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Construction and Performance Evaluation of a Vegetable Shredding Machine

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ABSTRACT
The need for vegetables because of its economic significance and nutritive value cannot be overstated with the expanding global population. As a way of adding value to vegetables before using them domestically, a portable shredding machine has been developed in order to evade the challenges of time consumption, contamination and wounds associated with the manual method of shredding vegetables by means of sharp knife. Vegetable shredding is a process of cutting vegetables into thin slices or pieces using a sharp knife or grater. The vegetable shredding machine which works on shear principle was fabricated using locally sourced materials and tested. The performance evaluation test shows that the machine driven by a 0.5-hp electric motor has an average performance shredding time of 29.2 seconds with a shredding efficiency of 75.28% and a throughput capacity of 17.25 g/secs. The vegetable shredder consists of simple components that can be effortlessly assembled. Hence, the operation and maintenance of the machine are quite simple and easy.

KEYWORDS: *Vegetable, Shredder, Cutting, Slicing, Shredding Efficiency.*

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I. INTRODUCTION

Vegetables are referred to the edible plants or the edible portions of plants that aid in the prevention of nutritional disorders and micronutrient deficits (Agbonkhese *et al.*, 2020). Vegetables are a great source of fibre, vitamins, and minerals, while its high fibre content lowers blood cholesterol, blood sugar, constipation risk and risk of digestive disorders and cardiovascular diseases (Lewis, 1994). Vegetables, when combined with fruits, improve energy production, strengthen the immune system and support healthy blood sugar regulation (Agbonkhese, *et al.*, 2020; Jane, 2005). However, because fresh vegetables are highly perishable, improper handling, and inadequate storage facilities result in significant post-harvest losses for farmers and marketers of vegetables. According to FAO (1995), spoilage, physiological deterioration, water loss, and mechanical damage account for more than 23% of the losses that occur to most perishable fruits and vegetables during their passage through the agricultural food chain (harvesting, transportation, processing, and packaging) (Agbonkhese, *et al.*, 2020). Vegetable processing is necessary to ensure proper preservation and maximise economic benefits from vegetables, therefore minimising losses, ensure quality preservation, safety, and extended shelf life. The manual method of cutting of vegetables is labour-intensive and produces low results and wastes time. This is actually carried out with use of knife to shred (slice, chop, or dice) vegetables, while subjecting people at risk for knife cuts.

By a way of improving the conventional method of shredding, different studies on shredding process and machine have been carried out. Some of which includes: design and fabrication of leafy vegetable shredding machine by Agbonkhese, *et al.* (2020); design, construction and performance evaluation of a motorized tomato slicing machine by Kabir *et al.* (2021); development of a motorized parboiled cassava tuber shredding machine by Ndukwua and Onyenwigwe (2013); design and development of an automated vegetable cutting machine by Tony *et al.* (2014); development of a functional multi-crop slicing machine by Leo and Balogun (2009); etc., while food processor by Lin (1992); vegetable shredder by Karl (1954); and processing apparatus for leafy vegetables by Hofmeister (1995) have been developed over the years, and a pedal operated chipping and slicing machine for tubers was also invented by Raji and Igbeka (1994). However, with the many vegetable shredding devices already in the market, it is still necessary to construct a portable and affordable vegetable cutting device in order to efficiently shred *Amaranthus Cruentus* and other beneficial vegetable leaves.

Considering the disadvantages of the manual shredding process (unhygienic, time-consuming, labour-intensive and dangerous due to the possibility of being hurt during the process), processing of vegetables quickly, effectively, and hygienically necessitates the use of an improved vegetable shredding or slicing machine. The freshness of the food is highly guaranteed as so many households can afford it, because most people chop their vegetables at the market and before returning home, the freshness may be compromised. The construction and performance evaluation of a vegetable shredding machine that can efficiently and quickly handle a small to medium-sized amount of vegetables in a hygienic manner are the main objectives of this research, which would be time saving and enhance productivity.

II. MATERIALS AND METHODS

2.1 Material Selection

The materials used for the construction of the vegetable shredding machine were obtained locally from various markets in Ibadan. The materials were selected for the fabrication based on the consideration of cost adaption for commercial and subsistence use, durability, case of utilization of the machine and their effects on the food ingredients. Selection of the materials is one of the most important part of effective engineering design as it determines the reliability of the design in terms of economic aspects. Great designs may fail to be profitable if unable to find the most needed and appropriate materials combination. It is then so vital to know the best materials for a particular design for the machine to be fabricated. The factors considered in selecting the materials include strength, durability, malleability, weldability, and corrosiveness.

2.2 Description of the Machine Components

The vegetable shredding machine was fabricated to serve farmers, households, small and medium-scale industries. It is designed to be powered by electric motor. The machine consists of the following essential parts, which are described below.

2.2.1 Frame

The frame of the machine serves as the base upon which all other components parts are supported. Therefore, the frame is constructed in such a way as to withstand excessive vibrations and other forces.

2.2.2 Hopper

The hopper (Plate 1) is the topmost part of the shredder, which is pyramidal in shape. This part of the machine holds the vegetable, while it is being fed gradually into the shredder. It is constructed using a stainless steel.

Plate 1: Hopper

2.2.3 Shredding Blades

The shredding blades (Plate 2) are internal component part of the shredder which performs the chopping, cutting, shredding of the vegetables into smaller sizes. These blades are closely arranged to the lowest degree of tolerance so that any size of vegetable leaves can be shredded. The cutting blades are made of hardened stainless-steel material with thickness of 2.0 mm. Shredding occurs when the machine is powered and the blades are rotated by the rotational movement of the electric motor.

Plate 2: Shredding Blades and Shredding Screen

2.2.4 Shredding Screen
The shredding screen (Plate 2) is an internal component of the machine. It is a set of stationary blades arranged perpendicularly to the action effect of the shredding blade, which is made of stainless plate arranged helically on the rotating shaft.

2.2.5 Spout
The spout is the chamber that receives the shredded vegetables from the shredding screen and discharges it to the machine outlet. It is located directly under the stationary blades to receive the shredded vegetables.

2.2.6 Discharge Chute
The discharge chute (Plate 3) is the component of the shredder that serves as the exit or outlet for the shredded materials (vegetables). The discharge chute is made of good grade stainless steel. Its primary function is to deliver already shredded vegetable leaves to a location where it can be collected easily.

Plate 3: Discharge Chute

2.2.7 Electric Motor
The electric motor (Plate 4) is the prime mover of the vegetable shredding machine. Since the blades are rotating in opposite direction, vegetable leaves packed full into the hopper is dragged into the cutting chamber and shredding is done as a result of relative pulley on the two rotor blades. The machine is driven by a 0.5-hp electric motor.

Plate 4: Electric Motor

2.2.8 Engine Seat
The engine seat of the vegetable shredding machine is the part to which the electric motor is been tightened for effective and convenient operation. This seat is situated at the lower side of the machine.

2.3 Description of the Machine
The vegetable shredding machine consists essentially of shredding blades which is enclosed in the shredding unit. The vegetable (*Amaranthus Cruentus*) leaves are fed through the hopper (the feeding unit) into the machine for processing and the feeding is aided by gravity. The bottom end of the hopper connects to the shredding unit which encloses the shredding blades. As the machine is powered by an electric motor, the driver pulley on the electric motor transmit motion to the pulley on the rotor blades (driven pulley), this enables the shredding blades to drag the vegetable leaves as a result of its opposite direction of rotation and with the assistance of the relative pulley motion on the shredding blades, while the shredding (cutting or slicing) of the vegetables is made possible. The machine is driven by a 0.5-hp electric motor at a speed of 2880 rpm. The speed of the motor is reduced by the pulley system when the machine is in operation. The machine is portable. However, the performance is encouraging, and able to add value to the end users. The orthographic drawing showing the

component parts of the vegetable shredding machine is shown in Figure 1, while the constructed vegetable shredding machine is shown in Plate 5.

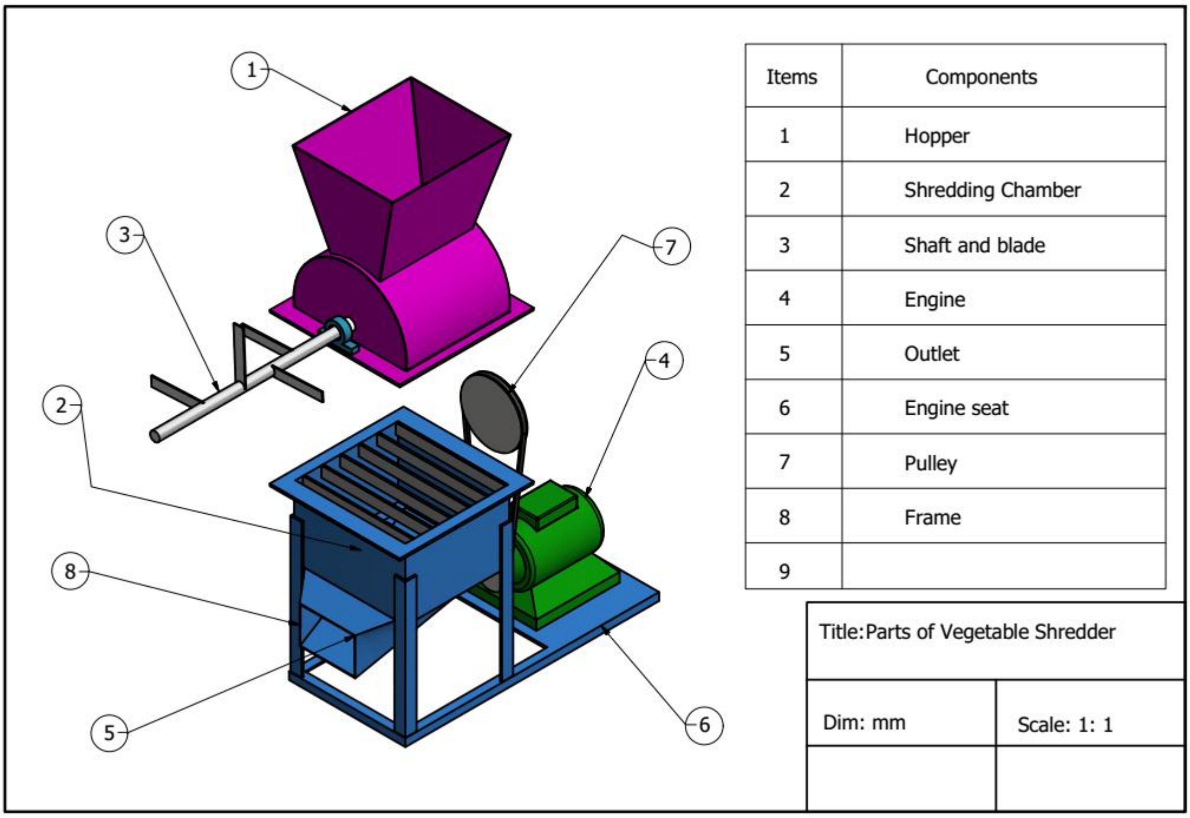

Figure 1: Orthographic Drawing of Vegetable Shredding Machine

Plate 5: Fabricated Vegetable Shredding Machine

2.4 Performance Evaluation of the Machine

The performance test was carried out after machine parts have been fabricated and assembled in the Department of Agricultural and Bio-Environmental Engineering, Federal College of Agriculture, Ibadan, Nigeria. The machine was started and five samples of equal mass of *Amaranthus Cruentus* vegetable leaves were fed through the hopper, each time. A stopwatch was used to monitor the time taken for the vegetables to be shredded per batch. A 0.5-hp electric motor with a speed of 2880 rpm was used as prime mover. Five tests were carried out. A total mass of 500 g of *Amaranths Cruentus* vegetables were fed through the hopper when the machine was in operation and the time for proper shredding was recorded. Therefore, the performance of the machine was evaluated using the following parameters:

2.4.1 Shredding Efficiency

The shredding efficiency measures how effective the vegetables were shredded by the shredding machine. It is calculated using the equation given by Kabir *et al.* (2021).

$$S_e = \frac{W_s}{W_t} \times 100 \quad (1)$$

Where:
$S_e = Shredding\ Efficiency, \%$
$W_s = Weight\ of\ shredded\ vegetables, g$
$W_t = Total\ weight\ of\ vegetables, g$

2.4.2 Shredding Capacity

The capacity of the vegetable shredder measures of the quantity the shredder can handle per unit load of operation. It is calculated using the equation given by Kabir *et al.* (2021).

$$S_c = \frac{W_t}{S_t} \quad (2)$$

Where:
$S_c = Shredding\ capacity, g/secs$
$W_t = Total\ weight\ of\ vegetables, g$
$T_t = Time\ taken\ to\ complete\ the\ shredding\ operation, secs$

2.4.5 Percentage Damage

The percentage damage of the shredding machine is a measure of a level damage done by the shredding machine. It is expressed using equation given by Kabir *et al.* (2021).

$$P_d = \frac{W_d}{W_t} \times 100 \quad (3)$$

Where:
$P_d = Percentage\ Damage, \%$
$W_d = Weight\ of\ damaged\ vegetables, g$
$W_t = Total\ weight\ of\ vegetables, g$

III. RESULTS AND DISCUSSION

3.1 Performance Evaluation Results of the Vegetable Shredder

The results of the performance evaluation test of the vegetable shredding machine are shown in Table 1, while the vegetables (*Amaranthus Cruentus*) before and after shredding are shown in Plate 6 and 7 respectively.

Table 1: Results of Performance Evaluation Tests on the Vegetable Shredder

Sample	Mass of Vegetables fed into the Machine (g)	Mass of Vegetables Properly Shredded (g)	Mass of Vegetables Not Properly Shredded (g)	Time Taken for Shredding of Vegetables (secs)	Shredding Efficiency (%)	Shredding Capacity (g/secs)	Percentage Damage (%)
1	500	350	150	33	70	15.15	30
2	500	367	133	29	73.4	17.24	26.6
3	500	375	125	31	75	16.13	25
4	500	390	110	26	78	19.23	22
5	500	400	100	27	80	18.52	20
Total	**2500**	**1882**	**618**	**146**	**376.4**	**86.27**	**123.6**
Average	**500**	**376.4**	**123.6**	**29.2**	**75.28**	**17.25**	**24.72**

Plate 6: Unshredded *Amaranthus Cruentus*

Plate 7: Shredded *Amaranthus Cruentus*

3.1.1 Shredding Efficiency

The performance evaluation results indicated that the vegetables (*Amaranthus Cruenthus*) were shredded seamlessly at an average efficiency of 75.28%. However, the shredding efficiency ranges from 70.00 to 80.00% against the equal mass of 500 g at a constant speed of 2880 rpm. It was observed that the threshing efficiency increases with the equal mass of the vegetables. Similar trends were reported by Agbonkhese, *et al.* (2020).

3.1.2 Shredding Capacity

It could be observed from the performance evaluation results that at equal mass of 500, shredding capacity of the machine ranges from 15.15 to 18.52 g/secs, with an average value of 17.25 g/secs. It was observed that the shredding capacity increases with same quantity of mass of vegetables.

3.1.3 Percentage Damage

The percentage damage of the machine with equal mass of vegetables ranges 30 to 20% at an average percentage loss of 24.72%. It was observed that the percentage damage reduces with same quantity of mass.

Generally, the relationship between mass of the vegetables, the shredding efficiency, shredding capacity and percentage damage is shown in Figure 1. It was observed that the shredding efficiency increased, threshing capacity increased, while percentage damage reduced, as the mass of vegetables remain same.

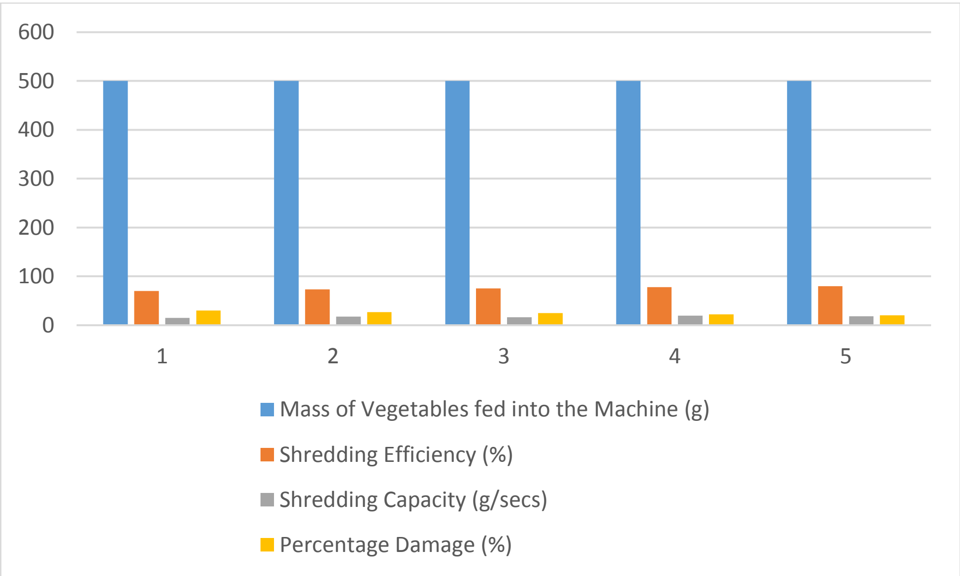

Figure 1: Relationship between Mass of Samples, Shredding Efficiency, Shredding Capacity and Percentage Damage

IV. CONCLUSION

A vegetable shredding machine was fabricated and performance evaluation successfully carried out. The test results revealed that the machine has a shredding efficiency of 75.28% and a shredding capacity of 17.25 g/secs. The machine has the capability of shredding various kinds of vegetables at the shortest possible time. The shredder is made up of simple components that can be easily assembled and was made from locally available materials in order to minimize the cost of production. The machine is affordable for farmers and households to acquire, while it can be maintained and operated with little or no training by local professionals. Thus, it is expected that the machine can meet the need of domestic and commercial operators when commercialized.

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