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Development of Integrated Coconut Oil Processing Machine

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ABSTRACT: Coconut oil extraction involves several stages and each of these stages require different machine, therefore, the objective of this research work is to develop a low-cost integrated unit machine for the extraction of coconut oil using standard procedures. The extraction process involves the cutting mechanism with the help of the transmission belt and pulley to slice the coconut meat. The chip is heated by the heating system after which it is pressed. The coconut oil drops on the oil tray, it passes through the oil tray to the oil tank. A 5kg sized Copra was used to examine the performance of the machine. Data obtained reveal that the required heating time was 15mins with a heater band of 2000 watts at 80°C. After the heating process a compression time of 8mins was recorded, taking place in the pressing cage with a compression ratio of 0.097 for the extraction process. This integrated method employed in the extraction of coconut oil is effective in terms of quality of oil produced, low-cost, time conservation and ease of usage. Therefore, regulatory bodies and governmental agencies could invest in this machine to be used by low income/small scale business operator.

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Coconut oil extraction is the process that has been into existence for a very long time and the production industry is regarded as one of the promising industries. Its benefits include it being used as raw material for enhancing beauty products or even for products for treating minor illness (Mansor *et al.*, 2012). Having the knowledge of a clear definition of Coconut oil is an important point of focus. It is also defined as the oil extracted from the coconut kernel through the tradition or mechanized means with or without the application of heat provided that there is no transformation or change of the oil (Mansor *et al.*, 2012). Extraction process is done in several ways which includes wet and cold extraction which are conventional processes (Nwadinobi and Ikeme, 2021). The wet extraction process is done by crushing the coconut meat to yield coconut milk which is stored in the fermentation tank present in the machine, the milk is allowed to ferment for hours, then changes to water and oil which is being separated, after which heating takes place. It is heated at high temperature that could remove the micronutrients, this process is not time conservative (Papade *et al.*, 2016). The cold extraction process is done by destabilization of coconut milk emulsion without heating the fermented milk, chilling and thawing or centrifugation (Jer Ng *et al.*, 2021). The oil extraction technology has been applicable for a very long time in the developed countries and the methods used in extracting the oil are laborious and relatively inefficient. There has not been any significant improvement in the oil extraction processes and even today a century old technology such as single screw press, hydraulic presses are being used. The product rate of coconut oil is affected by time factor, in order

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to eliminate existing limitation to a greater degree, the dry extraction method is proposed. This eliminates the need for crushing and fermentation which takes up to hours or a whole day in the preparation of coconut oil. Coconut oil is widely used and the need for coconut oil keep increasing cause of its value (Papade *et al.,* 2016). Industrial application of coconut oil include Helmiyati and Suci (2019) with the formation of biodiesel methyl esters was formed more efficiently, further promising a future application of coconut oil in fuel industries. Jaggernauth-Ali *et al.* (2015) stated that catalyst analysis may also be achieved with calcined marlstones to increase the biodiesel yield as well. In addition, Jaarin *et al.* (2014) laid emphasis that it was found that coconut oil has a potential in reducing cardiovascular risk factors. Joondan *et al.* (2020) also stated that to combat the pandemic caused by the covid-19 virus, studies were carried out on the antibacterial properties of coconut oil as well.

The dry oil extractor is a screw type machine, which presses nuts through a caged barrel-like cavity. Coconut enters through the hopper, sliced, heated, pressed and oil exit the other side. The machine uses friction and continuous pressure from the screw as it drives in and compresses the coconut meat. The coconut oil drops through small openings that do not allow solid fiber or chaff to pass through. Afterward, the pressed copra is formed into a hardened cake, which is removed from the machine through the barrel discharge. For enhancement, the development of this project, since separate machine is there for all this process, the processes were integrated into a single machine. The best scale down version of the helical thread is to use a screw press in a cage barrel or press chamber. It will act as a miniature extractor and it will be cost-effective for a setting up a small business. The dry coconut oil extractor in this work is such that is suitable for small business where the total cost of setting up and running the machine is low and can be handled by non-professionals. Therefore, the objective of this research work is to fabricate a low-cost integrated single machine for the extraction of coconut oil.

MATERIALS AND METHODS

The materials used for the fabricated coconut oil processing machine are shown in table 1.

Design Consideration: There are lot of things that were considered during the design of the oil extracting machine. There is the need to design the press barrel to accommodate the required quantity of coconut. Easy usage of the machine, the availability and construction of the machine materials. Need to design a slicer that will slice the coconut meat into desired chip instead of crushing. Need to design the screw press to ensure maximum pressing and conveyance of the coconut. Concern to incorporate a heating element to pre-heat coconut by conduction before extraction. It was considered to build a strong machine frame to ensure stable and firm support for machine parts.

Table 1: Part of the coconut oil processing machine

Parts	Materials Used
Hopper	Stainless Steel
Slicer	Stainless Steel
Industrial bearings	Mild Steel
Oil outlet	Stainless Steel
Cone	Stainless Steel
Pulley	Mild Steel
Belt	Rubber
Chamber Cover	Mild steel
Machine Frame	Mild Steel
Bolt and Nut	Mild Steel
Electric Motor (2 hp)	Cast Iron with Winding
Electric heater	Stainless Steel
Oil Barrel	Stainless Steel
Funnel	Stainless Steel
Conveying Shaft	Stainless Steel
Machine Stand	Galvanized steel
Cake outlet	Mild steel

The following assumptions for design consideration were made:

i. Pressure development does not take place in the feed section. The pressure development and extraction of oil takes place at the press section.

ii. Coconut meat mass temperature is at constant rate in the ram section. Furthermore the temperature would increase along the ram section due to the shearing action of the shaft.

iii. As the oil-solid mixture passes through the section it is subjected to radial pressure exerted by the worm shaft. The pressure causes flow of oil in the radial direction through the solid matrix and out through the barrel slot. The oil-flow in turn changes the flow rate of mixture in the axial direction.

Description of the Coconut Oil Extractor: The coconut oil extractor consists of an electric motor, feed hopper, slicer, extracting chamber, heater, conveying shaft, oil barrel, oil outlet, belt, pulley and machine frame.

The machine frame: This forms the housing of the whole machine components, including the motor. It has to be rigid to withstand all the forces generated in the component parts during operation and ensure continuous service with less vibration.

The Hopper: The hopper is a stationary part and mounted onto the machine. It forms the receptacle through which coconut meat is admitted into the machine for extraction. Feeding does not need any energy; gravity is sufficient for feeding. The passage

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hole of hopper has a moving grater to drag in the meat to the extracting chamber for pressing after crushing.

The Slicer: The slicer is a blade like component used in slicing the fresh coconut meat into desired chip. The blades are mounted vertically on the rotating shaft of about 20mm which is fixed inside the hopper mounted onto the machine.

Extracting Chamber: The extracting unit consists of a cylindrical barrel that housed a screw shaft to squeeze and transport the coconut meat, slots are provided on the bottom part of the barrel so that the pressed oil can drain through them.

Oil and Cake Outlet: The oil outlet is located below the press barrel, while the cake outlet is located at the end of the press barrel. They are made of mild steal.

The Electric Motor: This consists of a 2 hp, 1450 rpm, and single-phase AC electric motor. Speed of the motor is a high and low torque guided by the power requirements for driving the machine, transporting the coconut in the pressing barrel, crushing and exerting sufficient pressure for oil extraction.

The Conveying Shaft: The shaft speed is low and there is an accurate rigid axial alignment, the shaft assembly consists of a shaft fitted with worms of different pitches. The configuration of the worm section is such that the volume displacement at the feed section of the press is equal to the discharge end. The conveying shaft is enclosed inside the cylindrical barrel. The worm conveys the nuts through the barrel land at the same time exert pressure on the material.

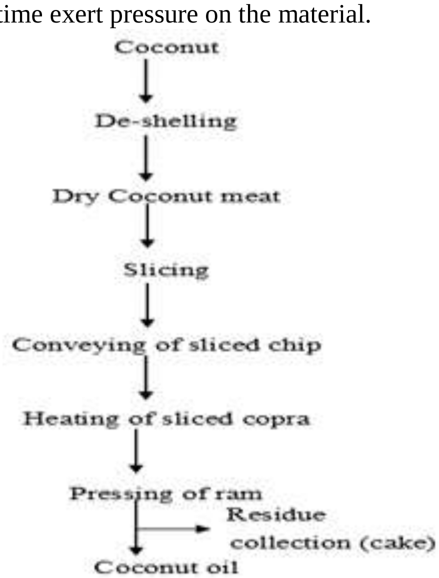
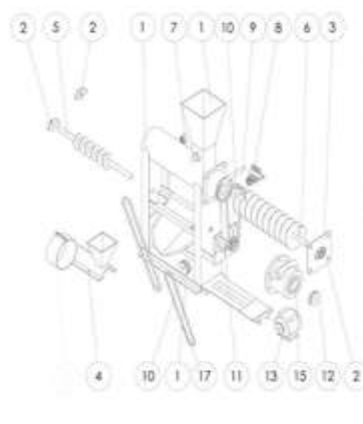


Fig. 1: Flow chart for the coconut oil extraction process

Design Calculations

Design Methodology: The volume, V_t of the drying trough will be determined using the relationship in Equation (1). Since a discharge/evaporation space will be required in the drying trough, it is assumed that half the volume of the dissected cylinder from which the trough will be formed shall be occupied by the total quantity of coconut copra for each processing batch. Thus, the total volume, V_c occupied by the coconut copra in the drying trough will be determined using the relation in Equation (2) and also the mass of coconut copra in the drying trough for each batch processing will be determined using the relation in Equation (3). Where l, r and ρ represent the radius of the cylindrical trough, length of the trough and bulk density of the coconut copra.



ITEM NO.	PART NUMBER	QTY.
1	Structur	1
2	Bearing case	4
3	Flang cover	1
4	expeller	1
5	expeller screw	1
6	screw	1
7	Bearing	2
8	slicer	1
9	slicer shaft	1
10	Pulley2	3
11	expeller pulley	1
12	Electric Motor	1
13	pulley	1
14	big pulley	1
15	Gear Box	1
16	Belt1	1
17	Belt2	1
18	Belt3	1
19	Electric Heater	1

Fig. 2 View of Coconut Oil Processing Machine with Labeled Parts

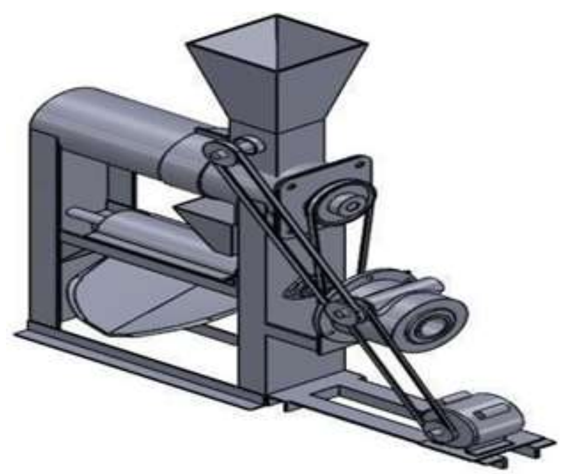


Fig. 3 Exploded View of Coconut Oil Processing Machine

$$V_t = \pi r^2 l \qquad (1)$$

$$V_c = {}^1\!/_2\, \pi r^2 l \qquad (2)$$

$$m_c = \rho \times V_{bf} \qquad (3)$$

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The heat required for drying the coconut copra (Q) will depend on the drying temperature(ΔT), specific heat capacity of the coconut copra (C_c) and mass of the coconut copra in the trough (m_c)during the drying process. The heat source which will be utilized in this design is an electric band worn within the bottom of the trough and the quantity of heat required will be obtained using eqn. (1).

$$Q = m_c \times C_c \times \Delta T \qquad (4)$$

To achieve gradual stirring process, a paddle is incorporated in the machine design and its slow speed is achieved by using a a speed reducer with respect to the speed of the electric motor (driver). The velocity ratio of the driver and driven pulleys will be obtained using equation 5 below where N and D are the speed and diameters of the pulleys also the subscripts $_1$ and $_2$represent the driver and driven pulleys respectively.

$$VR = \frac{N_1}{N_2} = \frac{D_2}{D_1} \qquad (5)$$

An assumed velocity ratio of 1:10 speed reducer driven by the electric motor via belt and pulley drive will be used to drive the paddle shaft due to the required large pulleys. Also, the design center distance between the pulleys of the paddle /screw conveyor drive will be determined using the relation in Equation 6 and the length of the belt required for the paddle shaft/screw conveyor drive will be determined using Equation 7. The speed of belt, v of the paddle shaft/ screw conveyor drive will be determined using the relation given in Equation 8 and the angle of lap, θ of the belt on the small pulley of the Paddle shaft/screw conveyor drive will be determined using Equation 9. Similarly, the tensions on the tight side, T_i and the slack side, $T_j$of the belt will be determined using Equations 10 and 1l respectively (Sharma and Aggarwal, 2006; Khurmi and Gupta, 2005).

$$C = \frac{1.5D_2}{(VR)^{1/3}} \qquad (6)$$

$$L = 2C + 1.57\,(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C} \qquad (7)$$

$$v = \frac{\pi D_2 N_2}{60} \qquad (8)$$

$$\theta = 180 - 2\left[\sin^{-1}\left(\frac{D_2 - D_1}{2C}\right)\right] \qquad (9)$$

$$T_i = T_{max} - T_c \qquad (10)$$

$$T_{max} = \sigma \times a \qquad (11)$$

$$T_c = mv^2 \qquad (12)$$

$$2.3\log\frac{T_i}{T_j} = \mu\theta cosec\beta \qquad (13)$$

The shaft diameters, d of the paddle shaft and the screw conveyor of this machine will be determined using the maximum stress relations given in Equation 14. Where τ, $M_t, M_b, K_b,$ and K_t are the allowable shear stress for paddle shaft with provision for key ways, maximum twisting moment on the shafts, maximum bending moment on the shafts, Combined shock and fatigue factor for bending and combined shock and fatigue factor for twisting respectively. The maximum twisting moment, M_t on the paddle/screw conveyor drive will be determined using equation 15 and also bending moments which occur on the shafts as a result of applied loads and belt tensions will be determined quantitatively.

$$d = \left[\frac{16}{\pi\tau}\left(\sqrt{(K_b M_b)^2 + (K_t M_t)^2}\right)\right]^{\frac{1}{3}} \qquad (14)$$

$$M_t = \left(T_i - T_j\right)\frac{D_2}{2} \qquad (15)$$

The power, P required for the operation of this machine is the sum of the power required to drive the paddle and to convey the dried coconut copra along the pressing chamber and pressing the dried coconut copra. Where $Q,\ F, \rho, p, h, N$ and T are the conveying capacity of the screw conveyor, material factor bulk density of coconut copra, pitch length of the screw conveyor, depth of the coconut copra in the drying trough, maximum speed of the paddles and twisting moment on the paddle shaft respectively (Burr and Chetam, 2002).

$$P = \frac{47.2(h^2) \times p \times N \times L \times \rho \times F}{4560} + \frac{2\pi NT}{60} \qquad (16)$$

Performance Evaluation and Analysis: The integrated coconut oil processing machine was tested after fabrication to evaluate its performance and the test performance indicators which include the throughput, TP pressing efficiency, η and the specific energy consumption, SE of the machine was determined under varying space between the fixed and rotating pressing disks (mm), pressing speed (rpm) and operational parameters using the following relations.

$$TP \ (kg/hr) = \frac{M_c}{t} \qquad (17)$$

$$\eta(\%) = \frac{M_o}{M_c} \times 100 \qquad (18)$$

$$SE\ (KJ/kg) = \frac{Pt}{1000 \times M_o} \qquad (19)$$

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Where: M_o = the mass of the coconut oil is extracted and t is the processing time for drying and pressing.

RESULTS AND DISCUSSION

From the results tabulated in table 2, the moisture content obtained from the five experimental runs from drying the coconut meat which weighs 1kg, 1.5kg, 2.5kg, 3.5kg and 4.5kg are 4.5%w.b, 3%w.b, 5%w.b, 4%w.b, and 5%w.b respectively. The drying time of the coconut meat increases with increases in the weight of the coconut meat feed into the extractor. In figure 4, the increase and decrease in the moisture content varies with the dried weight, the downward curve to the left in the graph indicates the reduction in moisture content with respect to increasing time.

Table 2: Weight of oil, cake and oil yield

Original Weight (kg)	Oil Weight (kg)	Cake Weight (kg)	Oil yield (%)	Extraction Time (sec)
1.0	0.08	0.8	8	100
1.5	0.2	1.2	16	140
2.5	0.4	2.0	19	160
3.5	0.5	2.8	23	180
4.5	0.99	3.0	25	180

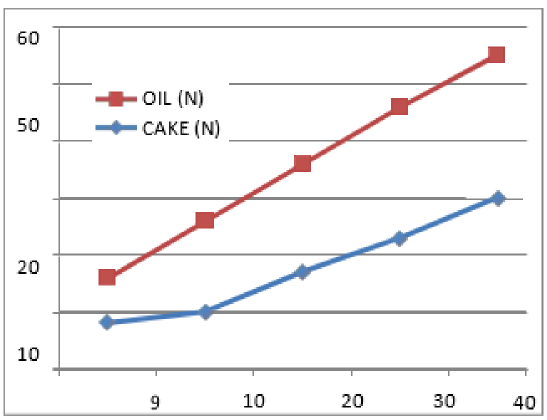

Fig 4: The graph of original weight against oil and cake yield

From figure 4, the graph shows that as the quantity of coconut fed into the hopper increases, there is an accompanying increase in the quantity of oil and cake yield. Therefore, the original weight is directly proportional to both the oil and cake yield. In addition, for a fresh cut coconut meat, it takes a longer time to leave the hopper to the extraction chamber because of much moisture which prevents ease of movement due to adhesive force along the stainless conveying chamber. In other samples, the reducing time shows the effect of drying. Drying brings out more oil which decreases friction and adhesive forces. The extraction time for each sample differs due to different moisture content. The extraction time gets low with reduced moisture content while samples with high moisture content have longer extraction time.

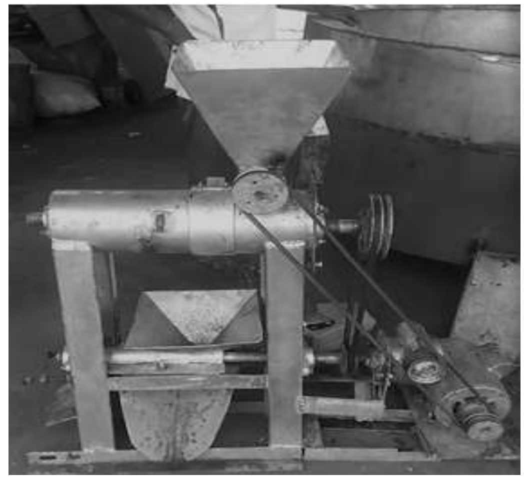

Fig 5: Picture of fabricated machine

Conclusion: The development of an integrated coconut oil processing machine has effectively offered a quality low-cost coconut oil extraction process. With components like heater band heating the sliced coconut of 5kg at 80°C for 15min with an extraction compression ratio at 0.097, a motorized speed of 1045 rpm. It was noted that a 5kg of sliced coconut yielded 1.075kg mass of oil. The machine availability is scaled down and likely to be made affordable in an average home in Nigeria because it is designed for both home and industry usage. This integrated method employed in the extraction of coconut oil is effective, low-cost and easy to use. This is because the coconut oil is a major product that is of utmost importance in regards to health and commercialization making both individuals and industries major beneficiaries.

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