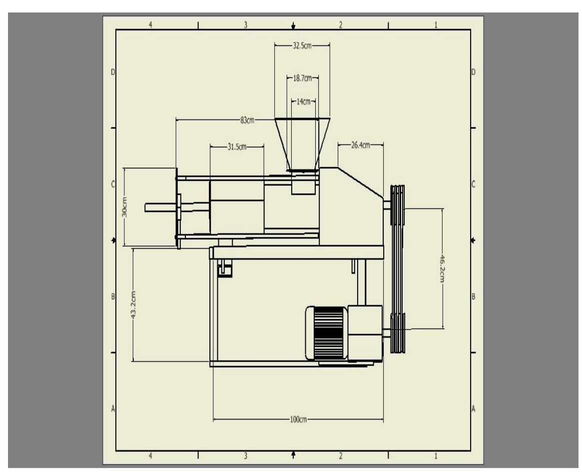
APPENDIX A: Isometric Drawing of the Oil Palm Screw Press Developed



Isometric drawing (front view).



Isometric drawing (plan view).



Isometric drawing (side view).

5. REFERENCES

[1]. PORIM in Palm Oil Factory Process Handbook Part 1, General Description of the Palm Oil Research Institute of Malaysia, 1985; p. 39, 55.

[2]. Babatunde O. O. Ph.D Thesis, Sterilization and mechanical digestion of oil palm fruit, Obafemi Awolowo University, Ile-Ife, Nigeria,1987.

[3].USDA in Palm Oil Production by Country in 1000 MT, available at http://www.usda.gov/ , 2011 retrieved 4th April, 2010.

[4]. Taiwo K. A., Owolarafe O. K., Sanni L. A., Jeje J. O., Adeloye K., and Ajibola O.O. Technological assessment of palm oil production in Osun and Ondo States of Nigeria, 2000; Technovation, 20, 215-223.

[5]. Owolarafe O. K., Faborode M. O., & Ajibola O. O. "Comparative evaluation of the digester-screw press and hand-operated hydraulic press for oil palm fruit processing", Journal of Food Engineering, U. K., Vol. 52, PP. 249–255, 2002.

[6]. Owolarafe O.K., Olabige M.T., and Faborode M.O. "Macro-structural characterization of palm fruit at different processing conditions" J. Food Eng., Vol. 79, PP. 31-36, 2007.

[7]. Ademosun O. C. The challenges of Development of Agricultural Engineering practice within a democratic system in Nigeria, Proceedings of COREN 11th Engineering Assembly held at the International Conference center, Abuja, Nigeria, PP. 36-50, 2002.

[8]. Olukunle O. J. Ph.D. Thesis, Development of an Indigenous Combine Harvester, Federal University Of Technology, Akure, Nigeria, 2002.

[9]. Ademosun O. C., Adewumi B. A., Olukunle O. J. and Adesina A. A. "Development of Indigenous Machines for Weeding and Grain Harvesting, FUTA Journal of Engineering and Engineering Technology, Vol. 3 No. 2, PP. 77-84, 2003.

[10]. Agbetoye L. A. S. "The Unsolved Problem of Cassava Harvesting Mechanization: Why and How? An Invited Paper Presented at the technical session of the Bi – Monthly Meeting of the Ondo State Branch of the Nigerian Institution of Agricultural Engineers, held at the Rufus Giwa Polytechnic, Owo, Ondo State, 11th January, 2004.

[11]. Shigley, J. E., & Mischke, C. R. "Mechanical engineering design, 6th edition, New York: McGraw-Hill Companies, Inc., Chapter 18, 2001.

[12]. Khurmi, R. S., & Gupta, J. K. "A textbook of machine design, 14th edition, New Delhi: Eurasia Publishing House (PVT) Ltd., Chapters 7 & 14, 2008.

[13]. Hall A.S, Holowenko A.R. and Laughlin H.G. "Theory and problems of machine design, 51 metric edition, schaum's outline series, McGraw-Hill book company, New-York, America PP. 113-130, 1980.

[14]. Ryder G. H. "Strength of materials, 3rd edition, London: Macmillan Publishers Ltd., Chapter 15, 1985.

[15]. Onwualu A. P., Akubuo C. O., & Ahaneku I. E. "Fundamentals of engineering in agriculture", 1st edition Lagos: Immaculate Publications Ltd., 2006.