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DESIGN AND DEVELOPMENT OF FLUTED PUMPKIN (*TELFAIRIA OCCIDENTALIS)* LEAVES SLICING MACHINE

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ABSTRACT
A motorized fluted pumpkin leaves slicer was designed, fabricated and tested. The machine comprises a conveyor system made from a rubber belt, two pairs of bearings and two hollow metal rods, a frame made from metal sheets for support. The slicing unit comprising the cutting blades and a drive (transmission) shaft, and finally a 746 W (1 hp) power drive mechanism (electric motor). Tests carried out on the machine involved placing 1 kg of fluted pumpkin leaves on the conveyor belt, which was then conveyed to the slicing unit, where it was chopped to desired size. It took an average of 9 minutes to process 1kg of the fluted pumpkin leaves during the test. Series of tests were carried out on the machine, which showed that it had an efficiency of 73.2% and is much faster than hand/manual slicing method.

Keywords: *design, development, fluted pumpkin, slicing machine*

1. INTRODUCTION
Fluted pumpkin is a tropical vine grown in West Africa as a leaf vegetable and for its edible seeds. Fluted pumpkin or *Ugu* is a member of the *curcurbitaceae* family and is indigenous to southern Nigeria [1]. The fluted gourd grows in many nations of West Africa but is mainly cultivated in Nigeria, and used primarily in soups and herbal medicines [2]. In Nigeria an estimated 30 to 35 million Indigenous people make use of the fluted pumpkin, including the Efik, Ibibio, and Urhobo [1]. However, it is predominantly used by the Igbos, who continue to cultivate the gourd for food sources and traditional medicines. The fluted gourd was an asset to international food trades of the Igbo tribe and is noted to have healing properties. It is used as a blood tonic, to be administered to the weak or ill [1]. It could also be used as herb to treat sudden attack of convulsion, malaria and anaemia. It also plays a vital and protective role in cardiovascular diseases [3]. The seeds are used for propagation, extraction of oil and as a soup thickening agent. Agatemor [4] reported that it contains 93% essential amino acids, 53% crude fat and 27% crude protein. Generally, seeds are potential raw materials for the local industries, especially the oleochemical industry. The fermented seeds of fluted pumpkin is used in the formulation of marmalade and cookies [5].

Fluted pumpkin is one of the most consumed vegetable leaves in West Africa, and slicing is one of the most popular ways of preparation. It is usually done manually with a knife, chopping board and a tray. This preparation method is not very efficient because of the accidents associated with the use of a knife. Time is also another major factor to consider because less work is achieved with the manual method over a specified time frame. The drudgery associated with the manual method is another disadvantage especially when processing a large quantity. Slicing of vegetable in theory and practice has been studied by many researchers [6, 7].

The objectives of the present work are (i) to design a prototype of a motorized fluted pumpkin leaves slicing machine (ii) to fabricate the motorized fluted pumpkin leaves slicing machine and (iii) to carry out some tests on the machine.

2. MATERIALS AND METHODS
The development of the slicing machine followed a systematic flow of activities. The drawing was done using AutoCAD 2016, version 20.1, a detailed orthographic view of the machine is presented in Fig. 1.

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Materials used for construction were pulleys, angle iron, cutting and filing tools, gears, electric motor and bearings. The machine was fabricated at the Fabrication Workshop, Department of Agricultural and Bioresources Engineering, University of Nigeria, Nsukka. Freshly harvested vegetables, were purchased from Ogige Market, Nsukka. During testing, the vegetables were conveyed to the slicing unit by the conveyor. As the blades rotated, the vegetables were sliced and collected through the discharge outlet.

2.1 Design Considerations

In the design of the slicer, types of forces and stresses caused by the applied load, motion of the parts or kinematics of the machine were considered. Finally, effort was made to minimize overall cost of the machine by carefully selecting materials that are available locally. Materials selected for the design include the following:

2.1.1 Frame

The weight of the shaft, the electric motor, conveyor unit, slicing unit, bearing and the nature of the material (fluted pumpkin) were considered in designing the frame. An angle iron having the strength and rigidity to withstand the load was used.

2.1.2 Conveyor

The conveyor design adopted for the slicer is the belt conveyor system. A belt conveyor system is one of many types of conveyor systems. It consists of two or more pulleys (sometimes referred to as drums), with an endless loop of carrying medium (the conveyor belt) that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward. The conveyor system adopted for this design comprises a pair of roller and a belt made from the combination of rubber and a strong textile material sown together. This was used due to its ability to withstand wear and tear resulting from the motion of some machine parts.

2.1.3 The Slicing Unit

This comprises of the cutting disc, power drive mechanism, drive shaft, and the bearing assembly. Isometric views of the machine (with slicing unit open and closed) are presented in Fig. 2 and Fig. 3 respectively.

The Cutting Disc: This is the primary or basic component that does the slicing. Some basic empirical properties were determined as shown below.

Diameter of the disc = 130mm (about twice the width of an average fluted pumpkin leaf) as recommended by Myer [8]. Speed of rotation of disc:
To determine this, the following equations were used.

$$v = \omega r \qquad (1)$$

Where, v is the linear velocity of the disc, m/s ,ω is the angular velocity, rad/s, and r is the radius of the disc, m
The angular velocity is also expressed as [9]:

$$\omega = \frac{2\pi N}{60} \qquad (2)$$

N is the number of revolution per minute (N is given as 2850rev per min)

The Power Drive Mechanism: The power, P required by the cutting disc was calculated using the relation:

$$P = T\omega \qquad (3)$$

Where, T is the torque (Nm). But T can be calculated from the equation:

$$T = Fr \qquad (4)$$

F is the Force required for the slicing, 1.121N (as recommended by Ogbobe, *et al.,* [6]), r is the radius of cutting disc, 0.065m. One horsepower was selected due to its availability and also to take care of power losses from the two gear mechanism transmitting rotary motion from the transmission shaft to the conveyor unit. Total kinetic energy stored in the disc is given by [9] in eqn. (5).

$$KE = \frac{1}{2} I\omega^2 \qquad (5)$$

I is the moment of inertia, kgm^2 ,

$$I = W_d R^2 \qquad (6)$$

But

$$W_d = \pi R^2 t\rho \qquad (7)$$

Where: W_d is the weight of the disc, kg, R is the radius of cutting disc, m, ρ is the density of disc material (mild steel), 7850kgm^{-3}, t is the thickness of the disk, 2mm
ASME (American Society of Mechanical Engineers) codes for the design of commercial shaft was used in determining the diameter of the shaft. Shaft design basically has to do with the determination of the correct shaft diameter to ensure satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions. The diameter is given by [9] in eqn. (8).

$$d^3 = \frac{16}{\pi\tau_{max}} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (8)$$

Where: M_t is the torsional moment, 136.05Nm (as presented by Olutayo, *et al.*, [10]), K_b is the combined shock and fatigue factor applied to bending, K_t is the combined shock and fatigue factor applied to torsional moment, M_b is the bending moment, 1051.26 Nm (as presented by Olutayo, *et al.*, [10]), τ_{max} is the allowable shear stress, as specified by ASME.

3 COMPUTED DESIGN PARAMETERS

Table 1 shows the computed results of the pertinent design parameters of the slicing machine.

Table 1: Pertinent design parameters

Quantity	Value	Unit
Angular velocity (ω)	298.49	rads^{-1}
Linear velocity (v)	19.40	ms^{-1}
Torque (T)	0.07	Nm
Power (P)	20.89	W
Weight of disc (W_d)	0.21	kg
Moment of inertia (I)	8.87×10^{-4}	kgm^2
Total kinetic energy in disc (KE)	39.5	J
Diameter of shaft (d)	63.5	mm

4. BEARING ASSEMBLY

The machine has a total of seven bearings located at different parts of the machine. A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. Static and dynamic load conditions were considered in selecting the bearings. Sealed pedestal bearings and diameter of bore were selected to satisfy the design requirement.

5. GEAR MECHANISM

Two gear mechanisms were used to transmit rotary motion from the transmission shaft to the conveyor design. The ratio of the pitch circles of mating gears defines the speed ratio and the mechanical advantage of the gear set.

5.1 Efficiency of Machine

The efficiency was measured by comparing the quantity sliced to that unsliced. Series of data were obtained from the five experimental trials carried out. The average quantity sliced was calculated to be 732g while that of unsliced measured 268g.

$$\varepsilon = \frac{work\ output}{work\ input} \times 100 = \frac{732}{1000} \times 100 = 73.2\% \quad (9)$$

6. RESULTS AND DISCUSSION

1kg of fresh fluted pumpkin leaves was fed into the machine through the conveyor unit and timed. The time taken to completely slice 1kg of the fluted pumpkin was recorded. For comparison a similar quantity of the fluted pumpkin was sliced manually by two individuals familiar with the process of vegetable slicing and the average time taken to slice each 1kg of the fluted pumpkin leaves was recorded. The above test evaluation for the motorized slicer and the manual slicing were repeated five times and average time presented in Table 2.

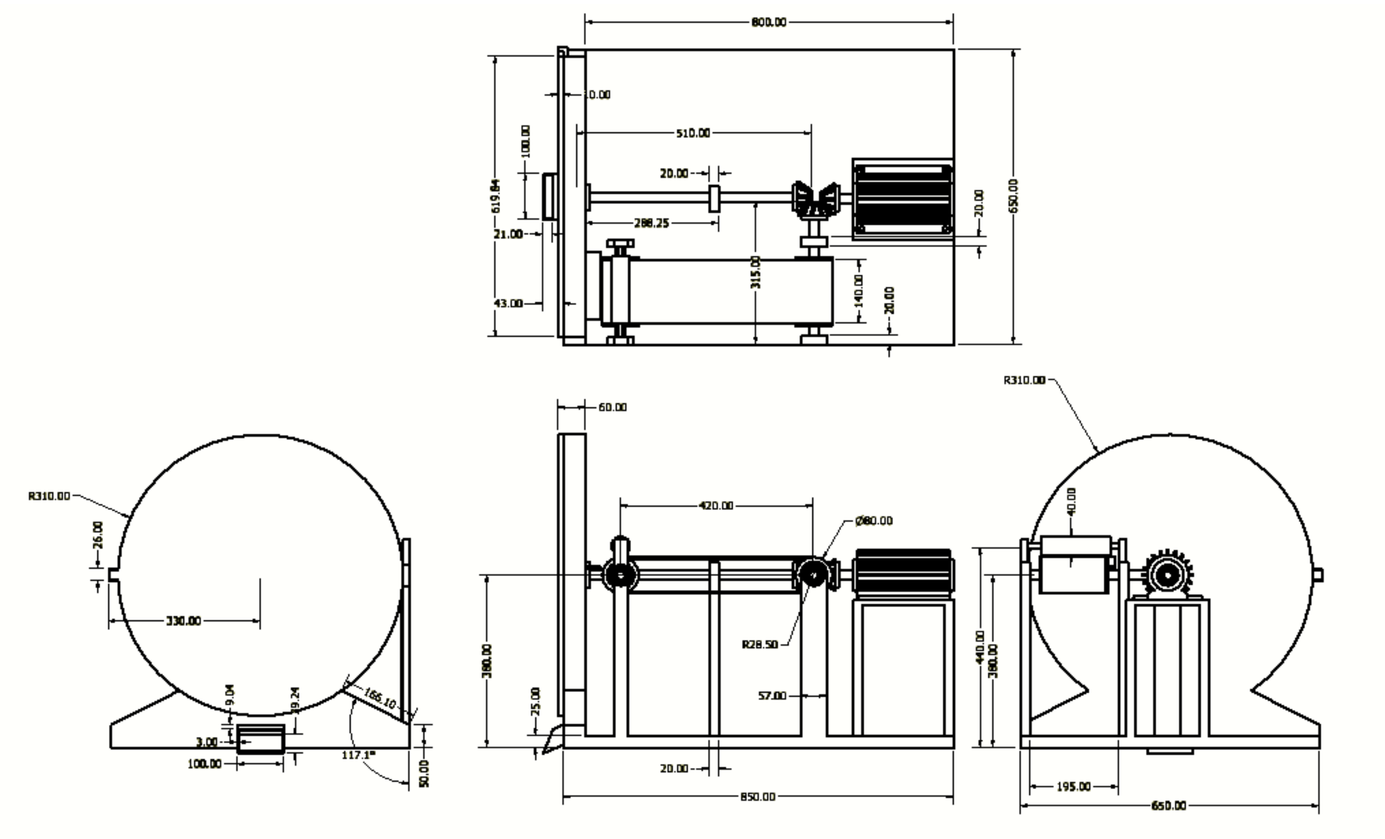

Figure 1: orthographic view of the slicing machine

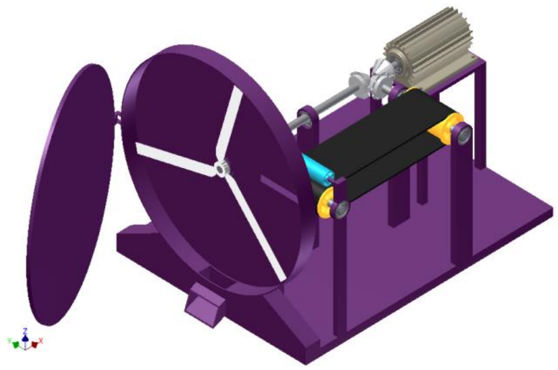

Figure 2: Isometric view of the slicer with slicing unit open

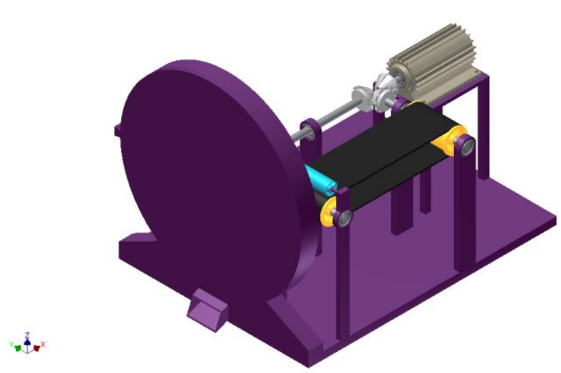

Figure 3: Isometric view of the slicer with slicing unit closed

Actual capacity of the machine was also determined by feeding fluted pumpkin leaves into the machine and finally weighing all the slices including the unsliced leaves. The unsliced were later selected and weighed and the efficiency was evaluated. A detailed comparison of the machine-sliced and manually-sliced fluted pumpkin was also conducted, the differences were very negligible. A handful of each samples were taken to a market place. People were selected at random to distinguish between the two, 35% of the people asked were able to differentiate between the machines sliced and manual sliced, 5% were not sure, and 60% were not able to tell the difference.

Considerable time was lost during the process of feeding the fluted pumpkin leaves to the slicer through the conveyor.

Table 2: Slicing time of fluted pumpkin leaves using the motorized and manual methods

Number of trials	Manual Slicing (min)	Motorized Slicing (min)
1	27.05	9.50
2	26.20	9.50
3	27.40	10.05
4	29.00	9.65
5	30.10	10.30
Average time	27.95	9.80

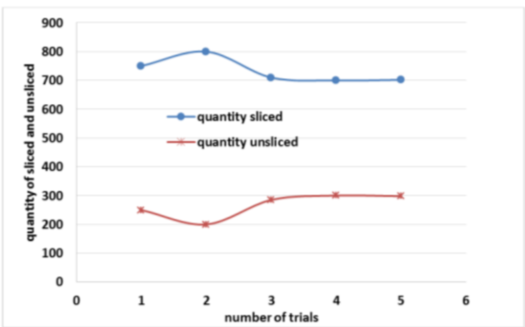

Figure 4: Graph showing the efficiency of the machine

Figure 4 illustrates the efficiency of the machine. From the graph, the blue curve represents the quantity sliced while the red curve represents the quantity unsliced.

The variation in width of the slices was greater in motorized slicing when compared to manual slicing because the feeding could not be adequately controlled. This is in consonance with the work reported by Ogbobe et al., [6].

7. CONCLUSION

Fluted pumpkin leaves can be processed in many ways depending on the need for it. Slicing is the most common method of preparing the fluted pumpkin leaves. This can be achieved locally with the help of a knife and a chopping board. This method has proven to be less efficient because of the longer time taken to slice the leaves. The manual method is only applicable to situations that require little or small quantity of vegetable. When slicing large quantities of the fluted pumpkin leaves, manual method is not always an option.

The design, development and performance evaluation of a motorized fluted pumpkin leaves slicer has been reported. Based on the result of performance evaluation, the equipment performed well in successfully slicing the fluted pumpkin leaves. The efficiency of the machine is rated at 73.2%. Time loss is due to human factor delay in feeding the leaves to the conveyor unit. The time required to slice 1kg of the fluted pumpkin leaves using manual method was considerably reduced from 27.95 minutes to approximately 9 minutes with a motorized slicer.

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