Journal of Inventive Engineering and Technology (JIET)
ISSN: 2705-3865
Volume-2, Issue-2, pp.22-29
www.jiengtech.com
Research Paper Open Access

DEVELOPMENT AND PERFORMANCE EVALUATION OF A GROUNDNUT OIL EXPELLER

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ABSTRACT : *The research work was carried to develop and evaluate the performance of a groundnut oil expeller. Design analysis and calculations were performed so as to determine and select appropriate materials for the machine component parts. The machine components include kneader shaft, hopper, kneader blades, extraction chamber, oil outlet, bearing, pulleys and frame. The machine was designed to kneed 10 kg of groundnut paste per batch using an electric motor of 1 hp, 1450 rpm speed with head pulley of 50 mm diameter. The kneading speed and kneading time ranged between 250 – 400 rpm and 6 – 12 minutes respectively. The operation of the machine is based on the traditional method of oil extraction. However it saves time, reduces the drudgery and improves the quantity of groundnut oil produce by our local processors. The mean throughput capacity, mean percentage oil yield, mean oil loss and mean oil extraction efficiency were found to be 40.44 kgh-1, 35.9%, 19.4% and 80.6% respectively.*

KEYWORDS*: Groundnut paste, oil expeller, design, fabrication, throughput capacity, oil yield, extraction efficiency*

Date of Submission: 22-07-2022 Date of acceptance: 29-07-2022

I. INTRODUCTION

Groundnut is botanically called *Arachis hypogaea Linnaeus*, which came from Greek words, *Arachis* (a legume) and *hypogaea* (below ground) which means the formation of pods in the soil (Wikipedia, 2019). Groundnut is also known as peanut, *goober* in United States of America, monkey nut in United Kingdom, *guzhia* in Nupe language, *epa* in Yoruba language and *gyeda* in Hausa language. It is also commonly called the poor man's nut and today it is an important oilseed and food crop (Food and Agriculture Organization of the United Nations, FAO, 2002).

Groundnut is a major annual oilseed crop and a good source of protein. Oil and protein content, fatty acid and amino acid composition, taste and flavour are important quality traits of groundnut. Groundnut can contain up to 50% oil, although the usual range is 40% to 45% (Ajao *et al.*, 2010). The oil has a high smoke point, which makes it ideal for cooking in high temperature without burning. It is known to possess a light nutty aroma and a pleasant taste (Olatunde *et al.*, 2014).

Oil extraction is the process of recovering oil from oil-bearing agricultural products through manual, mechanical, or chemical extraction (Ketan *et al.*, 2017). The sequence of operations of traditional method of oil extraction include, shelling, sieving, cleaning and sorting, roasting, cooling, threshing, winnowing, milling, (grinding to paste), kneading (to extract oil), frying the residue to cake locally called *Kuli-Kuli* and cooking the oil to refine it (Eke and Maigida, 1995). Groundnut oil extraction in most developing nations such as those of the south Asia and Africa is usually done manually by hand, and like all other manual operations it is drudgery and time consuming (Ajao *et al.*, 2010).

Mechanical extraction process is a more suitable method for both small and large (commercial) capacity operations; this may be due to the fact that it is economical compared to other extraction methods (Orhevba *et al.*, 2013a). Oil expellers are power driven, and are able to process 8 to 300kg of groundnut per hour or even more depending upon the type of expeller used (Nnanna *et al.*, 2018; Khangar and Jaju, 2012)

In Nigeria, the traditional method of manual processing of groundnut seeds to oil using mortar and pestle is a problem to the women engaged in the groundnut oil extraction business. This is because the method is tedious, time consuming and also involves a serious drudgery (Maduako, *et al.*, 2004). Study revealed that 75% of the rural women engaged in groundnut processing used the traditional technologies (Lawan *et al.*, 2015; Dunmade, 1991). Northern Nigeria which is the highest producer of groundnut in the country mostly practices the traditional method which has poor quality, low output and low efficiency.

Also, it was found that amongst 436 processors of groundnut oil in three Northern States (Niger, Kaduna and Kano), 74% claimed that they were processing for income generation (Lawan *et al.*, 2015; Nalumansi and Kaul, 1992). The mechanical oil expellers are not readily available and when available it requires technical know-how. Hence, the need to design and fabricate a groundnut oil expeller that is affordable and can easily be operated and maintained by these oil producers.

II. METHODOLOGY

A. MATERIAL SELECTION

The knowledge of available materials and their properties for any design consideration cannot be overemphasized. Material selection depends on severity and type of stress to which the components of the machine are being subjected to. Stainless steel is a steel alloy with a minimum of 10.5% to 11% chromium content by mass. Stainless does not readily corrode, rust or stain with water as ordinary steel does. It has high strength and the ability to withstand high temperature. (Faluyi and Opadoja, 2018; Kline *et al.*, 2014). As a result of these properties, it is used for the fabrication of the kneading chamber.

The appropriate and readily available materials such as stainless steel sheet, stainless steel flat bar and angle iron were used for the fabrication of the oil expeller. The machine comprises of the following components; kneader blades, shaft, bearing, belt and pulleys, oil outlet and frame.

B. MACHINE DESCRIPTION

The appropriate and readily available materials such as stainless steel sheet, stainless steel flat bar and angle iron were used for the fabrication of the oil expeller. The machine comprises of the following components; kneader blades, shaft, bearing, belt and pulleys, oil outlet and frame. Figure 2.1 shows the exploded view of the machine and detail description of the machine component is given below.

a. Kneader shaft

This is the most important part of the machine which transmits power from the prime mover to the kneading chamber for oil extraction mechanism. It is made from high speed steel to resist bending and twisting action during the extraction. The shaft has 500 mm length and 25 mm diameter.

b. Kneader blades

The kneader blades are 2-blade assembly. They are made up of stainless steel of 5 mm thickness and 25 mm width arranged at an angle of 180^{o} to each other on the kneader shaft.

c. Kneading chamber

The kneading chamber is the oil extraction compartment. It is made of stainless steel sheet of 3 mm thickness this was chosen due to its resistant to corrosion. It is fabricated in cylindrical shape with dimensions of 400 mm height and 300 mm diameter. The kneading chamber is provided with a lid to prevent splash to the surrounding environment.

d. Oil outlet

This is the point at which the extracted oil is collected. It is attached to the kneading drum at the bottom for easy flow of oil by gravity. It has a nob which regulates oil movement.

e. Bearings

These are machine elements that support shafts and allow circulatory motion of the shaft. They support kneading shaft for oil extraction mechanism at the top and at the bottom. Steel ball bearings of 35 mm diameter are used.

f. Pulleys and belt

Pulleys are grooved circular disc which accommodate belts for power transmission. Five pulleys of different diameters are used for performance evaluation of the machine, one for prime mover and the other four for four different kneading speeds. Belt is an element that transmits power from prime mover to the shaft. Belts are frequently necessary to reduce the higher rotational speed of electric motors to lower values required by mechanical equipment (Spott, 1985). A standard V-belt of 17 mm top width, 11 mm thickness and 18^o grove angle is selected.

g. Prime mover

This is the energy source that supplied power for the kneading operation. Based on the power requirement of the oil expeller, a 1 hp capacity and 1450 rpm speed electric motor with head pulley of diameter 50 mm was selected.

h. Frame

The frame is the main skeleton of the machine which bears the weight of the machine, provides stability and prevents wobbling and excessive vibration. It is made up of 25 mm by 25 mm angle iron of 3 mm thickness. Figure 1 shows the frame and the exploded view of the machine.

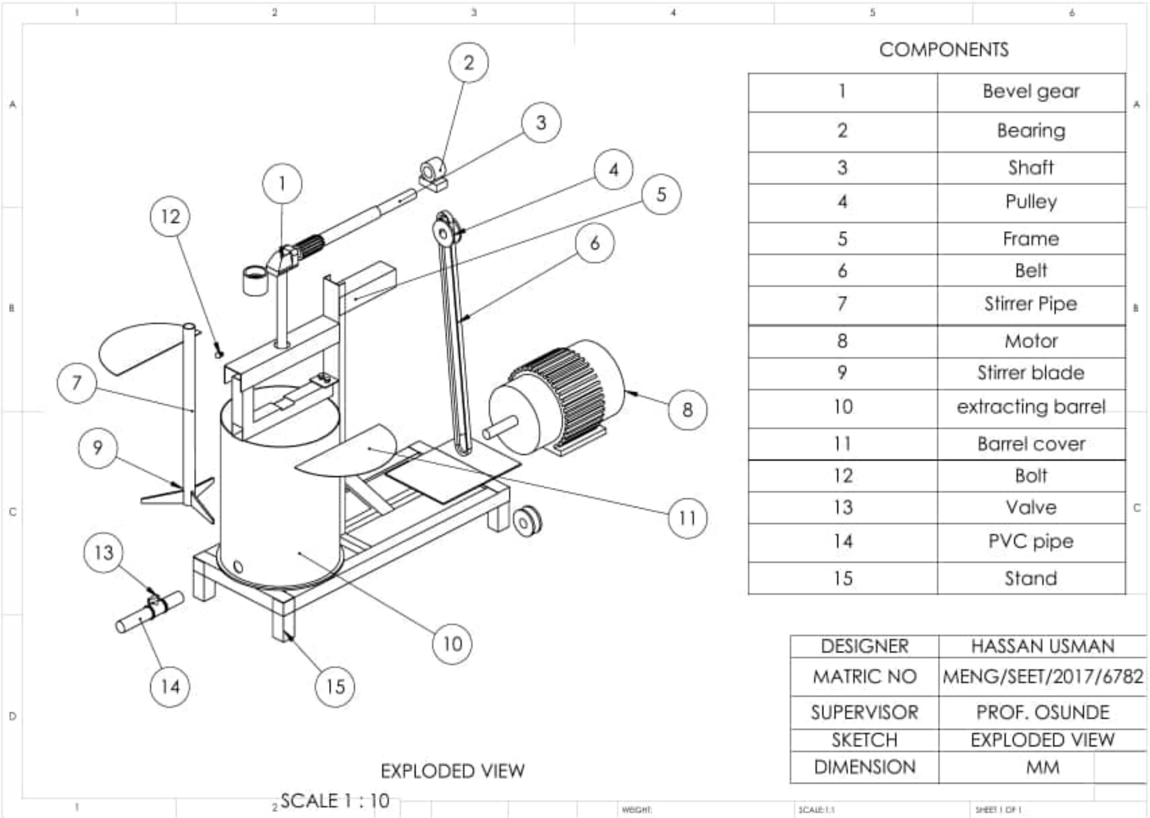

Fig. 1. Exploded view of the oil expeller

C. MODE OF OPERATION OF THE OIL EXPELLER

Groundnut paste of known quantity is introduced to the extraction chamber for kneading. Water of known quantity at a known temperature was added to the paste immediately to ease the kneading process. Once the electric motor is switched on, rotary power is transmitted to the kneading shaft through the V -belt. The high speed rotating shaft kneads the paste with the help of kneader blades. The kneading continues with addition of water at intervals until the oil begins to break away from the cake and process comes to an end when the colour of the mixture changes from milky to chocolate.

D. DESIGN ANALYSIS

a. Diameter of the kneading unit

The kneading unit is a cylindrical vessel, its diameter was determined using equation 3.8 and to compute the diameter, the height of the vessel was assumed to be 400 mm.

$$v = \frac{\pi d^2 h}{4} \quad (1)$$

Where, d = diameter of kneading unit (m), h = height of the knead unit (m) selected.

b. Determination of machine pulley sizes

The diameter of the machine pulleys at the different selected speeds were determined using the expression given by khurmi and Gupta (2005).

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

Where, D_1 = diameter of the electric motor (rpm), N_1 = speed of pulley on electric motor (m)
D_2 = diameter of the machine pulley (rpm), N_2 = speed of the machine pulley (m)

c. Torque transmitted

To determine the diameter of the kneading shaft, torque acting on the shaft is required and this was determined using the expression given by Khurmi and Gupta (2005).

$$T = w \times r \qquad (3)$$

Where, w = the total weight on kneading shaft (N), r = radius of kneading unit (mm)

d. Determination of power requirement

The power requirement of the machine depends on force in the material to be processed. The power required by electric motor to drive the oil expelling machine is given by Khurmi and Gupta (2005) as;

$$P = \frac{2\pi NT}{60} \qquad (4)$$

Where, P = power requirement of the machine (watts), N = speed of kneading (rpm), T = torque generated (Nm)

e. Design of shaft diameter

Khurmi and Gupta (2005) gave equation (5) to determine the shaft diameter.

$$d^3 = 16/\pi\tau \sqrt{(TK_t)^2 + (MK_b)^2} \qquad (5)$$

Where, T_e = equivalent twisting moment (Nm), d = shaft diameter (m), τ = permissible shear stress
T = torque transmitted (Nm), M = bending moment of shaft due to the pull on the belt (Nm)
K_b = shock and fatigue factor on bending moment, K_t = shock and fatigue factor on torsional moment

E. PERFORMANCE EVALUATION OF THE OIL EXPELLER

The designed machine was fabricated and tested to evaluate its performance. *Gargajiya* specie of groundnut was used to evaluate the machine and it was collected from Zungeru, Niger State. The performance of the oil expeller was evaluated based on throughput capacity and oil yield efficiency. The equations used to determine the throughput capacity and oil yield as expressed by Mikailu *et al.* (2018) are given as;

$$T_{cp} = \frac{W_p}{t_k} \qquad (6)$$

$$Y_o = \frac{W_o}{W_p} \times 100 \qquad (7)$$

Where, T_{cp} = Throughput capacity (kgh^{-1}), W_p = weight of groundnut paste (kg), t_k = Kneading time (h)
Y_o = oil yield of groundnut paste (%), W_o = Weight of extracted oil (kg)

The oil extraction efficiency of the machine was obtained using the equation expressed by Akerele and Ejiko, (2015).

$$E_o = \frac{Y_o}{C_o} \times 100 \qquad (8)$$

Where, E_o = Oil extraction efficiency (%), C_o = Oil content of groundnut (%)

III RESULTS AND DISCUSSION

The percentage oil yield, extraction efficiency, percentage oil loss and throughput capacity of the machine at different speeds of 250, 300, 350 and 400 rpm were evaluated. The time of extraction ranged between 6 to 12 min. Table 1 shows the result of performance evaluation of the developed oil expeller.

Table 1. Performance evaluation of the developed oil expeller

Runs (kgh^{-1})	X_1 (rpm)	X_2 (min)	Y (%)	E (%)	L(%)	T
8	250	12	40.0	89.7	10.3	30
9	250	8	33.8	75.8	24.2	45
15	250	8	34.7	77.8	22.2	45
21	250	12	36.5	81.8	18.2	30
3	250	12	38.3	85.9	14.1	30
11	250	6	33.2	74.4	25.6	60
19	250	8	36.5	81.8	18.2	45
5	300	10	30.5	68.4	31.6	36
17	300	6	31.2	70.0	30.0	30
20	300	6	38.2	85.7	14.3	30
1	300	10	39.7	89.0	11.0	36
7	300	10	38.3	85.9	14.1	36
16	300	6	31.0	69.5	30.5	60
2	350	12	35.7	80.0	20.0	30
6	350	8	34.7	77.8	22.2	45
14	350	12	35.0	78.5	21.5	30
22	350	8	39.5	88.6	11.4	45
13	350	8	34.3	77.1	22.9	45
23	350	8	40.0	89.7	10.3	45
10	400	10	36.8	82.5	17.5	36
12	400	6	35.5	79.6	20.4	60
25	400	10	33.3	74.7	25.3	36
4	400	10	34.2	76.7	23.3	36
24	400	6	38.2	85.7	14.3	60
18	400	12	39.5	88.6	11.4	30

Where, X_1 = Kneading speed X_2 = Kneading time Y = Oil yield E = Extraction efficiency L = Oil loss T = Throughput capacity

A. THROUGHPUT CAPACITY

The throughput capacity was determined using equation (6) was different for different extraction speeds. Highest throughput capacity of 60 kgh^{-1} was obtained at the extraction time of 6 min and this was due to reduced time of extraction and this is in agreement with research conducted by Ola and Suleiman (2001) and Mikailu *et al.*(2018).. The mean throughput capacity was determined to be 40.44 kgh^{-1}.

B. PERCENTAGE OIL YIELD

The percentage oil yield was determined using equation (7). The results of the experiment as presented in Table 1, shows that highest oil yield of 40% was obtained at extraction speed of 250 rpm and extraction time of 12 min and also at extraction speed and extraction time of 350 rpm and 8 min respectively. This means that the longer the kneading time, the higher the oil yield. The higher the speed, the higher the oil yield and the lower the time of kneading as reported by Ola and Suleiman (2001) and Maduako *et al.*(2004). The least oil yield of 30.5% was obtained at speed of 300 rpm, extraction time of 10 min, this could be due to other factors such as low water temperature and amount of water added that were involved during the extraction. The mean oil yield was determined to be 35.9%.

C. PERCENTAGE OIL LOSS

Table 1 shows that lowest oil loss of 10.3 % was obtained at extraction speed of 250 rpm and extraction time of 12 min and also at extraction speed and extraction time of 350 rpm and 8 min respectively. This is because the kneading time is maximum and at high speed, other factor that caused the low oil loss was high water temperature added which energises the oil molecules and causes easy separation from groundnut oil cells. The highest oil loss of 31.6% was obtained at speed of 300 rpm, extraction time of 10 min and this could be due to low temperature of water added and small amount of water added. The mean oil loss was determined to be 19.4%.

D. EXTRACTION EFFICIENCY

The extraction efficiency of the developed machine was determined using equation (8). Highest extraction efficiency of 89% was obtained at extraction speed of 250 rpm and extraction time of 12 min and also at extraction speed and extraction time of 350 rpm and 8 min respectively. The least extraction efficiency of 68.4% was obtained at speed of 300 rpm; extraction time of 10 min. Temperature of water added greatly influenced the extraction efficiency this is because at highest extraction efficiency of 89% temperature of water added was 100^{o}C and at the least extraction efficiency of 68.4% temperature of water added was 25^{o}C. The mean extraction efficiency was determined to be 80.6%.

IV. CONCLUSION

The aim and objectives of the research were achieved. The effects of extraction speed and extraction time were investigated. From the result, the performance of the groundnut oil extraction machine was satisfactory and this is because, the mean extraction efficiency of the machine obtained to be 80.6% was greater than extraction efficiency obtained by Ojomo *et al.* (2011), Aremu and Ogunlade (2013) and Lawan *et al.*(2015); Bashir (2014) which were 67%, 62.2% and 74.1% respectively. The mode of operation of the machine uses local concept of oil extraction but it saves time, reduces the drudgery and improves the quantity of groundnut oil production by our local farmers and this makes the machine suitable to replace traditional methods of oil extraction. The research has shown that there is always room for improvement in the development of food processing machines.

V. RECOMMENDATIONS

The following recommendations are made to validate and make improvement on this research.

- The machine testing should be done at higher kneading speeds.
- The gaps between the levels of the kneading speed should be wider.

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