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Design and Fabrication of a Hand Fed Motorized Oil Bean Slicing Machine

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ABSTRACT: *A hand fed African oil bean slicing machine which would be affordable, simple to operate and easy to maintain by local and/or small scale farmers and processors was designed and fabricated with locally available materials. The design was based on the engineering standard and specifications. Factors such as physical and mechanical properties of oil bean seeds, mechanical properties of construction materials, mach inability or deformability of construction materials, wear resistance, availability of power and cost of materials were considered in the fabrication of the device. 1hp electric motor powered the machine. The machine was tested for performance and it recorded an efficiency of 96.64% with minimal damage of the product. The bill of engineering measurement and evaluation revealed that the machine was fabricated at a total cost of ₦91,353.00. The device match the need of the oil bean processors and with adequate maintenance and/or management, it would ameliorate the difficulties involved in oil bean processing and, therefore boost the farmers' production.*

Keywords: *Fabrication, hand fed, local processors, oil bean, slicing machine*

I. INTRODUCTION

Oil bean (Pentaclethra Macrophylla Benth) is a tropical tree crop found mostly in the Southern and middle belt regions of Nigeria and in other coastal parts of west and central African (keay1989). It is a tree croprecognized by peasant farmers in those parts of the country for its soil improvement properties and as a component of an agro-forestry system (Okafor, 1991). It is called ugba in Igbo land and Ukana by the Efiks. Different ethnic groups call it different names. The tree provides economic products such as food, fodder and fuel. It protects the soil from erosion by wind and rain through its canopy and root systems and recycles plant nutrients from the deeper soil horizons to the top soil in the form of litter fall and decaying organic plant residues. Enujiugha (2003) observed that flat glossy brown edible seeds averaging 8, (6-10) in number are contained in the brownish flattened pod of the oil tree which explodes at maturity and disperses the seeds. The seeds are rich in protein and oil and require tedious but careful processing and fermentation before they can be eaten as food supplement. Abbiw (1990) maintained that it is a traditional food condiment generally produced by natural (local) fermentation in homes as a small family business. According to them it is an important and cheap source of protein for people whose staple foods are deficient in proteins and can be added to soup as flavour. The seed are cooked, processed and fermented and used for the preparation of many delicious African delicacies including African Salad, Soups and Sausages for eating different staples(Enujiugha 2003).The seed is a source of edible oil, it contains more than 52% oil in its cotyledons. It is rich in vitamins and minerals and in high demand for both local consumption and for export. It is a low –acid food which could be prepared into flour and explored in food fortification.

Despite the high nutritional values and economic importance of oil bean, the mechanization of its production in Nigeria has not received any attention and that may be the reason for its underutilization in Nigeria. The processing of the large brown glossy seeds of the oil bean involves several processes which include decorticating, softening of the cotyledon, slicing, fermentation and packaging. All these processing operations are basically traditional and yet to receive significant form of mechanization till date. The slicing of the cotyledon has been manual with few attempts by researchers to mechanize it using some specially curved knives on the bare hand. This method is tedious, drudgery, low quality and associated with low rate of production with some limitations. In order to ameliorate these difficulties observed with the manual slicing method, there is the need to developa local motorized oil beanslicing machine which will be affordable, easy to maintain and simple to operate by the oil bean processors in Nigeria. The objectives of this research workis to fabricate a machine that will serve as an important substitute to suite our peculiar situations using locally available materials and technology to produce an affordable machine to the local populace, to ease the problem of oil bean slicing especially for commercial consumption outfits, to achieve uniformity in sizes of the sliced oil bean seed at ease and to eliminate the danger and energy consumed in conventional slicing of the oil bean seed and also increase the rate and/or quality of production

II. MATERIALS AND METHOD

2.1 Design Consideration

Physical and mechanical properties of oil bean: Such as size, shape, diameters, toughness, stiffness and hardness of the oil bean seeds (Asoegwu and Maduike, 1999).

Mechanical properties of the construction materials: Which include strength rigidity toughness and ductility. This is important for the machine so that it can withstand the forces and stresses it will be subjected to in course of operation.

Mach inability or formability: This is also determined by the mechanical properties of the metal used for the machine. The steel used for the pulley that connects the machine and the driver has to be mild steel that can easily be machined.

Availability of material: For the reason of maintenance the material used to form the machine has to be readily available in case of replacement during preventive or corrective maintenance.

Wear resistance of materials: The material used in the fabrication of the oil bean seed slicing machine has to be considerably resistant to wear and corrosion since relative motions exist between moving parts.As such it has to be painted or treated so that it will last for a long time. If the materials wear easily the machine will fail easily.

Availability of power: The machine is designed to work with electricity, which is the major source of power for this machine. Since the driver is an electric motor. Thus, the availability of sufficient power supply in the place of use of the oil bean seed slicing machine is essential to its performance wherever it is to be used at least there should be power for a 1hp motor, a supply voltage of 220v for smooth running of the machine.

Cost of materials: In the design of the oil beans slicing machine, the total cost of the model at all stages of the design was considered, hence, the BEME shown in section 3 revealed the cost of the slicer.

2.2Machine Components Description

The machine comprises of the following components: electric motor, pulley and belt drive, shaft, bearing, hopper or feeder, feeding mechanism/lever, discharge chute, springs, sliding linkage, cutting disc with blades and support frame. Each of the components mentioned has one or more functions it must perform for the efficient performance of the oil bean slicing machine, and they include;

Electric motor: The electric motor serves as the driver that powers the slicing machine it generates mechanical energy in the form of rotary motion which is transmitted using the pulley and belt drive system.

Pulley and belt drive: The pulley transmits the mechanical energy from the shaft of electric motor to the shaft of the oil bean seed slicing machine

Shaft: The shaft of the oil bean seed slicing machine transmit the mechanical energy that was transmitted from the shaft of the electric motor through the pulley and belt drive system to set of blades on the cutting disc that uses the mechanical energy to slice the beans to the finished product.

Bearing: A bearing is an anti-friction device that reduces energy loss due to friction by eliminating friction in rubbing surface of shaft and bulb.

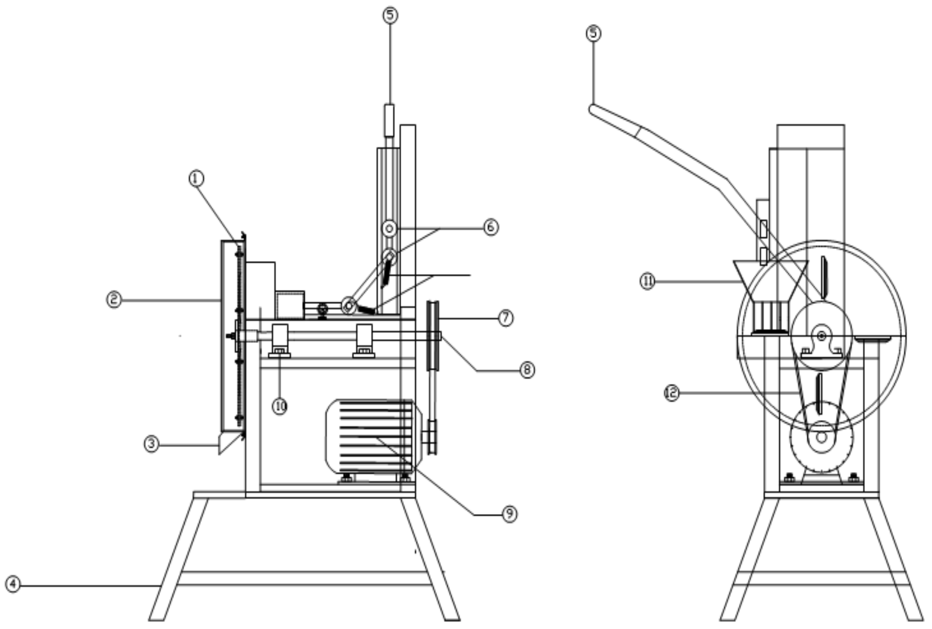
Hopper of feeder: The hopper feeds the oil bean seeds into the slicing chamber where the seed are subjected to slicing action from the set of blades that gets their action from the shaft rotation.

Feeding mechanism: It is manually, operated comprises of a lever, bearing, square-rod, extensionspring. This helps oil bean into the rotating blade for cutting.

Discharge chute: It is acasing covering the cutting disc so that during the slicing operation the oil bean does not splatter, rather it goes out through one direction, it can be dismantled.

Blades: The set of blades does the slicing of the oil bean seed. It transforms whole oil bean seed to slice just by acting on it. It is made of sharp metals that can cut through the oil bean seed. There are four blades used in this particular design attached to the cutting disc.

Support frame: The support frame or shield is designed to withstand torsional and vibrational forces. It holds all the components of the oil beans slicing device.



Orthographic view End view

Figure 1 Ortho graphic view of the machine

Plate 1 pictorial view of the constructed oil bean slicer

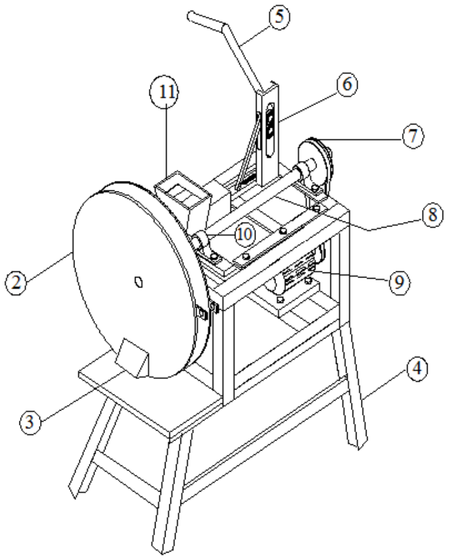


Figure 2 Isometric view of the oil bean seed slicing machine

LEGEND
1. Slizing Disc
2. Slizing Chamber
3. Discharge Spout
4. Structural frame
5. Feeding Handle
6. Feeding Linkage
7. Driven pulley
8. Shaft
9. Electric Motor
10. Bearing
11. Feeding Hopper
12. Belt

2.3 Component Design/Fabrication

2.3.1 Belt Drive

The belt drive is intended to give suitable revolutions per minute from the electric motor. The following speculations for electric motor and pulley were selected. Pulley diameter of electric motor, Dm = 57mm; Speed of electric motor shaft, Nm =1400r.p.m; Desired driven pulley diameter attached to shaft, Ds =137mm

The diameter of driven pulley (Ds) was designed to reduce and achieve the output speed desired for the cutter. The shafts/pulley diameters and their rotational speeds are related by the relationship suggested by Khurmi and Gupta(2006)

$NmDm = NsDs$ (1)

Shaft speed is determine from equation 1 as

$Ns = \frac{NmDm}{Ds}$ (2)

Where: Ns = shaft speed, rpm; Nm = speed of electric motor, rpm; Ds = diameter of driven pulley, mm and Dm = Pulley diameter of electric motor.

2.3.2 Belt Length

The centre distance between diameters of motor pulley and shaft pulley =230mm. The intended belt drive is an open one consequently in line with (Bur and Cheatam, 2002)and with the nomenclature for shaft diameter Ds and motor pulley diameter Dm, the length is expressed as,

$L = [1.57(Dm + Ds) + 2c + (\frac{Ds - Dm}{4c})^2]$ (3)

Where: c = centre distance, mm; L= belt length.

2.3.3 Peripheral Belt Speed

The belt speed is given by the expression as suggested by Khumi and Gupta(2006)

V = wr(4)

Where: V = belt speed, m/s; w = angular speed, rad/sec and r = angular radius, mm

The radiusr = $\frac{D}{2}$(5)

Where: D = angular diameter, mm

And the angular velocity (w) rad/sec

$$W = \frac{2\pi N}{60} \quad (6)$$

$$v = \frac{2\pi N}{60} . \frac{D}{2} . = \frac{\pi ND}{60} \quad (7)$$

Where: N = the revolutions per minute (rpm)

2.3.4 Angle of Lap

The angle of lap on the shaft pulley is obtained from the relationship (Hannah and Stephens, 1998)

Cos $(\underline{\theta})$= $\frac{Ds-Dm}{2C}$(8)

2

θ = 2Cos^{-1} [$\frac{Ds-Dm}{2c}$](9)

2.3.5 Tension on the Belt Drive

The tensions on the belt are considered in three ways namely: tension due to centrifugal Force, tension on tight (T_1) and slack (T_2) sides of belt. From Khumi and Gupta (2006) the value for centrifugal tension on belt is given by

Tc = mv^2(10)

Where m is the mass of belt per length=area *length * density of belt

But since W = mg

$\therefore T_c = \frac{Wv2}{g}$(11)

Where w = weight per length v = belt speed and g = acceleration due to gravity

Since the machine is to operate from a power source, less than 3-5kw, therefore belt properties of "type A'' will be used (Khumi and Gupta 2006) .

The tension on tight side of belt is given by (Khumi and Gupta, 2006).

$T_{1} =$ Tmax+ Tc(12)

Tmax is the maximum tension Obtained as

Tmax = $\delta\partial$(13)

∂ = area of cross-section of belt (mm)^2; δ = maximum safe stress for belt. Tc = Tensiondue to Centrifugal Force. Using IS: 2494-1974(Khurmi and Gupta, 2006). From enables of v- belt specification transmitting, Less than 3.5kw; A = 81mm^2 σ = 2.1N/mm^2; Coefficient of friction μ =0.3, Top width b. =13mm

Thickness t = 8mm;

$\therefore$Tmax 2.1N/mm^2 x81mm^2

Tmax = 170.1N

ButT_1 =Tmax + T_c

$\therefore T_1$ = 170.1+1.88

T_1 =171.98N

The tension on slack side of pulley T_2 is obtained from the expression,

2.3log $\frac{T1}{T2}$ = $\mu\theta$ Cosecβ(14)

Log T_2=logT_{1}-$\frac{\mu\theta}{2.3}$ Cosec β (15)

T_2 = 10[logT_{1}- $\frac{\mu\theta}{2.3}$ Cosec β] (16)

(Groove angle is equal to 35^0; 2 β = 35^0; $\therefore$ β = 35/2 = 17.5^0

2.3.6 Selection of Electric Motor

The minimum power required to drive the equipment is obtained from

P = (T_1-T_2) (17)

From our evaluation in equation 17, an electric motor of rated power 1HP is to be used for the equipment.

2.3.7Shaft Design

The shaft diameter is determined using the relationship below (Burr and Cheatham, 2002; khurmi and Gupta, 2006;Iwuola,2003; Sharma andAgawam2006)

$D = \left(\frac{16}{\pi\,\tau}\sqrt{(k_b.M_b)^2 + (K_t.M_t)^2}\right)^{1/3}$ (18)

Where

τ= Allowable shear stress for steel shaft with provision for keyways = 42N/mm^2

Mt = maximum twisting moment on the shaft (N-mm)

M_b = maximum bending moment on shaft (N-mm)

K_b = combined shock and fatigue factor

For bending: this is taken as K_b =2 for suddenly applied loadand shock (Khumi and Gupta, 2006)

K_t = combined shock and fatigue factor taken also as K_t =2

2.3.8Maximum Twisting Moment

Maximum twisting moment, Mt on the shaft obtained as,

$M_T = (T_1 - T_2).\ D^s/2$ (19)

2.3.9Determination of weight ofpulley systems and Cutter of the slicer.

Densit ,ρ = 6800kg/m^3; Diameter D= 137mm =70.137m; Thickness t = 10mm = 0.01mm

Volume of pulley, V= $\frac{\pi D^2 t}{4}$ (20)

mass of pulley , m = ρ v(21)

weight of pulley , w = mg (22)

The weight of the cutter was determined from the expression

$W_T = \rho Vg$ (23)

Where: ρ= density = $\frac{mass}{volume}$, of construction material (cutter) kg/m^3

V = volume = $\frac{\pi D^2}{4}t$, of construction material (cutter), m^3

D = diameter of construction material (cutter),m

t = thickness cutter,m

2.4 Machine Operation

The machine functions by the action of high speed turning blades attached to cutting disc. The oil bean seeds are fed into the hopper and are then drawn into the slicing chamber by the action of an extension spring and movement of a link attached to the feeder. Cutting blades are attached to a power shaft that is connected to the electric motor by means of a belt drive, which then slices the oil bean seed hence producing the finished sliced product.

2.5 Machine Test

The machine was tested for performance in terms of output and efficiency. The output is measured in terms of mass of slice per unit time. The hopper of the machine was filled with 10kg of oil bean seed and sliced. The time taken to slice the oil bean seed was noted. Performance efficiency of the machine was evaluated from the expression,

$\alpha = \frac{Wt - WD}{Wt}$ x100(24)

Where: α =slicing efficiency (%); Wt= weight of total slice (kg);W_D = weight of damage/loss slices (kg)

III. 3.0RESULTS AND DISCUSSIONS

3.1 Results

Table 1.The machine design technical parameters

Technical/Calculated parameter	Symbol	Value	Unit
Shaft speed	N_2	582	Rpm
Belt length	L	771.5	Mm
Peripheral belt speed	V	4.2	m/s
Angleof lap	θ	2.79	Radians
Tension due to centrifugal Force	Tc	1.88	N
Tension on tight side of belt	T_1	171.98	N
Tension on slack side of belt	T_2	10.71	N
Power transmitted to the shaft	P	673.3	W
Shaft design	MT	11046.995	N-mm
Maximum bending moment	Mb(maR)	11551.6.2	N-mm
Diameter of motor Shaft	D	15.71	Mm
Weight of cutter (disc)	Wc	41.3	N
Force needed to pull Lever	F	30	N
Power required to operate the slicer	P	1	Hp

Table 2. Machine performance

Trials	Mass of Oil beans Seed before slicing (kg)	Mass of sliced d product (kg)	Mass of f damaged product (kg)	Time taken (minutes)	Slicing efficiency (%)
1	10	9.6	0.4	2.45	95.83
2	10	9.5	0.5	2.47	94.74
3	10	9.8	0.2	2.47	97.96
4	10	9.8	0.2	2.43	97.96
Average	10	9.675	0.325	2.46	96.64

Table3. Bill of Engineering Measurement and Evaluation (BEME)

ITEM No	Item Description	Dimension	Unit	Qty	Rate ₦	Amount
1	Angle iron	0.050x 0.050	M	1½	1200	1800
2	Cryptoniron	0.050x 0.050	M	1	1600	1600
3	Square rod	6.096x Dia 0.012	M	½	2000	1000
4	Shaft	20mm	M	½	3000	1500
5	Angle iron	½ inch	M	½	750	475
6	Pulley (driven)	137mm	M	1	200	400
7	Pulley (driver)	57mm	M	1	600	3000
8	Mild steel plate	3mm	M	½	600	3000
9	Mild steel plate	5mm	M	1/6sheet	200	3000
10	Bearing	P204	M	2	1000	2000
11	Bearing	600z-2z	M	3	700	200
12	Bearing	500z-2z	M	1	300	300
13	Spring			2	300	600
14	Electric motor	1hp. 140 Rpm	No	1	12500	12500
15	V- belt	A650	No	1	200	300
16	Cable	5inch	No	1	300	1500
17	Plug	15Amp	No	1	450	450
18	Cutting disk	∅ 330		1	2000	3000
19	Backing plate	∅ 340		1	500	2000
20	Bolts	M10 M12	M	10	200	300
21	Green paint	No		1	1000	1500
22	Sub material cost					₦46825
23	Transport cost					₦2000
24	Handling cost					₦500
25	Sub Total					₦49325
26	Vat				5%	₦2466.25
27	Total material cost					₦51, 791
28	Labour cost					₦16000
29	Overhead cost				30%	₦20, 337
30	**Total production cost**					**₦ 91,353 ₦**

3.2 Discussion

Results of this research work are presented in Table 1 to 3. Table 1 revealed the machine design technical parameters. According to the result, the power requirement of the machine is 673.3W which entails that 1hp electric motor with speed of 1400 rpm will power the machine. This power is transmitted to the shaft bearing the cutters that slices the oil bean seeds. The cutter has the weight of 41.3N and rotates at speed of 582 rpm under a pulling force of 30N.

Table 2 presents the machine performance. From the results as recorded in this table, it is observable that the machine completely sliced average of 10kg of oil bean at 2.46minutes. The machine has average slicing efficiency of 96.64% with minimal damage of 3.25% of sliced materials.

From the bill of engineering measurements and evaluation, as recorded in Table 3, the total cost of fabrication of the device is ninety one thousand, three hundred and three naira (₦91,353.00).

IV. CONCLUSION AND RECOMMENDATIONS

The hand fed oil bean slicer was designed and fabricated with locally available materials to suit the need and reduce the difficulties encountered by local processors of African oil bean. The slicer was powered by a 1hp electric motor. It has an average efficiency of 96.64% with average seed damage of 3.25% of total sliced materials. The device is portable, simple to operate and easy to maintain; and was constructed at a total cost of ₦91,353.00 which can be afforded by an average oil bean producer and/or processor.

For effective and efficient utilization of the machine, the following recommendations should be adhered to:

i. Proper attention should be given to its maintenance (preventive maintenance) such as regular lubrication of moving and/or robbing parts, replacement of damaged or worn out parts and adequate cleaning after use.
ii. It should be properly stored under shed or indoors after use.
iii. It should not be used for jobs other than slicing of oil bean which it is made for.

Above all, the device is a hand fed operated contrivance, researchers may further the development to complete automated system.

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