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Fabrication and Testing of a Manual Charcoal-Fired Groundnut Fryer

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Abstract
Groundnut is an agricultural product that is of great value to both man and animals. It serves as raw material for industries. Frying is the process of generating characteristic aroma, flavour and colour required by consumers for acceptance of such fried food. The wide range usage of groundnut and its products has led to increase in its demand. However, the local methods of roasting Groundnut seeds after it has been shelled has some associated problems and difficulties which make it ineffective, laborious and time consuming. A manually operated Groundnut seed roaster was constructed with the aim of improving on the traditional methods commonly used in the Nigeria. The machine shows the roasting efficiency (Er) to be in the realm of 98.0% with percentages of seed damaged (loss) in the range of 2.00-20.0%. The average and optimum time for roasting was estimated to be in the range of 4 minutes.
Keywords: Groundnut, charcoal, groundnut fryer, mechanization, heat , manual
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1.0 INTRODUCTION

Groundnut is an agricultural product that is of great value to both man and animals. It serves as raw material for industries. Groundnut oil is also as vegetable oil for human consumption, while groundnut seed cake is being used as part of ingredients in animal and poultry feeds (Brian, 2005). The wide range of usage of this agricultural product has led to increase in its demand. Among the problems in processing agricultural materials is that of frying the seeds.

Frying is the process of generating characteristic aroma, flavor and colour required by consumers for acceptance of such fried food. Frying of food brings about thermal changes in the chemical components at relatively high temperature. This is accomplished by either using a hot air or small metal surface to heat up the material to the required temperature at which the material changes to required colour. Frying operation is traditionally done using different pots such as clay pots, aluminum pot, etc, on an open fire until they are brown (Williams and Chew, 2003). This method is ineffective, time consuming and laborious and subject people to back pain and expose them to smokes and heat from fire apart from firewood wastage.

Groundnut is roasted either by applying dry heat or using some vegetable oil. Mature groundnut can be soaked in brine and subsequently roasted. Dry roasted groundnut can be used in the preparation of groundnut butter, confectionery or bakery products. Roasting reduces the moisture content, develops a pleasant flavour and makes the product more acceptable for consumption. The reduction in moisture during roasting prevents moulding and reduces staling and rancidity. It is important to note that excessive heating during roasting lowers the nutritional quality of proteins (Brian, 2005).

Mechanized agriculture is the process of using agricultural machinery to mechanize the work of agriculture, greatly increasing farm worker productivity. In modern times, powered machinery has replaced many farm jobs formerly carried out by manual labour or by working animals such as oxen, horses and mules. The entire history of agriculture contains many examples of the use of tools, such as the hoe and the plough. But the ongoing integration of machines since the Industrial Revolution has allowed farming to become much less labor-intensive. Mechanization was one of the large factors responsible for urbanization and industrial economies. Besides improving production efficiency, mechanization encourages large scale production and sometimes can improve the quality of farm produce *(*Hounshell, *1994).*

The processing of groundnut in the form of roasting has been carried out in the traditional way by local farmers and low income earners who indulge in frying of groundnut for business. Traditionally, it has been carried out using local fire such as wood, charcoal etc., sand and a spatula which is used to turn continuously until it is well fried. The local roasting of groundnut produces uneven roast due to the unavailability of accurate temperature regulation devices and apart from exposing the groundnut to unhygienic conditions. It is a tedious process involving hand stirring and exposure to heat. It has been discovered that roasted groundnuts are of essential nutrients including phosphorus, manganese, copper and foliate and also lowers the risk of heart disease. This research work will go a long way in addressing the above mentioned problems and will also ensure that roasted groundnut are readily available in adequate quantity and quality.

The objective of this paper is to fabricate and test a manually operated groundnut seed roasting machine with charcoal as heat source.

2.0 MATERIALS AND METHODS

CONSTRUCTION THEORY AND DEVELOPMENT

In order to achieve a good construction, the selection of materials plays a vital role. Therefore, a good, rigid and durable structure of machinery indicates a good selection of materials during its construction. This chapter therefore, present theory and the design analysis of some machine part and the applicable engineering graphic representation.

DESCRIPTION OF THE GROUNDNUT ROASTING MACHINE

The major components of the machine are the loading opening in the drum as shown in plate 1 and 2, roasting chamber, the shaft, the paddles, the heating unit (charcoal), the discharge outlet and handle. The hopper is made up of welded metal sheets together with a flat metal sheet used for closure and exposure of the hopper.

The roasting compartment is made of a cylindrical metal plate of 28 cm diameter and 46 cm length with 2 mm plate thickness, a solid shaft of diameter 2 cm and length 55 cm that carries a set of paddles or flange of 22 x 40 cm made of metal sheet with 2 mm thickness, a metal plate of 46 x 36 cm containing charcoal placed under a metal plate at the bottom of the roasting chamber and handle for efficient operation.

DESCRIPTION OF MACHINE ELEMENT

i. **Loading Unit:** This is a rectangular shaped opening situated at the drum. It is the inlet in which the groundnut seeds are admitted into the roasting chamber with a dimension of 41.5 x 13 cm.
ii. **Roasting Chamber:** This is the core of the roasting section of the machine, it consists of a drum and it also carries the rotating shaft which houses the paddles. It is made of mild steel plate and supported by two bearing. Heating chamber is housed in this chamber.
iii. **Heat Chamber:** This is where the hot coals are kept, just below the roasting chamber, with perforations to allow the entrance of air.
iv. **Frame**: This is the mounting support of all the components of the machine. It is made of metal angle rod with a thickness of 5mm welded alongside the units which provide support on which the whole unit rest.
v. **Handle:** The handle in this case is the prime mover which is 20 cm long, this is connected to the shaft which turns the paddles/flanges in the roasting chamber (drum).

DESIGN CALCULATIONS

Before the machine was constructed, the following design calculations were carried out:

Shaft Design

The shaft design will be based on maximum shear theory (Hall, 1988). Diameter of the shaft is given as

$$d^3 = \frac{16}{\pi \delta_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (1)$$

Where: δ_s = allowable shear stress = 42 N/m^2 (maximum allowable stress for shaft ASME code of design of transmission shaft)

M_b = bending moment on shaft

M_t = Torsional moment

K_b = combined shock and factor applied to bending moment

K_t = combined shock and fatigue factor applied to torsional moment

Using K_b = 1.5 and K_t = 1.0 (Hall, 1988)

Determination of Torsional Moment on Shaft

M_t = torsional moment transmitted by the electric motor to the shaft through belt

From equation (1);

$$power = \frac{2\pi NT}{60}$$

Where: T = Torque or Torsional moment transmitted = M_t

$$P = T\omega \qquad (2)$$

Where: P = Power (kw)

$\omega =$ Angular speed (rad/sec)

T = Torque (Nm)

$$T = \frac{P}{\omega}$$

$$\omega = \frac{2\pi N}{60} \qquad (3)$$

$$= \frac{2 \times \pi \times 35}{60}$$

= 3.66rad/sec

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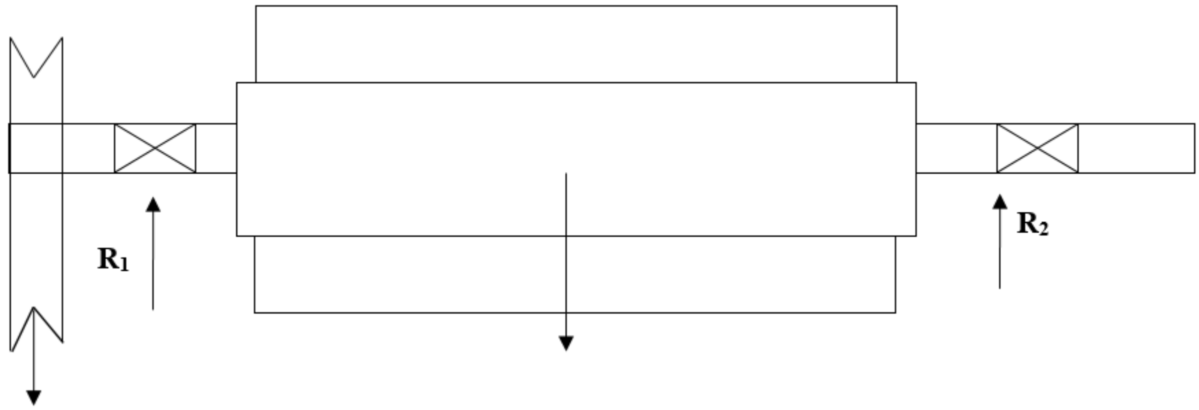
$$T = \frac{P}{\omega}$$
$$T = \frac{0.64441}{3.66}$$
$$= 0.176\text{Nm}$$
$$T = 0.176\text{Nm} = M_t$$

Loads on the Shaft

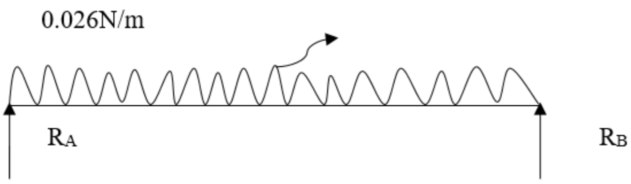


$$Density = \frac{mass}{volume} \qquad (4)$$
$$mass = density \times volume$$
$$volume = l \times b \times h$$

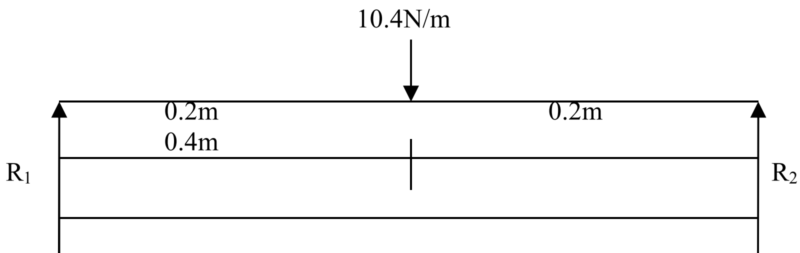
$$= 0.4 \times 0.22 \times 0.0015$$
$$= 0.000132m^3$$

$$mass = density \times volume$$
$$= 0.00013 \times 7850$$
$$= 1.0362kg$$
$$= 1.0362 \times 10$$
$$= \frac{10.362}{400}$$

$$= 0.026N/m$$



Converting from uniformly distributed load to point load = 0.026×400
$= 10.4N$



$$R_1 + R_2 = W$$
Taking moment about R_1
$$10.4 \times 0.2 = R_2 \times 0.4$$
$$R_2 = 5.2N$$
Recall $R_1 + R_2 = W$

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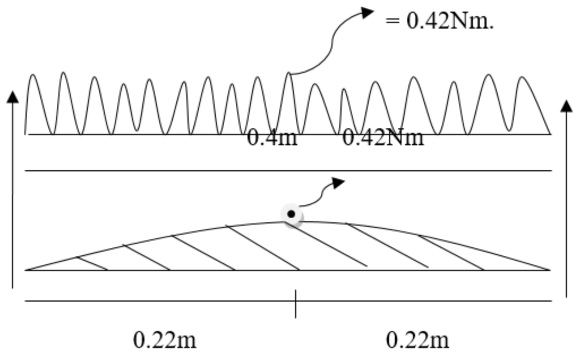
$$R_1 + 5.2 = W$$
$$R_1 = 10.4 - 5.2$$
$$R_1 = 5.2$$
$$\therefore R_1 = R_2 = 10.4N$$
$$BM_A = BM_A = 0$$
$$\text{At mid span} = \frac{wl^2}{4}$$
$$= \frac{10.4 \times 0.4^2}{4}$$



From equation (10);

$$d^3 = \frac{16}{\pi \times 42}\sqrt{(1.0 \times 0.42)^2 + (1.5 \times 0.176)^2}$$
$$d^3 = \frac{16}{\pi \times 42}\sqrt{(0.1764) + (0.069696)}$$
$$d^3 = 0.0602$$
$$d = \sqrt[3]{0.0602}$$
$$d = 0.0392m = 39.2mm$$

Due to factor of safety 40mm diameter shaft will be recommended.

Design for Volumetric Capacity of the Roaster

$$V_{rh} = \pi r^2 h$$

Where: V_{rh} = Volume of roasting chamber
r = radius of the chamber
h = height of the roasting chamber

$$V_{rh} = \pi \times 0.152 \times 0.41 = 0.03m^3$$
$$V_{sp} = \pi r^2 h - l \times b \times h$$

Where: V_{sp} = Volume of shaft and paddle
r = radius of shaft
h = height of shaft
l = length of paddle
b = breadth of paddle
h = thickness of paddle

$$V_{sp} = (\pi \times 0.0175^2 \times 0.41) - (0.4 \times 0.22 \times 0.0015)$$
$$= 0.00039 - 0.00013$$
$$= 0.00026m^3$$
$$V_{sg} = V_{rh} - V_{sp}$$

Where: V_{sg} = Volume of sand and groundnut

$$V_{sg} = 0.03 - 0.00026$$
$$= 0.02974m^3$$

$$Density = \frac{Mass}{Volume} \quad (5)$$
$$D_{sg} = \frac{M_{sg}}{V_{sg}} \quad (6)$$

Where: D_{sg} = Density of sand and groundnut
M_{sg} = Mass of sand and groundnut
V_{sg} = Volume of sand and groundnut

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Density of sand = 1602kg/m^3
Density of groundnut = 1010kg/m^3

$$D_{sg} = 1602 + 1010 = 2612\text{kg/m}^3$$

$$M_{sg} = D_{sg} \times V_{sg}$$
$$= 2612 \times 0.02974$$
$$= 77.7\text{kg}$$

$$M_g = \frac{D_g}{D_{sg}} \times M_{sg} \qquad (7)$$

Where: Mg = Mass of groundnut
Dg = Density of groundnut

$$= \frac{1010}{2612} \times 77.7 = 30.0kg$$

$$M_s = \frac{D_s}{D_{sg}} \times M_{sg} \qquad (8)$$

Where: M_g = Mass of groundnut
D_g = Density of groundnut $M_s = \frac{1602}{2612} \times 77.7$

$$M_s = \frac{1602}{2612} \times 77.7 = 47.7kg$$

MODE OF OPERATION
The roaster employs the principle of heat absorption by the groundnut seeds and attains uniform roasting as a result of heat supplied from the heating element and the action of the paddles housed by the shaft which causes the cotyledon to rotate with the aid of the an attached handle.

Harvested groundnut seeds with the desired moisture content are fed into the hopper of the roasting chamber when the medium (sand) already introduced attains a suitable temperature and the seed control device is opened to allow the seed to fall directly into the roasting chamber. The groundnut seed which are dropped into the roasting chamber mixes with the hot sand and it turns anti-clockwise at a given temperature to ensure even roasting. When the discharge unit of the roasting chamber is opened, the cotyledon and the bath moves out of the roasting chamber into the sieve suspended on top of the tray.

Performance Evaluation
The parameters used in evaluating the groundnut seed drum roaster are the roasting efficiency (Er)% and percentage seed loss. The mathematical for these parameters are.
Roasting efficiency

$$(Er)\% = \left(\frac{Wr}{Wt}\right) X\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

$$Percentage\ of\ seed\ damage/losses\ (Sd) = \left(\frac{Wd}{Wt}\right) X\ 100 \ldots\ldots\ldots\ldots\ldots (10)$$

Where:
W_d = weight of roasted seed damaged (over roasted)
Wr = weight of roasted seed not damaged
Wt = total weight of seed roasted (Wr + W_d)

Plate 1: Charcoal in the Heating Chamber

Plate 2: The Groundnut Fryer

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3.0 RESULT AND DISCUSSION

Results Obtained

Table 4.1 shows the comprehensive performance of the groundnut seed roaster. The evaluation parameters used are the roasting efficiency (Er) and percentage losses of seeds.

Table 4.1 Performance Evaluation Parameters of the Groundnut Seed Fryer

S/N	Weight of G/nut seed (g)	Weight of roasted seed (g)	Weight of damaged seed (g)	Time (min)	Roasting Efficiency (%)	% Seed damage/ Loss
1	250.00	200.00	50.00	8.00	80.00	20.00
2	250.00	230.00	20.00	6.00	92.00	8.00
3	250.00	240.00	10.00	4.00	96.00	4.00
4	250.00	245.00	5.00	2.00	98.00	2.00

Roasting Efficiency

$$\frac{w_r}{w_t} \times 100$$

For 200 g

$$= \frac{200}{50 + 200} \times 100$$
$$80\%$$

For 230 g

$$= \frac{230}{20 + 230} \times 100$$
$$= \frac{230}{250} \times 100$$
$$92\%$$

For 240 g

$$= \frac{240}{10 + 240} \times 100$$
$$= \frac{240}{250} \times 100$$
$$96\%$$

For 245 g

$$= \frac{245}{5 + 245} \times 100$$
$$= \frac{240}{250} \times 100$$
$$98\%$$

Discussion of Results

The roaster efficiency appears to be generally high in the range of 80.00 to 98.00% at four different level of roasting groundnut seeds in the drum roaster. Seed losses (EI), was observed but at a low level in the range of 2 to 20%. One of the distinguishing features of the roaster is that instead of using conventional firewood as the source of energy, wood Charcoal was used to supply heat the roaster.

4.0 CONCLUSION

The groundnut seed roaster constructed during this investigation was observed to roast groundnut seeds at faster rate than the traditional that was takes 20 – 30 minutes and exposes the health of rural women to great danger. The drying required was observed to be lighter, because the moisture content required for frying is the moisture content require for the safe storage and preservation of groundnut seeds.

5.0 RECOMMENDATIONS

After achieving the aim and objectives of this research work, recommendations are made as follows:

i. It is recommended that for optimum roasting the groundnut should be sun dried before roasting.
ii. Further investigation on other groundnut seed varieties should be carried out at various roasting moisture content to determine the optimum moisture level that would be convenient for roasting.

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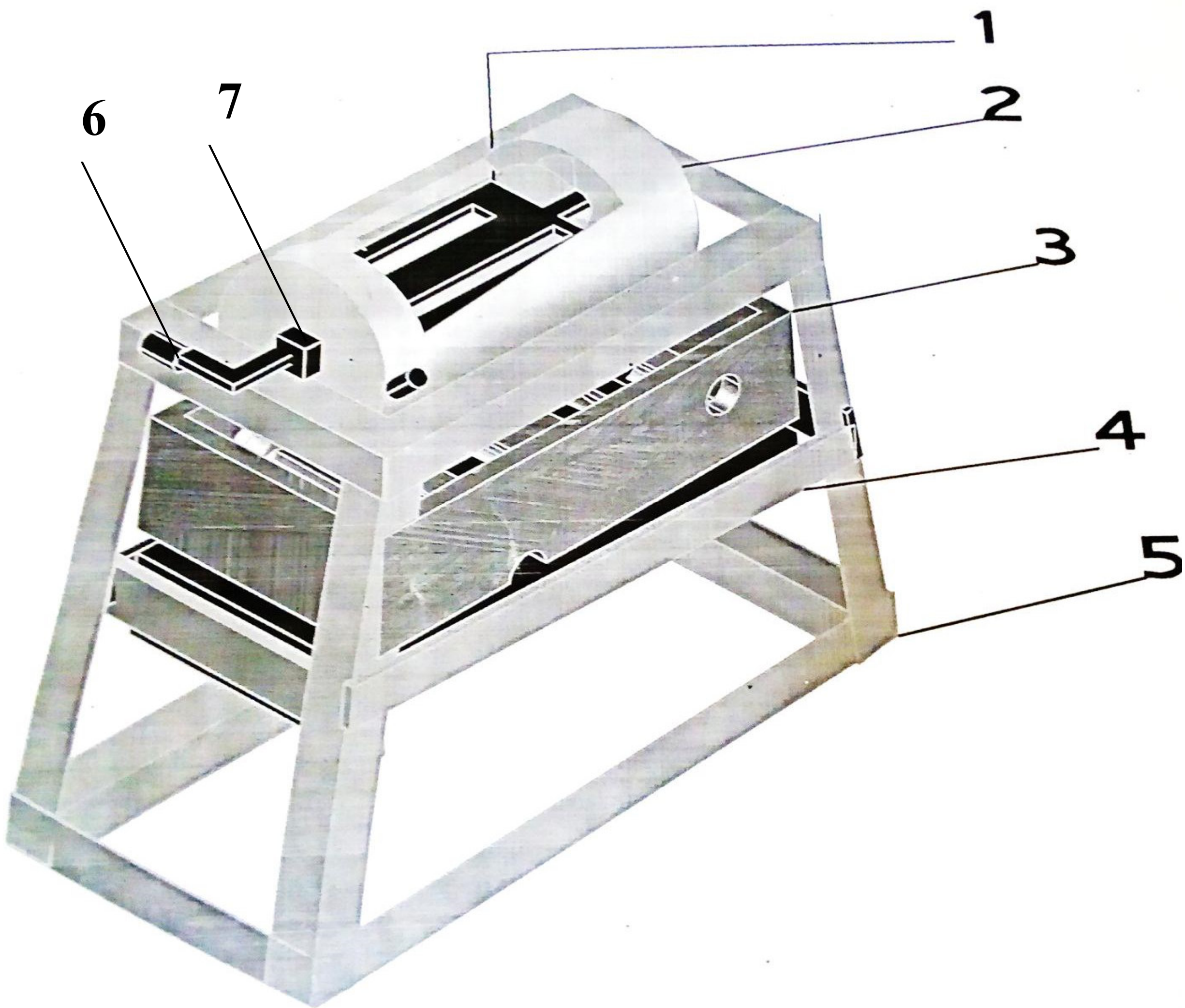
APPENDIX



LEGEND:
1. Off loading handle
2. Seed drum
3. Charcoal tray
4. Tray handle
5. Frame
6. Operating handle
7. Bearing housing