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ORIGINAL RESEARCH ARTICLE

DEVELOPMENT AND PERFORMANCE EVALUATION OF A MANUALLY OPERATED GROUNDNUT ROASTER

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ABSTRACT

A manually operated groundnut roaster was developed and evaluated. The present Institute for Agricultural Research, Zaria (IAR) roasting equipment consists of a frying pan and an IAR charcoal fire wood cooking stove. The roaster was designed to help local processors obtain uniformly roasted products, with acceptable roast color. The performance of the roaster was carried out using IAR groundnut species known as SAMNUT 11 as specimen. The roaster was found to have a roasting capacity of 0.92 kg/min which is above the (IAR) roaster that has a roasting capacity of 0.28 kg/min. The roaster was found to have efficiencies of 98.3%, 98.6%, and 98.9% at 25%, 50% 100% loadings, respectively. The parameters that affect the roasting capacity include: heat from charcoal, crop moisture content and crop variety.

1.0 Introduction

Peanuts (*Arachis hypogea*) also known as groundnut are a major world oil seed crop. In Nigeria, approximately 3.1 million metric tons of groundnut in shell was produced in 2015 (FAO, 2016). In the northern part of Nigeria, processing of groundnut at small and medium scale is an important economic activity especially for women in villages and towns. Engin et al. (2017) observed the amount of oil present in groundnut ranged between 31.7 – 57.0%. However, this is dependent of the variety used Additionally, groundnut is rich in protein, making it a valuable feed for poultry (Asiedu, 1989). It is noteworthy that the main commercial product of groundnut is oil, which is an essential part of human diet; nutritionally they provide calories, vitamins and essential fatty acids in an easily digestible form. Therefore, the processes involved in processing the groundnut to oil requires adequate considerations. The extraction of oil from groundnut seeds are done largely as traditional or industrial (Ajao et al., 2010). The traditional method consists of decorticating the pods; sorting, roasting, deskining, grinding, kneading, forming and frying of the residual meal into edible cake called "kuli kuli"in Hausa The traditional method of processing the oil is considered to be time and energy consuming. Conversely, considerable improvement had been made on the traditional method by the Institute of Agricultural Research (IAR), Ahmadu Bello University, Samaru Zaria (Abubakar and Yiljep, 2000). Recently, there exist a motorized systems based on the traditional concept. However, in commercial (industrial) operation oil may be removed from groundnut by solvent extractor or mechanical expression (Kumar et al., 2017). A two-step combination of mechanical pressing and solvent extraction method is being used to improve the overall yields and reduce solvent requirement. The seed oil meal is first pressed to reduce the oil content to about 20% while the remaining is solvent extracted. Small and medium scale extractors use the mechanical oil expression which consists of pressing out the oil out of the oil containing seeds

(Akindele and Nsuhoridem, 2018). It uses either hydraulic presses or the screw presses. The screw press is more efficient which his expelled and the residual meal known as groundnut cake is used for poultry feed. Many factors could affect oil extraction for a given variety; the composition of seed oil is known to be affected by storage time and condition. Some processing factors such as roasting and pressing conditions affects the quantity of oil expelled. Among other factors roasting of the groundnut seeds before oil extraction is of utmost importance. This is due to the fact that roasting influences both the physical and chemical properties of the oil (Gokhan et al. 2010). Currently the process is done in a traditional way with frying fan in a charcoal stove or with firewood in a three fire stone. This process was characterized by high time consuming, low output, tedious, and expose to heat by the operator. The objectives of this study therefore are to develop and evaluate a manually operated groundnut roaster.

2.0 Materials and Method

2.1 Construction Materials

In constructing the manually operated groundnut roaster, gauge 16 mild steel sheet was used for the drum, gauge 13 mild steel sheet was used for the charcoal tray considering the heat generated from burning charcoal. 2.00 X 2.00 X 0.125 inch angle iron was used for the frame because of its higher strength to withstand pressure. Chains and sprockets were used to transmit power due to their ability to withstand elevated temperatures. The capacity of the machine was designed to match the existing IAR motorized oil extractor capacity which is 20 kg (Isiaka, 2005).

2.2 Design Calculation

2.2.1 Determination of drum capacity

The drum is in a cylindrical shape. The capacity of the drum is gotten from the volume of a cylinder by (Kurmi and Gupta, 2007)
Volume of Cylinder

$$V = \frac{\pi d^2 L}{4} \qquad (1)$$

where: d is the drum diameter (m) and L is the drum length (m)

2.2.2 Drum rotational speed

Determination of the drum rotational speed ratio formula as recommended by Hannah and Stephen (1984)

$$\omega = \left(\frac{2\pi N}{60}\right) \qquad (2)$$

where: ω is angular velocity (rad/s) and N is angular rotation (rev/min)

2.2.3 Shaft design

The shaft is to be subjected to two forms of load; axial load due to drum and seed weight and torsional load due to rotation speed.
Drum weight W_d = 14.8 kg × 9.81ms^{-2}
Maximum seed weight W_S = 20 kg × 9.81ms^{-2}
Total weight due to drum and seed W = 341.388 N
Assumption: that the weight is acting at the points of attachment of drum to shaft.
The axial load will be shared equally on both points of attachment.
Thus each point will carry $\frac{W}{2}$ = 170.694 N

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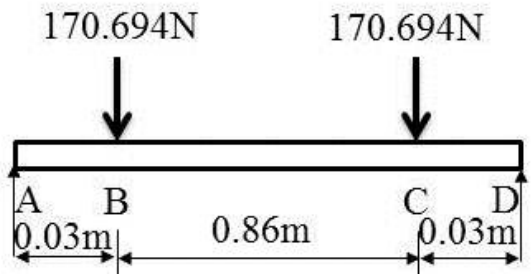

Figure 1: Loadings on the central shaft of drum

$R_A = R_D = 170.694$ N

2.2.4 *Determination of the cylinder shaft diameter*

The shaft diameter was obtained given by (Khurmi and Gupta, 2007)

$$d^3 = \frac{16}{\pi\sigma_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (3)$$

where: d is shaft diameter (mm), K_b is combine shock and fatigue factors for bending moment (1.5), K_t is combine shock and fatigue factors for tensional moment (1.0), M_b is maximum bending moment (Nm) and Mt is tensional moment (Nm).
The allowable shear stress for shaft with keyway, $\sigma_s = 75 \times 106$ N/m^2

2.3 Description of the Roaster

The roaster consists of the frame; Chain and sprocket, fan housing, shaft and charcoal tray
i. Frame :- The frame which is the supporting structure of the machine was constructed with 2 × 2 × 1/8 inch angle iron. Each doubled for stability and strength. The dimensions are as follows height is 900 mm; breath 860 mm and width 460 mm. total weight due to the frame is approximately 40 kg

ii. Drum :- The drum which serves as the groundnut containing chamber during roasting was constructed with a 1 mm mild steel sheet. 1 mm mild steel sheet was used due to its high thermal conductivity. The drum has a diameter of 400 mm and length of 800 mm. one side of the drum was constructed with a meshed wire for smoke outlet and to enable direct visualization of the groundnut seeds while roasting. A helical structure was constructed lying at the inside wall of the drum, this helix is to enable efficient mixing of the seed while roasting and for conveying the roasted seed after roasting to the outlet.

iii. Chain and Sprocket :- Chains and sprocket were used instead of belt and pulley due to their higher thermal resistance. The bigger sprocket has (42 teeth) is attached to the central shaft of the drum while the smaller sprocket with (14 teeth) is attached to the fan shaft. This arrangement is to allow for higher fan rotation.

iv. Fan :- An axial fan is used because it gives more output over centrifugal when the rotation is low. The fan has a diameter of 240 mm; the fan is equipped with housing, the housing is to allow for air flow direction.

v. Charcoal tray :- The charcoal tray is constructed with a 3 mm mild steel sheet. The sides of the tray were constructed with wire mesh to serve as air vent. It is located directly below the drum in a chamber so that maximum heat is transferred to the drum. The charcoal chamber can contain about 20 kg of charcoal. Heat is transfer to the groundnut by conduction principle through the drum.

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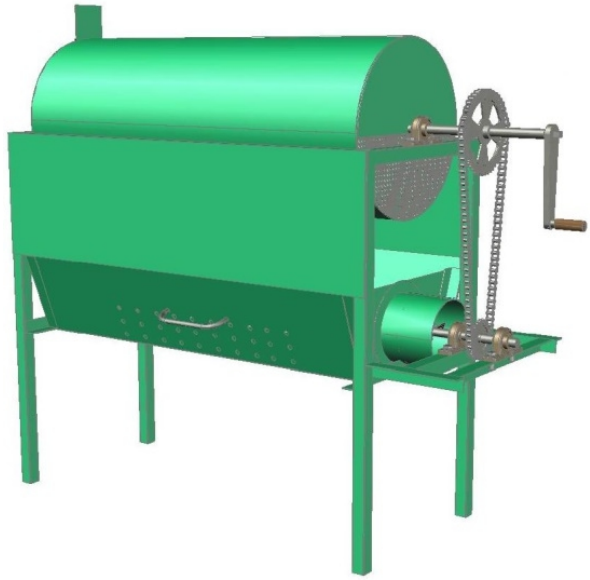

Figure 1. Isometric Views of the Roaster

2.4 Working Principle of the Roaster

The machine operated manually. When operating the machine charcoal tray was filled with charcoal and then ignited with matches or lighter. A 20 kg groundnut was then introduced into the drum through the loading opening. The drum was then rotated slowly at approximately 24 rev/min. The rotations were either clockwise or anticlockwise. Furthermore the rotation was continues with intermittently stoppage to check the roast level of the seeds. When the groundnut was fully roasted (when the color change from red to brown), the charcoal tray was move away from directly under the drum and then the groundnut was collected at the discharge side.

2.5 Experimental Procedure

A single factor experiment with three (3) different seed loading at 25, 50 and 100% capacity (5, 10, and 20 kg) was considered. The experiment replicated three times to reduce the bias. SAMNUT 11 varieties of groundnut seeds were used for these experiments. A similar experiment is conducted on the existing IAR roasting method (charcoal stove and frying pan). Figure 2 shows the constructed roaster during the evaluation process. External blowers had to be used to augment the axial fan.

Figure 2. Constructed manually operated groundnut roaster during evaluation

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2.5.1 Performance indicator

After developing the machine, it's performance was evaluated for the following parameters

Roasting capacity

This is a measure of the time taken for a given quantity of groundnut seeds to roast. It is expressed as, (Ikechukwu et al. 2014),

$$R_c = \frac{Q_f}{T} \quad (4)$$

Where: R_C is roasting capacity (kg/min), Q_f is quantity of groundnut in the drum (kg) and T is time taken to roast the groundnut (min).

Roasting efficiency

During the roasting process some seeds are damaged either by burning or breakage. The seed is consider burnt when it turn from red to black. The percentage of seeds was determined as, (Ikechukwu et al. 2014)

$$R_e = \frac{Q_f - Q_d}{Q_f} \times 100 \quad (5)$$

Where: R_e is roasting efficiency (%), Q_f is quantity of groundnut in the drum (kg) and Q_d is quantity of seed damage (kg)

3.0 Results and Discussion

3.1 Groundnut Roasting Time Under IAR Roasting Method

Table 1 shows the roasting time of groundnut seeds using the existing IAR groundnut roasting method. The time taken to roast 5 kg of groundnut was 14min to attain the desired roast colour while 56min was required to roast 20 kg of groundnut seeds to attain the desired roast colour.

Table 1: Roasting time using the IAR roasting method

Mass of fresh seeds (kg)	Mass of roasted seed (kg)	Time of roasting (min)
5	4.80	14
10	9.65	36
20	19.0	56

3.2 Effect of Seed Quantity on Roasting Time of Groundnut seeds

Table 2 shows the effective roasting time increases with increase in seed weight. It was observed that 20 kg had the highest roasting time of 21.67 mins. Additionally, roasting time was found to be affected by seed quantity alongside other factors such as moisture content and temperature. In general, a7.5% moisture content increases the roasting time as observed. This is because roasting takes place where there is rapid removal of water from the seeds and then millard browning. The result obtained is in accordance with the findings of Kabir et al., (2010) who obtained 9.5min effective roasting time for 5.5kg (maximum load) of groundnut seeds.

Table 2: Roasting time, weight of roasted groundnut, weight of damaged seeds.

Mass of Fresh seed (kg)	Roasting Time (min)	Mass of Roasted seeds (kg)	Mass of damaged seeds (kg)	Roasting capacity (kg/min)	Roasting efficiency (%)
5.0	12.17	4.73	0.07	0.41	98.60
10	16.50	9.43	0.17	0.61	98.30
20	21.67	18.98	0.22	0.92	98.90

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3.3 Effect of Seed Quantity on Roasting Capacity and Efficiency

Table 2 also shows the performance evaluation for different mass of groundnut seeds. The results show that full load capacity (20 kg) had the highest roasting capacity of 0.92 kg/min and also highest roasting efficiency of 98.90%. This implies that the machine could perform optimally when operated at full load capacity. The roasting capacity was better than the results obtained by Kabir et al., (2010) with roasting capacity of 0.567 kg/min . However, Ogijo (2019) obtained a higher roasting capacity of 1.69 kg/min than in this study. The reason for the higher roasting capacity is because the roaster was motorized.

Figure 3 shows a sample of the roasted groundnut using the manually operated drum type groundnut roaster. As can be observed a relatively uniform roasting was achieved, with less visible burnt surfaces. The result agree with the previous researches such as Abubakar et al., 2017; Kabir et al., 2010, Abdulsalam et al., 2013 and Olatunde et al., 2014. The authors obtained similar findings of uniform roasting.

Figure 3. Sample of roasted nut using the roaster.

3.4 Comparison of the Manually Operated Groundnut Roaster and the IAR Roasting Method

The IAR method uses a pan and a burner to roast groundnut. The IAR method of roasting leaves dark spot (indicating burn), on the seeds after roasting while in the case of manually operated Roaster, the roasting color is relatively uniform due to intermittent rotation of the drum thereby control the heat transfer by conduction. The manually operated groundnut roaster has a fairly more capacity (0.92 kg/min) than the IAR roasting method (0.28 kg/min).

3.5 The Traditional Roasting Method and the Manually Operated Roaster

Research work conducted by Nalumansi and Kaul, (1992) obtained a 20 mins roasting time for 2.5kg of groundnut seeds. Thus it will be time consuming and strenuous to roast 20 kg of groundnut using the traditional method. When compared to the constructed manually operated groundnut roaster, 72.91% reduction in roasting time is obtained.

4.0 Conclusion

The manual groundnut roaster, which was initially designed to roast groundnut seeds have been constructed and evaluated. The roaster has the ability to roast 55.2 kg of groundnut seeds in 1h. A maximum of 98.90 % roasting efficiency was obtained when roasting on full load capacity. Uniform roasting of the groundnut seeds was achieved. Instead of using an axial fan, a centrifugal blower can be used to enhance charcoal burning in order to obtain higher temperature in the drum.

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