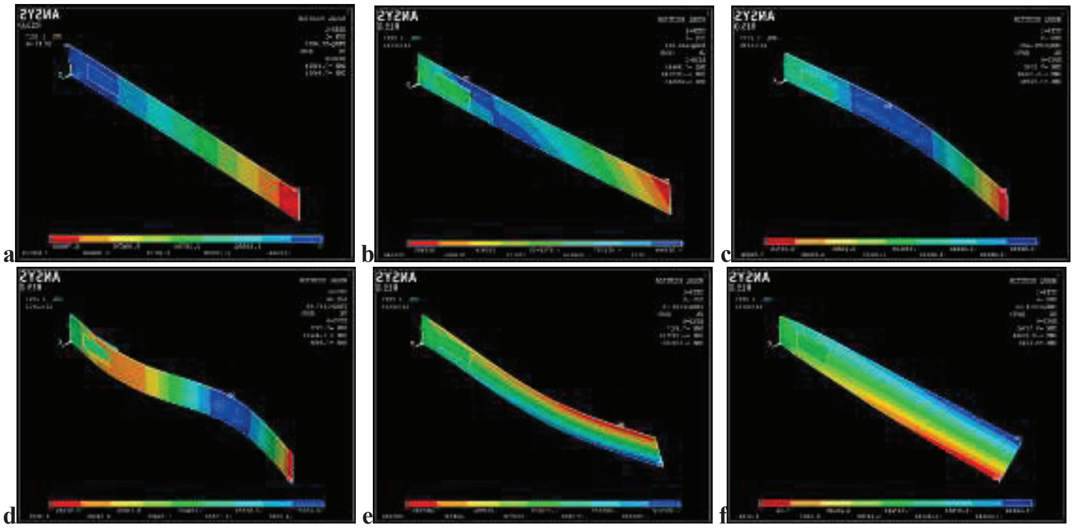

Figure 8: Model Shape of Cantilever Beam with piezo a) 1st mode, b) 2nd mode, c) 3rd mode, d) 4th mode, e) 5th mode, f) 6th mode

7. Comparison

The results of Finite Element Method obtained natural frequencies of mild steel are taken from paper[1], beam are calculated using the material properties and dimensions of beam given in Table (6). The finite element natural frequencies are determined using ANSYS 14.5 and the results are tabulated in Table (7).

Table (6): Material and Geometry parameters

Material Property	Geometry Parameter
$E = 20.5 * 10^{10} N/M^2$	$L = 2m$
$\rho = 7830\, Kg/m^3$	$B = 0.3m$
$v = 0.33$	$H = 0.1\, m$

Table (7): Natural frequency of Beam

Mode	Natural Frequency of paper	Natural Frequency
1	20.818	20.53
2	129.25	128.48
3	357.05	361.34

When compare the result of paper with the result that I get from ANSYS 15.0, found the results are very close.

8. Conclusions

The natural frequency of cantilever beam was decreasing when the length increase, that leading led to there is a retrograde connection between length and natural frequency of cantilever beam. In case by letting a piezo on beam near the fixed end, the natural frequency of beam with same length is increasing, because the mass and stiffness of piezo was add to the beam and led to increase natural frequency. But increasing the length of beam with piezo is leading to make the natural frequency to decrease. From this work, the main conclusion is when the length of cantilever beam with and without piezo is increased the natural frequencies are decreased, and the mode shape of cantilever beam was different between the lengths of the beam, because the natural frequency was changed when the lengths changed.

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Design and Fabrication of Shea Nut Steam Roaster

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Abstract

Sheanut (Butyrospernum paradoxum) is an oil rich tropical tree crop, which is indigenous to the West African savannah zone. In Nigeria, most of the shea nut roasters are made of light mild steel materials with openings. The source of heat for the roasting is open fire. This takes time and the mild steel can easily get rusted and contaminate the product. In addition, open fire roasting has the disadvantage of producing burnt crushed kernels which in turn lead to black shea oil formation, loss of vital and essential nutrients. A shea nut roaster which makes use of steam as source of heat energy was designed and fabricated to be used in roasting shea nut prior to extracting oil from them. It was developed to address the aforementioned problems. The equipment consists of heating unit, roasting unit, power transmission unit and the supporting frame. A gear motor of 0.25kW was selected to supply power to the shaft whose end was welded to the stirrer. The roasting unit consists of three compartments: roasting chamber, steam chamber and insulator chamber. The heating unit has two pipes: water inlet pipe and steam delivery pipe. Also, charcoal burner was attached to the heating unit to help boil the water for steam to form; this steam will then be transported by the steam delivery pipe to the steam chamber which in turn heats up the outer surface of the roasting chamber and thus the crushed nuts inside are roasted through the heat being supplied. The machine was fabricated with about 90% local materials. Test results of the roaster using shea nuts indicate successful heating/roasting, the nuts were not scorched or burnt, rather they were looking dry but fresh, this indicates that the design of the machine suits its purpose for roasting shea nuts prior to oil expelling . Also, roasting capacity of 45kg/hr was achieved. The successful development of this machine will reduce drudgery and time taken associated with the traditional method of roasting shea nuts and therefore will increase productivity and utilization.

Keywords: Heating, steam; shea nut; roaster; design

Introduction

Shea nut is obtained from shea tree, and is grows mostly throughout West and Central Africa in the semi arid Sahel areas from Senegal to Ethiopia (Lovett, 2000;Yonas, 2015). Shea nut hails from *Sapotaceae* family. It contains reasonably high amounts of oleic acids from which shea butter is extracted.

Shea butter is one of the basic raw materials for most food, cosmetics, soap as well as the pharmaceutical industries (Addaquay, 2004; Eneh, 2010) and it is sometimes used as a substitute for cocoa butter (Adgidzi *et al*., 2003). The kernel is obtained from the nut by cracking with stones or mortar and pestle. Traditional methods of extraction of shea butter from the kernel involve a series of operations which includes steeping, roasting, pounding or grinding and boiling (Aviara *et al.,* 2005). Shea butter is marketed as being effective at treating the following conditions; burns, eczema, rashes, severely dry skin, dark spots, skin discoloration, chapped lips, stretch marks, wrinkles and provides natural UV sun protection (Onwualu,. 2010; Garba *et al.,*2011).

In cosmetic and pharmaceutical industries it is used as raw materials in, soaps and candles (McNally, 2008). Other important uses are; as anti-microbial agent for promotion of rapid healing of wounds, as a pan-releasing agent in bread baking and also serve as a lubricant for donkey carts (McNally, 2008; Lisa, 2010).

In Nigeria rural women use shea butter for daily applications as well as product to earn income. The current manual method of production of shea butter processes is physically demanding. Moreover it results into product of poor quality (Olaoye, 2012). Most of the existing equipment for processing of shea butter especially the roasters is made of light mild steel materials with openings. The source of heat for the roasting is open fire. The light mild steel can easily become rusted and cause contaminant of the product. Particles form as a result of the rusting settlement at the bottom of the equipment, thus causing contamination of the resulting shea butter. Smoke from open fire can result in contamination of the polycyclic aromatic hydrocarbon (PAHS), some of which are said to be highly carcinogenic. In addition, normal (common) roasting has the disadvantage of producing burnt crushed kernels which in turn leads to black shea oil formation and loss of vital and essential nutrients (Orhevba *et al*., 2013). The few existing mixing machines are only available in large scale which is costly, requires skill to operate and maintain by small and medium scale operators (Balami *et al.,* 2013 and Olaoye, 2012).

The problems enumerated above calls for intervention to improve the traditional methods of production by reducing the manual labour and time consumed so as to increase the yield and quality of product. As modernized approach to solving this sectional problem is to design and fabricate a shea nut steam roaster capable of using steam to roast the shea nut. The aim of this work is to design and fabricate a shea nut roasting machines, for Shea butter production.

Material and Methods

Descriptions of the Components of the Roaster

Inlet Unit

This is primarily the hopper which guides the crushed kernels into the roasting chamber. The hopper is cylindrical in shape.

Discharge Unit

The roasted crushed kernels discharge outlet is within the base of the roasting chamber, cut and inclined at 45^o from the horizontal plane in order to allow the free flow of the roasted crushed kernels into the collection pan.

Steam Generating Unit

The unit is in cylindrical form, made of 2.5 mm mild steel plate. Water is filled to 2/3 of its height, this is to allow for an empty space that can aid or bring about steam generation. The boiling unit consists of two pipes: water inlet pipe which allows water passage into the tank and a steam exit pipe which serves to transfer the steam generated at the upper part of the tank into the steam chamber of the roaster. The flow of steam is regulated by a gate valve. The water inlet and the steam outlet pipes are located close to the top of the tank. A charcoal fuelled burner is fixed to the bottom of the tank to serve as heat source.

Crushed Kernel Roaster

The kernel roaster is a cylindrical shaped vessel of stainless steel plate with three separate compartments viz: the roasting chamber, the steam chamber, and the insulator chamber. The roasting chamber house the crushed kernels with stirring blades attached to the shaft and then to the gear motor. The blades aid in stirring the crushed kernels as the steam enters into the walls of the roasting chamber. Thus, this constant stirring and heat application bring about a uniform roasting of the kernels.

The steam chamber is a vacuum chamber in between the roasting chamber and the insulator chamber. The steam chamber receives the heat from the incoming steam and heat up the outer wall surface of the roasting chamber, thus enabling the roasting of the kernels to take place.

The insulator chamber is a compartment filled up with an insulator (fabric). The insulator helps in reducing the heat loss by conduction though the surface of the walls of the roaster, as such conserving the heat generated in the system.

Blades

This is the component used for stirring of the crushed shea kernels. It is made of stainless steel sheet (gauge 16) due to its non-corrosive material.

Power Transmission Unit

The unit comprises of a 0.25 kW gear motor. Since labor requirement is low as an expected input power that can be supplied from women or children is assumed to be 0.25 - 0.30 kW; and an average man can supply 0.25-0.30 kW of power continuously for 6-8 hours, including rest hours for relaxation and refreshment (Akinnuli *et al*., 2015).

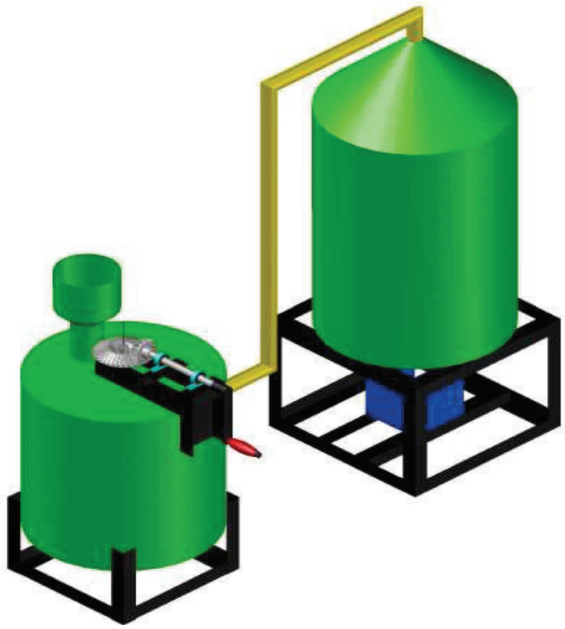
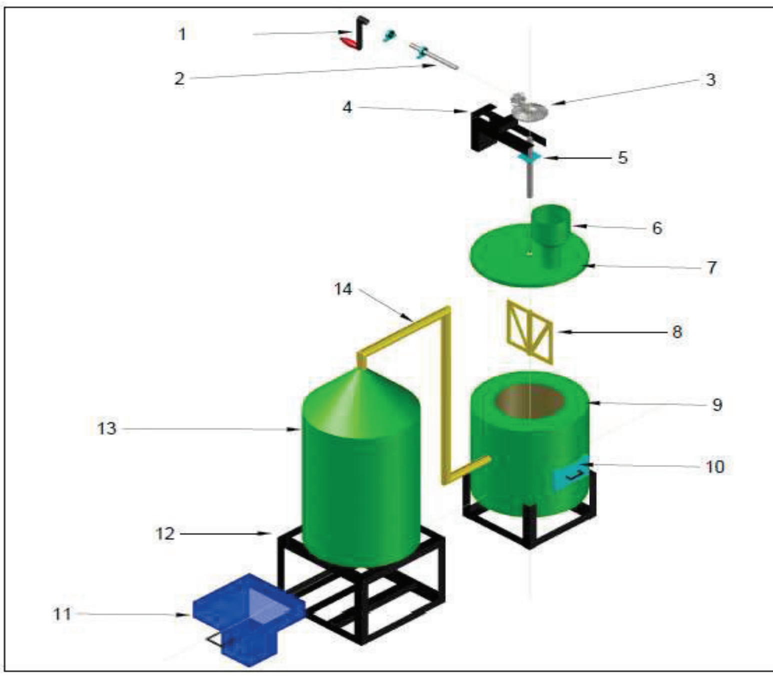


Figure 1 Pictorial View of Shea kernel Roaster



S/NO	COMPONENTS
1	CRANK ARM
2	SHAFT
3	BEVEL GEAR
4	BEARING SIT
5	BEARING WITH HOUSING
6	SHEA KERNEL FEEDING TROUGH
7	ROASTER LID
8	ROASTER STIRRING BLADE
9	STEAM ROASTER COMPACTMENT
10	CARNEL DELIVERY CHUTE
11	BURNING CHAMBER
12	CHASSIS
13	BOILER/STEAM TANK
14	STEAM PIPE WITH VALVES

Figure 2 Exploded View of the Shea Kernel Roaster

Design consideration

The design consideration was carried out with a view to evaluate the necessary design parameters such as strength and size of materials of the various machine components in order to avoid failure by excessive yielding and fatigue during the required working life of the machine.

Design Calculation of Major Components of a Shea kernel

Roaster

The shea kernel roaster was designed with respect to its mean heat transfer rate, amount of steam, steam flow rate, volume of the roasting chamber, timing heating area and dimension of the tank. Figure 1 below depicts the arrangement of the steam roaster for shea kernel.

Capacity of Roasting Chamber

The capacity of the roasting chamber is a function of the bulk density and mass of shea kernel to be roasted. For cylindrical roasting chamber the capacity was assumed to be in the ratio of two to three times the calculated capacity (Lawson *et al*., 2014; Gbabo *et al*., 2013). The roasting chamber was obtained from the relationship in equation 1 as described by (Gbabo *et al*., 2013).

$$\rho_b = \left(\frac{M_b}{V}\right) \qquad 1$$

Where, M_b = mass of material to be processed (kg), ρ_g = Bulk density of the kernal (kg/m^3) V = volume of material to be processed (m^3)

Considering safety and volume as per ratio of 2 to 3, 33 % of the calculated volume was added to the volume determined from equation 2

$$V_{TR} = V_{rd} + V_{rd}\,(0.24) \qquad 2$$

Where, V_{TR} is the total volume at the roasting chamber, V_{rd} is the volume of the roasting chamber

The dimension of the roasting chamber if the height of the roaster was assumed to be 0.5m, the diameter at the chamber was obtained using the following relationship in equation 3

$$D_R = [\sqrt{(\frac{VTR}{\pi hTR})}] \qquad 3$$

D_R is diameter of the roasting chamber; VTR is the total volume of the roaster

h_{TR} is the height of the roasting chamber , π is constant.

Design of the Steam Jacket

The volume of steam required to roast the shea kernel was assumed to be 90 % the volume of the shea kernel. The volume was obtained as reported by Gbabo *et al*., 2013.

$$V_{s.} = 90\ \%\ V_K \qquad 4$$

Where, V_s is the volume of steam required to cook the kernel, V_k is the volume of the shea kernel

The total volume of the steam jacket was obtained from equation 5

$$V_{TS} = V_S + V_{TR} \qquad 5$$

Where V_{TS} is the total volume of the stem jacket , V_S is the volume of the steam

V_{TR} is the total volume of the roasting chamber

Dimension of the Water Jacket

The dimension of the water jacket was taken as the height of the steam jacket, the diameter, was therefore obtained using the following relationship in equation 6

$$D_{TS} = 2[\sqrt{\frac{Vts}{\pi Hts}}] \qquad 6$$

Where, D_{TS} is the diameter of the steam jacket, V_{ts} is the total volume of the steam jacket

H_{ts} is the height of the steam jacket

Thickness of Insulating Material

Determining the thickness of insulating material to be used in roasting unit, Ali and shitu (2013) gave the expression for thickness of insulating material as in equation 7

$$\frac{q}{l} = \frac{2\pi k(T4-T5)}{\ln\left(\frac{r5}{r4}\right)} \qquad 7$$

Where; q is heat loss per unit length, L is length (heated) at the drum, K is thermal conductivity of the insulating material, R_1 = internal radius f the roasting chamber, R_2 = external radius of the roasting chamber, R_3 = internal radius of the water jacket, R_4 = external radius of the water jacket
R_5 = radius of the insulating material, R_6 = external radius of external casing.

Determination of the volume of the heating tank
The heating tank is cylindrical in shape; and the volume of the heating tank is designed based on capacity of 130 liters of water, using the volume of a cylinder and assuming the height of the cylinder to be 0.66 m. The diameter of the cylinder is obtained from equation 8 as reported Ali and shitu, (2013), Gbabo et al., (2013) and Orhevba et al, (2014).

$$V_h = \pi r_h^2 h_h = \sqrt{\frac{V_h}{\pi h_h}} \qquad 8$$

Where, V_h = Volume of the heating tank, h_h = height of the tank, r_h = internal radius of the heating/water tank

Mean Heat Transfer Rate

The volume of heat generating tank was assume to be 130 litres and 2/3 of the volume was filled with water and the other 1/3 was left empty for formation and expansion of the steam (Gbabo et al., 2013). The expression, given in equation (10), was used to compute the mean heat transfer rate of the shea kernel roaster

$$= M_{Cp}\, {dT}/{t} \qquad 9$$

Where, q is mean heat transfer rate (kW), M is mass of the water, C_P is specific heat capacity of water, dT is change in temperature, *t* is total time taken

Amount of Steam

The mass flow rate of the liquid was computed from the expression given by Rajput, (2011) in equation 10.

$$M = {q}/{he} \qquad 10$$

Steam Flow Rate

The steam flow rate was also computed from the expression given by Rajput, (2011) in equation 11.

$$S_f = \frac{kw \times 3600}{he} \qquad 11$$

Design of the Stirrer
The stirrer consists of two pairs of blades with different dimensions (breath), spaced equally on the shaft. Each pair is made of two blades and each blade is welded on the opposite side of the shaft.

$$From\ \rho = {m}/{V}, V = A \times t, and\ A = L \times B \qquad 12$$

Where ρ = density of the material. M = mass of the material V= volume, A = area, L = Length of the stirrer blades,B = Breadth of the blade and t = thickness
Therefore the mass of each stirrer blades was calculated from the equation 13 below.
Weight (N) = m x a 13

Where a = acceleration due to gravity

Power Required to Drive the Stirrer
The power required to drive the stirrer was calculated from the relationship given below as reported by (Maduako *et al*., 2004; Orhevba *et a*l., 2013)

$$P = T_s \omega_s \quad 14$$

Where;P= Power to drive the stirrer (kW), $T_s =$ Torque of the stirrer (Nm), $\omega_s =$Angular speed of the stirrer (rad/sec)

$$\omega_s = \frac{2\pi N}{60} \quad 15$$

Where,
N= Speed of rotation (rpm)

Determination of the Shaft Minimum Diameter
Shaft design is necessary for the determination of the minimum diameter that will guarantee a satisfactory strength and rigidity of the shaft under operation. in the roasting machine when the blade and shaft were loaded with kernels to be roasted, the shaft was subjected to torque and bending moment is neglected as shaft was mounted vertically. In order to determine the minimum shaft diameter that will withstand the roasting strength of the kernels, the following equations (16 and 17) were employed.

(Khurmi and Gupta, 2008; Gana *et al*., 2016)

$$\sigma = \frac{16 T_s}{\pi d^3} 3.34 \quad 16$$

$$d = \sqrt[3]{\frac{16 T_s}{\pi \sigma}} \quad 17$$

Where; $T_s =$ Torque of the shaft/ stirrer (Nm), σ = Maximum permissible working stress (MN/m2)
d = Minimum shaft diameter (m)

Methods for Testing

The fabricated machine was tested to ascertain its throughput capacity and roasting efficiency. The machine components were set up, the steam generator/boiler was fired using biomass as fuel; as steam begins to flow onto the steam chamber through steam pipes with flow valves in 'ON' position, temperature in the roasting chamber begins to build up. As temperature in the roasting chamber got to the required level, shea nuts were loaded into the roasting chamber through the hopper. stirring continuous until pleasant odor is perceived and color changed confirming the roasting done. This is achieved with respect to a particular time limit. The capacity of the shea nut roaster was calculated by summing the total number of batches in kilograms divided by the total time required for the roasting:

$$c_m = \frac{w_g}{t} \quad 18$$

Where,
$c_m =$ = Machine capacity (Kg/day)
w_g= Weight of crushed shea nut roasted (g)

t = Time taken to roast the crushed nuts.

Materials Selection and Fabrication of Machine Components

Fig. 1 ana Fig. 2 shows a pictorial view and exploided view of the roaster. The hopper was fabricated from a standard length of 1.5 mm thick mild steel sheet. The insulator chamber was made with fabric materials. The steam generating compartment was made with the steel plate and a charcoal burner was attached to it. The main frame was made from 5mm angle iron which was cut to the required dimensions and welded together. Fabrication process included: marking out, machining, cutting, joining, drilling, welding,fitting and machine assembly. The workshop tools and machines used included: scriber, steel rule, compass, centre punch, treadleoperated guillotine for cutting and welding machine for joining. The specification of construction materials is shown in Table 1.

Table 3.1: Bill of Engineering Measurements and Evaluations (BEME) of the Steam Roasting Machine.

S/N	Component	Material	Specification (mm)	Qnty	Unit Price(₦)	Qnty Price(₦)
1	Shaft	Stainless Steel	20 x 50	2	1500	3000
2	1 mm Stainless Sheet	Stainless Steel	1200 x 2400	1	35,000	35,000
3	1 inch Flat bar	Stainless steel	25 x 1200	1	4000	4000
4	2 inch Angle bar Iron	Mild Steel	75 x 2400	1.5	3000	4500
5	16 gauge Metal Sheet	Mild Steel	600 x 1200	1	5500	5500
6	Pillow bearing	Cast Iron	ISI NO 6204	2	1000	1000
7	Paints		1 Tins	1	1500	1500
8	Bolt & Nuts	Mild Steel	Variable sizes	12	50	600
9	Bevel gear	Cast iron		1	3000	3000
10	Pipe Adaptor	Galvanize Iron	37.5	2	1250	2500
11	Valve	Galvanize Iron	18.75	2	750	1500
12	Plug Valve	Galvanize Iron	37.5	2	200	400
13	Clip	Mild Steel		2	50	100
14	Electrode	Stainless	E 10	1pkt	9000	9000
15	Steam pipe	Aluminium		2	100	200
16	Grinding disc			1	600	600
17	14 gauge Metal Sheet	Mild steel	600 x 1200	1	6500	6500
18	Temperature gauge			1	3000	3000
19	Fabric material					1500
	Sub Total					**₦85,100**
20	Labour Cost		20% of Sub Total			17020
21	Over-head Cost		10% of Sub Total			13510
	Grand Total					**₦110,630**

Results and Discussion

The results obtained showed that roasting of the shea nut with the fabricated machine was successful and efficient because the nuts obtained from it after the testing were heated well, looking dry yet without looking burnt. The results also indicate that, through put capacity of 45kg/hr meaning that for 8hrs/day, the capacity will be 360kg/day. The shea nut steam roaster saves time and energy when compared with local roasting using light mild steel on open fire. The local machine has an average capacity of 12kg/hr and 96kg/day. The machine will thus serve as a right partner and complementary equipment to oil expellers. It can therefore serve as a part of shea butter production process. The machine is simple, easy to operate and maintain.

Conclusion

A viable machine for roasting shea nuts using steam was fabricated from the available locally sourced materials. The roasting machine is very applicable for local production, operation, repair and maintenance. Also a roasted shea nuts based on this technology could provide employment and at the same time make available quality shea butter for domestic use and export. Finally the shea nut steam roaster saves time and energy when compared with local roasting using light mild steel on open fire..

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