Design of a Combined Groundnut Roaster and Oil Expeller Machine

Olawale Okegbile
Federal University of Technology Minna

Abdulkadir Baba Hassan
Federal University of Technology Minna

International Journal of
Science and Engineering Investigations vol. 3, issue 26, March 2014
ISSN: 2251-8843

Design of a Combined Groundnut Roaster and Oil Expeller Machine

Olawale J. Okegbile[1], Abdulkadir B. Hassan[2], Abubakar Mohammed[3], Osigbodi Obajulu[4]

[1,2,3,4]Department of Mechanical Engineering, Federal University of Technology, Minna, Nigeria
([3]a.mohammed@futminna.edu.ng)

Abstract- This paper presents the design of a combined groundnut roaster and oil expeller machine. The designs consist of two distinct units: the roasting and expelling units. The components design includes the hopper, machine capacity, casing, conveyor trays, vibrator motor, heating filament, shaft diameter, auger, belt length and velocity of electric motor. The various units were combined so as to remove the drudgery and constraints associated with having to do the roasting and expelling processes separately. This combination makes it portable and reduces space.

Keywords-*Design, Groundnut, Groundnut Roaster, Oil Expeller,*

I. INTRODUCTION

Groundnut (*Arachis hypogea)* is a member of the *Papilionaceae* and is the largest and most important member of the *Leguminosae* [1, 2]. It originated from Latin America and was introduced into West Africa by Portuguese traders in the 16th century. The origin of this crop dates back to 350BC [3]. The first probable domestication of groundnut took place in the valley of the Panama and Paraguay River systems in the grain Chiaco area of South America and then moved to the North America through slave trade. Major groundnut zones are the Sudan and Northern Guinea Savanna where the soil and agro climatological conditions are favorable. Groundnut requires 500 to 1600mm of rainfall, which may last for 70 to 200 days of rainy season in the Sudan Savanna. It also requires well-drained light colored, loosed friable sandy loam soil, optimum moisture in pod zone and mean daily temperature of about 30^0 [3]. The rainfall should be well distributed during the flowering and pegging of the crop.

The production of oil from groundnut involves a post processing of groundnut which includes shelling, roasting and pressing. Several groundnuts shelling machines has been fabricated [4, 5]. Roasting reduces moisture content and develops a pleasant flavor which makes the products more acceptable for consumption [6]. Roasting also enhances better extraction as it reduces the oil's viscosity, releases oil from intact cells and reduces the moisture content. The amount of oil produced will be much if it is properly roasted. However, excess heating during roasting results in low nutritional quality of protein. It also reduces the quantity of oil as well as it makes the colour of the oil extracted to be dark [7].

In many part of the world, groundnut oil has proved to be a very valuable product with universal demand. The possible income from groundnut oil extraction is therefore often enough to justify the relatively high cost of setting up and running a small scale oil businesses. However, interest in small to intermediate scale oil seed processing on the part of farmers grew dramatically in the last decade. Various small scale techniques are available to ensure people in rural areas to process their own oil seeds locally. Careful consideration is needed to select the systems that will best suit the local circumstances. These circumstances include the scale of operation required, the availability of power sources and a number of other factors [6].

Some of the roasting machines in used include a manually operated rotating drum that is heated externally. The drum is housed in a brick and clay construction, similar to a scale bakery oven. For uniform roasting, the drum is rotated continuously throughout the process. The drum roaster consists of two drums. The outer drum is fitted to the brick work. The inner drum is made in form a drawer that is detachable for loading and unloading the groundnut [8]. A high intensity pulse infrared radiation for roasting groundnut was also reported [9]. Due to the radiation, it has optimum product quality in terms of colour, texture and free acid content. This method of roasting yields increased oil compared to previous methods as well as better oil quality. However, the cost of setting up a pulsed infrared roaster is exorbitant [2]. Batch roasters offers the advantage of adjusting for different moisture contents of groundnut lost from storage. Batch roasters are typically natural gas-fired revolving oven (drum-shaped). Continuous dry roasters vary considerably in type. Continuous roasting labour, ensures a steady flow of groundnut for other processes and decreases spillage. The continuous roaster move groundnut through oven on a conveyor tray by gravity feed. In this system, the groundnut is agitated to ensure that air passes around the individual kernels to promote an even roast [2]. Some groundnut oil expelling machine has been produced [10-12].

Roasting of this crop and extraction of oil from this crop has however been a serious issue to its processing. Machines which could combine roasting of the nut and expelling of the oil from the nut are not commonly available. In some rural parts of the country, roasting and extraction of the oil is achieved by traditional method. This process is very slow, tedious and time consuming considering the present level of production. In order to sustain the increase in oil production from groundnut, there is the need to improve on the technology especially at the rural level. There is usually a problem when several units of the oil processing operations are separated. The time taken to move the raw materials from one unit to another is sometimes enormous. Apart from that, the labour required to man these separate unit also add to the cost of production. However, if some of these units can be integrated it can generally enhance the efficiency of the entire process. It is in view of these that the present study is to carry out a combine roasting and expelling units of a groundnut oil processing into a single unit.

II. COMPONENTS DESIGN

The design of the machine consists of a roasting and expelling units. Figure 1 below shows the combined groundnut roaster and oil expeller machine.

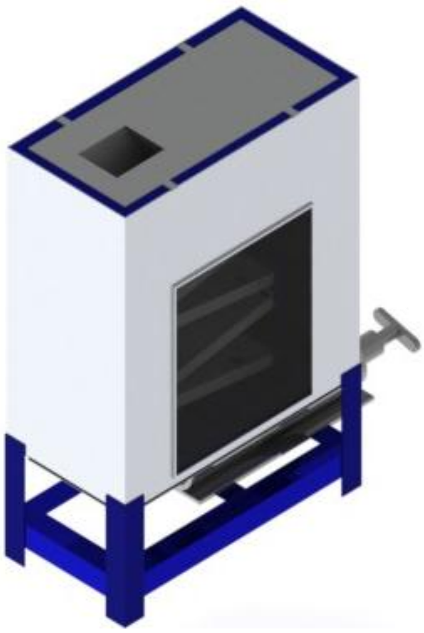

Figure 1. Combined groundnut roaster and oil expeller machine

A. Roasting Unit

The roasting unit consists of the hopper, conveyor trays, vibrator motor, cabinet (casing) and lagging materials, bearings, heating filament, frame and exhaust.

1) Determination of Hopper and machine capacity

The volume of the hopper is derived from the expression

$$Volume = surface\ area \times width\ of\ hopper \qquad (1)$$

The machines capacity in volume per hour is given as

$$C_{vph} = \frac{M}{\rho T} \qquad (2)$$

Where, C_{vph} is the machine capacity (m^3/h); T is the roasting time of groundnut (hr); ρ is density of groundnut (kg/m^3) and M is the mass of the groundnut (Kg).

Using equations (1) and (2), the volume of hopper is $0.0037m^3$, the density of groundnut was determined experimentally as 983.5kg/m^3, and the roasted time of 3kg of groundnut to be 30 mins, the machines capacity obtained using equation (1) and (2) is $6.1 \times 10^{-3} m^3/h$.

2) Determination of Power Required To Roast Groundnut

The power of the heating element that is required to roast the groundnut must be sufficient to withstand heating process. The power required to roast groundnut is given as

$$P = \frac{Q}{t} \qquad (3)$$

The quantity of heat required to roast the groundnut is giving as

$$Q = M_c(T_2 - T_1) \qquad (4)$$

Where, P is the power required; Q is the quantity of heat required to heat the groundnut (KJ); t is the time it takes to roast the groundnut (t); M is the mass the groundnut (Kg); c is the specific heat capacity (KJ/kg/K); T_1 is initial temperature and T_2 is the final temperature.

For 30kg mass of groundnut and a temperature range of 30^0C to 90^0C, the power required calculated from equation (3) and (4) is 1.5KW and resulted in the selection of a heating filament of 1.8KW to account for factor of safety of 20%.

3) Determination of Heat Loss

The amount of heat loss through the inner wall of the tank and the insulators to the environment is given as:

$$q = \frac{\Delta T}{\sum R_{thermal}} \qquad (5)$$

The thermal resistance of the material used is given as

$$R_{thermal=} \frac{x_i}{K_i A_i} \qquad (6)$$

The area of the mild steel is given as:

$$A_1 = l_1 \times b_1 \qquad (7)$$

The area of the insulating material is given as:

$$A_2 = l_2 \times b_2 \qquad (8)$$

Where, q is the heat transfer rate (W); ΔT is the change in temperature (^{0}C); $\sum R_{thermal}$ is the total thermal resistance (ohms); x_i is the thickness of the materials (m); A_i is the areas (m), K_i is the thermal conductivity of the materials

(W/m°C), A_1 is the area of mild steel (m^2), A_2 is the area of insulator (m^2), b_1 is the breadth of mild steel material (m), l_1 is length of mild steel (m), b_2 is the breadth of insulating material (m) and l_2 is length of insulator material (m).

Given that the thermal conductivities of mild steel and insulator are respectively 42.9W/m℃ and 0.04W/℃, the total thermal resistance obtained from equation (6) is $3.29℃/W$. With a temperature difference of 60^0C and thickness of insulating material and mild steel are 25mm and 2mm, the values obtained for the heat transfer rate from calculation using equations (5) to (8) above is 18.24W.

4) Determination of Power Required to Vibrate Trays

The power required to vibrate the trays is given as

$$P_v = Mr\omega \tag{9}$$

And

$$\omega = \frac{2\pi N}{60} \tag{10}$$

Where, P_v is the power required to vibrate trays (W); M is the vibrator Mass (Kg); r is the radius of mass (m); ω is the angular velocity (rad/sec) and N is the revolution per minute (rpm).

Given that N is 3000 rpm, radius of mass is 0.05m and the vibrator mass is 1.4kg, the power required to vibrate the trays using equation (9) and (10) is 22W.

5) Determination of Angle of Inclination of Conveyor Trays

The angle of inclination of conveyor trays is given as (Douglas, 2001):

$$\emptyset i = \frac{\theta}{6} \tag{11}$$

Where, $\emptyset i$ is angle of inclination and θ the angle of repose.

Given that the angle of repose is 30℃, the angle of inclination calculated from equation (11) is 5℃.

B. *Oil Expelling Unit*

1) Determination of shaft diameter

The diameter of the shaft is calculated from the relationship:

$$d^3 = \frac{16}{s_s\pi}\sqrt{(K_bM_b)^2 + (K_tM_t)^2} \tag{12}$$

a) Torsional moment

The torsional moment is given as:

$$M_t = \frac{P}{\omega} \tag{13}$$

The angular velocity of the shaft is given as:

$$\omega = \frac{2\pi N}{60} \tag{14}$$

$$\theta = \frac{584M_tL}{Gd^4} \tag{15}$$

b) Bending moment

The bending moment of the shaft is determine by considering the forces acting on the shaft. The total loads on shaft are the load due to the hopper, groundnut collector and the gear.

The load due to the hopper and groundnut collector is given as:

$$W_h = F_w + F_g \tag{16}$$

Where,

$$F_w = mg \tag{17}$$

And

$$F_g = V_T \times \rho \times g \tag{18}$$

The load due to the gear is defined as

$$W_y = F_h tan\alpha \tag{19}$$

Where,

$$F_h = \frac{M_t \times 2}{D_G} \tag{20}$$

Where, d is the shaft diameter (m), P is the power of motor (kw), ω is angular velocity (rad/s), M_t is the Maximum torsional moment (Nm), M_b is the Maximum bending moment (Nm), N is the speed of shaft (rpm), S_s is the allowable stress (N/m^2), K_b is the combined shock and fatique applied to bending moment (1.5), K_t is the combined shock and fatique factor applied to torsional moment (1.0), W_h is the total weight of groundnut collector (N), W_v is the vertical load of gear (N), ρ is the density of roasted groundnut (kg/m^3), m is the mass of metal sheet (kg), D_G is the diameter of gear (m), V_T is the total volume (m^3).

c) Shaft diameter

Given that P=0.746kw, N= 60 rpm, D_G=250mm, ρ =983.4kg/m^3, m=1.802kg, $S_s = 4 \times 10^6 Nm^{-2}$. The diameter of the shaft is calculated using equations (12) to (20) as 29mm.

2) Determination of Auger Capacity

The surface area of the Auger where pressure is exerted most is given as;

$$A = \frac{\pi(D^2 - d^2)}{4} \tag{21}$$

The force required for extraction is given as;

$$F = P \times A \tag{22}$$

Tangential Force

$$F_t = Ftan(\alpha + \beta) \quad (23)$$

Where,

$$\beta = \tan^{-1}\mu \quad (24)$$

and

$$\alpha = \frac{\tan^{-1}P_x}{d_{mean}} \quad (25)$$

Pressure developed at the expelling end by the auger ,

$$P = \frac{F_t}{A} \quad (26)$$

The pressure generated equals the maximum pressure that is required to expell oil in a continuous expeller. Hence the auger will expell oil.

The Torque required is given as;

$$T = F_t \frac{d_m}{2} \quad (27)$$

The capacity of the auger is given as;

$$Q = 60(D^2 - d^2)PN \quad (28)$$

The mass is given as:

$$m = \rho \times V \quad (29)$$

The minimum power requirement of auger is given as;

$$P_c = Q \times L \times W \times F \quad (30)$$

Where; P_x is the mean Pitch of shaft (m), μ is the coefficient of friction (0.2), L is the length of shaft (m), Q is the Capacity of Auger (), W is the bulk weight of groundnut (N/m^3), F is the material factor = 0.3, P_c minimum power requirement (), ρ is the density of material (kg/m^3), T is the torque required, d_{mean} is the mean diameter of the auger (m), D is the diameter at the auger's feeding end (m), *d* is the diameter of the auger's expelling end (m), F_t is the tangential Force (N), N is the speed (rpm), A is the cross sectional area of the auger (m^2), m is the mass of the auger (kg), V is the volume of the auger (m^3), F is the force required for extraction, and P is the maximum pressure to expell oil (N/m^2).

Given that P = $13.6\times 10^6 N/m^2$, d=40mm, D = 50mm, d_{mean}=45mm, N=60rpm, ρ=983.4kg/m^3, L=0.45m and P_x=30mm, using equations (21) to (30), the minimum power requirement of auger is 374.7Watts (with factor of safety 1hp motor rating is used) and the Capacity of the auger is 0.288 m^3/hr.

3) Casing Design

The surface area of the casing is given as:

$$A = \pi rL + \pi r^2 \quad (32)$$

The Volume of the casing is given as:

$$V = \frac{\pi}{3}h(R^2 + Rr + r^2) \quad (33)$$

a) Thickness of the casing;

The casing was constructed considering its thickness to withstand the increase in pressure with depth due to increase in area.

$$t = \frac{Pd}{2S_h} \quad (34)$$

Where P is the Maximum pressure on the casing (Mpa), d is the internal diameter of casing where pressure is highest (m), S_h is the tensile strenght of the material (Mpa), *t* is the thickness of the casing (m), *A* is the surface area of the casing (m^2), *V* is the Volume of the casing (m^3), *L* is the length of casing (m), *R* is the radius of larger end (m) and r is the radius of smaller end (m).

Given that S_h =450Mpa, d= 60mm and P=23.6Mpa, the volume and thickness of the casing are $0.99 \times 10^{-3} m^3$ and 1.57mm.

4) Design for Belt Drive

a) Length of Belt

The Length of Motor-Gear box Belt is given as:

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) + \left[\frac{(D_2 - D_1)^2}{4C}\right] \quad (35)$$

The centre distance between the motor pulley and the gear box shaft pulley is given as:

$$C = \left[\frac{D_2 + D_1}{2}\right] + D_1 \quad (36)$$

Where, L is the length of Belt (m), C is the centre distance between the motor pulley and the gear box shaft pulley (m), D_1 is the diameter of gear box pulley (mm) and D_2 is the Diameter of motor pulley (m).

Given that D_1 =30mm and D_2 =60mm, the length of Motor-Gear box Belt is 294.3mm. A belt of 300mm was selected.

b) Determination of the Velocity of Motor – Gear Box Belt

The velocity of the belt can be determined by using the expression

$$V = \frac{\pi N_1 D_1}{60} \quad (37)$$

Where, V is the velocity of the belt (m/s), $N_1$is the speed of the motor pulley (1500rpm), and D_1 is the diameter of the motor pulley (60mm).

Given that N_1=1500rpm, and D_1 = 60mm, the velocity of the belt is $4.712 m/s$.

c) Determination of the Angle of Contact of Belt between the Motor and Gear Box Pulleys

The angle of lap of the belt between the two pulleys can be calculated from the expression below

$$\theta = (180 - 2\alpha) \times \frac{\pi}{180} rad \tag{38}$$

Such that

$$\alpha = sin^{-1}(\frac{r_2 - r_1}{c}) \tag{39}$$

Where, θ is the angle of contact of the belt between the two pulleys (rad), $r_1$is the radius of the Gear Box pulley (m), $r_2$is the radius of the motor pulley (m) and c is the centre difference between the two pulleys (m).

Given that r_1=15mm, r_2=30mm and c=75mm, the angle of contact of belt between the motor pulley and the gear box pulley is $2.75 rad$.

d) Weight of Pulley

The weight of gear box pulley is expressed as:

$$W = mg \tag{40}$$

Where, W is the weight of the drum pulley (N), m is the mass of pulley (kg) and g is the acceleration due to gravity (m/s^2). The weight of the gear box pulley is 9.81N

III. CONCLUSION

The design of a combined groundnut roaster and oil expeller machine has been presented. The components design includes the hopper, machine capacity, casing, conveyor trays, vibrator motor, heating filament, shaft diameter, auger, belt length and velocity of electric motor. The machine was designed for a capacity of $6.1 \times 10^{-3} m^3/h$ for a 3kg of groundnut.

REFERENCES

[1] Hans-Jürgen Wiemer, Frans W. Korthals Altes. (1989). Small Scale Processing Of Oil fruits And Oilseeds. Friedr Vieweg & Sohn, Braunschweig/Weisbaden.

[2] Shankarappa T., Robert E. R. and Virginia N. (2003). World geography of groundnut: distribution, production, use and trade.

[3] Hommons, R. O. (1994): The origin and History of groundnut, In: Smart, J. (Ed), The Groundnut crop; A scientific Basis for Improvement. New York, U.S.A. Chapman and Hall, pp: 56-78.

[4] Mohammed A., Hassan A. B. (2012). Design and Evaluation of a Motorized and Manually Operated Groundnut Shelling Machine, International Journal of Emerging Trends in Engineering and Development, Vol. 4 (2):673-682.

[5] Maduako J. N., Saidu, M., Matthias, P., Vanke, I. (2006). Testing of an Engine-Powered groundnut shelling machine. Journal of Agricultural Engineering and Technology, 14: 29-37.

[6] Asiedu, J. J. (1988): Processing Tropical Crops, a technological approach, London Macmillan press.

[7] Gerald L. (2009). The application of fluid mixers in edible oil processing. Available at www.emimixers.com.

[8] Peanut roaster. Practical action, the Schumacher centre, Bourton on Dunsmore, Rugby, Warwickshire, UK. Accessed on 22/03/2014. http://practicalaction.org/media/preview/10616.

[9] Food and Agriculture Organization (F.A.O), 2005

[10] Ajao K. R., Ajimotokan H. A. and Olaomi J. (2009). Development and performance evaluation of a groundnut oil expelling machine, New York science journal, Vol. 2(6):76-79.

[11] Manta, I.B (1995): design and construction of groundnut oil expeller. Unpublished B.Eng Thesis submitted to the Department of Agricultural Engineering, Federal University of Technology, Minna.

[12] Garba D.S (2011): Design and construction of groundnut oil expeller. Unpublished B.Eng Thesis submitted to the Department of Agricultural Engineering, Federal University of Technology, Minna.