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DESIGN, FABRICATION AND PRELIMINARY TESTING OF A LEAFY VEGETABLE CUTTING MACHINE

Oyerinde, A.S.

Department of Agricultural and Environmental Engineering
Federal University of Technology, Akure, Ondo State, Nigeria
Email: asoyerinde@futa.edu.ng

Abstract

Vegetables play an important role in meeting the needs of human beings for vitamins and minerals. Leafy vegetable especially helps to lower susceptibility to infection and contains large amount of squalene, a compound that has both health and industrial benefits. Vegetables are cut into smaller sizes which aids its preservation and packaging. In order to achieve this a leafy vegetable slicing machine was designed and fabricated for both domestic and commercial use in final processing of vegetable in an attempt to make cut and preserved vegetables available to consumers. The machine components consist of frame, the loading hopper, blade cutter, outlet chute and engine seat. The leafy vegetable cutting machine was subjected to preliminary tests using four different speeds (1440 rpm, 930 rpm, 720 rpm and 510 rpm) with one-, two- and three- blade cutter arrangements. The machine was evaluated to determine the effect of speed on the slicing efficiency and machine capacity. The leafy vegetable cutting machine had a capacity of 29 kg/hr with over 80% functional efficiency. At speed 510 rpm using three- blade cutter arrangement, the leafy vegetable cutting machine was at its best as it took 472 seconds to reduce 1kg of vegetables with a slicing efficiency of 88.2%. The machine is easy to operate and maintain as it operates on a 1 Hp electric motor and convertible on a crank arrangement to be used manually.

Keywords: Cutting machine, leafy vegetables, *Amaranthus hybridus,* Machine capacity, Design and fabrication

Introduction

The size of agricultural products may be reduced in several ways. The main methods used are crushing, impact, shearing and cutting. Size reduction devices include crushers, slicers, grinders, and hammer mills (Fellows, 2003, Adekunle et al., 2009). Cutting is a compressive and shearing phenomenon and occurs only when the total stress generated by the cutting implement exceeds the ultimate strength of the material being cut . Cutting has been described as the continuous process in which penetration of a sharp knife through a material result in a new surface due to failure in shear accompanied by deformation in bending and compression Kachru et al., (1996). The method is particularly well adapted to the reduction of sizes of vegetables, fruits, fish, meat, roots and tubers. Cutting operation for large scale processing is used severally today in food processing industries, outdoor catering services, confectionaries, snacks centers and restaurants. The reduction in size of agricultural products is brought about by mechanical means without change in chemical properties of the materials (James et al., 2011). They are used to improve the eating quality or suitability of foods for further processing and to increase the range of available products Kachru et al., (1996). With the development of a variety of cutting tools for size reduction, a lot of drudgery had been removed from processes which hitherto were tedious to accomplish (Adetoro, 2012).

Vegetables play an important role in meeting the needs of human beings for vitamins and minerals. Vegetables are eaten in a variety of ways, as part of main meals and as snacks. *Amaranthus hybridus* is an example of a leafy green vegetable and popular in parts of India, Mexico, the southern USA and Africa because of its edible leaves and soft stem (Sealy *et al*., 1990; Norman and Shongwe, 1993; Allemann *et al*., 1996; Mapes *et al*., 1997). The leaves have high energy value and are rich in protein, calcium, potassium, iron and ascorbic acid, although they may contain appreciable amounts of nitrate, oxalate and phytate (Hill and Rawate, 1982; Aletor and Adeogun, 1995). *Amaranthus hybridus*, popularly called "Amaranth or pigweed", is an annual herbaceous plant which can grow between 30 cm and 180 cm. The leaves are alternate petiole, 7.62 cm to 15.24 cm long, dull green, and rough, hairy, ovate or rhombic with wavy margins. The vegetable is frost tender. The seeds are small and lent cellular in shape. The chemical constituents of *A. hybridus* predicate that it may not only be useful due to its dietetic value but also medicinally and pharmacologically (Shukla *et al*., 2006),.

A manually operated equipment for slicing vegetables (Tomatoes, Okro and Carrot) with claw cutter (scissors) had earlier been designed and fabricated at the National Centre for Agricultural mechanization

(NCAM), Ilorin by Samaila *et al.* (2008). The cutting machines reduces drudgery and time of cutting before the leaves are packaged for sale either in the malls or at the gate of vegetable farms, the slices are smaller enough that it needs no further processing before disposal. . The overall objective of this work is to design, fabricate and evaluate the performance of a leafy vegetable cutting machine using *Amaranthus hybridus* leaves as test material.

Materials and Methods

The vegetable samples used in the testing were bought from Oja-Oba market in Akure, Ondo State, Nigeria. The vegetable slicing machine was evaluated using three blades (one blade cutter, two blade cutters and three blade cutters) and the effect of speed on each of blade cutters was determined, putting into consideration the speed at which efficient cut was achieved.

Design Assumptions and Considerations

The materials used in the construction were made of stainless steel to prevent corrosion which might lead to contamination of vegetables. It was assumed that the machine will only cut leafy vegetables. The stem part and the roots were assumed to have been removed before processing. The machine was designed with the aim of reducing time of operation, wastage and drudgery. It is also to eradicate the crude unhygienic and cumbersome methods of slicing vegetables manually. The slicing was to be done with high efficiency in an attempt to make cut and preserved vegetables available to consumer, so as to facilitate the final processing of vegetables.

Loading Chamber/Hopper Design

The hopper dimensions were designed by calculation obtained from Hall (1985) as shown in equation 1for area while the volume was calculated using equation 2.

$$A = \{L \times H\} + \{L \times B\} + \{1/2 \times B \times H\} \quad (1)$$

$$A = (0.20 \times 0.30) + (0.20 \times 0.14) + (1/2 \times 0.14 \times 0.$$

$$A = 0.148\ m^2$$

The Thickness of the hopper=1.2mm

$$\text{Volume} = \text{Area} \times \text{Thickness}$$

$$= 0.148 \times 0.0012$$

$$= 1.776 \times 10^{-4} m^3$$

(2)

Where A = area; B= is the breadth of the hopper; L = is the length of the hopper and H = height of the hopper

Velocity

The velocity of the blade cutter pulley was obtained from equation 3

$$V = \frac{\pi d_1}{60} \times N_1 \quad (3)$$

Where d = 70 mm is the pulley diameter, N_1 is the speed of the motor (rpm), the speed of motor is 1440 rpm (selected)

Pulley Design

The selection of power of the engine required to operate the rotating shaft of the machine was selected based on the speed of the driving motor, the shaft layout and centre distance between the shafts at the condition under which the cutting action must take place. An electric motor with 1440 rev/min was used with a pulley diameter of 70 mm. A low speed of shaft rotation is needed for the operation of the slicing operation. The diameter of a pulley for the driven

$$\pi d_1 N_1 = \pi d_2 N_2 \quad (4)$$

Where d_1 is the diameter of the motor, N_1 is the speed of the motor (rpm), d_2 is the diameter of the shaft pulley while N_2 is the speed of shaft (rpm)

The speed of shaft 510 rpm, 720 rpm, 930 rpm and 1440 rpm is desired and pulley diameter of 198 mm, 140 mm, 108 mm and 70 mm respectively was selected.

Shaft Design

The diameter of the shaft is given as shown in equation (5) by Khurmi and Gupta, (2004) as

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b \times M_b)^2 + (K_t \times M_t)^2} \quad (5)$$

Where, S_s *is the allowable shear stress*

K_b *is the combined shock and fatigue fa*

K_t *is the combined shock and fatigue fa*

M_b *is the maximum bending moment*

M_t *is the maximum twisting moment*

Machine Description

A designed and fabricated vegetable slicing machine consists of the frame, the loading chamber, blade cutter and outlet chute. The machine comprised of the following components (Figure 1):

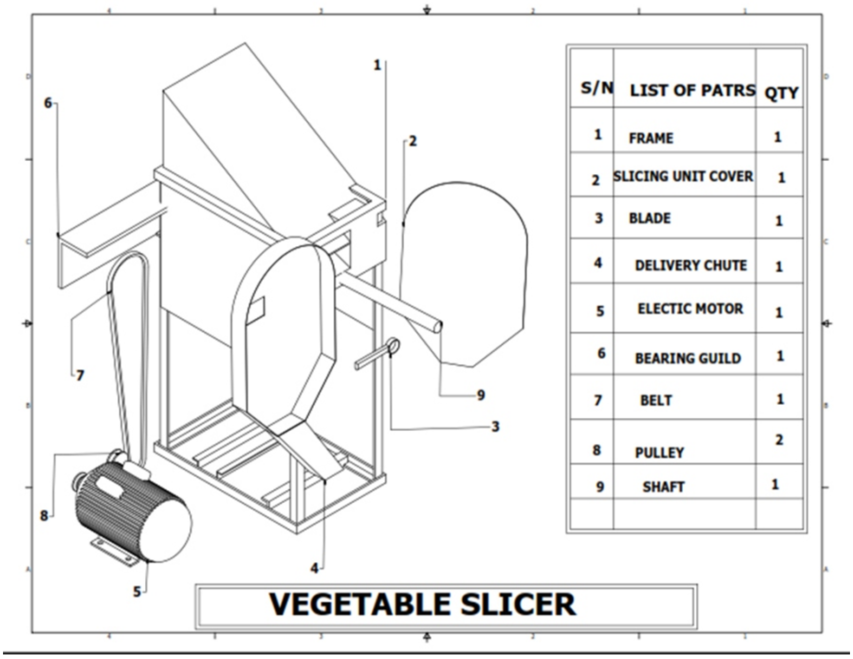

Figure 1: Isometric view of the leafy vegetable cutting machine

a) The Frame

This is the part that supports all the components of the vegetable slicing machine. It consists of stand and motor seat. Angle iron of (35 by 35 by 2) mm was used to make a stand with length, height and breadth of 505 mm, 700 mm and 300mm, respectively and was brazed at different point for rigidity. The engine seat had dimension of length and breadth of 230 mm and 100 mm, respectively.

b) Loading Chamber

This consist the hopper, which is the receptive part for the unsliced vegetable for onward transportation to the blade cutter. The loading chamber is made of galvanized sheet, raised at an angle30 °C to the machine frame, in order to facilitate feeding of the unsliced vegetable. The loading chamber has a dimension of 240 mm by 590 mm by 105 mm.

a) Outlet Chute

This is made of galvanized sheet and encloses the blade (i.e. it serves as a cover for the blade cutter). It has a lock which can be opened, it helps to aid the maintenance of the cutting blade.

b) Blade Cutter

The blades are made up of stainless steel to prevent corrosion, it impacts the cutting force on the vegetable. Each of the blade cutters is shaped as a rectangle with a curved well shaped edge of length 7 mm welded to a holder.

c) Bearing Selection

Single roll ball bearing was selected for the design work because it has a good support for loads.

d) Pulleys and Belts

The pulleys perform the final speed reduction. Motion is transmitted from the electric motor to the pulleys via the belts driven by the pinion through the shaft. For machine speeds of 510 rpm, 720 rpm, 930 rpm and 1440 rpm, the pulley diameters selected were 200 mm, 140 mm, 110 mm and 70 mm, respectively.

a) Power Transmission Unit

This provides necessary power required by the machine for effective operation. It transmits power via the belts and pulley of the machine. The motor used is a 1 hp motor.

Machine Mode of Operation

The machine power unit transmits the power needed by the machine. Vegetables fed into the loading chamber passes through the hopper inclined at an angle and moves to the cutting chamber. At the cutting chamber, the rotating effects of the blade cutters gets in contact with the vegetables and cuts into slices of various sizes. The sliced vegetables were collected at the outlet chute. The sliced vegetables are then ready for further processing.

Performance Testing

After the machine was fabricated, preliminary tests were carried out to ascertain the efficiency and the workability of the machine. This was estimated under various working conditions and variation of speed and cutter blades arrangement. At speed 930 rpm with two cutter blade arrangement the following performance indices for 1.0 kg vegetables were taken: the quantity of vegetables collected from the outlet chute, the quantity of unsliced vegetables as well as the time taken to slice the vegetables. This procedure was repeated for one blade and three blade cutter as well as for the various machine speeds of 510 rpm, 720 rpm and 1440 rpm. The fabricated machine is shown in plate 1

Plate 1: The fabricated leafy vegetable cutting machine

The capacity of the machine, which is the amount of the vegetable sliced by the machine within a specific given time, was calculated using equation 6;

$$Machine\ capacity = \frac{M}{T} \qquad (6)$$

Where M = mass of vegetable sliced in tons and T = time taken in hour. The machine functional efficiency is the measure of the effectiveness with which the machine performs its intended function. The functional efficiency of the machine was calculated using equation 7;

$$Ef = \frac{U}{V}\ x\ 100 \qquad (7)$$

Where *Ef* = functional efficiency, U= total mass of quantity output in kg and V= total mass of quantity input in kg

The machine quality performance efficiency is the measure of the quality of work done by the machine. The performance of the machine is not solely based on its slicing capacity and efficiency (i.e. the quantity of vegetables sliced with time or relative to the input) but also on its ability to slice an appreciable quantity of vegetables in the total quantity output. This is also known as the quality performance or slicing efficiency of the machine. The quality performance efficiency of the machine was calculated using equation 8;

$$Eq = \frac{U-W}{V}\ x\ 100 \qquad (8)$$

Quality performance efficiency, U = Total mass of quantity output in kg, W = Total mass of quantity unsliced in kg and V = Total mass of quantity input in kg

Results and Discussion

The leafy vegetable cutting machine was subjected to preliminary tests The test was carried out to evaluate the capacity and efficiency of the machine with respect to speed and blade cutter arrangements. Tables 1, 2 and 3 shows the test results of the machine for one blade cutter, two blade cutter and three blade cutter arrangements.

Effect of Speed and Blade Cutter on Slicing Efficiency of the Machine

The results of the effect of speed and blade cutter on slicing efficiency of the machine (Tables 1-3) indicate that the quantity of vegetables sliced and the slicing efficiency of the machine increased with increase in machine speed across the varying blade cutters. When the vegetables were loaded into the machine at high speed (1440 rpm), the quantity of unsliced portion reduced, which resulted into a high slicing efficiency. The slicing efficiency increased from 66 % for one blade cutter to 78 % for two blades and 80 % for three blade cutting arrangement at various speeds, thus the higher the number of blades and speed, the better the slicing efficiency of the machine.

The slicing time was also noted to decrease as the

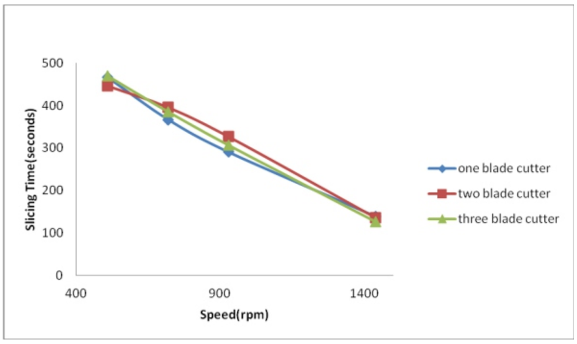

Figure 2: Effect of Speed and Blade Cutter on Slicing Time

Table 1: Evaluation Results for One Blade Cutter Leafy Vegetable Machine Performance

Speeds (rpm)	Quantity Input (kg)	Quantity sliced (kg)	Quantity unsliced (kg)	Time used(s)	Slicing efficiency (%)	Functional efficiency (%)	Quality performance efficiency (%)	Capacity(kg/hr)	Capacity for 10 working hours/day
510	1	0.648	0.352	451	64.8	100	64.8	7.982262	79.82262
720	1	0.617	0.383	376	61.7	100	61.7	9.574468	95.74468
930	1	0.588	0.412	289	58.8	100	58.8	12.45675	124.5675
1440	1	0.659	0.341	143	65.9	100	65.9	25.17483	251.7483

Table 2: Evaluation Results for Two Blade Cutter Leafy Vegetable Machine Performance

Speed (rpm)	Quantity Input (kg)	Quantity sliced (kg)	Quantity unsliced (kg)	Time used(s)	Slicing efficiency (%)	Functional efficiency (%)	Quality performance efficiency (%)	Capacity(kg/hr)	Capacity for 10 working hours/day
510	1	0.754	0.246	440	75.4	100	75.4	8.181818	81.81818
720	1	0.731	0.269	402	73.1	100	73.1	8.955224	89.55224
930	1	0.689	0.311	313	68.9	100	68.9	11.5016	115.016
1440	1	0.723	0.277	133	72.3	100	72.3	27.06767	270.6767

Table 3: Evaluation Results for Three Blade Cutter Leafy Vegetable Machine Performance

Speed (rpm)	Quantity Input (kg)	Quantity sliced (kg)	Quantity unsliced (kg)	Time used(s)	Slicing efficiency (%)	Functional Efficiency (%)	Quality performance efficiency (%)	Capacity (kg/hr)	Capacity for 10 working hours/day
510	1	0.874	0.126	466	87.4	100	87.4	7.725322	77.25322
720	1	0.848	0.152	393	84.8	100	84.8	9.160305	91.60305
930	1	0.826	0.174	302	82.6	100	82.6	11.92053	119.2053
1440	1	0.787	0.213	124	78.7	100	78.7	29.03226	290.3226

Effect of Speed and Blade Cutter on the Machine Capacity

The machine capacity is small when subjected to low speed but increased as speed increases as shown in the Tables 1-3, i.e the more the speed, the more the machine can handle with the different cutter arrangements. The effect of the speed and blade cutter on the slicing capacity of the machine is presented in Figure 4. The slicing capacity of the machine generally increased with increase in speed across the blade cutters (Figure 4). The highest slicing capacity of 29kg/hr was recorded at the three blade cutter and speed 1440 rpm. This was also performed at the least time of 124 seconds.

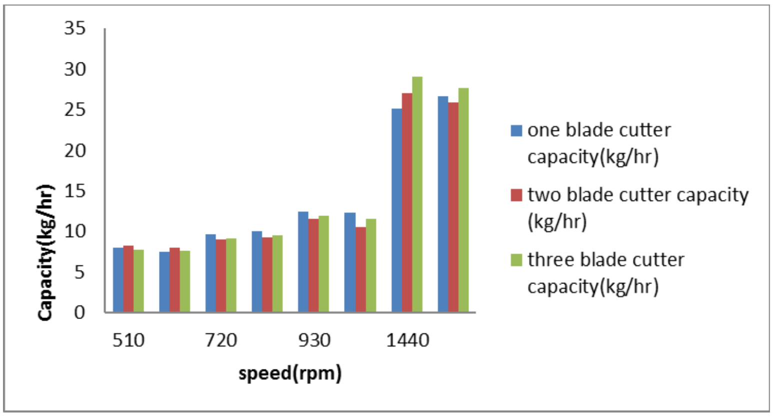

Figure 4: Effect of machine speed and blade cutter on leafy vegetable machine capacity

Conclusion

A leafy vegetable cutting machine was designed, fabricated and preliminary tests were carried out to determine its performance. The machine is suitable for reducing sizes of leafy vegetables which can also be adapted for root and fruit vegetables. The machine has a capacity of cutting 29kg of vegetables per hour with 79% functional efficiency which shows that it did not only eliminate drudgery associated with manual slicing of leafy vegetables but also reduces wastage. At speed 510 rpm using three blade cutter, the leafy vegetable cutting machine is at its best as it takes 472 secs to reduce 1kg of vegetables with a slicing efficiency of 80.2%. The machine can be operated with 1 Hp electric motor.

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