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Development of a Motorized Groundnut Roasting Machine

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Abstract: A motorized groundnut roasting machine was designed to ease the drudgery operations encountered by small and medium scale groundnut oil processors during roasting of shelled groundnut. The machine basically consists of a roasting chamber, a heating chamber, and a blower chamber and power transmission unit with an electric motor. A shaft carrying three set of paddles for stirring of groundnut seeds is situated inside a cylindrical shaped drum. An electrical axial fan was incorporated in the blower chamber to supply air to the burning charcoal in order to maintain even distribution of heat in the roasting chamber. The roaster was evaluated to determine the machine output capacity using shelled groundnut seeds as test crop. Collected data were analyzed using Statistical Analysis Software. The effects of variation of the independent factors were verified using Analysis of variance (ANOVA) at 1% and 5% levels of significant. Mean separation was carried out on significant factors using Duncan Multiple Range Test (DMRT). The results obtained indicate that the machine output capacity was in the range of 58.8 to 130.2 kg/hr.

Keywords: Groundnut, Roasting, Charcoal, machine, output capacity.

1. Introduction

Groundnut *(Arachis hypogaea L.)*, is a leguminous oil seed crop cultivated in the semi-arid and subtropical regions of the world. According to FAO (2016), groundnut is grown in nearly 100 countries of the world in an estimated area of 27.6 million hectares with a total production of 43.9 million metric tonnes, and an average yield of 1.4 metric tonnes per hectare with China, India, Nigeria, U.S.A, Sudan and Myanmar as major producers. Nigeria ranks third, in production, with a total volume of 3.1 million tons as at 2016(FAO).

Groundnuts have several health benefits; the nuts contain monounsaturated fats and other nutrients that are healthy for the functioning of the heart. They are rich source of antioxidants such as oleic acid which improves the blood flow in the brain and reduces the risk of stroke and coronary diseases (Kelly and Sabate 2006). In developing countries especially in sub-Saharan Africa like Nigeria, groundnutsare mainly used to produce cooking oil for household use and could also be consumed as a source of protein for both human and animals. Following oil extraction, the residual cake is

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processed largely for animal feed, but is also used for human consumption as groundnut cake, which in northern Nigeria is popularly known as *"Kulikuli"*.

Traditionally, post-harvest processing of groundnut includes (but not limited to) shelling, winnowing, roasting, blanching, grinding and oil extraction. Shelling, roasting and oil extraction are the most tedious and time consuming among the various processes (Ajao *et al*., 2010). Roasting is a process by which the food products are subjected to thermal and irreversible structural changes accompanied by reduction of moisture contents purposely for human consumption (Fellows, 2000). Groundnuts seeds are roasted for two major purposes i.e for direct consumption and for oil extraction. In both cases roasting is achieved by the use of open pan with or without ash or sand over direct fire, by the use of a rotating drum over a fire source or by the use of microwave or oven. Locally roasting involves the use of open pan or locally made clay pot placed on open wood fire. The shelled groundnut seeds are deposited in the open pan and constantly stirred to bring about even roasting and avoid the burning of seeds. This operation is tedious, time consuming and inefficient. The processors are equally exposed to excessive heat and sustenance of burns resulting to uneven roasting and low productivity (NAERLS, 1990). Mechanical roasters for cashew, coffee beans, and groundnuts, have been developed to reduce the drudgery of roasting to a great extent but the traditional roasting is still predominant due to high cost of the mechanical roasting equipment. The high cost has made them inaccessible to most small and medium scale groundnut processors (Peters, 1985). Oil expellers are mostly used for direct crushing of groundnut seeds and oil extraction without roasting the groundnut. However, study has revealed that oil obtained from roasted groundnuts has a pleasant flavor which makes the products more acceptable for consumption (Asiedu, 1988) and the shelf life of oil extracted from roasted groundnut is longer when compared with unroasted groundnut (Gokhan *et al.* 2010). Gerald (2009) also showed that roasting enhances better extraction as it reduces the oil viscosity, releases oil from intact cells, reduces the moisture content, and increase the amount of oil that can be extracted.

Development of this motorized roaster has the benefit of reducing drudgery associated with traditional roasters. The roaster has the advantage of easy fabrication and maintenance by local artisan. It also suit the small and medium scale processors who are into oil and groundnut cake production and the cost of acquiring the roaster is within their reach as compared with the industrial roasters.

2. Materials and Methods.

2.1. Groundnut roaster design

Designing is a crucial aspect of engineering work, as such a motorized groundnut roaster if not properly designed cannot perform its intended functions as desired. Some considerations were necessary in the design which includes; a roaster with batch capacity of 30kg shelled groundnut, the roaster should be simple to operated, durable, reliable and should be safe to operate.

2.2. Basic theory

Volume and diameter of roasting drum was calculated using the formula,

$$V = \frac{\pi D^2 L}{4} \qquad (1.1)$$

Where, D is drum diameter (m) and Lis drum length (m)

Weight of paddles was determined from the relationship;

$W_p = \delta g v$ (1.2)

Where, W is weight of the paddles (N) and δ is density of material (kg m^{-3}).

The total power requirement to drive the machine was determined using, the equation,

$$P = \frac{2\pi NT}{60} \quad (1.3)$$

Where, P is power (W), N is revolution of shaft per minute and T is torque on rotating shaft (Nm).

Pulley diameters were gotten from the expression;

$$N_1 D_1 = N_2 D_2 \quad (1.4)$$

Where; N_1 is speed of driving pulley (rpm), N_2 is speed of the driven pulley (rpm), D_1 is diameter of driving pulley (mm) and D_2 is diameter of driven pulley (mm).

Centre to centre distance between the driven and driving pulleys was estimated by;

$$D < C < 3\,(D + d) \quad (1.5)$$

Where; D is diameter of the driving pulley (mm), d is diameter of driven pulley (mm) and C is centre to centre distance between pulleys (mm).

Effective bent length was determined by;

$$L = \frac{\pi}{2}(D + d) + 2c + \frac{(D-d)^2}{4c} \quad (1.6)$$

Where; L is Effective length of belt in (mm), c is Centre distance from the driving to the driven pulley (mm), d is Diameter of driving pulley (mm) and D is Diameter of driven pulley (mm).

Angle of lap was calculated using;

$$\theta = (180 - 2\alpha)\frac{\pi}{180} \quad (1.7)$$

Where; $\alpha = \sin^{-1}\frac{r_1 - r_2}{c}$, r_1 is radius of larger pulley (mm), r_2 is radius of smaller pulley(mm) and c is distance between the centers of the two pulleys (mm).

Shaft diameter was determined using the formula;

$$T_e = \sqrt{(K_b \times M_b)^2 + (K_t \times M_t)^2} \quad (1.8)$$

And

$$T_e = \frac{\pi\, \tau\, d^3}{16} \quad (1.9)$$

Where; T_e is twisting moment(N-mm), d is Solid shaft diameter (mm), M_b is Bending moment (Nm), k_b is combined shock and fatigue factor applied to bending moment, k_t is combined shock and fatigue factor applied to torsional moment, M_t =Torsional shear stress (Nm) and τ is maximum allowable shear stress (Nm^2) in the shaft material.

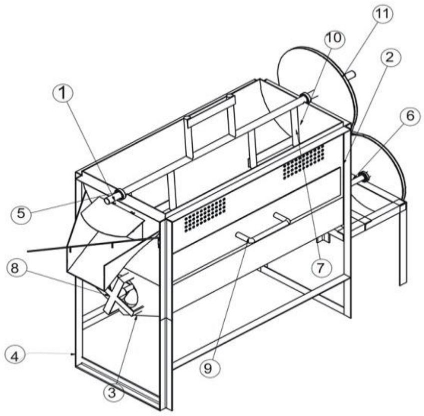

Figure 1. Groundnut roaster

Component:

Shaft	Heater case	Fan case
Frame	Bearing	Idler
Paddle	Fan vent	Tray
Drum	Pulley	

2.3. Construction details

Figure 1 is the designed groundnut roaster. The materials used in construction were sourced for locally. A 30mm by 30mm by 3mm angle iron was used in constructing the structural frame and engine seat. Gauge 18 mild steel sheets was used in constructing the roasting drum, heating chamber, charcoal tray, blower chamber, hopper and discharge unit. A 30mm (c1040) mild steel shaft was used as the rotating roasting shaft. The whole assembly of the roasting machine was mounted on the frame as shown in plate 1.

Figure 2. Plate 1: Pictorial view of the constructed roasting machine

2.4. Experimental Procedures

The performance of the developed roaster was evaluated base on the machines output capacity. A 3 x 3 x 3 factorial experiment design was used in evaluating the performance of the developed roaster.

Data collected were analyzed using Statistical Analysis Software (SAS) and Mean separation was done for the significant factors using Duncan Multiple Range Test (DMRT). The effects of the variation of each of three independent factors and their interactions on the performance of the modified groundnut roaster were verified at 5 and 1 % levels of probability using the analysis of variance (ANOVA).

3. Results and discussions

The developed motorized groundnut roasting machine was used to roast shelled groundnut seeds. Plate 2 shows the roasted groundnut seeds, from plate one it can be seen that the developed roaster, roasted the seeds uniformly.

Figure 3. Plate 2: Roasted Groundnut Seeds

3.1. Effect of Fan Speed on the Machine Output Capacity

Table 1 shows the effect of fan speed on the output capacity of the roasting machine. For fan speed, the output capacity of the machine (106.2kg/hr) was significantly higher $(P \leq 0.05)$ at 1400rpm, followed by 91.8kg/hr at 1200rpm and the lowest, 76.2kg/hr at 1000rpm. This implies that higher output capacity can be achieved at high fan speed. High heat intensity or temperature is generated from the air circulation supplied by the fan, this is because high fan speed blows the charcoal more as a result more heat is generated from the burning charcoals hence reducing roasting time.

3.2. Effect of Shaft Speed on the Machine Output Capacity

Table 2 shows the effect of shaft speed on the machine output capacity. The paddles that constantly stir the groundnut seeds while roasting are connected to the roasting shaft. For shaft speed, at 25rpm, the machine capacity (92.4kg/hr) was significantly different ($P \leq 0.05$) from the other two shaft speeds (26 and 27 rpm) values of 91.8kg/hr and 91.2 kg/hrrespectively which were statistically at par ($P \geq 0.05$). This showed that output capacity of the roaster using the varied shaft speeds are of the same range for 26 and 27 rpm.

3.3. Combined Effect of Fan Speed and Shaft Speed on the Machine Output Capacity

Table 3 shows the combined effects of the fan speed and shaft speed on the machine output capacity. The output capacity of 106.8, 106.2 and 105.6 kg/hrat 1400 rpm fan speed was significantly higher for all the various levels of shaft speed of 25, 26 and 27 rpm when compared with other two levels of fan speed. The output capacity obtained for 1200rpm irrespective of shaft speed is statistically higher than the values obtained at 1000rpm. It can therefore be concluded that heat intensity resulting from air circulation supplied by the fan is the only factor influencing output capacity.

Table 1. Effect of Fan Speed on Machine Output

Treatment	Machine output (kg/hr)
Fan speed(V) (rpm)	
1000	76.2
1200	93.0
1400	106.2
SE± 0.3	

Table 2. Effect of Shaft Speed on Machine Output

Treatment	Machine output (kg/hr)
Shaft speed(V) (rpm)	
25	92.4
26	91.8
27	91.2
SE± 0.3	

Table 3. combined effects of Fan Speed and Shaft Speed on Machine Output Capacity

Treatments	Mean
S_2V_3	106.8
S_1V_3	106.2
S_3V_3	105.6
S_1V_2	93.6
S_2V_2	93.0
S_3V_2	92.4
S_1V_1	77.4
S_3V_1	77.4
S_2V_1	74.4
SE±	

V_1=1000rpm, V_2=1200rpmV_3= 1400rpm, S_1=25rpm,S_2=26rpm,S_3= 27rpm

4. Conclusion

A motorized groundnut roasting machine has been developed. The roaster was used to roast shelled groundnut seeds. Results obtained shows that machine output capacity of 101.4, 106.2, and 91.8 kg/hr were obtained when 20kg groundnut seeds per batch, 1400 rpm of fan speed and 26 rpm of shaft speed were used respectively. The combination factors of 20kg of groundnut seed per batch, 1400 rpm of fan speed and 27 rpm of shaft speed gave the best output capacity of 130.2%, which could be recommended as the best combination to the end user.

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