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Design and Construction of a Motorized Okra Slicer

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Abstract: *The motorized Okra slicing machine was designed to help farmers' process okra with ease and stress-free. The machine was designed, constructed with locally available materials and it performance was evaluated. The average slicing efficiency, throughput capacity and scattered losses were 90.37%, 62.2kg/hr and 8.32% respectively.*

Key words: *Okra, Designed, Constructed, Evaluated, and Slicing Efficiency*

1. INTRODUCTION

1.1 BACKGROUND

Okra or Okra, known in many English speaking countries as Ladies fingers, Okro or gumbo, is a flowering plant in the mallow family. It is valued for it edible green seed pods. The origin of Okra is disputed, with supporters of West Africa, Ethiopian, and South Asian original. The plant is cultivated in the tropical, subtropical and warm temperate regions around the world (John, 2000).

The main objective of the project is to design a simple okra slicer. The specific objectives are:

i. To design a machine to cut okra.
ii. To construct the machine.
iii. To test the performance of the machine.

Using Okra slicing machine help to reduce difficulties that are encountered with the processing of okra using hands which is laborious and very slow and result in wastage of okra. This machine makes it easy for okra processing. This machine was constructed using local materials which make it affordable for local farmers to own and use.

2. DESIGN METHODOLOGY

2.1DESCRIPTION AND WORKING PRINCIPLE OF MACHINE

2.1.1Description of machine

The okra slicer consists of the following main features:

i. A feed hopper

ii. Casing
iii. Shaft
iv. Transmission unit.
v. Outlet chute
vi. Slicing units (cutting blades)
vii. Power unit

2.1.2 MATERIAL SELECTION

Materials for the construction were selected base on strength, functionality, durability, ability to withstand vibration and the cost of such material. In the choice of material, their physical properties and behavior were considered such that when subjected to the machine running condition should be able to withstand their service condition.

2.2 WORKING PRINCIPLE OF THE MACHINE

The crop (okra) is fed into the machine through the hopper and it goes into the slicing chamber with the help of the force of gravity where there are blades attached to the shaft. The machine is operated by an electric motor. As the electric motor is on, then the power is transmitted to the slicing chamber by the transmission units such as the pulley and the belt which rotate the shaft and cut or slice the okra. As the okra is sliced it goes out of the machine through the outlet chamber.

2.3 DESIGN CALCULATIONS

2.3.1 **Feed hopper:**

The hopper will be designed to be a frustum, trapezoidal in shape and the dimensions will be chosen based on proportionality and aestatics (Ndirika, 1993). The angle of the base to the vertical is (α) which will be the measured angle of repose of okra.

Volume of hopper will be determined from the following equation.

$$V_f = \frac{h_f}{3}\left(A_1 + A_2 + \sqrt{A_1 \times A_2}\right) \qquad \text{(Ndirika, 1993)} \quad 1$$

$$A_1 = L_f \times B_1$$

$$A_2 = L_f \times B_2$$

$$A_3 = L_f \times h_f$$

Where;

V_f = Volume of frustum, m^3

A_1 = Area of the top of the frustum, m^2

A_2 = Area of the base of the frustum, m^2

A_3 = Area of rectangular side of frustum, m^2

h_f = Height of frustum, m

H_h = Height of hopper, m

L_f = Length of frustum , m

B_1 = Breadth of the top frustum, m

B_2 = Breadth of the base frustum, m

2.3.2 Angle of repose of okra

The angle of repose is the angle between a base and a slope of a cone formed on a free vertical fall of grain mass to a horizontal plane.

Formula for calculating angle of repose

$\theta = \tan^{-1}\left(\frac{2HP}{DP}\right)$ (Ndirika, 1993)

The angle of repose of okra was determined by allowing the fruits to fall freely from a height, and a rule was used to measure the height of the heap formed. The following values were obtained:

Height of the pile HP = 20cm

Diameter of pile DP = 40cm

$$\theta = \tan^{-1}\left(\frac{2HP}{DP}\right)$$

Where HP = height of the pile in cm

DP = diameter of the pile in cm.

2.3.3 Weight of shaft

Main shaft: shaft material is mild steel with density of 7.83 x 10^3kg/m^3

D = 10mm

$$Area = \frac{\pi D^2}{4}$$

Volume of the shaft V = A x L

Mass of shaft M = PV

Where P = density of shaft material

2.3.4 Determination of pulley dimension

$N_I D_I = N_2 D_2$ (Ndirika, 1993)

Where N_I = speed of electric motor (1426rpm)

D_I = diameter of driving pulley (50mm)

N_2 = speed of driven pulley (366mm)

D_2 = diameter of driven pulley?

Belt drive dimension

The amount of power transmitted depends on the following;

i. The velocity of the belt,
ii. The tension under which the belt is placed on the pulleys,
iii. The arc of contact between the belt and the smaller pulley,
iv. The conditions under which the belt is used.

V-belt: According to Khurmi and Gupta, (2013) V-belt is mostly used where a great amount of power is to be transmitted, from one pulley to another, when the two pulleys are very near to each other. And where both pulleys rotate in the same direction open belt drive is used (Figure 4). Therefore V-belt will be used.

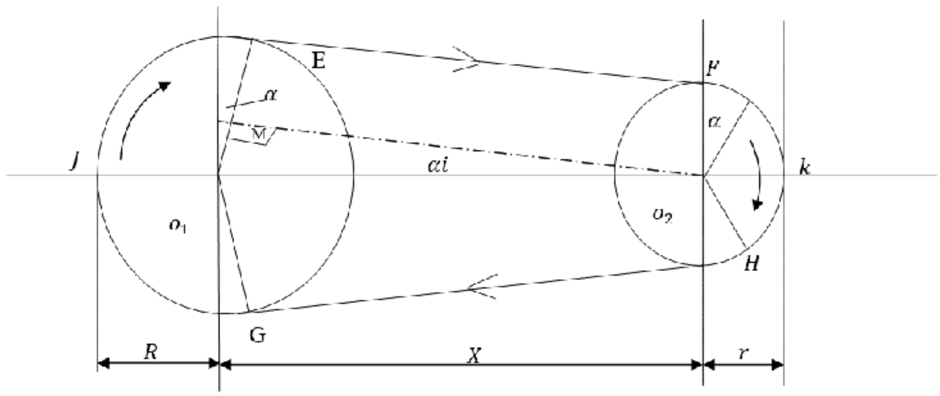

Figure 1: Open belt drive **(Source: Khurmi and Gupta, 2013)**

Where,

R = Radius of the larger pulley,

r = Radius of the smaller pulley,

x = Distance between the centers of two pulleys (i.e. 0_1, 0_2) and

L = Total length of the belt.

2.3.6 Distance between pulley centers

The distance between pulley centers according to Khurmi and Gupta, (1992) is given by:

$X = Max\ (2R: 3r + R)$

Where; R= radius of big (driven) pulley,

r= radius of small (motor) pulley.

The larger of the two values of X is usually chosen.

$$R = \frac{d_2}{2}$$

$$r = \frac{d_1}{2}$$

2.3.7 Belt length

The belt length L_1 will be determined using equation 2 (Khurmi and Gupta (2013).

$$L_1 = \frac{\pi}{2}(d_1 + d_2) + 2x_1 + \frac{(d_2 - d_1)^2}{4x_1} \quad 2$$

Where;

x_1 = Distance between pulley centers mm

d_1= Driver (electric motor) pulley diameter mm

d_2 = Driven pulley diameter mm

2.3.8 Bearing selection

This was done base on ASAE (1979) standard. The factors considered are:

i. Speed of the shaft
ii. Size of the shaft
Bearing allows motion between mechanical elements and lower the friction between them. (James, 2017).

A single row deep groove ball bearing was selected with inner diameter of 10mm and external diameter of 20mm which are four in number and have the same size. That is for the main shaft and the lower shaft.

2.3.9 Power requirement

The belt torsion would be determined using the equation given by Khurmi and Gupta, (2013).

$P = T_1 - T_2$

$$\frac{T_1}{T_2} = e^u\theta$$

$$V = \frac{\pi dN}{60}$$

Where;

P = Power from the prime mover (W)

T_1& T_2 = tension on the slack and tight side of the belt respectively (N)

N = Speed of prime mover (rpm)

D = Diameter of pulley (m)

θ = Angle of the lab (rad)

μ = Co-efficient of friction between the belt and the pulley

V = Velocity of belt (m/s).

2.3.10. Design of shaft

The required diameter for a solid shaft having combined bending and torsional loads is obtained from two basic theories of failure namely,

i. Maximum Shear Stress Theory or Guest's theory used for ductile materials such as mild steel,
ii. Maximum Normal Stress Theory or Rankin's theory used for brittle materials such as cast iron (Hannah, 1984).

Since mild steel is used for the shaft, maximum shear stress theory was used for the design of the shaft diameter and it is given in the equation 5 (Khurmi and Gupta, 2013).

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

Where;

S_S = Maximum permissible shear stress,

$$Ss = \frac{Ultimate\ Strength\ in\ Shear}{Factor\ of\ Safety, FS} \qquad 6$$

K_b = Combined shock and fatigue factor applied to bending moment,

K_t = Combined shock and fatigue factor applied to torsional moment,

M_b = Maximum bending moment, Nm,

M_t = Torsional moment, Nm.

2.4 INSTRUMENTATION

The instruments used include;

i. **Protemeter**: It is a digital instrument used to measure content of grains. The grain master is protemeter moisture meter used was manufactured by Martin Linshman Ltd and has a range of 0 – 100%.
ii. **Tachometer**: This is used to measure the speed of shaft in revolution per minute.
iii. **Stop watch**: This is used to obtained time for each experiment in second. The stop watch model KK – 1045, and manufactured by Kenko it had a range of 0.00 – 9.59.59.
iv. **Lysimeter**: This is use to measure the weight in kilograms of materials. The Lysimeter was manufactured by Norwood instruments Ltd and has a range of 30kg maximum weight.

2.5 PERFORMANCE EVALUATION

The formulae for evaluating the different parameters for the performance of the machine were obtained from Ndirika (1993).

i. **Slicing efficiency Se (%)**: This is defined as the ratio of the weight of the fruits collected to the weight of total fruits.

$$S_e = \frac{W_{cs}}{W_t}$$

Where; W_t = total weight of fruits put into the hopper.

W_{cs} = weights of fruits collected at the outlet.

ii. **Scatter loss, SCL (%)**: This is the loss acquired due fruits scattering around the slicer during slicing operation.

$$scl = \frac{Q_l}{Q_t} \times 100\%$$

Where: Q_l = quantity of okra scattered around the machine

Q_t = total quantity of okra introduced into the machine

iii. **Throughput capacity, T_C (kg/h):** This is the total material quantity that pass through the machine in a given time.

$$\text{Through-put-capacity} = \frac{Q_s}{T}$$

Where: Qs = Quantity of sliced okra

T = time taken to sliced the okra

3. RESULT AND DISCUSSION

3.1 RESULTS

The machine was designed, constructed and tested by slicing the okra. The experiment was carried out on the machine using the okra of different quantity up to four times and it is as follows in table below.

Table 1: results of the Okra slicing machine

S/N	**Mass of okra(kg)**	**mass of scattered okra(kg)**	**mass of sliced okra(kg)**	**Time take(s)**	**S_e (%)**	**T_C (kg/h)**	**SCL (%)**
1	0.70	0.092	0.595	40s	85	53.5	13.14
2	1.00	0.103	0.880	60s	88	52.6	10.33
3	1.50	0.1012	1.38	75s	92.5	66.0	6.75
4	2.00	0.0614	1.92	90s	96	76.8	3.07
mean					**90.37**	**62.2**	**8.32**

From the results on the table above, the average slicing efficiency, throughput capacity and scattered losses are 90.37%, 6.22kg/hr and 8.32% respectfully. The result shows that the slicing efficiency and throughput capacity increases with increase in mass of okra introduced into the machine but the scatter losses decreases with increase in mass of okra introduced into the machine.

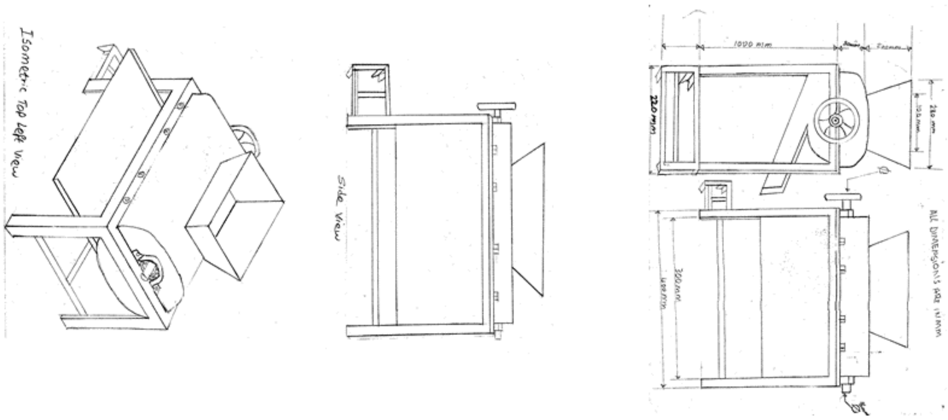

Figure 2: Developed Okra Slicing Machine.

4. CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSION

The design and fabrication of a okra slicing machine was successfully done. The machine can also be used to process other agricultural materials that have similar physical rheology and mechanical properties. The machine was designed to replace the traditional method of slicing okra which is very laborious.

4.2 RECOMMENDATIONS

As a result of some bottlenecks encountered during the construction and testing of the machine, the following are recommended for further improvement on the machine.

i. The size of the hopper should be increased and a means of pressing the okra inside the hopper should be provided.
ii. The outlet chute should be encased for safety and hygiene.

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