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Development of a Manually Operated Multi-purpose Roasting Machine

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: The aim of this research is to design and fabricate multi-purpose roasting machine.
Study Design: Development of a manually operated multi-purpose roasting machine was achieved with the aid of conceptual sketch, design analysis and creo parametric software.
Place and Duration of Study: Department of Mechanical Engineering, Federal University of Technology, Akure, Ondo State, Nigeria, between July 2014 and October 2016.
Methodology: Design of the developed multi-purpose roasting machine was done using creo parametric software. Some factors were considered before fabrication of the developed machine such as selection of materials, operating parameters, manufacturing processes and functional requirements.
Results: The multi-purpose roasting machine was developed and tested on food items (maize and plantain).
Conclusion: The multi-purpose roasting machine was developed based on the design. The machine developed is a simple technology which can be easily operated by a single person of an average height of 1.4 m. The developed machine is a capable of roasting food items (maize, yams and plantain) depending on the choice of the operator and season of harvest. The bill of engineering measurements and evaluation (BEME) of the developed machine is 231.26 dollars.

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Keywords: Roasting machine; multi-purpose; development.

1. INTRODUCTION

Nearly all the foods we consume are processed in some way such as milling, frying and roasting. Food processing is defined as the practices used by food and beverage industries to transform raw plant and animal materials into products for consumption. The processing of food items has become an important aspect in human daily consumption of food [1].

The method of application of heat for food processing is the most prominent method in Nigeria. It is common in urban household and among the rural dwellers, who themselves through farming take roasting as an important food processing technique.

Roasting is a process by which the food product are subjected to thermal and irreversible structural changes accompanied by reduction of moisture contents purposely to enhance digestible content for human consumption [2]. Transfer of heat can be determined by the property of matter and temperature. It is governed by the second law of thermodynamics which dictates that a free flow of heat is possible only from a body of higher temperature to a lower temperature. Three mechanisms modes of heat transfer are conduction, convection and radiation [3].

Thermal radiation is one of the basic mechanisms for energy transfer between regions of two or more different temperatures by which heat is conveyed from one place to another without heating the intervening medium. It involves the emission of heat rays through spaces and roasting will be successfully obtained in the exposure of fresh maize to the radiant heat emitted from charcoal contained inside an enclosure chamber [4]. Therefore, this research work was carried out to develop a manually operated multi-purpose roasting machine in Nigeria.

1.1 Brief Description of the Existing Roasting Machine

Ilori et al. [5] fabricated a maize roasting machine that has a treadle drive mechanism which serves as a power transmission system. The machine basically consisted of a roasting chamber, a longitudinal main shaft which carried a circular disc and four charcoal trays with different pattern of air flow dust.

With traditional method, roasting of maize is done by placing the charcoal inside a tray and a metal grill is placed on top of the tray mainly to separate the maize to be roasted and charcoal. The maize to be roasted is placed on top of metal grill and hand fan is used to blow air which support combustion. The faster the hand fan blows, the faster the air current, the faster the rate of combustion and the rate of heat transfer from the charcoal to the maize The process becomes strenuous as the operator tired out with time before the maize is completely roasted. Also, direct contact and exposure of the human body to direct heat emitted from the charcoal may have side effect on the human skin.

1.2 Brief Description of the Developed Machine

The developed machine has a sliding mechanism connected to the charcoal chamber which allows the regulation of temperature of the heat depending on the food items to be roasted. The developed machine operates in such a way that once the handle attached to the flywheel is roasting, flywheel undergoes rotatory motion. As the motion from the handle rotates the flywheel, it allows the chains and sprockets to rotate which has being incorporated with the flywheel. Food item holder and blower have being incorporated with chains and sprockets. Once the chains and sprockets rotate, the food item holder rotates likewise the blower will generate air that has being channeled to the charcoal chamber. The developed machine is capable of roasting food items such as maize, plantain and yam depending on the choice of the operator. It can be operated by single person with an average height of 1.4 meters.

2. METHODOLOGY

The Table 1 gives a summary of the choice of material selected for the fabrication of component parts of the machine. Research methodology used is:

Table 1. Material selection

Machine components	Criteria for material selection	Material selected	Remarks
Frame	Must be strong, low cost and not too massive	Angle Iron (mild Steel)	It does not twist and ability to maintain stability.
Handle	Ability to resist corrosion	Rod and Galvanized pipe	Available at low cost
Chain	Must be tough and hard	High Speed Steel	Suitability
Charcoal chamber	Must be high in weight	Galvanized Iron Sheet	It must be light
Sprocket	Ability to have good wear property	Mild Steel	Availability
Bolt and Nut	Must be hard, durable and tough	Alloy Steel	Available at low cost

2.1 Design Analysis

The development of the multi-purpose roasting machine was achieved with the aid of conceptual sketch, design and analysis. Design of the developed machine was done using creo parametric software and some of the design analysis of the machine is;

2.1.1 Design analysis of the frame

A frame is a structure on which the components of a machine are assembled. The frame of the multi-purpose roaster was designed to accommodate the flywheel, chains, sprockets, roasting chamber and charcoal chamber etc. The frame is made from 40 mm L-shaped angle bar.

$$V_O = L_O \times B_O \times T_O \quad (1)$$

Where V_O, L_O, B_O and T_O represents outer volume of the long braze (mm^3), length of the outer braze (mm), breadth of the outer long braze and thickness of outer long braze (mm) respectively.

$$V_O = 556 \times 40 \times 40$$
$$V_I = L_I \times B_I \times T_I \quad (2)$$

Where V_I, L_I, B_I and T_I represents inner volume of the long braze (mm^3), length of the inner braze (mm), breadth of the inner long braze and thickness of inner long braze (mm) respectively.

$V_I = 556 \times 38 \times 38$

Total Volume of Long Braze = V_O - V_I
Total Volume of Long Braze = 86736.0 mm^3

$$M = \rho V \quad (3)$$

Where M, ρ and V represents mass of long braze (kg), the density of angle bar (7.82 x 10^{-6} kg/mm^3) and volume of the long braze (mm^3)

$$M = 0.00000782 \times 86736$$

M = 0.68 kg

$Total\ Mass\ of\ Long\ Braze = 3 \times 0.68$
Total Mass of Long Braze = 2.04 kg

$$V_{So} = L_{So} \times B_{So} \times T_{So} \quad (4)$$

Where V_{So}, L_{So}, B_{So} and T_{So} represents outer volume of the short braze (mm^3), length of the outer short braze (mm), breadth of the outer short braze and thickness of the outer short braze (mm) respectively.

$$V_{SO} = 416 \times 40 \times 40$$
$$V_{SI} = L_{SI} \times B_{SI} \times T_{SI} \quad (5)$$

Where V_{SI}, L_{SI}, B_{SI} and T_{SI} represents inner volume of the short braze (mm^3), length of the inner short braze (mm), breadth of the inner short braze and thickness of inner short braze (mm) respectively.

$$V_{SI} = 416 \times 38 \times 38$$

Total volume of the short braze $= V_{SO} - V_{SI}$

Total volume of the short braze is 64896 mm^3 and mass of short braze is 0.51 kg.

Therefore, total volume of short braze is 64896 mm^3 and total mass of short braze is 2.04 kg.

$$V_{LO} = L_{LO} \times B_{LO} \times T_{LO} \quad (6)$$

Where V_{LO}, L_{LO}, B_{LO} and T_{LO} represents outer volume of the outer leg (mm^3), length of the outer leg (mm), breadth of the outer leg (mm) and thickness of the outer leg (mm) respectively.

$$V_{LO} = 617.2 \times 40 \times 40$$
$$V_{IL} = L_{IL} \times B_{IL} \times T_{IL} \quad (7)$$

Where V_{IL}, L_{IL}, B_{IL} and T_{IL} represents inner volume of the inner leg (mm^3), length of the inner leg (mm), breadth of the inner leg and thickness of inner leg (mm) respectively.

V_I = 617.2 × 38 × 38 cm^3

$$Total\ volume\ of\ the\ leg = V_{LO} - V_{IL}$$

Total volume of leg = 96283.2 mm^3
Mass of the leg is 0.76 kg

Total volume of the leg is 96283.2 mm^3 and total mass of leg is 3.04 kg.

Total mass of the frame = Total mass of the long braze + total mass of the short braze + total mass of the Leg.

Total Mass of the Frame = 7.12 kg.

2.1.2 Design analysis of roasting chamber

In designing the roasting chamber, various lengths and diameters of maize and plantain were considered. The Roasting Chamber is formed from a galvanized sheet of 600 mm by 500 mm.

$$V_{RO} = L_{RO} \times B_{RO} \times T_{RO} \quad (8)$$

Where V_{RO}, L_{RO}, B_{RO} and T_{RO} represents outer volume of the roasting chamber (mm^3), length of the outer roasting chamber (mm), breadth of the outer roasting chamber and thickness of outer roasting chamber (mm) respectively.

$$V_{RO} = 600 \times 500 \times 145$$
$$V_{RI} = L_{RI} \times B_{RI} \times T_{RI} \quad (9)$$

Where V_{RI}, L_{RI}, B_{RI} and T_{RI} represents inner volume of the roasting chamber (mm^3), length of the inner roasting chamber (mm), breadth of the inner roasting chamber and thickness of inner roasting chamber (mm) respectively.

$$V_{RI} = 580 \times 480 \times 125$$

Volume (V_H) of the Holes = $\frac{\pi d^2 h}{4} \times 160$ (10)

Where V_H, d and h represents volume of the hole (mm^3), diameter of the hole (mm) and height of the hole (mm) respectively.

$$V_H = \frac{3.142 \times 20^2 \times 2}{4} \times 160 \quad (11)$$

Volume (V_{hh}) of the hanger holes = $\frac{\pi d^2 h}{4} \times 10$

Where V_{hh}, d and h represents volume of the hanger hole (mm^3), diameter of the hanger hole (mm) and height of the hanger hole (mm) respectively.

$$V_{hh} = \frac{3.142 \times 40^2 \times 145}{4} \times 10$$

Total volume of roasting chamber = V_{RO} – (V_{RI} + V_H + V_{hh})

Density of galvanized sheet is 0.00000785 kg/mm^3.

Total volume of roasting chamber is 6827368 mm^3 and mass of roasting chamber is 5.36 kg

2.1.3 Design analysis of charcoal chamber

The charcoal chamber was constructed with adjusted mechanism having dimensions quite lesser than that of the roasting chamber. The material used was sheet metal of 2mm thickness.

$$V_{CO} = L_{CO} \times B_{CO} \times T_{CO} \quad (12)$$

Where V_{CO}, L_{CO}, B_{CO} and T_{CO} represents outer volume of the charcoal chamber (mm^3), length of the outer charcoal chamber (mm), breadth of the outer charcoal chamber and thickness of outer charcoal chamber (mm) respectively

$$V_{CO} = 580 \times 460 \times 60$$
$$V_{CI} = L_{CI} \times B_{CI} \times T_{CI} \quad (13)$$
$$V_{CI} = 560 \times 440 \times 40$$

$$Total\ volume\ of\ the\ charcoal\ chamber = V_{CO} - V_{CI}$$

Density of sheet metal is 0.00000782 kg/mm^3.

Total volume of the charcoal chamber is 6152000 mm^3 and mass of charcoal chamber is 4.81 kg.

2.1.4 Design analysis of chain

Chain is used for transmission of mechanical power on much domestic and industrial mechanism. It has a surprising number of parts;

roller turns freely on the bushing which is attached on each end to the inner plate and a pin passes through the bushing and is attached at each end to the outer plate [6].

2.1.5 Design analysis of sprocket

Sprocket is a toothed wheel upon which a chain rides. Selection of a sprocket depends on the dimensions of the chain which is to run upon it (i.e. pitch, roller diameter, roller width of the chain and number of teeth in the sprocket.

2.1.6 Design analysis of bearing

Bearing is a machine element that constrains relative motion to only the desired motion. The design of roller bearing used provided free linear movement and prevented motion by controlling the vectors of normal forces that bear on the moving parts [7].

2.2 Fabrication Process

The construction of the developed machine was done at Adesuyi welding shop located at Car street, Akure, Ondo State. Before construction, some factors were considered such as selection of materials, operating parameters, manufacturing processes and functional requirements. The selection of materials for the construction of multi-purpose roasting machine was based on availability of the material, cost of materials and overall weight of the machine.

2.2.1 Frame

The frame is a table like structure meant to accommodate and provide necessary support for various parts of the machine. The frame is made from 40 mm L-shaped angle iron bar. Three long braze, four short braze and four legs were welded together based on the design analysis to form Fig. 1. Dimension of the Long braze, short braze and legs were 556 mm, 416 mm and 617.2 mm respectively.

2.2.2 Roasting chamber

The roasting chamber is an important component in the machine because it accommodates other components such as food item holder, chains and sprockets etc. Two pieces of 2 mm galvanized sheet of length 600 mm by 145 mm were marked out and cut using cutting machine. Two pieces of 2 mm galvanized sheet of breadth 500 mm by 145 mm were marked out and cut using cutting machine. Also, one piece of 2 mm galvanized sheet of 600 mm by 500 mm was marked out; cut and 160 holes of diameter 40 mm were driven by drilling machine. Ten hanger holes of diameter 40 mm were driven on the sides of the roasting chamber of dimension 600 mm by 145 mm. All the pieces were welded together based on design analysis to form Fig. 2. Dimension of the length, breadth and height were 600 mm, 500 mm and 145 mm respectively.

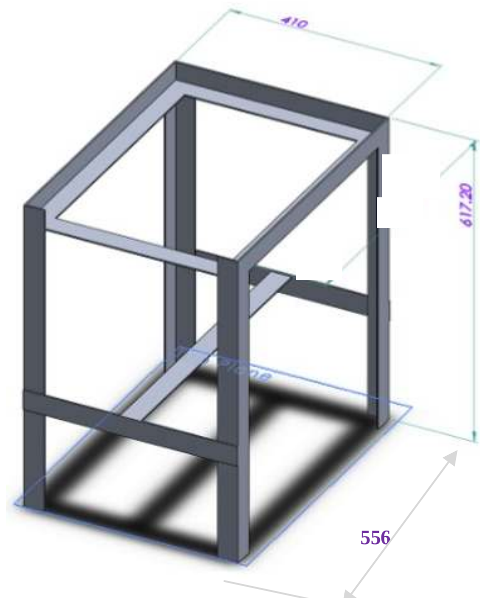

Fig. 1. Frame

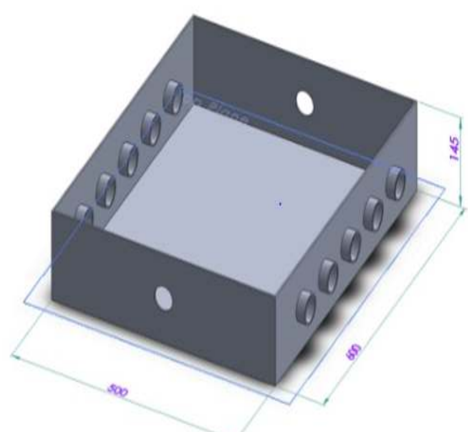

Fig. 2. Roasting chamber

2.2.3 Charcoal chamber

Charcoal chamber was constructed with adjusted mechanism having dimensions quite lesser than that of the roasting chamber. Two pieces of 2 mm galvanized sheet of length 580 mm by 60 mm were marked out and cut using cutting machine. Two pieces of 2 mm galvanized sheet of breadth 460 mm by 60 mm were marked out and cut using cutting machine. Also, one piece of 2 mm galvanized sheet of 580 mm by 460 mm was marked out and cut. All the pieces were welded together based on design analysis to form charcoal chamber.

The charcoal chamber stands on supports that are fabricated from metal stripes that run through the length and breadth of the roasting chamber so that the charcoal chamber can slide out from the stand.

2.2.4 Blower housing

It was fabricated from 2.0 mm thick metal sheet, folded and there was inlet of incoming air from the impeller. The incoming air from the impeller was channeled directly into the charcoal chamber to support combustion.

2.2.5 Food item holder

It was fabricated from mild steel and was used to hold whatever is meant to be roasted in the machine. It is a tiny rod that has a cylindrical cross section and was designed to rotate once the chains and sprockets is rotating.

2.3 Welding and Assembly of Fabricated Machine Component

The various parts of the machine that were welded together include the frame, roasting chamber, food item holder and charcoal chamber etc.

These machine members include; the insertion of the roasting chamber which accommodates chains, sprockets, bearings, food item holder, construction of the stand for the charcoal chamber, fixing of the bearing into its housing and attaching the food item holder to the sprockets. Ten small sprockets were inserted on the both outside of the roasting chamber while three small sprockets were rigidly attached with nuts to the blower shafts. Ten ball bearings were inserted to the shaft of the both inside of the roasting chamber while another ten ball bearings were rigidly inserted to the shaft of the both outside of the roasting chamber. All parts of the machine were firmly secured to ensure rigidity and support. The finishing of the fabricated machine involves grinding the welded joints and painting with emulsion paint.

3. RESULTS AND DISCUSSION

The fabricated multi-purpose roasting machine was developed has shown in Fig. 4, tested and used to roast ten different weights of maize cobs (120 g, 120 g, 120 g, 125 g, 130 g, 130 g, 133 g, 135 g, 140 g and 140 g) and plantains (160 g, 160 g, 170 g, 170 g, 175 g, 175 g, 180 g, 190 g, 200 g and 200 g). Three experiments were carried out on each set of food item. Roasting time for maize cobs are 12.3 minutes, 11.8 minutes and 11.9 minutes while roasting time for plantains are 20.2 minutes, 19.8 minutes and 20.0 minutes using 2.0 kg of charcoal. The average roasting time for maize cobs and plantains were 12 minutes and 20 minutes respectively compared to the existing method which took 15 minutes and 35 minutes respectively. The roasting time depends on the moisture content of the food items and charcoal. The higher the moisture contents, the higher the roasting time. Inflammation ratio of maize cob and plantain after roasting is 0.97 and 1.63 respectively.

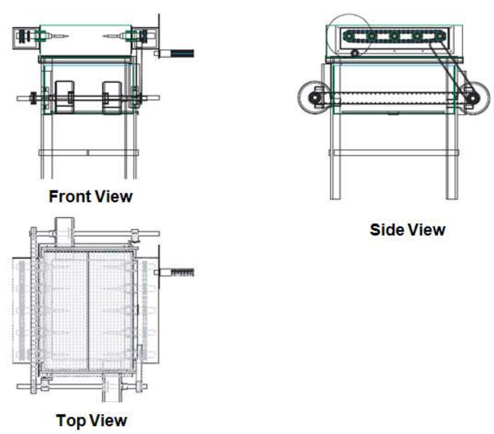

Fig. 3. Orthographic view of the multi-purpose roasting machine

3.1 Recommended Maintenance Schedule for the Fabricated Machine

The following maintenance should be carried out on the machine;

i. The machine should be kept clean and avoid moisture place.
ii. Preventive and routine maintenance should be adopted to prevent total breakdown of the machine.

iii. The food item holder should be cleaned after roasting the food items to avoid the material sticking on it.

Fig. 4. Developed multi-purpose roasting machine

4. CONCLUSION

The multi-purpose roasting machine has been developed based on the design. The machine developed is a simple technology which can be easily operated by a single person of an average height of 1.4 m. Machine developed is on the current form and is up to standard in terms of competition, marketing and cost.

The machine is capable of roasting food items (maize, yams and plantains) depending on the choice of the operator. For optimal use, the ratio of maize cobs to charcoal is 1.29 to 2 while for plantains is 1.78 to 2. For optimal regimes, 30 maize cobs and plantains were chosen. The developed machine was used to roast ten cobs of maize and ten plantains within 12 minutes and 20 minutes respectively. This result is in line with the work of Oke [8], whose machine produced ten cobs of maize and plantains for 15 minutes and 35 minutes respectively. The bill of engineering measurements and evaluation (BEME) of the developed machine is 231.26 dollars. For mass production, stainless steel will be used for the construction. However, the research target was for low income earners. Machine developed can be recommended in the form of user manual.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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