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ORIGINAL RESEARCH ARTICLE

DEVELOPMENT AND PERFORMANCE EVALUATION OF A MOTORIZED TIGERNUT OIL EXTRACTION MACHINE

P. A. Omale[1]*, A. K. Aremu[2], M. O. Omobowale[2]

[1]*Department of Agricultural and Environmental Engineering, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria.*
[2]*Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Oyo State, Nigeria*
**Corresponding author's email address: omale.paul@uam.edu.ng*

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ABSTRACT

Tiger nut is a common nut in Africa which contains 24.5% oil. The extraction of this oil has been a major challenge to developing countries as most oil is locally extracted because of high cost of importation of oil expellers. A motorized tiger nut oil extracting machine was designed and fabricated consisting of four sections namely feeding, extraction, heating and power sections using available local materials, and was evaluated and optimized. The oil yield (OY), operational rate (OR), extraction efficiency (EE), throughput capacity (TC) and extraction loss (EL) of the machine were determined as affected by barrel temperatures (BT) of 30°C, 45°C, 60°C range, screw speeds (SS) of 60 rpm, 75 rpm, 90 rpm range., 0.5 mm, 1 mm, 1.5 mm range of choke clearance (CC) of the machine and yellow/brown varieties of tiger nut. The optimum ER, EE, OY, EL and TC values of 9.93 kg/hr., 89.02%, 23.78%, 1 kg/hr. and 50.06 kg/hr. were achieved at 60°C barrel temperature, 60 rpm and 0.5 mm choke clearance while the lowest values gotten at 30°C barrel temperature, 90 rpm and 1.5 mm choke clearance were 6.33 kg/hr., 52.40%, 13.90%, 0.33 kg/hr. and 33.96 kg/hr. respectively. Analysis of variance revealed that barrel temperature, screw speed, choke clearance and variety have significant effects on all the machine parameters evaluated at p<0.05 except for the EL. The evaluation results revealed that the brown tiger nut has more oil than the yellow tiger nut and that the developed machine is deemed efficient for small scale tiger nut oil production.

1.0 Introduction

The extraction of oil from oil seeds and nuts such as cotton, soyabean, olive, corn, mustard seed, palm tree, coconut, carrot, groundnut, sunflower seed, rapeseed, sesame, castor seed etc. across the globe is a common practice and have played a significant part in human diet as source of fat and oil (Aremu and Ogunlade, 2016, Akomaye and Fehintola, 2019). The oil extracted from these oil seeds and nuts are applied in different areas and for different purposes such as food nutrients, cosmetics, medications, Biodiesel, paints (Samaila and Chukwu, 2014, Omale and Omobowale, 2018, Yusuf, 2018). The extensive range of applications for vegetable oil and the high demand in society attract researchers to explore and uncover new oil seeds. Bamgboye and Adejumo (2011) emphasized the vital role of oil extraction in oil seed processing, highlighting its significance in terms of quality and quantity. They also noted that extraction methods include chemical, mechanical, and traditional approaches. Various extraction methods have different oil yield which can be improved upon by optimizing the extraction conditions (Divine and Anuanwen, 2020, Naquib and Faisal, 2020).

Africa is reported to have produced several oil seeds, with oil palm, groundnut, soybeans, and cotton topping the list as observed by Boadi et al. (2022) where many other oil seeds and nuts have not been utilized such as tiger nut are in abundance. Yet, the demand of vegetable oil in Africa (especially Nigeria) is more than its supply as such, causes constant increase in the price of available vegetable oil.

Tiger-nut (*Cyperus esculentus* L) is a grass like root plant that is rich in nutrients needed by both human and animal. It is cultivated in many African countries including northern Nigeria (Omale *et al*., 2020). Tiger nut has 24.5% oil (Zhen-shan *et al*., 2022). It has different varieties and have different names by different ethnic groups. It is generally known in Nigeria as "Aya" in Hausa, "Ofio" in Yoruba, "Akiausa" in Igbo and "Shoho" (Awulu *et al*., 2018 and Omale *et al*., 2020). Itcontains golden brown oil which is consumable compared to several other vegetable oil because of its nutritional quality (Yali *et al*., 2022, Ezebor *et al.,* 2005). However, the manual process of extracting the oil from tiger nuts is time-consuming and labor-intensive. Bamgboye and Adejumo (2007) and Olayanju et al. (2006) found that the traditional extraction method is widely used in Africa due to expensive imports of oil expeller and screw press, resulting in slow, tedious, time-consuming, and demotivating oil extraction processes. In an effort to improve efficiency and increase production, the development and performance evaluation of a motorized tiger nut oil extraction machine was undertaken. This machine is expected to revolutionize the tiger nut oil extraction industry, offering faster and more efficient oil extraction potential.

2 Methodology

2.1 Design Conception

The developed tiger nut oil extraction machine has five main components: the feeding, extraction, power, heating, and the frame components. The feeding section is made up of stainless-steel hopper, while the extraction section has a screw shaft, barrel, barrel guide, cake collector, oil collector, and choke. The power section has an electric motor, gear box, belt, and pulleys. The heating section has a heating element, temperature sensor, and control panel, and the frame supports the other parts. Plate 1 shows the pictorial view of the machine while Figures 1, 2, and 3 show the machine's isometric drawing, exploded drawing, and orthographic drawing, respectively.

2.2 Design Consideration

The utmost consideration was given to the tiger nut's engineering properties, availability, durability, strength, corrosion resistance, and safety of construction materials, as well as overall cost.

2.3 Design of Machine Components

2.3.1 Design of the Hopper

The hopper was made with a stainless-steel material. The passing hole of the hopper was designed to be sizeable enough to avoid choking of the materials using a mass flow pattern as described by Khurmi and Gupta (2008).

The volume of the hopper was calculated using equation 1:

$$V = \frac{1}{3} \times h \times (a^2 + b^2 + ab) \quad (1)$$

where: V = volume, h = height of the Hopper, a = length of the larger base, b = length of the smaller base

2.3.2 Belt drive design

A rubber V-Belt was used to transmit power from the prime mover to the screw shaft by means of pulleys.

2.3.3 Selection of the pulleys of the machine

The diameters of the pulleys were selected considering the speeds (in revolutions per minute) to be transmitted between the electric motor and the screw (worm) shaft. The diameters of the pulleys were calculated using equation 2 as given by Khurmi and Gupta (2008):

$$N_1 D_1 = N_2 D_2 \quad (2)$$

where: N_1 = Speed of the electric motor (rpm), N_2= Speed of the screw shaft, (rpm),

D_1= diameter of the electric motor pulley (mm), D_2= pulley diameter of screw shaft

2.3.3.1 Distance between pulley centre

The distance between pulley centre was calculated from equation 3 (Cleghorn and Nikolai, 2015).

$$X = C^2 + ((R1 + R2) - (2R1R2\cos\,\Theta))^{0.5} \quad (3)$$

where: X is the distance between the centers of the pulleys, C is the distance between the axes of the pulleys, R1 and R2 are the radii of the two pulleys, and theta is the angle between the belts as they wrap around the pulleys.

2.3.4 Belt length

According to Shigley *et al.* (2011), the length of an open belt drive is given by.

$$\text{Belt Length (L)} = 2X + \frac{\pi}{2}(d_1 + d_2) + \frac{(d_2 - d_1)^2}{4X} \quad (4)$$

where: X = Distance between pulleys centre (mm), d_1= Driver (electric motor) pulley diameter (mm), d_2 = Driven (Screw shaft) pulley diameter (mm).

2.3.5 Design of the screw shaft of the oil extraction machine

The screw shaft is the major oil extraction part of the tiger nut oil extraction machine and acted upon by the material weight, pulley, and screw flights. When in use, the screw shaft conveys, press and squeeze the biomaterial for oil extraction.

2.3.5.1 Diameter of the worm shaft

To safeguard against bending and tensional stresses, the shaft diameter was estimated from equation 5 (Callister *et al*., (2018; Khurmi and Gupta, 2008; Adesoji *et al*., 2012).

$$d_s{}^3 = \frac{16T}{0.27\pi\delta_0} \quad (5)$$

where: d_s = Diameter of the screw shaft, T = Torque transmitted by the shaft (Nm) and

Δ_0 = Yield stress for stainless steel (N/mm^2).

2.3.5.2 Estimation of the pitches of the decreasing pitch screw conveyor

The inlet velocity of raw material (V) was estimated from Equation 6 (Jones and Kocher, 1995).

$$V = \frac{P_s \times \frac{\pi}{4}(D^2 - d^2)N}{4DL} \quad (6)$$

where: V = Inlet velocity (mm/s), P_s = Screw pitch (mm), D = Outside diameter of screw (mm), d = Inside diameter of screw (mm), L = Length of the screw shaft (mm), N = Shaft speed (rpm).

2.3.5.3 The screw winding length

The screw winding length (L) was estimated applying Pythagoras rule as the square root of the sum of squares of the circumference (C) of the shaft diameter and the screw pitch (P_s) (Omote and Mwangi, 2012) as given in Equation 7.

$$L = \sqrt{C^2 - P_s{}^2} \quad (7)$$

The circumference of the shaft diameter = πd (mm)

2.3.5.4 Axes of flight screw distance

Axes of flight screw distance was estimated applying the relation shown in Equation 8 (Fadeyibi *et al.*, 2016).

$$\frac{a}{D_s} \leq \frac{\sqrt{2}}{2} \quad (8)$$

where: a = flight axis distance (mm), D_s = barrel diameter (mm).

2.3.5.5 Maximum flight height

Maximum flight height (channel depth) (h_{max}) was estimated following the equation reported by Fadeyibi *et al.* (2016) as.

$$h_{max} = D_s - a \quad (9)$$

where: h_{max} = Maximum height of flight (mm), D_s = Barrel diameter (mm), a = flight axis distance (mm)

2.3.5.6 Helix angle (Pitch angle)

The helix angle (angle of pitch) at the barrel surface (α), which is associated to lead, and diameter was estimated applying equation 10 (Fadeyibi *et al.*, 2016).

$$\alpha = \tan^{-1}\left(\frac{P}{\pi D_s}\right) \quad (10)$$

where: α = Helix angle (°), P = Mean screw pitch (lead) (mm), D_s = Barrel diameter (mm).

2.3.6 Pressurized Cone (choke)

The choke was conical in shape and made of stainless-steel material which was attached to the shaft at the end of the screw flight to effectively pressurize the tiger nut.

The linear movement of the worm shaft was controlled by adjustable nuts that estimate the extraction ratio. The weight of the choke was calculated from Equations 11 and 12 (Hannah and Hillier, 1999).

Weight of choke = density × (Volume of cone – Volume of bore) (11)

$$W = \rho \times \left(\frac{1}{3}\pi(R^2 + r^2 + Rr)h - \pi r^2 h\right) \quad (12)$$

where: W = Weight of choke (kg), ρ = Density of stainless steel (kg/m^3), R = Bigger radius of conical choke (mm), r = Smaller radius of conical choke (h) = height of conical choke (mm).

2.3.7 Press cage (barrel) design

The press cage (barrel) was designed to have a large hole for feeding oil bearing material. This feeding hole was machined at the beginning of the screw shaft where the screw pitch was maximum. On the mid zone, the barrel has an oil outlet sieve.

The inner diameter of the press cage was determined from Equation 13 (Olaniyan, 2010).

$$D_I = D + 2C \quad (13)$$

where: D_I = Inner diameter of the press cage, D = Screw shaft diameter (mm),

C = Clearance between the internal wall of press cage and screw thread (mm).

The outer diameter of the press cage was estimated using equation 14 (Olaniyan, 2010).

$$D_I = 0.95\, D_0 \quad (14)$$

where: D_0 = Outer diameter of the press cage in mm.

The thickness (t) of the press cage was determined from equation 15 (Olaniyan, 2010).

$$t = D_0 - D_I \quad (15)$$

2.3.8 Screw press power requirement

The design of the tiger nut oil extraction machine considered the entire areas where power is needed such as power to overcome the inertia of the screw shaft, power to drive and convey the tiger nut through the entire length of the press, power to effectively press and squeeze out entrapped oil from the tiger nut and power compensation for friction and heat losses during operation. 2,982 Watts power was designed for to run the developed machine.

2.3.9 Design of machine frame

The frame was designed to avoid failure of the beam by bending and the column by buckling by considering the entire weight of components and constructed with mild steel material.

2.4 Machine Description

The isometric drawing, pictorial view, exploded views and orthographic projections of the machine assembly are presented in Figures 1 to 4.

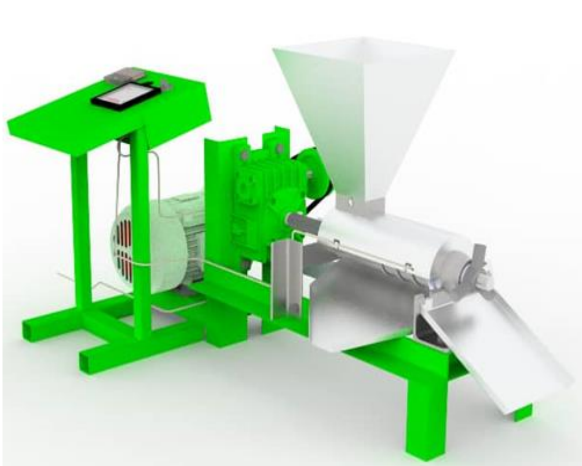

Figure 1: Isometric drawing of the tiger nut oil extraction machine

Figure 2: Pictorial view of the machine

ITEM NO.	PART NUMBER	QTY.
1	Heat Sensor	1
2	Barrel	1
3	Barrel Jacket	1
4	Barrel Frame	1
5	Hopper	1
6	Screw Connector	1
7	M12 Nut	8
8	Panel frame	1
9	Temperature meter	1
10	Switch	1
11	Bulb	1
12	Voltmeter	1
13	Panel	1
14	Panel Base	1
15	M12 Bolt	6
16	Gearbox	1
17	Electric Motor	1
18	Belt	1
19	Gearbox Pulley	1
20	EM Pulley	1
21	Oil Collector	1
22	Frame	1
23	Allen Key	2
24	Barrel Screw	1
25	Heat sensor holder	1
26	Heater	1
27	Choke Pin	1
28	Choke Washer	1
29	Choke Screw	1
30	Cake Collector	1

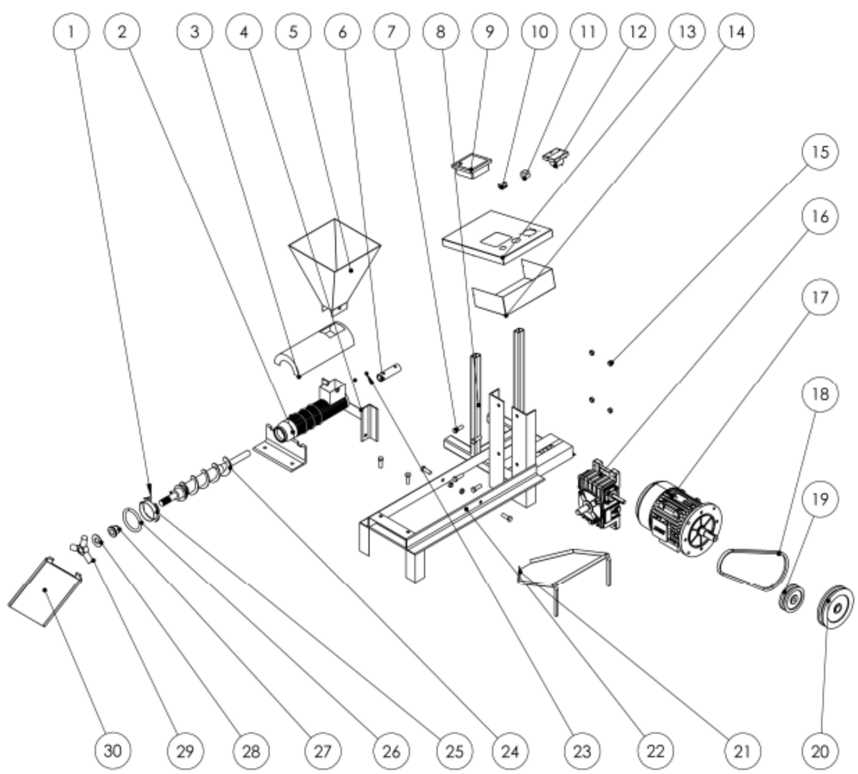

Figure 3: Exploded drawing of a motorized tiger nut oil extracting machine

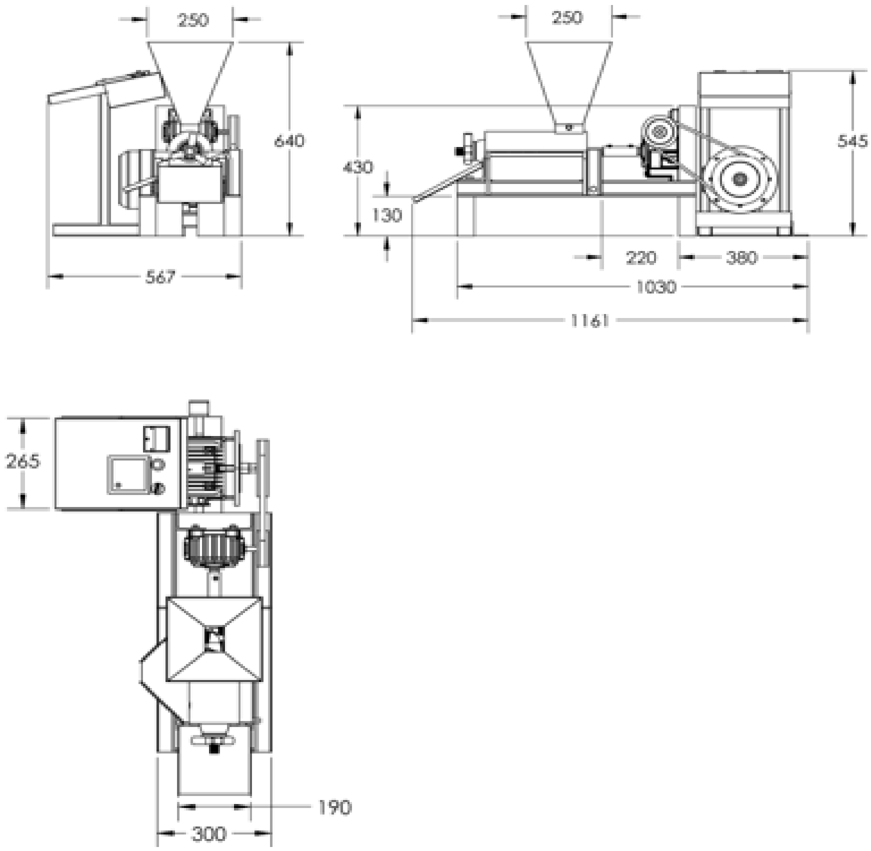

Figure 4: Orthographic drawing of a motorized tiger nut oil extracting machine

3 Performance Evaluation

The developed machine's throughput capacity, extraction rate, oil yield, extraction efficiency and extraction loss as affected by different machine parameters such as choke clearances (0.5mm, 1mm and 1.5mm), shaft speeds (60rpm, 75rpm and 90rpm), Barrel temperature (30°C, 45°C and 60°C) and variety (brown and yellow) were evaluated by operating the machine at different speeds, choke clearances and barrel temperatures respectively for tiger nut oil extraction.

3.1 Determination of the throughput capacity

This is the machine's capability in terms of quantity of tiger nut it processes per unit time. It was quantified using the relationship according to Adesoji *et al.* (2012) given in Equation 16:

$$O_R = \frac{W_{FS}}{T} \quad (16)$$

where: O_R = Rate of operation (kg/hr), W_{FS} = Weight of fed sample (kg), T = Operation time (hr).

3.2 Determination of the extraction rate

Extraction rate is the weight of oil that the machine could bring out per unit time (Adesoji *et al.*, 2012) and this was calculated applying Equation 17.

$$E_R = \frac{W_O}{T} \quad (17)$$

where: E_R = Extraction rate (kg/hr), W_O = Weight of oil extract (kg), T = Operation time (hr).

3.3 Determination of the oil yield

The extraction oil yield was expressed as the percentage fraction of the mass of extracted oil to the mass of pressed tiger nut sample. Tiger nut oil yield was calculated using the Equation 18 stated by Olaniyan and Oje (2011) and Adesoji *et al.* (2012) as:

$$O_Y = \frac{100\ W_{OE}}{W_{OE}+W_{RC}} \tag{18}$$

where: O_Y = Oil yield (%), W_{OE} = Weight of oil extracted (kg), W_{RC} = Weight of residual cake (kg).

3.4 Estimation of extraction efficiency

The extraction efficiency of the machine was evaluated by expressing the oil extracted as a percentage of the total oil content of the tiger nut samples. This was calculated using Equation 19 (Olaniyan and Oje, 2011; Adesoji *et al.*, 2012).

$$O_E = \frac{100\ W_{OE}}{XW_{FS}} \tag{19}$$

where: O_E = Extraction efficiency (%), W_{OE} = Weight of oil extracted (kg), W_{FS} = Weight of fed sample (kg) and X = Oil content of tiger nut in decimal.

3.5 Determination of extraction loss

Extraction loss is the fraction of the unrecovered sample to the fed sample. This was estimated according to Olaniyan and Oje (2011) and Adesoji *et al.*, (2012) using Equation 20:

$$E_L = \frac{100[W_{FS} - (W_{OE}+W_{RC})]}{W_{FS}} \tag{20}$$

where: E_L = Extraction loss (%), W_{FS} = Weight of fed sample (kg), W_{OE} = Weight of oil extracted (kg), W_{RC} = Weight of residual cake (kg).

4 Results and Discussion

4.1 Extraction rate

The oil extraction rate of the brown tiger nut ranged from 6.3312 - 9.9300 (kg/hr) while that of the yellow tiger nut ranged from 6.4708 -9.4070 (kg/hr) as shown in Figure 5. It was observed that the least extraction rate for the brown tiger nut was achieved when the machine was set to 30°C barrel temperature, speed of 90 rpm and choke clearance of 1.5mm and that of yellow tiger nut was gotten at 60°C barrel temperature, 90 rpm and 1.5 mm choke clearance. The highest extraction rate for both the brown and yellow tiger nut were obtained at 45°C barrel temperature, 60 rpm speed and 0.5 mm choke clearance. Analysis of variance revealed that tiger nut variety, barrel temperature, screw speed and choke clearance all have significant effects on the extraction rate of the developed machine at $p < 0.05$. The extraction rate was observed to increase as the choke clearance decreases and the speed and barrel temperature increases respectively.

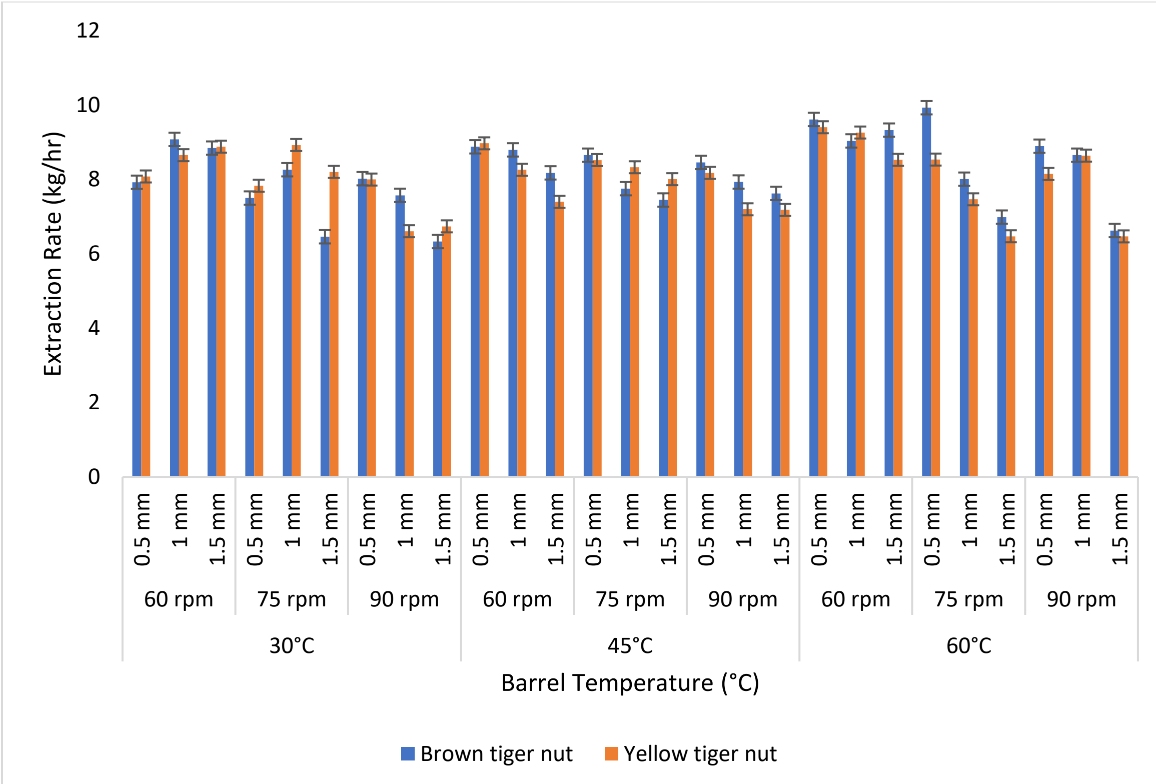

Figure 5: Extraction Rate results of the Machine

4.2 Extraction Efficiency

The extraction efficiency of brown tiger nut was found to be between 53.6616% and 90.22778% while that of yellow tiger nut was between 52.3990% and 89.0152% (Figure 6). It was observed that the lowest extraction efficiency for brown tiger nut was obtained at 60°C barrel temperature, 90 rpm speed, and 1.5mm choke clearance, and for yellow tiger nut it was also obtained at 60°C barrel temperature, 90 rpm speed, and 1.5mm choke clearance. The highest extraction efficiency for both brown and yellow tiger nut was obtained at 45°C barrel temperature, 60 rpm speed, and 0.5mm choke clearance, respectively. Analysis showed that the tiger nut variety, barrel temperature, screw speed, and choke clearance all have a significant impact on the extraction efficiency ($p < 0.05$) as shown on Table 1. The efficiency was found to decrease as choke clearance and speed decreased and as barrel temperature increased.

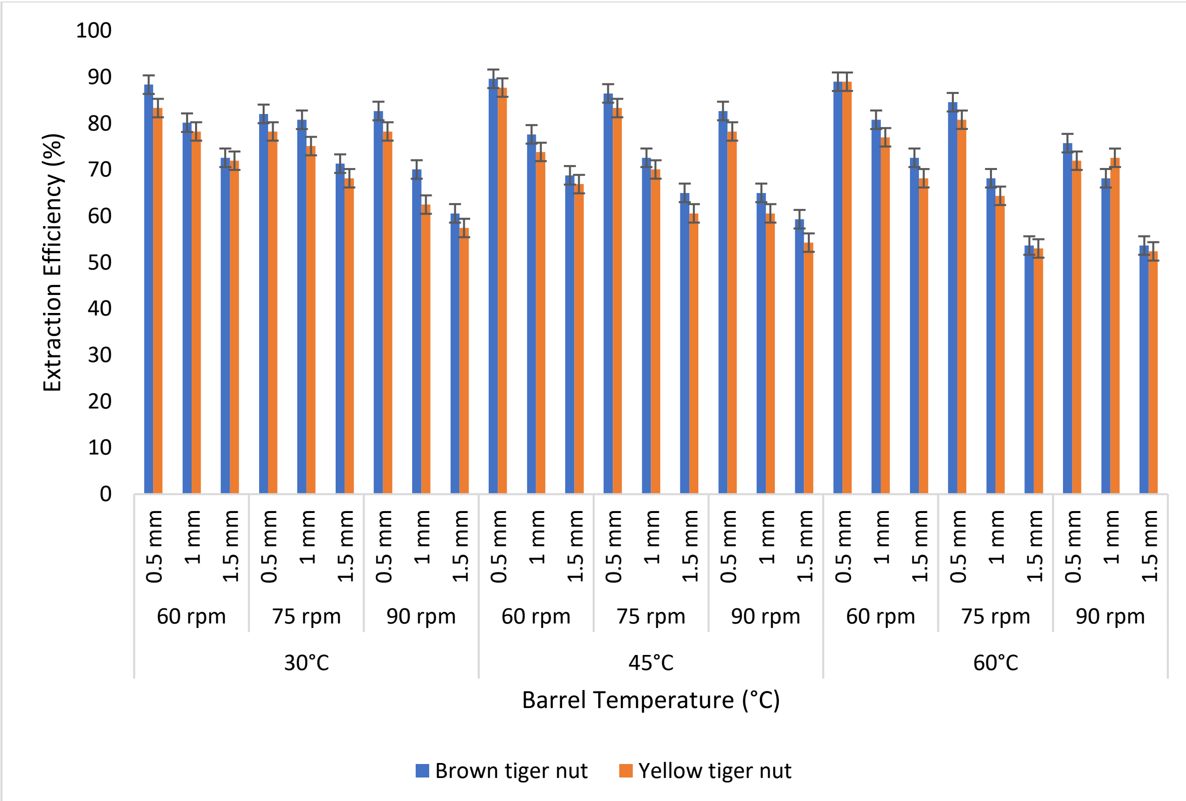

Figure 6: Extraction Efficiency of the Machine

Table 1: ANOVA Result of the Machine evaluation
Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Variety	Weight of Cake	.012	1	.012	107.884	**<.001**
	Weight of Oil	.011	1	.011	93.593	**<.001**
	Operation Time	7.697E-5	1	7.697E-5	49.330	**<.001**
	Extraction Rate	.846	1	.846	6.203	**.014**
	Extraction Efficiency	391.670	1	391.670	93.593	**<.001**
	Oil Yield	27.945	1	27.945	99.619	**<.001**
	Extraction Loss	.020	1	.020	.286	**.594**
	Throughput Capacity	43.736	1	43.736	32.209	**<.001**
Barrel Temperature	Weight of Cake	.008	2	.004	37.324	**<.001**
	Weight of Oil	.010	2	.005	44.228	**<.001**
	Operation Time	.001	2	.000	254.714	**<.001**
	Extraction Rate	5.468	2	2.734	20.046	**<.001**
	Extraction Efficiency	370.170	2	185.085	44.228	**<.001**
	Oil Yield	24.875	2	12.438	44.339	**<.001**
	Extraction Loss	.668	2	.334	4.770	**.010**
	Throughput Capacity	569.860	2	284.930	209.833	**<.001**
Screw Speed	Weight of Cake	.104	2	.052	485.451	**<.001**
	Weight of Oil	.103	2	.051	439.513	**<.001**
	Operation Time	7.421E-5	2	3.711E-5	23.780	**<.001**
	Extraction Rate	34.523	2	17.262	126.558	**<.001**
	Extraction Efficiency	3678.586	2	1839.293	439.513	**<.001**
	Oil Yield	260.172	2	130.086	463.744	**<.001**
	Extraction Loss	.334	2	.167	2.389	**.097**
	Throughput Capacity	52.439	2	26.220	19.309	**<.001**
Choke Clearance	Weight of Cake	.308	2	.154	1440.226	**<.001**
	Weight of Oil	.305	2	.152	1305.339	**<.001**
	Operation Time	.002	2	.001	488.747	**<.001**
	Extraction Rate	28.153	2	14.077	103.206	**<.001**
	Extraction Efficiency	10925.269	2	5462.634	1305.339	**<.001**
	Oil Yield	773.140	2	386.570	1378.083	**<.001**
	Extraction Loss	.049	2	.025	.352	**.704**
	Throughput Capacity	1205.484	2	602.742	443.882	**<.001**
Error	Weight of Cake	.012	108	.000		
	Weight of Oil	.013	108	.000		
	Operation Time	.000	108	1.560E-6		
	Extraction Rate	14.730	108	.136		
	Extraction Efficiency	451.963	108	4.185		
	Oil Yield	30.295	108	.281		
	Extraction Loss	7.560	108	.070		
	Throughput Capacity	146.652	108	1.358		

a. R Squared = .977 (Adjusted R Squared = .965)
b. R Squared = .974 (Adjusted R Squared = .962)
c. R Squared = .955 (Adjusted R Squared = .933)
d. R Squared = .893 (Adjusted R Squared = .841)

e. R Squared = .974 (Adjusted R Squared = .962)
f. R Squared = .976 (Adjusted R Squared = .964)
g. R Squared = .321 (Adjusted R Squared = -.012)
h. R Squared = .949 (Adjusted R Squared = .924)

4.3 Oil Yield

The oil yield of brown tiger nuts ranged from 14.2615% to 24.033%, while the yield of yellow tiger nuts ranged from 13.9028% to 23.6181%, as shown in Figure 7. It was noted that the lowest oil yields for both types of tiger nuts were obtained when the machine was set at 60°C barrel temperature, a speed of 90 RPM, and a choke clearance of 1.5mm. The highest oil yield for brown tiger nuts was obtained at 45°C barrel temperature, 90 RPM speed, and 0.5mm choke clearance, and for yellow tiger nuts, it was obtained at 45°C barrel temperature, 60 RPM speed, and 0.5mm choke clearance. An analysis of variance revealed that the tiger nut variety, barrel temperature, screw speed, and choke clearance all significantly impacted the oil yield of the machine, with $p < 0.05$. This aligns with the findings reported by Aremu and Ogunlade (2016) in their study of African oil bean seeds. The oil yield decreases as the choke clearance and speed increases but increases as the barrel temperature increases and this is because increased choke clearance and speed in an oil extraction machine reduce oil yield due to limited contact time, hindering efficient extraction. Conversely, higher barrel temperature improves oil yield by enhancing fluidity, reducing viscosity, and increasing solubility and separation, facilitating oil extraction.

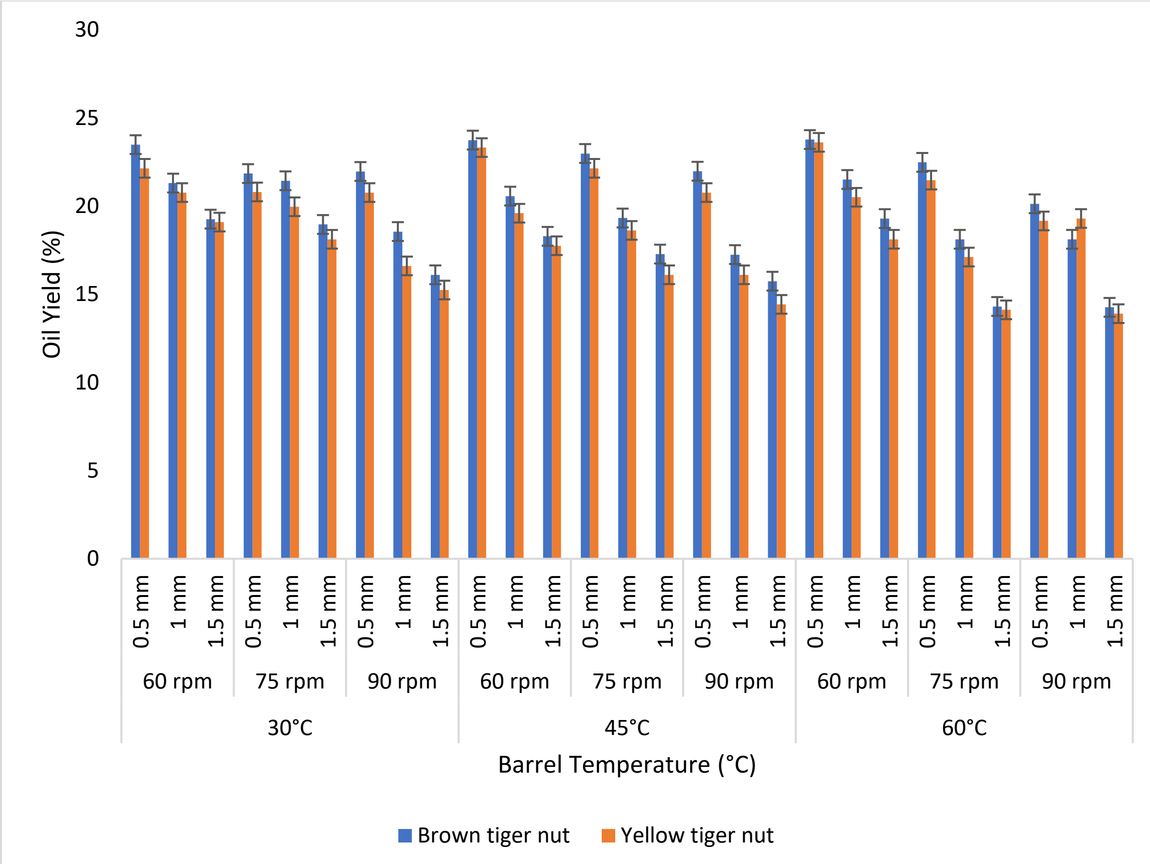

Figure 7: Oil Yield of the Machine

4.4 Extraction Loss

The extraction loss of brown tiger nuts varied from 0.5 to 1 kg/hr, while that of yellow tiger nuts ranged from 0 to 0.8333 kg/hr, as depicted in Table 2. It was noted that the lowest extraction loss for brown tiger nuts was achieved with a machine set at 30°C barrel temperature, 90 rpm speed, and choke clearance of 1.5mm, 1mm, and 0.5mm. For yellow tiger nuts, the lowest extraction loss was obtained at 60°C barrel temperature, 90 rpm speed, and 1.5mm choke clearance. The highest extraction loss for brown tiger nuts was achieved at 45°C barrel temperature, 90 rpm speed, and 1.5mm choke clearance, while the highest extraction loss for yellow tiger nuts was obtained at 45°C barrel temperature, 90 rpm speed, and 1.5mm choke clearance. Analysis showed that the factors of tiger nut variety, barrel temperature, screw speed, and choke clearance all had no significant impact ($p < 0.05$) on the extraction loss of the machine. The extraction loss increased as the barrel temperature, speed, and choke clearance increased, which is in line with the findings reported by Ishola *et al.* (2022).

Table 2: Results of the Extraction Loss of the Machine

			Brown Tigernut		Yellow Tigernut	
Barrel Temp. (°C)	Speed (rpm)	Choke clearance (mm)	Extraction Loss (kg/hr)	Std. Deviation	Extraction Loss (kg/hr)	Std. Deviation
30	60	0.5a	.6667	.28868	.6667	.28868
		1a	.6667	.28868	.5000	.00000
		1.5a	.5000	.00000	.5000	.00000
	75	0.5	.8333	.28868	.6667	.28868
		1	.5000	.50000	.6667	.28868
		1.5	.6667	.28868	.6667	.28868
	90	0.5	.6000	.17321	.5000	.00000
		1	.3333	.28868	.6667	.28868
		1.5	.6667	.28868	.5000	.00000
45	60	0.5	.3333	.28868	.6667	.28868
		1	.3333	.28868	.5000	.00000
		1.5	.6667	.28868	.5000	.00000
	75	0.5	.6667	.28868	.6667	.28868
		1	.8333	.28868	.5000	.00000
		1.5	.6667	.28868	.5000	.00000
	90	0.5	.6667	.28868	.5000	.00000
		1	.5000	.00000	.6667	.28868
		1.5	.5000	.50000	.6667	.28868
60	60	0.5	1.1667	.28868	.5000	.00000
		1	.8333	.28868	.8333	.28868
		1.5	.6667	.28868	.6667	.28868
	75	0.5	.6667	.28868	.6667	.28868
		1	.6667	.28868	.6667	.28868
		1.5	1.0000	.00000	.8333	.28868
	90	0.5	.6667	.28868	.8333	.28868
		1	.6667	.28868	.6667	.28868
		1.5	.6667	.28868	.5000	.00000

4.5 Throughput Capacity

Table 3 shows the throughput capacity of the developed machine to extract tiger nut oil varied between 33.9683 and 49.3333 kg/hr for brown tiger nuts and 36.7424 to 50.0580 kg/hr for yellow tiger nuts. The lowest processing throughput capacity for both types of tiger nuts was observed when the machine was set at a barrel temperature of 30°C, a speed of 60 rpm, and a choke clearance of 0.5 mm. The highest extraction throughput capacity for both brown and yellow tiger nuts was achieved at a barrel temperature of 60°C, a speed of 75 rpm, and a choke clearance of 1.5 mm. the analysis further showed that variety of tiger nut, barrel temperature, screw speed, and choke clearance significantly impacted the processing throughput capacity of the machine. In addition, an increase in choke clearance, barrel temperature, and speed leading to an increase in throughput capacity.

Table 3: Results of the Throughput Capacity of the Machine

				Brown Tigernut		Yellow Tigernut	
Variety	Barrel Temp. (°C)	Speed (rpm)	Choke clearance (mm)	Throughput Capacity (kg/hr)	Std. Deviation	Throughput Capacity (kg/hr)	Std. Deviation
	30a	60a	0.5a	33.9683	.54986	36.7424	.65608
			1b	42.8936	1.53289	41.8719	.85323
			1.5c	46.1538	.00000	46.7692	1.06588
		75a	0.5	34.6218	.58220	37.9032	.69841
			1	38.7366	1.25022	45.0142	.98692
			1.5	34.3044	.98053	45.5840	.98692
		90b	0.5	36.7424	.65608	38.7097	.00000
			1	40.9195	.79635	40.0297	1.33506
			1.5	39.5699	.74497	44.4444	.00000
	45b	60	0.5	37.5244	1.17321	38.7366	1.25022
			1	42.8936	1.53289	42.3645	.85323
			1.5	45.0142	.98692	41.8719	.85323
		75	0.5	37.9032	.69841	38.7366	1.25022
			1	40.4598	.79635	45.0142	.98692
			1.5	43.3862	.91643	50.0580	2.08756
		90	0.5	38.7366	1.25022	39.5699	.74497
			1	46.1994	1.77822	45.0142	.98692
			1.5	48.6667	1.15470	50.0580	2.08756
	60c	60	0.5	40.9195	.79635	40.0297	1.33506
			1	42.3645	.85323	45.5840	.98692
			1.5	48.6667	1.15470	47.3846	1.06588
		75	0.5	44.4851	1.64873	40.0297	1.33506
			1	44.4851	1.64873	43.9153	.91643
			1.5	49.3333	1.15470	46.1994	1.77822
		90	0.5	44.4851	1.64873	42.8936	1.53289
			1	48.0513	1.92359	45.0142	.98692
			1.5	46.7692	1.06588	46.7692	1.06588

5 Conclusion

A motorized tiger nut oil extraction machine was developed and evaluated to provide an economic means of processing oil from tiger nuts. The main aim of developing the machine is to provide the most economical means for processing oil from tiger nut. The machine achieved optimum extraction parameters at 45°C barrel temperature, 60rpm speed, and 0.5 choke clearance, resulting in a throughput capacity of 9.9kg/hr, 90.23% extraction efficiency, 24.032% oil yield, and 1kg/hr extraction loss. Lower values were obtained at 30°C barrel temperature, 90rpm speed, and 1.5 choke clearance. Analysis of variance revealed that barrel temperature, screw speed, choke clearance and variety have significant impacts on all the machine evaluated parameters at $p \leq 0.05$ except for the extraction loss. It is confirmed that the brown tiger nut has more oil than the yellow tiger nut and the developed machine is efficient for small scale tiger nut oil production.

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