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Design and Construction of a Groundnut (*Arachis hypogeaa L*) Roasting Machine in Delta State, Nigeria

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ABSTRACT: The global quest for sustainable and environmentally responsible food processing practices has led to groundbreaking innovations in the design and construction of agricultural machineries. Hence, the objective of this paper was to design and fabricate a groundnut *(Arachis hypogaea* L*)* roasting machine in Delta State, Nigeria using appropriate standard engineering and technological procedures. The results demonstrate that the designed and fabricated groundnut (Arachis hypogaea L) roasting machine these innovations yielded an exceptional roasting efficiency of up to 87%. This paper further explores the interplay between the machine's components and provides insights into its functionality. Visual inspection tests guarantee the quality of welding, component alignment, and overall aesthetic appeal. This research could be an innovative design and fabrication that could lead to the path of sustainable nut processing.

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In a world grappling with a growing demand for sustainable food processing techniques and equipment, the design and construction of efficient, eco-friendly, and cost-effective machinery has become a priority. Among these innovations, the groundnut roasting machine has emerged as a noteworthy focal point in the journey towards sustainable nut processing. Groundnuts, also known as peanuts, have long been a staple in diets worldwide and a critical source of essential nutrients. As we confront environmental challenges and seek to reduce our carbon footprint, the need for inventive solutions in the realm of food production cannot be overstated (Alao *et al*., 2020). This paper explores the groundbreaking developments in the design and construction of groundnut roasting machines, delving into the technological advancements that promise to reshape the landscape of nut processing. Not only do these innovations aim to improve the efficiency and quality of roasted groundnuts, but they also align with the broader objective of sustainability in food production, which includes energy efficiency, reduced waste generation, and environmentally friendly practices (Ikechukwu *et al*., 2014). Groundnut roasting machines have historically played a pivotal role in nut processing, contributing to the enhancement of flavors, textures, and preservation of nutritional content. However, the traditional methods and outdated machinery have often fallen short in terms of sustainability, as they consume excessive energy and generate unnecessary waste. This is where the recent advancements come into play, ushering in a new era of nut processing that is not only more efficient but also more environmentally responsible (Ahanmisi *et al*., 2019). In the subsequent sections of this paper, we will delve into the key innovations in groundnut

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roasting machine design, which encompass energy-efficient heating mechanisms, smart automation, reduced carbon emissions, and improved product quality. Furthermore, we will explore the implications of these innovations for the broader landscape of sustainable food processing, shedding light on the potential benefits they hold for both the industry and the environment (Unguwanrimi *et al*., 2020). The journey to a sustainable future for nut processing begins with these innovations in groundnut roasting machines, serving as a testament to the creative and progressive spirit of engineering and design. By embracing the opportunities presented by these advancements, we can unlock a path to sustainable nut processing that not only satisfies the appetites of the present but also ensures the well-being of generations to come (Adesoji *et al*., 2017).

MATERIALS AND METHODS

The construction of a groundnut roasting machine typically involves the use of various materials, chosen for their durability, heat resistance, and suitability for food processing equipment. The specific materials can vary depending on the design and scale of the machine, but common components and materials often include:

Stainless Steel: Stainless steel is a preferred material for the exterior casing and structural components of the machine. It is corrosion-resistant, easy to clean, and provides a hygienic surface for food processing equipment.

Mild Steel: Mild steel is often used for the frame or structural support of the machine due to its strength and durability. It is usually coated or treated to prevent rust and corrosion.

Aluminum: Some parts of the machine, especially those requiring lightweight yet robust components, may be made of aluminum. It is valued for its high strength-to-weight ratio and resistance to corrosion.

Heat-Resistant Alloys: Components that are exposed to high temperatures, such as the roasting drum or the heating element, are typically constructed using heat-resistant alloys like stainless steel with higher heat resistance or specialized materials designed to withstand high temperatures.

Insulation Materials: Thermal insulation is essential to prevent heat loss and ensure energy efficiency. Insulating materials like ceramic fiber, fiberglass, or rock wool are commonly used to line the roasting chamber.

Conveyor Belt Material: In conveyor-type roasting machines, the conveyor belt is usually made of materials that can withstand high temperatures, such as PTFE-coated fiberglass or metal mesh belts.

Electrical Components: Wiring, switches, and other electrical components are made of materials designed to meet safety and electrical standards. They include copper wires, heat-resistant connectors, and insulating materials.

Bearings: Bearings are essential for the rotating components of the machine, such as the roasting drum. Bearings are typically made of materials like stainless steel, ceramic, or self-lubricating materials for smooth and reliable operation.

Seals and Gaskets: Food-grade seals and gaskets are used to prevent leaks and maintain a controlled environment within the roasting chamber. These are often made from silicone or other food-safe elastomers.

Glass: Some roasting machines have inspection windows or viewing ports made of tempered glass, allowing operators to monitor the roasting process.

Fasteners: Nuts, bolts, and screws used for assembly are typically made of stainless steel or other corrosion-resistant materials.

Control Panels: The control panel housing and components are often made of materials like stainless steel or high-temperature plastics.

Ceramic or Stone Plates: In certain traditional roasting machines, ceramic or stone plates are used as the roasting surface for a more traditional roasting method.

It's important to note that the materials chosen for a groundnut roasting machine must comply with safety and food-grade standards to ensure the quality and safety of the roasted nuts. The selection of materials also considers factors such as heat distribution, sanitation, and maintenance requirements.

Main component parts of the roasting machine are (i). The shaft, (ii). V- Belt (iii). Pulley (iv). Gas hose (v). Stainless steel, (vi). Gas burner, (vii). Gas cylinder with regulator, (viii). Electric motor (0.25hp), (x). Stirrer, (xi). Bearing

Description of the groundnut roasting machine: The groundnut roasting machine features an electric heating element positioned beneath the roasting chamber, equipped with regulators for precise temperature monitoring and control. Within the roasting chamber, a shaft is affixed, complete with pedals designed to agitate and evenly roast the nuts. For visual reference, Figure 1 provides the assembled view of the roasting machine.

Fig 1: Pictorial view of the roasting machine

Design calculation

Shaft design: A shaft serves as a dynamic machine component employed to transfer power between two points. In the context of this machine, the shaft accommodates a pulley, which receives its power through a belt-driven connection from an electric motor, and subsequently, this power is distributed to the peeling drum and two bearings. The chosen material for the driven shaft is low carbon steel 1018, characterized by a yield strength of 370 mPa, and possessing a diameter, denoted as 'd,' of 260 mm. Additionally, the maximum bending moment applied to the shaft is calculated to be 35.94 mPa. Utilizing the torsion equation, we can further analyze and understand the behavior of this shaft under the given conditions (Equation 1).

$$\frac{T}{1} = \frac{T}{y} \qquad 1$$

Where T = twisting moment actin upon the shaft; I = Polar moment of inertia of the shaft about the axis of rotation; τ = Torsional shear stress; Y = distance from neutral axis to the outer most fiber

$$Y = x = \frac{D}{2}$$

Where D = diameter of the shaft; $T = \frac{\tau J}{r}; J = \frac{\pi \mathrm{d}\,4}{\pi \mathrm{d}}$

$$J = \frac{\pi}{32} \times \mathrm{d}4 \qquad 2$$

$$= \frac{3.142}{32} \times (0.012)4 = 2.04 \times 10 - 9$$

The Equation 1 may now be written as

$$\frac{T}{\frac{\pi}{32} \mathrm{x}\, d^4} = \frac{\tau}{\frac{d}{2}} \; T = \frac{\pi}{16} \mathrm{x}\, \tau \,\mathrm{x}\, d^3 \qquad 3$$

or

$$T = \tau_x y \times \frac{\pi}{16} \mathrm{x}\, d^3$$

$$= 300 \times \frac{3.142}{16} X\, 0.26^3 \; 300 \times 0.196 \times 0.017576$$

$$= 1.0334 Nm$$

The bending stress developed in the shaft

$$\sigma b = \frac{M}{Z} \qquad 4$$

$$Z = \frac{\pi}{32} \mathrm{x}\, d^3$$

$$\sigma b = \frac{32xM}{\pi\, x\, 0.26^3} = \frac{32x35.94}{\pi\, x\, 0.3^3} = 4.067$$

Bending Moment Calculations

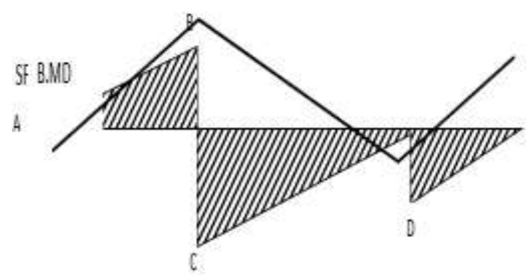

Fig. 2: bending moment and shear force diagram

$$A = F1, B = F2, C = R1, D = R2$$

$$F2 = (0.05 = F1\,(0.035 + 0.08) + R1\,(0.08)$$

$$F2 = 1.62\,(0.035 + 0.08) + 0.98(0.08)$$

$$F2 = 5.294\, N$$

From Equilibrium of forces

$$F2 = R2 + F1 + R1$$

$$R2 = 5.294 - (1.62 + 0.98\, x\, 2)$$

R_2 = -2.694 N (the negative sign shows the direction is in opposite direction).

To find the Horizontal Bending Moment (MB)

Moment about A is zero, since no displacement

$\Sigma ma = 0$

Moment about B

$$\Sigma mb = F2\,(0.05 = 5.294\, x\, 0.05\, Nm$$

$$= 264.7\, Nmm$$

Moment about C

$$\Sigma mc = F2\,(0.05 + 0.08) - R2\,(0.05)$$

$$\Sigma mc = 0.5537\, Nm = 553.7\, Nmm$$

Moment about D

$$\Sigma md = R1\,(0.05 + 0.08 + 0.035) - R2\,(0.05 + 0.035) - R1(0.04)$$
$$\Sigma md = 0.0.61025\,Nm = 610.3\,Nmm$$

Selecting the maximum horizontal bending moment for design**.**

We thus neglect the vertical bending moment since there are no vertical loading $\sqrt{\sum M_V^2 + \sum M_h^2}$

Where $\Sigma mv = 0$

$$\Sigma MB = \surd(\Sigma Mv2 + 0 = \surd 336.52 = 336.5\,Nmm$$
$$\Sigma MB = 0\sqrt{(0 + \sum M_h^2)}$$
$$\Sigma MB = \sqrt{610.24^2} = 610.24\,Nmm$$

Torque Calculation: Using a 0.25 Horse power (0.25hp) electric motor

Standard speed = 1400rpm, maximum speed of the machine used

To find the maximum torque,

We know that,

$$T = P * 60/2\pi N$$

Where P= Power in Watt, N = speed in revolution per minute,

$$1hp = 0.746KW$$
$$0.25\,x\,0.746 = 0.1865KW$$

Inserting the corresponding values in the above equation

$$T = \frac{186.5\,x\,60}{2x\pi x\,1400} = 1.272Nm = 1271.9Nmm$$

NOTE: The shaft is subjected to both twisting and bending moments.

$$Torque\ of\ \ Motor = \frac{60p}{2\pi N} \qquad 5$$

$$T = \frac{60\,x\,(7460)}{2\,x\,3.142\,x\,266.7} = 267N - m$$

To calculate for shear stress, we use,

$$T = \frac{\pi}{16}\,\tau\,xd3 \qquad 6$$

But, T = 267 N-m.

$$267 = \frac{\pi}{16}\,X\,T\,X\,d3$$
$$267 = \frac{\pi}{16}\,X\,T\,X\,d3$$

$$Diameter\ of\ shaft\ d, \quad = 12mm \quad = 0.012m$$

$$= 267 = \frac{3.142}{16}\,x\,\tau\,x\,(0.012)3$$
$$267 = 0.1964\,x\,\tau\,x\,1.728\,x\,10 - 6$$
$$\tau = \frac{267}{0.1964\,x\,1.728\,x\,10 - 6}$$
$$\tau = \frac{267\,x\,106}{0.1964\,x\,1.728}$$
$$\tau = 83.39\,x\,106\,N/M2$$

Belt Design

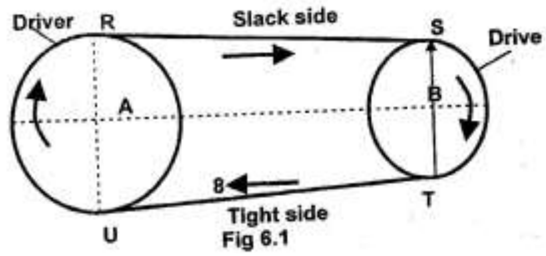

Fig 3: Belt and pulley mechanism

$$N1D1 = N2D2 \qquad 7$$

Where, D_1 = diameter of the motor (driver) pulley = 43mm = 0.043m; D2 = diameter of the driven pulley = 302mm = 0.302m; N_1 = Revolution per minute of the driver pulley = 1400rpm; N_2 = Revolution per minute of the driven pulley

$$N2 = \frac{N_1D_1}{D_2} = \frac{1400\,x0.043}{0.302} = 199.34rep/min$$

Power requirement to drive the machine

Recall that

$$P = (T1 - T2)\,V \qquad 8$$

Where, P = Power required to drive the machine

$$T1 = Tension\ on\ the\ tight\ side\ of\ the\ belt, N$$
$$T2 = Tension\ on\ the\ slack\ side\ of\ the\ belt, N$$
$$V = Velocity\ of\ the\ belt.$$

Since the power rating of the motor is 0.25 hp and 1hp = 0.746kw

Therefore , $0.25hp = 0.25\,x\,0.746 = 0.1865$

$$V = x = \frac{\pi\,x\,d^1xN^1}{60} \qquad 9$$

$$= (\pi\,X\,0.043\,X\,1400)/60 = 3.152m/s$$

Substituting the value of V into Equation 1

$$P = (T1 - T2)\,V$$

Since,
$P = 0.1865$
$V = 3.152$

$0.1865 = (T1 - T2)\ 3.152$

$(T1 - T2) = 0.0592$ 10

Pulley Centre Distance: When the diameter of the smaller pulley is less than one – than that of the larger pulley, The distance between the centers of the two pulleys must not be less than the difference of the two pulley diameters. In this case

$$D1 - D2 = 0$$

$Where, C = Pulley\ centre\ distance$
$D1 = diameter\ of\ the\ motor\ pulley = 302mm$
$= 0.302m$
$D2 = diameter\ of\ drum\ pulley = 43mm$
$= 0.043m$

Centre to center distance of the machine and the motor pulley is = 388mm was selected-
Length of belt required for power transmission:

$$L = \frac{\pi}{2}(d_1 + d_2) + 2x += \frac{1}{4\chi}\ (d2 - d1)2 \qquad 11$$

$$L = \frac{\pi}{2}\ (43 + 302) + 2\ x\ 388 +$$
$$= \frac{1}{4\ X\ 388}\ (302 - 43)^2$$
$$= 1250mm$$

Angle of contact between pulleys and belt

The contact angle α_1 and α_2 for small and large pulley respectively may be calculated as follows

$$\theta^1 = 1800 + 2\alpha^1 \qquad 12$$

$$But\ \alpha = sin\ -1\ (x = \frac{d_2 - d_1}{2x}) \qquad 13$$

$$\alpha = sin\ -1 = (\frac{302 - 43}{2\ x\ 388}) = 19.490$$
$$\theta_1 = 1800 + 2\ x\ 19.490 = 218.980\ radians$$
$$\theta_1 = 218.980 \times \frac{\pi}{180} = 3.8220\ rad.$$

For the driven pulley

$$\theta_2 = 180 - 2\alpha_2 \qquad 14$$

$$\theta_2 = 180 - 2\ x\ 19.490 = 140.00$$

$$\theta_2 = 140.00\ x\ \frac{\pi}{180} = 2.44\ rad.$$

Slip of belt (s): With the chosen belt A42, the thickness of the standard belt therefore is 10 mm and then the slip of the belt can be determined using standard speed ratio relationship equations as follows

$$\frac{N1}{N2} = \frac{d1}{d2}\ (\frac{1^{-s}}{100}) \qquad 15$$

The slip of belt was however determined using appropriate values and equals 7.4%.

Belt tension: When two pulleys of different diameters are connected by an uncrossed belt, the angle of contact of the smaller pulley should be considered for determining tension T_1 and T_2 of the tight and slack side of the belt respectively. Also, for rubberized belt, $\mu = 0.30$.

$$\text{Therefore. } 2.3\ log\ \frac{T1}{T2} = \mu\theta \qquad 16$$

$$2.3\ log\ (\frac{T1}{T2}) = 0.30\ x\ 3.8220 = 1.1466$$

$$Log\ (\frac{T1}{T2})v = \frac{1.1466}{2.3} = 0.4985$$

$$(\frac{T1}{T2}) = 2.88$$

Recall that eqn. 3.8

$T1 - T2 = 0.0592$

Substituting in the value of T_1

$2.88\ T1 - T2 = 683.5$

$$T2 = \frac{683.5}{2.88} = 363.56N$$

$T1 = 1057.05N$

Mass of belt per metre length and centrifugal tension
$Mass\ of\ Belt\ per\ meter\ length$:
$is\ the\ area\ x\ length\ x\ density\ of\ the\ belt$

Mass of belt per metre length is calculated thus; using an equation defined by Khurmi and Gupta, (2005);

m = area x length x density

The $\rho leath\ er$ value is a constant experimentally as 1000 kg/m^3 presented by Khurmi and Gupta, (2005); Therefore m = 1170 kg/m

Centrifugal tension in belt: The centrifugal tension in the belt can be represented by Tc and this can be calculated using

$$Tc = mv2 \qquad 17$$

$Tc = 1170a \ x\ 2.262$

The maximum tension on the belt can also be determined as in equation 29

$$T = stress\ x\ area = \sigma\ x\ a \qquad 18$$

The standard maximum stress for belt performance chosen is σ = 2.8 MPa

Thus $T = 2.8 * 106 * a\ (d)$

Combining equations c and d

$1170a \times 2.262 = 2.8\ x\ 106\ x\ a$

The cross-sectional area (a) is then calculated to be 200.57 mm^2; The centrifugal tension is also equal to 394.44 N; Mass of belt per metre also equal 0.235 kg; Maximum initial tension for operation without slip

This can be calculated using

$$\frac{T_{1+}T_{2+}2T_c}{2}$$

The calculated maximum initial tension for operation without slip is 394N

Design for Roasting pan:

Fig 4: Heating pan

The quantity of heat required to raise the temperature of the groundnut from ambient temperature (T_k) to the roasting level (T_s) is given as:

$$Q = MC\Delta T \qquad 19$$

Where $Q = Quantity\ of\ heat\ required$;
$M = Mass\ of\ the\ roasted\ groundnut$
$C = Specific\ heat\ capacity\ of\ groundnut$
$\Delta T = Change\ in\ temperature$
$Mass = density\ x\ volume$

$Where\ density\ of\ groundnut$
$= 1.5kg/m3 \times 9.81$

Volume = area x thickness of groundnut

$Initial\ temperature\ T1 = 25oC$
$Final\ temperature, T2 = 120oC$
$Area = (length\ x\ breadth\ x\ height)$,
$Length\ of\ roasting\ pan = 36cm = 0.36m$
$Breadth\ of\ the\ roasting\ pan = 18cm = 0.18m$
$Height\ of\ the\ roasting\ pan = 10cm = 0.1m$
$Specific\ heat\ capacity\ of\ roasting\ pan$
$= 0.45kJ$
$Area\ of\ roasting\ pan = (0.36\ x\ 0.18\ x\ 0.1)$
$= 0.0064m2$

Therefore, quantity of heat required

$Q = MC\Delta T$

$Where\ \Delta T = T2 - T1 = 120oC - 25oC = 95oC$

$Q = 1.5kg/m3\ x\ 9.81\ x\ 0.45kJ\ x\ 95$

$= 629.07KJ$

Volume of the Roasting pan: Volume of frustum

$$V = \tfrac{1}{3}\pi h\ (R2 + Rr + r2) \qquad 20$$

$Where\ h = height\ of\ the\ roasting\ machine,$
$= 10cm = 0.01m$
$Radius, R\ of\ the\ top\ diameter\ of\ the\ roasting\ machine,$
$= 36cm = 0.36m$
$Radius\ of\ the\ base\ diameter, r = 18cm$
$= 0.18m\ of\ the\ roasting\ pan)$
Substituting into Equation 20

$$V = \frac{1}{3}\ x \frac{22}{7}\ x\ 0.01\ (0.362 + 0.36 + 0.182)$$

$V = 5.45litres$

Mass of the roasting pan
$\rho\ density\ of\ stainless\ steel = 7500kg/m3$
$Mass\ (M) = (density * volume)$
$M = 7500x\ 0.000022 = 0.165kg$
$Weight = mass\ x\ g\ (g = 9.81)$
$0.165\ x\ 9.81 = 5.294\ N$

$W1 = W2$
$= the\ weight\ of\ the\ roasting\ pan\ (because\ they\ are\ of\ the\ same\ material\ and\ same\ size)$
$F1 = W1 = 1.619\ N$
$(F1\ and\ F2\ being\ the\ respective$
$forces\ at\ point\ 1\ and\ point\ 2)$

Heat Transfer; Quantity of heat given by the burner to the heating pan is

$$Q = CM\varDelta T \qquad 21$$

$Q = Heat\ supplied\ to\ the\ system$
$\varDelta T = Change\ in\ temperature$
$C = Specific\ heat\ capacity$
$M = Mass\ of\ the\ system$
$T1 = Initial\ temperature = 300C$
$T2 = Final\ temperature = 600C$

Calorific value of LPG is 50kj/gm that is, if 1gram of LPG burnt completely it will produce 50kJ of heat energy.

$1g\ of\ gas = 50kJ$

$Specific\ heat\ capacity = 0.45kJ/kg$
$Substituting\ into\ the\ formulae\ above$
$Q = 0.45kJ/kg\ x\ 50\ x\ 30$
$= 675000kJ \quad (input\ work\ )$

Heat loss: Heat loss from the groundnut roasting machine

$$Qc = UX\ a\ x\ \varDelta T \qquad 22$$

Where
$Q = Heat\ loss\ through\ the\ material$
$U = Heat\ transfer\ coefficient$
$A = Exposed\ surface\ area\ (m2)$
$\varDelta T = Temperature\ difference$
$between\ the\ inside\ temperature\ (0C)$

$$Area\ of\ the\ pan = \frac{\pi d}{4}2$$

Diameter of roasting pan = 60cm. = 0.6m

Area = $\frac{3.142\ x\ 0.62}{4}$
Area = 0.283m^2

Heat transfer coefficient of mild steel
$U = 345w/m2K$
$DT = T2 - T1$
$Where\ T2$
$= temperature\ of\ the\ heated\ peanut$
$= 1360C$
$T1$
$= temperature\ of\ the\ unheated\ peanut$
$= 250C$

Substituting into eqn 3.3
$\therefore\ Heat\ loss = U \times A \times \Delta T$
$= 345 \times 0.283 \times (136°c - 25°c)$
$= 345 \times 0.283 \times 111$
$= 10837.485J = 10.837485KJ$

Efficiency of the machine: Efficiency is the percentage of work put into a machine by the user (input work) that becomes work done by the machine (output work). The output work is always less than the input work because some energy is loss to the surroundings as heat. Therefore,

∴ Efficiency of the machine is less than 100 percent (%)

$$Efficiency\ of\ machine = \frac{output}{input} \times \frac{100}{1}\%$$
$$\eta\ of\ groundnut\ roasting\ machine = \frac{Work\ output}{Work\ Input} \times \frac{100}{1}\%$$
$$Work\ input = (mass\ of\ groundnut\ x\ g) = 22.5kg \times 9.8$$
= 220.5KJ (output work)
$Heat\ loss = 10.837485KJ$
$$= \frac{work\ input - heat\ loss}{output\ work} \times \frac{100}{1}\%$$
$\eta\ of\ groundnut\ roasting\ machine$
$= (94.4815 - 10.84)/94.815 \times 100/1$
$\therefore\ \eta\ of\ the\ groundnut\ roasting\ machine$
$= 0.882 \times 100\%$
= 88.2%

∴ The efficiency of the machine is 88.2%

Machine Frame: The machine frame supports the other parts of the cassava peeler machine, as well as providing balance. It is subjected to the direct weight or load of other members of the machine (hence compressive forces) and also to torque and vibration from the peeling drum and motor. The desired material should be of high rigidity, hardness, adequate toughness and posses' good machining characteristics. For this purpose, angular high carbon steel rods were chosen.

Bearing: A bearing is a machine element that contains relative motion to only the desired motion, and reduces friction between moving parts. The bearing selection for this design is the ball and the split bearing of the radial type. These bearing uses because of the bearing work under higher speeds but only light loads and heavy support by split bearing. The bearing selected has a standard bore size of 35mm using standard Code as chart for bearing selection.

Electric motor: Electric motor is the electro-mechanical machine which converts the electrical energy into mechanical energy. In other words, the devices which produce rotational force is known as the motor. The motor we use for this design is (0.25hp) single phase electric motor. The reason for choosing this motor is because it is less expensive to manufacture than other types of motor and it require little maintenance. The working principle of the electric motor mainly depends on the interaction of magnetic and electric field. The electric motor is mainly classified into two types. They are the AC motor and the DC motor. The AC motor takes alternating current as an input, whereas the DC motor takes direct current.

Materials Selection: When it comes to the construction of machinery and equipment, a wide array of materials is frequently used. Nonetheless, the process of selecting the right material is a crucial aspect of the design and is indispensable in achieving a functional and effective end product. Moreover, it plays a pivotal role in fulfilling customer requirements. In the process of choosing the most appropriate materials for producing various components, several factors were meticulously considered.

i. Cost of material
ii. The strength of the material
iii. Availability of the material
iv. Material resistance to wear and tear
v. Other mechanical properties –stiffness, toughness and the influence of temperature on these properties.

Construction Details: The design and fabrication of the groundnut frying machine was carried out after careful selection of the right materials to be use. The frame was use fabricated onto which the stainless-steel plate to the heating of the gas burner unit with the burner was welded to it and the shaft connected to both ends of the pulley and belt. It can be operated using gas as source of heat.

Components Construction Procedures: The components construction procedures are stated below

i. Marking out the metal plate or the material to cut
ii. Cutting of marked out metal sheet to the required size
iii. Assembling of the various component's parts
iv. Grinding of the cut chips and rough edges from the machine
v. Painting of the machine.

RESULTS AND DISCUSSION

Experiments were carried out with the groundnut roasting machine, and this testing phase holds significant importance for several reasons. It is a crucial step in assessing the machine's effectiveness and efficiency, allowing for a comparison of its performance against existing counterparts. Additionally, this testing process serves as a means to confirm the machine's functionality and durability. During the testing phase, the machine performed admirably, successfully roasting groundnuts to satisfaction. The outcomes derived from the operation of the newly constructed groundnut roasting machine provide a clear demonstration of its functionality. Significantly, the results reveal that utilizing gas as the power source enhances the machine's reliability, primarily because it streamlines the operation, making it both easier and faster. As per the test findings, the machine exhibited a maximum roasting capacity of 87%.

$$Efficiency = \frac{work\ output}{work\ input}\ x\ 100$$

$$= \frac{87}{100}\ x\ 100 = 87\%$$

The newly constructed groundnut roasting machine offers the flexibility of gas burner operation, making it a simple and versatile solution. The estimated total production cost for a single unit stands at N 207,700. In terms of performance, rigorous testing demonstrated a robust roasting efficiency, with the machine achieving an impressive 87% efficiency rate, signifying a high level of performance. Upon the completion of the construction phase for the groundnut roasting machine, it becomes imperative to subject it to a series of tests to ensure its faultless functionality during usage. In standard circumstances, the optimal roasting temperature falls within the range of 120°C to 136°C. These parameters served as the basis for testing the model we fabricated. This process involved four individual tests, yielding temperatures of 120°C, 136°C, 130°C, and 118°C. To determine the coating temperature, we summed all these values and divided the total by the number of tests conducted, providing an average temperature for the roasting process.

$$Average.Temp. = \frac{Sum\ of\ all\ temperature}{Overall\ temperature}$$

$$Average\ temperature = 614/5 = 122.8°C$$

Where Average. Temp. = average temperature;

The calculated mean average temperature was determined to be 122.8°C, which is the temperature at which the roasting process in the fabricated model is optimized. The machine's design ensures that the temperature within the heating chamber does not exceed 136°C before the cooling phase is initiated. In the course of testing, roasted groundnuts were examined using a rubber bowl shortly before the cooling process commenced, with a total duration of 20 minutes. It is worth noting that, based on the machine's design, the maximum allowed duration before the cooling phase initiates is approximately 40 minutes. During this period, a minimal temperature differential between the machine's body and its surroundings is maintained.

The rate of cooling within the heating chambers is influenced by various factors, including:

1. The temperature of the heating chambers
2. The temperature of the enclosure
3. The area of the exposed surface
4. The nature and extent of the surface of the containing vessel.

Table 1: Frying Temperature for Groundnut in Kelvin

S/N	No of groundnut	Time (min)	Temperature in Kelvin (273k)
1	200	30	136˚C (409k)
2	200	28.8	130˚C (403k)
3	200	28.7	120˚C (393k)
4	200	28.8	1180˚C (391k)
5	200	28.9	110˚C (383k)

The visual inspection: Test serves the dual purpose of ensuring the aesthetic quality of the finished groundnut roasting machine and verifying the precision of welding to prevent any potential leaks. It also guarantees the proper finishing of the machine's body and checks the alignment of its components during operation.

Performance test: The efficiency of the groundnut roasting machine may be defined in terms as the time taken to fry groundnut to the desired taste, colour, texture. The performance test shows that it took approximately 40 minutes to fry groundnut to the desired quality.
Design roasting time – 35 minutes
Actual roasting time – 40 minutes
Roasting efficiency, n = 35/40 x 100% = 87.5%
Different sizes of groundnut were examining the effect of groundnut roasted size on heating time.

Operation Procedure: The newly constructed groundnut roasting machine is adaptable for operation using a gas burner as the heat source. Upon ignition of the burner, the electrical energy powers an electric motor, the prime mover, which transforms this energy into mechanical energy in the form of rotational motion. This rotation drives the stirrer to turn in a clockwise direction, facilitating the even distribution of groundnuts within the pan. This process is facilitated by the interplay of the shaft and pulley system. Additionally, the machine can be electrically operated with the same stirring actions. The maximum roasting time required to complete a batch of groundnuts using this machine is 40 minutes.

Conclusion: A potential approach to accomplishing sustainable nut processing is through the design and construction of groundnut roasting machines. One cannot emphasize how crucial groundnut roasting machines are to improving the effectiveness and quality of nut processing. This unique design marks the beginning of an era in sustainable production, replacing conventional, energy-intensive methods. These creative ideas demonstrate a commitment to cutting energy use, eliminating waste, and producing a higher-quality outcome.

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