DEVELOPMENT AND PERFORMANCE EVALUATION OF GREEN - VEGETABLES SLICING MACHINE

[1]Alabi O. O., [2*]Adeaga O. A., [3]Ogunsiji G. O., and [4]Dada S. A.

[1]Department of Mechanical Engineering, University of Ibadan
[2*]Department of Mechanical and Mechatronics Engineering,
First Technical University Ibadan, Nigeria
[3]Department of Mechanical Engineering, Teesside University Middleborough, UK
[4]Department of Mechanical Engineering, Kwara State Polytechnic Ilorin, Nigeria
[1]engrseyialabi@gmail.com, [2]oyeadeaga@tech-u.edu.ng, [3]B1665910@live.tees.ac.uk
[4]mrsamueldada@gmail.com,
Corresponding author's email (2*): oyeadeaga@tech-u.edu.ng

ABSTRACT

Requirements of food processing units are sensitive and must be in conformity with hygiene and time requirement. Continuous work on the development of machines that are involved in the processing of edibles should be carried out. Traditionally, green-vegetables are plucked raw which often require time and also compromise hygiene. However, the several works done on green-vegetable slicing equipment have added improvement to ways by processing and or consumption. This article attempted the development of green-vegetable slicing machine and also evaluated the performance of same. Existing vegetable slicing machines were studied through literature and process design for development was carried out. Cutting capacity of 1.5 kg and 25 g of uniform slicing were used to evaluate the performance of the developed green-vegetable slicing machine. The shortcomings in the existing slicing machines reduced while reducing loss of sliced and also with uniform slices. Existing vegetable machines has experienced loss and associated time. The developed machine has a significantly improved efficiency to 96%.

Keywords: *Food, Slicing Machine, Manual Operation, Green Vegetables*

INTRODUCTION

Green vegetables are foods taken by humans and animals. Essentially, green vegetables has formed part of human dietary. Green vegetables also serves as medicine when eaten raw, boiled or cooked. Diet rich in green-vegetables has been noticed to lower blood pressure, reduce the risk of heart disease and stroke, prevent some types of cancer, lower risk of sight and digestive troubles, and also encourage low blood sugar, which in turn regulates appetite.

Foods (vegetables) processing businesses are working continuously to create novel technologies that boost and ease production, increase efficiency, and ensure high-quality end products in order to fulfill rising demand (Kazeem et-al.,2022).

Common methods of preparing vegetables for consumption are slicing, munching, boiling and cooking. Among the many parts of preparation, slicing vegetables is crucial as big impact on the final product's overall quality and appeal (Aaron et-al., 2023). Green-vegetables are manually sliced before been boiled or cooked, which requires specialized labour to achieve uniform thickness and presentable regular shape. Manual slicing, however, results in inconsistent slice thickness and dimensions because it is labour intensive, time consuming and subject to human error (*D'Amato et-al.,* 2019). There is high tendency for quantity reduction during processing. The creation of automated vegetable-slicing equipment has attracted lots of interest as solution to these problems and to satisfy the changing needs of the food sector. Further developments in the design and technology of home vegetable-slicing machines will be necessary to ease the aforementioned shortcomings. The capacity of the machines to process delicate and oddly shaped veggies can be improved with better blade design and systems, customizable slicing options, and optimum motor operation. By addressing these issues, green-vegetable slicing equipment that is incredibly adjustable, versatile that can accommodate varieties of domestic and operational needs.

Available literature reported several designs but not towards domestication (Ezeanya,2020).

Ezeanya, 2020 reported significance of chopping vegetable leaves for salads, stir-fries, and garnishes with a view to reducing slicing time and reducing inaccuracy by manual slicing. And also to accommodate delicacies in processing green vegetables, which can result in uneven slices and eventual wastages. The authors stressed the need for device that can speed up leaf slicing. Concept and construction domestic slicers of green-vegetables were thoroughly described. Machine parts include, handle for manual operation, frame, slicing blade, and adjustable guides. The machine can handle variety of leafy crops and offers versatility in slicing various leaf types and sizes.

Several vegetables, including lettuce, spinach, and cabbage were used for evaluation of the performance. Parameters such as slice quality, cutting speed, and slice thickness were noted. Ikpoza *et-al.,* 2021, illustrated manual vegetable leaf-slicing machine's design and construction. They reported that the device offers efficient and precise answer to the problems associated with manual leaf slicing. The researchers go into great depth about the manual vegetable leaf-slicing machine's concept and construction procedure. Shun & Jin, 2017 revealed the rising demand in the food industry for processed okra. The manual slicing procedure is labor- and time-intensive, frequently leading to uneven slice thickness and waste. They offer comprehensive details about the parts of the machine, cutting blades, conveyor system, and control panel, features to ensure safe operation were also incorporated into the design, including emergency stop buttons and safety guards. The study focuses on the design, development, and assessment of a machine specifically made for slicing green vegetables in domestic settings with improved efficiency and ease of vegetable preparation in home kitchens (Kahandage *et-al.,*2017). Jibril *et al.,* 2022, created a cucumber-slicing device with a 468 kg/h output capacity, a 28.40% loss in percentage, and a 60.34% slicing efficiency. (Adewale *et-al.,* 2023) presented an automated vegetable slicer to make vast volumes of chips from veggies. The mechanical slicer's goal is to make chopping enormous amounts of veggies into chips less time-consuming and labor-intensive. Medium-sized vegetable can be cut into chips that are 2-3 mm in size using a kitchen knife in 40–80 seconds, as opposed to 5-7 seconds with a machine. This development will help improve product quality, streamline vegetable processing operations, and eventually fulfill the growing demands of the global food market regarding green-vegetables.

MATERIAL AND METHODS

One of the major materials is stainless-steel for the slicing chamber (shaft and blades revolves here to cut the veggies). The hopper is a feeder wherein veggies to be chopped into slices is fed into the slicing chamber. For safety purposes, there is a 120-mm gap between the top of the hopper and the area where the blade actually slices. Some of the considerations listed below had impact on the selection of the materials.

1. Accessibility of the material

2. Suitability of material for the operational circumstances

3. Cost of the material

Design and Fabrication Requirements

The welding procedure on stainless steel is extremely straightforward when using a TIG (Tungsten Inert Gas) welding machine. Mild steel is used for some machine parts and components that are not in direct contact with food. The engine stand and frame surface have been covered in oil paint. Table 1 presents list of required materials for the development. The hopper is made of stainless steel with 2 mm thickness. However, veneer caliper was used for measurements. The slicing blades were also made of stainless steel. The frame was constructed using 40 x 40 mm angle iron. The frame cover was made using mild steel sheet with a 2 mm thickness. The shaft was constructed using 459 mm-long by 30 mm-diameter stainless steel rod. Cast iron was used to make the pulleys. The fabrication of the other portions, where water is commonly utilized, was done with stainless steel (SS 304).

Design Consideration and Calculations

Analysis of Transmitted Torque

The cutting blades receives torque from the transmitted power of electric motor and it is determined as; $T = \frac{60P}{2\pi}$ (1)

Where:

T is the torque (Nm)

P is Power of the electric motor (Watt) = 735 W

N is Rotational speed off the motor (rpm) = 30 rpm

and π is constant = 3.142

$T = \frac{60 \times 735}{2 \times 3.142 \times 30}$ $T = 233.9Nm$

Twisting moment of the cutter shaft

$$\frac{T}{J} = \frac{\tau}{r} \quad (2)$$

$$J = \frac{\pi d^4}{32} \quad (3)$$

Where:

T is the Torque

J is Poplar moment of inertia of the shaft

τ is the shear stress =17.5MPa

r is the radius of the shaft = 25mm or 0.025m

From equation (3)

$$J = \frac{\pi d^4}{32} = \frac{3.142 \times 0.05^4}{32}$$

J = 6.136 x 10^{-7} m^4

From equation (2)

$$T = \frac{\tau \times J}{r} \quad (4)$$

$$T = \frac{17500000 \times 6.136 \times 10^{-7}}{0.025}$$

T = 429.52Nm

From equation (1)

$$P = \frac{2\pi NT}{60} \quad (5)$$

$$P = \frac{2 \times 3.142 \times 30 \times 429.52}{60}$$

$P = 1349.55$W

Angle of twist of the rotating shaft

$$\boldsymbol{\theta} = \frac{\boldsymbol{TL}}{\boldsymbol{GJ}} \quad (6)$$

Where G = Modulus of rigidity of stainless steel and is given as:

GPa= 86×10^9 N/m

Where L = 459mm = 0.459m T = 429.52Nm

J = $6.136 \times 10^{-7} m^4$

From equation (6)

$$\theta = \frac{429.52 \times 0.459}{86 \times 10^9 \times 6.136 \times 10^{-7} m^4}$$

$\theta = 0.0037°$

The velocity of the motor can be calculated using equation (7)

$$v = \omega r; \qquad \omega = \frac{2\pi N}{60} \quad (7)$$

where r is the radius of the blade = 1.4 m

v is the angular speed of the motor

N is the constant speed of the motor = 30 rpm.

RESULTS AND DISCUSSION

The vegetable slashing device, in the way it was created and constructed, performs effectively and efficiently, as seen in Fig. 4. The veggies were separated into five separate batches and fed into the slicing machine in order to assess the efficiency of the equipment.

Table 1. Materials for machine components

SN.	Materials	Purpose
1	2mm stainless steel plate	To build the upper and the cutter
2	Mild steel pipe	To build Machine frame & motor stand.
3	2mm Stainless steel plate	To build slicing chamber.
4	2mm Stainless steel	To build cutter and shaft.
5	1hp Electric motor	To make the cutter and shaft revolve

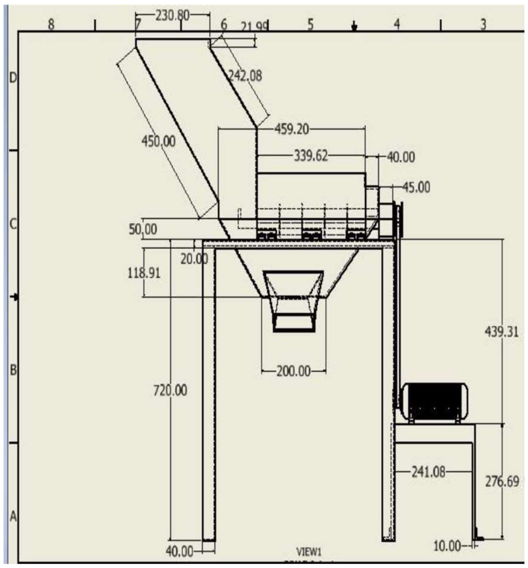

Fig 1: Isometric View

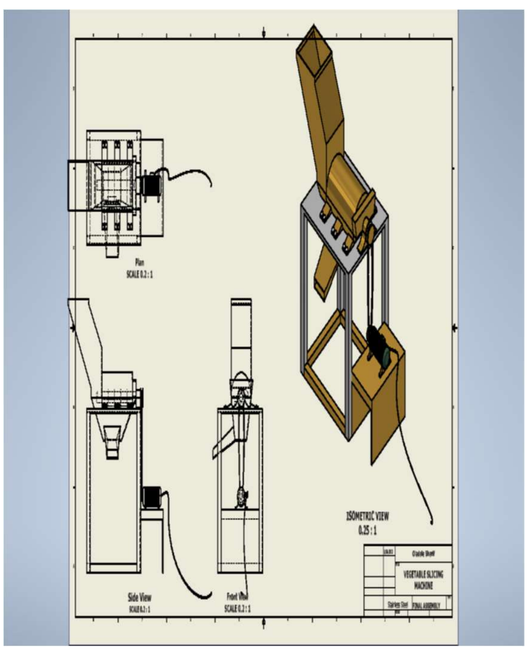

Fig 2: Orthograhic drawing

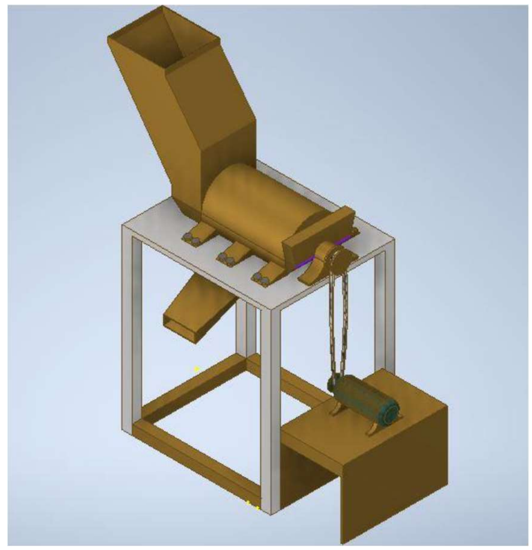

Fig 3: 3D Drawing

Five speeds—very low, low, medium, high, and very high—were used for every task. Regarding the amount of time required for the slicing operation, the impact of the fluctuating speed was taken into account. A pneumatic weight scale was used to calculate the mass of the vegetables that had been fully and partially sliced. The cutting test with four revolving cutters positioned at 90° is shown in Tables 2 and 3. The outcome will strongly depend on the operator's expertise. The various rate levels are denoted by the numbers 5, 4, 3, 2, and 1, with 5 denoting a very fast rate and 1 denoting a very low speed. For each speed level, the time elapsed, slice weight, and weight reduction were recorded. Several vegetable masses were cut at each rotor speed, and the corresponding slice time was recorded. This doesn't include the time needed for picking and preparing the vegetables. With an equal rise in speed, cutting action can be performed in a considerable fraction of the time. As a result of an increase in the cutting region, cutting at the highest rate produces thinner, finer cuts than cutting at a lower rate, according to Tables 2 and 3. Fig. 5 demonstrates that the leaf's morphology improved as its speed increased at the expense of its weight. This discrepancy between the relative speeds at which the greens flow into the hopper and the speed at which the cutting blade impacts the vegetables during slicing may be the cause of the decrease in weight of the vegetable segments that occurs as cutting speed increases. When compared to the previous one, the efficiency significantly improved and was 96%.

Principle of Operation

You can use this vegetable cutter by adhering to these procedures:

i. Using nuts and bolts, the machine is firmly secured to a level platform.
ii. hand-introducing the bundle of harvested vegetables into the reception chamber.
iii. The veggies are forced into the cutting compartment through the cylindrical channel with the help of the turbine.
iv. As the veggies escape the cylindrical chamber and enter the cutting space, the revolving stainless steel cutter blades come into contact with the vegetables and cut them.
v. To cut the vegetable, electric motors produce a rotating motion that is transferred to the shaft holding the blade.
vi. The cutter is supported by and stabilized by the revolving shaft.
vii. To generate vegetable slices with an aggregate weight of 1.5 kg at once, the feed rate of the motor's speed is adjusted to produce the desired cut size.

Fig 4: Vegetable slicing Machine

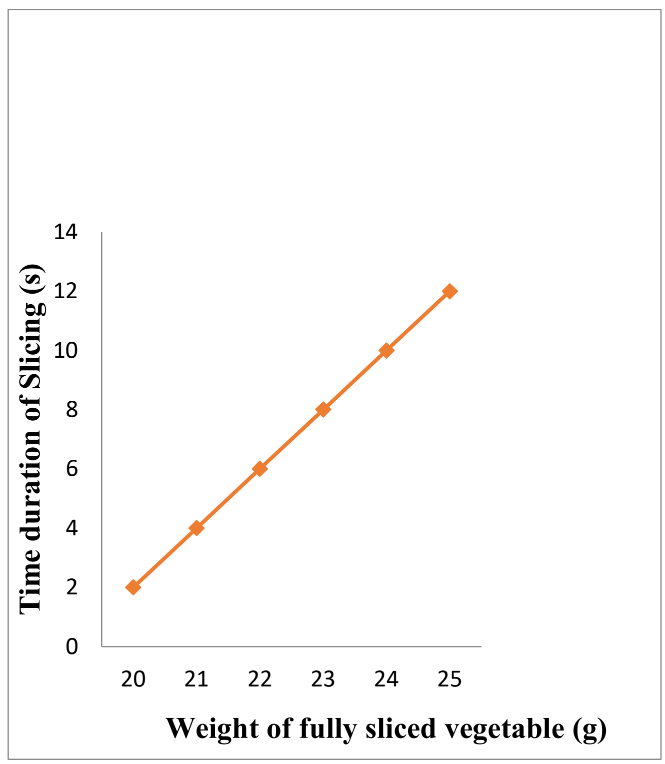

Fig. 5: Time duration of slicing (sec) against weight of fully sliced vegetable (g)

Table 2: Effect of slicing speed on time duration and weight

Regular position	Speed of the motor (rpm)	Weight of vegetable (g)	Time duration of slicing (s)	Weight of fully sliced vegetable (g)	Weight of partial sliced vegetable (g)
Very low	800	25	7.37	23.30	1.70
Low	950	25	7.14	22.42	2.58
Medium	1150	25	6.90	21.04	3.90
High	1350	25	6.70	21.02	3.94
Very high	1500	25	6.24	21.00	4.0

Table 3: Effect of slicing speed on time duration and weight

Regular position	Speed of the motor(rpm)	Weight of vegetable in (g)	Time duration of slicing (s)	Weight of fully sliced vegetable (g)	Weight of partial sliced vegetable (g)
Very low	800	50	13.7	48.20	1.80
Low	950	50	13.3	47.70	2.19
Medium	1150	50	12.8	46.40	3.66
High	1350	50	12.4	45.21	4.79
Very high	1500	50	11.5	45.50	4.90

CONCLUSION AND RECOMMENATION

The development of the machine has shown to be worthwhile since the processing efficiency has been tremendously improved and the period of processing has also been greatly reduced. The quantity to be sliced per period has been shown to be increased too. It is therefore recommended the machine be developed further to with a view to automating the device in line within the domain of artificial intelligence

REFERENCES

Aaron, J. Z., Adamu, M. B., and Jones, N. . (2023). *Development of indigenous vegetable leaf (amarantus hybridus) slicing machine aaron*. *27*(9), 155–162.

Adewale, M., Raji, A., and Sedara, A. (2023). *Development of a Motorized Leafy Vegetable Slicing Machine for Vegetables Development of a Motorized Leafy Vegetable Slicing Machine for Vegetables*. *March*.

D'Amato, R., Wang, C., Calvo, R., Valášek, P., and Ruggiero, A. (2019). Characterization of vegetable oil as cutting fluid. *Procedia Manufacturing*, *41*, 145–152. https://doi.org/10.1016/j.promfg.2019.07.040

Ezeanya, N. C. (2020). Development and Performance Evaluation of a Slicing Machine for Selected vegetables. *Journal of Physical Sciences*, *6*(1), 1–9.

Ikpoza, E., Usiobaifo, E. J., and Erhunmwun, I. D. (2021). Design and Fabrication of a Manually Operated Vegetable Leaf Slicing Machine. *Journal of Applied Sciences and Environmental Management*, *25*(2), 195–198. https://doi.org/10.4314/jasem.v25i2.9

Jibril, A. N., Mashi, A. A., and Muazu, S. (2022). *Design , construction and performance evaluation of a cucumber slicing machine*. *07*, 70–74.

Kahandage, P.., Wathsala, R. H. G., and Dharmasena, D.A.N et al. (2017). Designing, Development and Performance Evaluation of a Manualy Operated Leafy Vegetable Slicing Machine for Domestic Use. *Pharmacoeconomics: Theory and Practice*, *5*(1), 84–84.

Kazeem, R. A., Fadare, D. A., Ikumapayi, O. M., Azeez, T. M., and Adediran, A. A. (2022). Development of bio-cutting fluid (Cirtullus lanatus) and its performance assessment on the machining of AISI 1525 steel using taguchi technique and grey relational analysis. *Biointerface Research in Applied Chemistry*, *12*(4), 5324–5346. https://doi.org/10.33263/BRIAC124.53245346

Msuya, J. (2023). Designing and Manufacturing of Vegetable Slicing Machine. *Tanzania Journal of Engineering and Technology*, *42*(1), 182–199. https://doi.org/10.52339/tjet.v42i1.898

Shun, X., and Jin, T. (2017). *Development and performance evaluation of a motorized okra slicing machine*. 250–256.