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DEVELOPMENT OF A SMALL SCALE OKRO SLICING MACHINE

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Abstract

The technique of slicing Okro using kitchen knife often exposes users to the danger of knife cut and the output of the technique has been found to be low due to the drudgery involved in the process. It was in recognition of the need to reduce drudgery, injury and associated rigors to the user and to enhance quality, hygiene and efficiency in Okro processing that the research of developing a suitable Okro slicing machine was initiated. A simple motorized device was developed for slicing okra using locally available materials which include: bearings, shaft, pulleys, electric motor, cutting blade, rail, bolts and nuts. The slicing mechanism was based on the high shear stress that is generated when a blade edge is brought into contact with fibrous material causing the blade to move in rotary motion and to the direction of the applied force. After coupling and testing the machine, results obtained showed that it takes 3 seconds to slice one Okro using machine while in the case of manual slicing, it takes 8.22 seconds. The device has a slicing efficiency of 66.67%. The machine has shown to enhance processing of okra in small scale industry application. The machine therefore is of great importance to the industries within the country and beyond where preservation of Okro in sliced and dried form is important.

Keywords: Okro, slicer, slicing efficiency, machine

1. Introduction

Okro also known as *Hibiscus esculents* is very important to man and animal which cannot be overemphasized. Okro is a vegetable grown on commercial and house hold consumption scale during wet and dry seasons. Okro is a widely cultivated vegetable and can be found in almost every market in Africa. Its most reliable part is the tender and non-fibrous which is usually eaten as a fried or cooked vegetable. Okro pod has so many nutritive values which includes minerals, vitamins, carbohydrates, protein and contain sizable amount of essential amino acid (Adeboye and Oputa, 1996; Okro food, 2003).

Slicing is a cutting process for size reduction of fruits and vegetables. It involves pushing or forcing a thin sharp knife to shear through the materials intended to be sliced (Owolarafe *et al*. 2007). There are different types of slicing machines designed and constructed for different purposes. This includes bread slicing machine. It works on the principle of gravity loaf in-feed system and the up-and-down reciprocating motion of the blade frame that carries 22 parallel cutting blades spaced at a regular interval of 14.5mm apart. It is driven by a 2 horsepower electric motor via V-belt. Considering the results of the performance test, it was observed that the machine will serve the purpose of slicing operation at reduced vibration, reduced cost and clean slicing environment with optimum efficiency as very smooth slices were obtained (Kolawole *et al*. 2016). Aji *et al*. (2013) developed an electrically operated cassava slicing machine. The machine is portable and easy to operate which can be adapted to medium scale industries. Others include development of plantain slicers, yam slicers, meat slicers, tomatoes slicers and many others. All these slicers work with the different principle of cutting using blades of different types. A manually operated device for slicing okro was developed by Owolarafe *et al.* (2007) based on this mechanism has been adopted as a unit of an integrated system for okro processing by rural women in South-Western Nigeria because it reduced the drudgery associated with manual slicing.

Kitchen knife is the most common tool used for slicing okro but it is also associated with a lot of rigors to the users and farmers. This paper therefore presents the development of a suitable small scale okro slicing machine in other to ease the work of okro farmers and to save them from the danger of knife cut.

2. Design Analysis

The frame is designed to carry all the machine components such as the electric motor, shaft, feeder and receiver.

Length of frame $(LF) = 600mm$

Breadth of frame $(BF) = 260mm$

Height of frame $(HF) = 530mm$

Since the frame shape is rectangular in shape, the area (A) of the frame is given by

$$A = LF \times BF \quad (1)$$

$$= 0.6 \times 0.26$$

$$= 0.156m^2$$

According to the relations provided by Khurmi and Gupta (2005),

Speed of Rotation is given by:

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} \quad (2)$$

where:

N_1 = speed of electric motor $(1400\,rpm)$, N_2 = speed of shaft (?), D_1 = diameter of the driving pulley $(67mm)$, D_2 = diameter of the driven pulley $(150mm)$

Using equation (2), $N_2 = 625rpm$

The length of the belt was determined from the relation;

$$L_b = 2C + \frac{\pi(D_1+D_2)}{2} + \frac{(D_1-D_2)^2}{4C} \quad (3)$$

where:

D_1 = diameter of the driver pulley,

D_2 = diameter of the driven pulley,

C = distance from center to center between the driving and driven pulley $(520mm)$.

Using equation (3), L_b = 1479.57mm

Velocity of moving belt:

$$v = \frac{\pi DN}{60} \quad (4)$$

$$v = 4.9\ m/s$$

Power driven mechanism:

$$T_1 = T - T_C \quad (5)$$

where: T = maximum tension in the tight side of the belt, T_c = centrifugal tension

T_1 = tension in the tight side of the belt.

$$T = \delta \times a \quad (6)$$

where: T = maximum tension in the tight side of the belt, δ = stress in the tight side of the belt, a = area of the belt ($104\,mm^2$)

$$T = 260N,\ T_c = 2.85N,\ T_1 = 257.15N$$

The power transmitted (P) was determined from the relation;

$$P = (T_1 - T_2)V \tag{7}$$

where:
T_1 = tension in the tight side of the belt,
T_2 = tension in the slack side of the belt
P = power transmitted,
V = velocity of the belt in meters per second.

$$P = 686.1\,W$$

Shaft design:

$$m = \rho v \tag{8}$$

M = mass of the shaft, ρ = density of the shaft, V = volume of the shaft,
Mass of shaft is calculated as 0.381kg
However,
Volume of shaft

$$V = A \times L \tag{9}$$

where: A = cross sectional area and L = length of the shaft (100 mm)

$$A = \frac{d^2}{4} \tag{10}$$

Volume calculated to be $4.997\ x\ 10^{-5}\ m^3$

2.1 Slicing unit (cutting blade)

The slicer is the basic part that does the slicing/cutting. It is made up of the transmission shaft, cutting blade and the power driven mechanism.
Area of cutting blade = $180mm \times 30mm$
The blade is rectangular in shade and placed horizontally on the shaft. There are four blades on the shaft.

2.2 Feeder (hopper)

The feeder is where the okro pods are first collected before it is discharged into the slicing unit for further processing. The feeder is designed to take an average of five (5) average Okro sizes per entry.

3. Materials and Method

The material used for the different component in this design involves the following considerations: cost and availability of the material, strength, ductility, corrosion resistance, ease of fabrication. The best selection of materials could be made after considering factors such as spectrum of material properties, ease of fabrication, its durability and alterability with frequency of use, corrosion resistance an economic-cost advantage (Olagoke, 2002). The table below describes the selection of appropriate components based on some suitable reasons.

Table 1: Selection of Components

Component/ Construction Process	Used
Transmission shaft	To gears and gear trains to provide speed and torque conversions from a rotating power source to another device.
Pulley	In order to transmit power from one rotating shaft to another.
Belt	Used as a source of motion to transmit power efficiently or to track relative movement.
Bearing	Used to enable rotational or linear movement while reducing friction.
Frame	The construction started with the main frame; the mild steel angle iron was bought from the market and welded together after considering all the necessary dimensions.
Cutting Blade	Used for slicing the Okro.
Electric Motor	Used to produce linear or rotary force (torque) and used to converts electrical energy into mechanical energy.

3.1 Assembly and Principle of Operation

- The construction started with the main frame.
- The mild steel angle iron was welded together after considering all the necessary dimensions.
- The bearings were fixed into the bearing housing of the top edge of the frame side into which the shaft was inserted.
- This was followed by the mounting of the pulleys on the shaft that transmits the motion from electric motor to shaft by the use of belt.
- The cutting blade and the bearings were placed on the rail in order to obtain the rotary motion as a result of connecting the shaft, and the feeder is fitted to the receiver on the frame which is joined by bolts and nuts.

This machine is driven by 1hp electric motor which is the main source of power. It works on the principle of rotary motion of the blades. Torque is generated on the shaft which gives the rotary motion on the pulley and transmitted by a V-belt. The rotating blade then slices the loaded Okro by shear and cutting force. Sliced Okro is collected through the receiver fitted on the frame beneath the hopper.

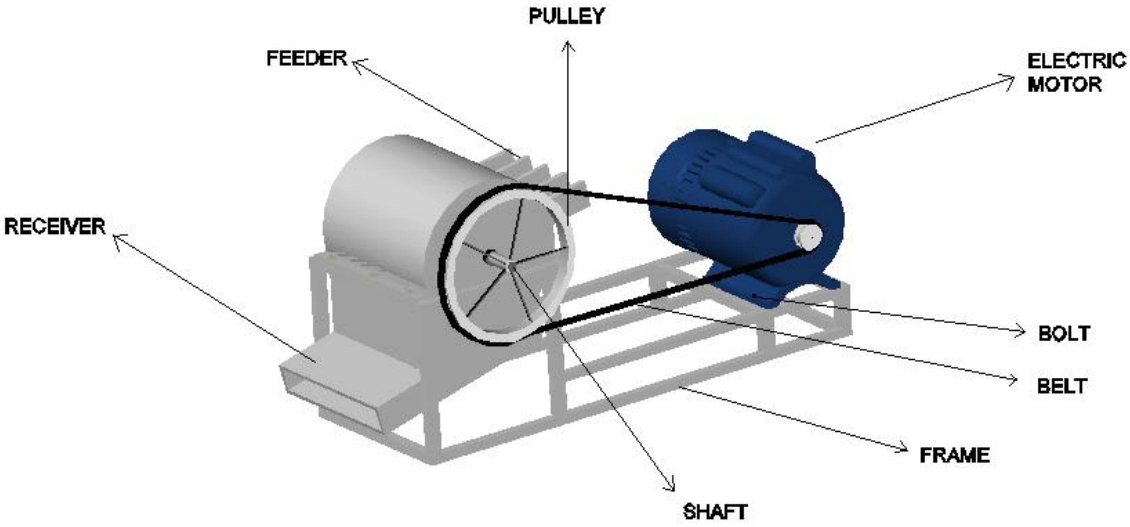

Fig. 1: Assembly Drawing of the Machine

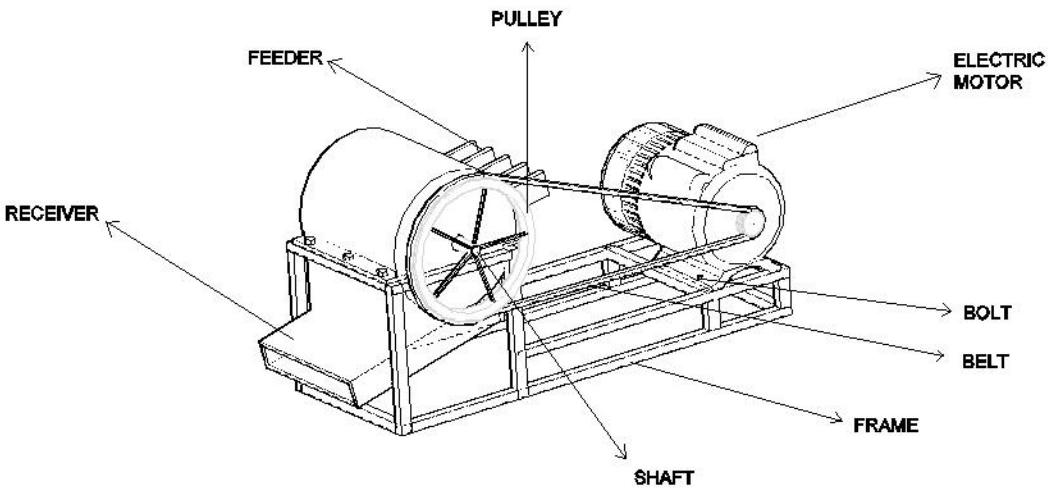

Fig. 2: Shows the Wire Frame of the Machine

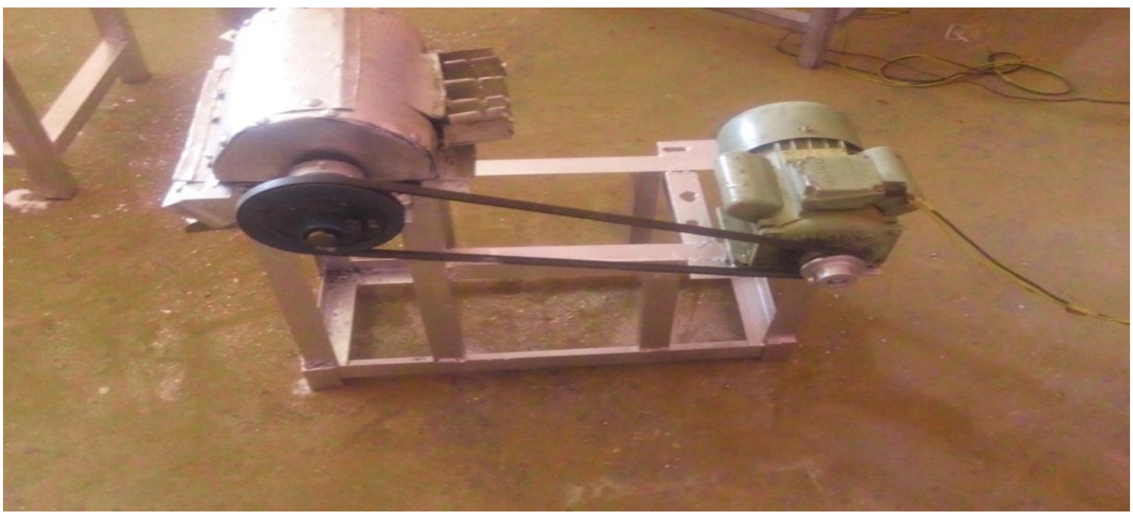

Plate 1: Small Scale Okro Slicing Machine.

4. Results and Discussions

4.1 Efficiency of the Machine

To obtain the efficiency of the machine:

Mass of unsliced Okro $(m_1) = 0.9\ kg$

Mass of sliced Okro $(m_2) = 0.6\ kg$

$$Efficiency\ (\mu) = \frac{m_2}{m_1} \times 100\% \qquad (11)$$

$$= 66.67\%$$

Okro used for the purpose of this experiment has an average of 80mm length, 30mm diameter and 10mm thickness.

Table 2: Results of load testing specimen ($80 \times 30 \times 10\ mm$ of okro)

	Sample	Number of Okro	Time (sec)	Average
Sample	Result of slicing operation using machine			
	A1	1	3.28	
1	B1	1	2.95	2.992sec
	C1	1	3.62	
	D1	1	2.16	
	E1	1	2.95	
Sample	Result of slicing operation using machine			
	A2	4	5.05	
	B2	4	6.02	4.556sec
2	C2	4	2.49	
	D2	4	6.23	
	E2	4	2.99	
Sample	Results of slicing operation manually			
	A3	1	9.18	
3	B3	1	8.23	8.22sec
	C3	1	8.00	
	D3	1	7.90	
	E3	1	7.80	

From Table 2, the time taken to slice one okro at a time for sample A1 to E1 is within the range of 2.16 seconds to 3.62 seconds respectively. The average time taken to slice one okro is 2.99 seconds. Approximately 3 seconds was used to slice one okro, this shows greater efficiency of the machine for use in okro slicing units semi-industrial use. Furthermore, the machine can slice up to 5 okro at a time, this can help increase the total quantity of okro to be processed. The time taken to complete the operation for sample A2 to E2 is within the time frame of 2.496 seconds to 6.23 seconds respectively. The average time taken to slice four (4) okro is 4.55 seconds, which is an indication of utilizing little time to process the okro using the slicing machine.

Similarly, result in table 2 show that the use of knife to slice one pod of okro at a time is within the range of 7.80 seconds to 9.18 seconds. The average time taken to slice one okro manually is 8.22 seconds.

Manual processing shows less efficiency in processing okro for small scale industries, this is in addition to the problem of hygiene which can be a factor in manual processing. Comparing the test results of A1 to E1 and A3 to E3, it can be seen that the average time taken to slice or process okro using machine and knife is very far apart. The advantage of using the slicing machine cannot therefore be overemphasized. The economy in processing large quantity and the fatigue that comes in when the process is undertaken manually is obvious.

5. Conclusion

An okro slicing device has been developed using locally available materials as an improvement on existing manually operated devices. The machine designed and constructed is used to ease the work of processing okro thereby enhancing quality, hygiene and efficiency of okro processing in small scale industries. The average time taken to slice the okro using the machine is 3 seconds which is faster compared to manual process which is 8.22 seconds. The device is a step further in okro processing in Nigeria and other places in sub-Saharan African region where preservation of okro in sliced and dried form is important.

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