ISSN: 2716-9227 Algerian Journal of Engineering and Technology 07 (2022) 070–074 e-ISSN: 2716-9278

Algerian Journal of Engineering and Technology

Journal homepage: https://jetjournal.org/index.php/ajet

Original Article

Design, construction and performance evaluation of a cucumber slicing machine

Abdulaziz Nuhu Jibril*, Abubakar Aliyu Mashi, Suleiman Muazu Shu'aibu

Department of Agricultural and Environmental Engineering, Bayero University, Kano, Nigeria

ARTICLE INFO

Article history:
Received 12 January 2022
Revised 26 July 2022
Accepted 02 October 2022

Keywords:
Cucumber;
Design;
Construction;
Performance;
Slicing Machine.

ABSTRACT

The cucumber slicing machine was designed, constructed and it is performance was evaluated. The major components of the slicing machine are the power unit, slicing compartment, knife compartment, collecting vessel were all fabricated and mounted on the machine. The performance parameters of the machine such as slicing efficiency, percentage loss, and output capacity were evaluated. T-test was used to compare the mean values of these parameters for manual and mechanical slicing. The average efficiency of the manual and mechanical slicing was found to be 71.84 % and 90.0 % respectively. The average percentage loss of the manual and mechanical slicing was found to be 5.5 % and 14.08 % respectively. The average output capacity of the manual and mechanical slicing was found to be 30 kg/hr and 165.60 kg/hr respectively. The efficiency of manual slicing is significantly higher than mechanical slicing. However, the mean value for mechanical percentage losses and output capacity is significant than manual slicing.

1. Introduction

Cucumber *(Cucumissativus*) is a gourd family plant that is commonly cultivated. It is native to South Asia, although it currently flourishes on every continent. Many different types of cucumber are traded on the global market. It has agriculture value to the development of various economies, especially countries in Africa, like Nigeria, it has continued to give way to the accelerated growth of several agribusiness sectors [1]. Cucumber is cultivated because its extract has soothing, cleansing, and softening properties which are important for the cosmetics industry. It is a very good source of phytonutrients such as flavonoid, beta carotene, triterpene, lycopene, lignin vitamins A, C, K, B6, potassium, and provides dietary fibers, pantothenic acid, magnesium, phosphorus, copper, and manganese [2]. Slicing machines are used to slice a variety of foods into thin and consistent slices. Automatic slicers are safer, faster, cleaner, more exact, and better at slicing. They require less time from the operator and do not require special strength to use due to their automatic operation [3]. Looking into the problems in cucumber processing due to its irregular shapes and sizes, a better method of utilizing the limited time available and equally reducing the energy required is necessary, cucumber slicing machines are needed to improve the processing aspect as well as the hygienic condition. The objective of the study was to design, construct and evaluate the performance of the cucumber slicing machine.

2. Materials and Methods

The cucumber slicing machine was fabricated using locally available materials such as knife compartment, ball bearings, frame, stainless knife, slicing compartment, crankshaft, collection tray, power unit (DC motor).

2.1. Design Considerations

Several factors were considered in the design of the slicing machine include the slicing knife, physical properties, and weight of the materials. This will help in the design of the

* *Corresponding author.*
E-mail address: abdul3787@yahoo.com
Peer review under responsibility of University of El Oued.

cutting blades which will be able to penetrate the cucumber and the material which must neither contaminate the cucumber nor be corroded when in contact with water.

2.2 Working Principle of the Cucumber Slicer

The cucumber slicer was designed based on the principle of shearing where the rotational motion of the DC motor is converted to translational motion of the knife compartment with the help of a crank slider mechanism which will move the set of knives to cut the cucumbers arranged on the slicing unit. The mainframe is the unit of the machine on which all other components of the machine were supported. The slicer stands measuring 70 cm each was constructed using angle iron of thickness 1.5 mm and were welded directly to the mainframe. The knife compartment measuring 37 cm by 14 cm by 1.5 cm has a set of stainless-steel knives arranged 1 cm apart and were constructed and welded to the knife housing. Ball-bearing was used for easy movement of the knife compartment, and at one side of the compartment, the slider-crank mechanism was attached because of the rotational motion of the DC motor, hence, converting the rotational motion of the DC motor into translational motion of the knife compartment. Thus, cucumber slicing is achieved on the forward stroke of the knife compartment. A collection tray is provided for the collection of the sliced cucumber.

2.3 Design Requirements

2.3.1 Knife Thickness Design

Selection of the right thickness of slicing knife is very essential as it directly affects the slicing effectiveness. The thickness of slicing knife was calculated using the expression given by [4].

$$t = \frac{W_k}{L_k \, x \, B_K \, x \, g \, x \, (\rho_k - \rho_t)} \quad (1)$$

Where;

t = knife thickness (m), W_k = knife weight = 1.55N measured, L_k = Knife length = 10.22 (m), B_k = Knife width = 0.015 (m), g = acceleration due to gravity = 9.81(m/s^2), ρ_k= knife density = 1682 Kg/m^3, ρ_t= cucumber density = 500 kg/m^3 (measured)

$$t = \frac{1.55}{10.22 \, x \, 0.015 \, x \, 9.81 \, x \, (1682 - 500)} = 0.6mm$$

2.3.2 Weight of the Slicing Compartment

The weight of the slicing compartment was calculated using the equation given by [4].

$$W_s = M \, x \, g = V \, x \, \rho \, x \, g = \; l \, x \, b \, x \, t \, x \, \rho \, x \, g \quad (2)$$

Where;

W = Weight of the cucumber compartment, (kg) M = Mass of the cucumber compartment, (kg) g = Acceleration due to gravity, (m^2/s), v = Volume of the compartment, (m^3), ρ = Density of the galvanized steel, (kg/m^3), b = Breadth of the knife compartment, (m), L = Length of the knife compartment, (m), t = Thickness of the knife compartment, (m)

$l = 72 \; cm, b = 30.5 \; cm, \; t = 2 \; cm$ and g = 9.81 m/sec^2, ρ = Density of Stainless Steel = 7850 kg/m^3

But, $V = 0.004392 \; m^3$, $\rho = 7850 \; kg/m^3$ and $g = 9.81 m/s^2$, $W_s = 0.72 \; x \; 0.305 \; x \; 0.02 \; x \; 7850 \; x \; 9.81 = 338.2N$

2.3.3 Weight of Knives

The weight of knives was calculated using the equation given by [4].

$$W_k = V \, x \, \rho \; = \; l \, x \, b \, x \, t \, x \, \rho \, x \, g \quad (3)$$

Where;

ρ = Density of Stainless Steel = 8000 kg/m^3 (selected material)

l = 14 (cm), b = 0.25 (cm), t = 0.06 (cm), g = 9.81 (m/s^2)

$W_k = 0.14 \; x \; 0.025 \; x \; 0.0006 \; x \; 8000 \; x \; 9.81 = 0.165N$

Since fifteen knifes were used, hence, the total weight of knives was W_k = 15 x 0.165 = 2.475 N

2.3.4 Weight of the Knife Compartment

The weight of the knife compartment was determined using the equation given by [4].

$$W_c = V \, x \, \rho \; = \; l \, x \, b \, x \, t \, x \, \rho \, x \, g \quad (4)$$

Where;

$l = 37 \; (cm), \; b = 19 \; (cm) \; , t = 1.5 \; (cm), and \; g = 9.81 \; (m/s^2)$

ρ = Density of mild steel = $7880 kgm/s^3$

$W_c = 0.37 \; x \; 0.19 \; x \; 0.015 \; x \; 7880 \; x \; 9.81 = 30.84N$

2.3.5 Weight of Metal Handle

The weight of the metal handle attached to the knife was determined using the equation given by [4].

$$W_m = V \, x \, \rho \; = \; l \, x \, b \, x \, t \, x \, \rho \, x \, g \quad (5)$$

Where;

$l = 10 \; (cm), b = 0.25 \; (cm), t = 0.3 \; (cm) and \; g = 9.81 \; (m/s^2)$

l = Density of mild steel = $7880 kgm/s^3$

$W_m = 0.1 \; x \; 0.0025 \; x \; 0.003 \; x \; 7880 \; x \; 9.81 = 0.58N$

Since fifteen of the handles were used thus, weights of the handles $W = 15 \; x \; 0.58 = 8.7N$

2.3.6 Weight of Cast Iron

The weight of the cast iron used for bearing was determined using the equation given by [4].

$$W_{cast} = \rho \, x \, v \, x \, g \quad (6)$$

Where;
$h = 1.5\ (cm), \pi = 3.142, and\ \rho =$
Density of mild steel = 7850 (kg/m^3)
Since four bearing slots were used.
Hence; $W_{cast} = 4\ x\ 0.36 = 1.44N$

2.3.7 Cutting Resistance

The cutting resistance of cucumber fruit was determined using the equation given by [5].
Maximum puncture resistance of a cucumber = 0.4750 (N/mm), Measured average major diameter cucumber = 58.00 (mm), Puncture resistance of cucumber is therefore, = 0.4750 x 58.00 = 27.55 N.
But since the slicer was designed to cut through five cucumbers at a time.
Force due to resistance of five cucumbers = 5 x 27.55 = 137.75N
Hence; the total load to be lifted by the slider crank mechanism W = 500 + 137.75 = 638N
Therefore; $P = 140.35\ N$
Torque required to operate the slider crank mechanism; $T = 1.123\ Nm$
The angular speed of the slider was obtained from equation below as given by [5].

$$\omega = \frac{2\pi N}{60} \quad (7)$$

Where; N = number of revolutions of the crank, ω = the angular speed of the crank. It was required that the cucumber was cut at a knife speed of 0.2 m/s (12000 mm/min)
Hence; $N = \frac{V}{P} = \frac{600}{4} = 150\ rpm$

$$\omega = \frac{2\pi N}{60} = 314.16\ rpm/sec$$

2.4 Construction Procedure

2.4.1 Frame

The mainframe of the cucumber slicing machine was constructed using angle iron. The angle iron was marked, measured, and cut to the required dimensions using an electric grinder machine, and then joined by welding.

2.4.2 Compartment

The slicing compartment was constructed using a stainless quarter road of 5 mm thickness, it serves as a cucumber sit. These were measured, marked out, and cut to the required dimensions using a tape, scriber, and grinder machine respectively, and then joined by welding.

2.4.3 Knife Compartment

The knife compartment was constructed using a mild steel sheet of 1.5mm thickness and. The knife holders and the bearing slot were measured, marked, and cut to the required dimensions using a tri square, scriber, and a grinder machine respectively, and then joined by arc and gas welding.

2.4.4 Collection Tray

The collection tray on which the sliced cucumber was collected was constructed using a galvanized sheet of 2 mm thickness. The tray was measured, marked out, and cut to the required dimensions using a tape, scriber, and a grinder machine respectively, and then joined by an electric arc welding.

2.4.5 Assembly of Parts

All the parts making up the machine were assembled after necessary fabrication. Firstly, the mainframe was formed by welding together the slicer stands to the frame. The slicer box was then mounted on the frame and joined by welding. The square road on which the ball bearing moves was formed and welded to the box. The slicer compartment was joined inside the box. The knives were welded to the knife holders, then arranged and fastened using bolts and nuts to the knife compartment. Therefore, the bearing slots will then be formed. Finally, the ball bearings were mounted on the slots to enable the knife compartment moves along the slicer box.

2.4.6 Finishing

The welded slots and rough edges were dressed smoothly using sand paper, hand file and electric grinder, paint was also sprayed.

2.5 Performance Evaluation

2.5.1 Efficiency of the Slicer

The efficiency of the slicing machine was determined by the equation given by [6].

$$Slicing\ Efficiency = \frac{W_S - W_D}{W_T} x\ 100$$

Where;
$W_S = Total\ weight\ of\ cucumber\ sliced\ correctly\ (kg)$
$W_D = Weight\ of\ damaged\ slices\ (kg)$
$W_T = Total\ weight\ of\ sample$

2.5.2 Percentage Loss

The percentage loss was be determined by the expression given by [6].

$$Percentage\ loss = \frac{Total\ mass\ of\ sample - mass\ after\ slicing}{Total\ mass\ of\ sample} x100$$

2.5.3 Output Capacity

The output capacity of the machine was determined by the expression given by [6].

$$Output\ capacity = \frac{Weight\ of\ sliced\ cucumber\ (kg)}{Time\ taken\ (Hour)}$$

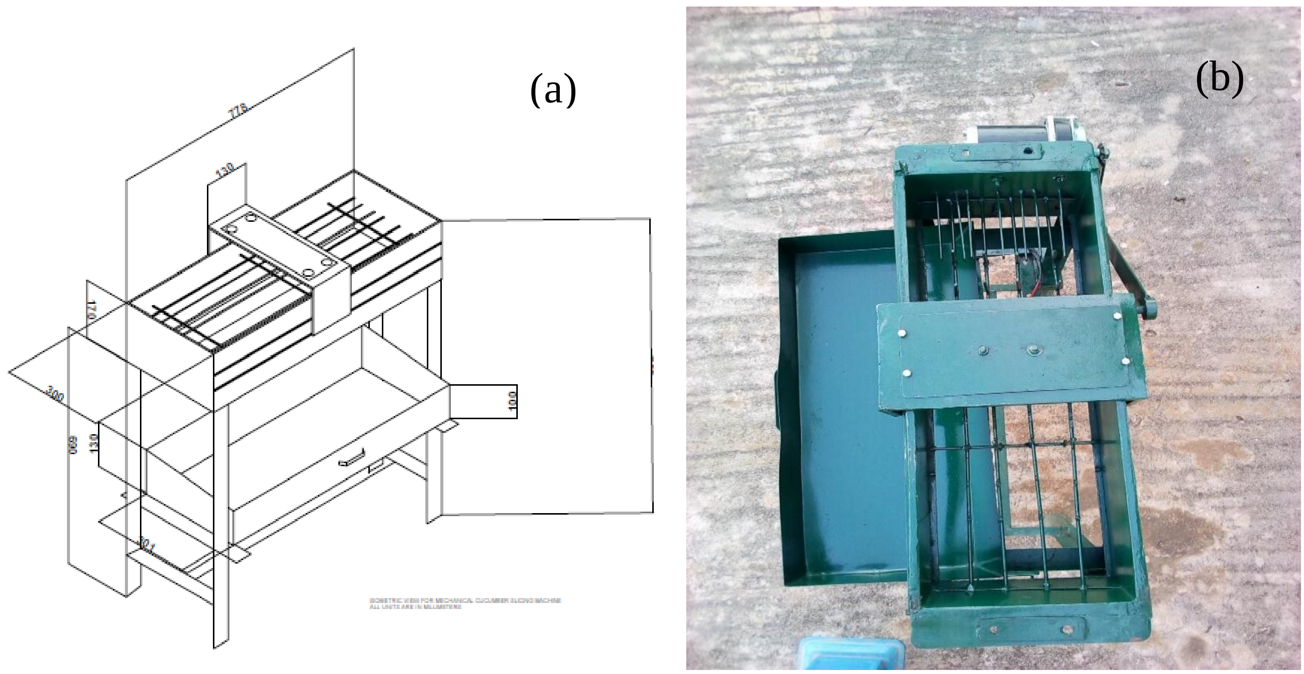

Fig 1. (a) Isometric View of Cucumber Slicing Machine; (b) Constructed Cucumber Slicing Machine.

3. Results and Discussion

The mean values for the performance evaluation of manual and mechanical cucumber slicing machine were presented in table 1.

Table 1: Performance Evaluation of Manual and Mechanical Cucumber Slicing Machine

Parameters	Mean		Std. Deviation		Std. Error Mean		Table of t-value
	Manual	Mechanical	Manual	Mechanical	Manual	Mechanical	
Efficiency (%)	90.12	71.84	6.14	4.98	2.74	2.23	17.182**
Percentage Loss (%)	5.54	14.10	3.66	2.50	1.64	1.12	4.307*
Output Capacity (Kg/hr)	30.20	165.60	11.56	55.34	5.17	24.75	5.356*

** Highly significant at 5% level
* Significant at 5% level

From table 1, it can be seen the average efficiency of the manual and mechanical slicing was found to be 71.84 % and 90.0 % respectively. However, the manual slicing efficiency of a vegetable slicer for tomato was 71.52% which is almost similar to the value obtained by [7]. The average percentage loss of the manual and mechanical slicing was found to be 5.5 % and 14.08 % respectively. Further, [8] reported the percentage loss for mechanical slicing of star fruit slicer to be 9.53% which is more than the value obtained. This was because during machine slicing, the cutting of edges was dependent on setting of the thickness of the slice. The average output capacity of the manual and mechanical slicing was found to be 30 kg/hr and 165.60 kg/hr respectively. [7] evaluated a manual vegetable slicer and the capacities were found to be 37.49 kg/hr which shows small difference in value for the manual cucumber slicing machine. Low slicing efficiency and high percentage loss obtained in the mechanical slicing can be attributed to wobbling action of the blade carriage observed during performance tests [3]. From the t-test observed, the efficiency for the manual slicing is significantly higher than mechanical slicing. However, the mean value for mechanical percentage losses and output capacity are significant than manual slicing.

4. Conclusion

The cucumber slicing machine has been designed, fabricated and evaluated. The overall performance of both manual and mechanical efficiency, output capacity and percentage loss were computed as 90.12%, 5.54%, 30.20 kg/hr and 71.84%, 14.08%, 165.60 kg/hr respectively. The objectives of this study were achieved.

Conflict of Interest

We the author of this paper declare that there is no conflict of Interest.

References

1. Tahir SM, Kabir AM, Ibrahim H, Sufiyanu S. Studies on the performance of organic and inorganic fertilizer on the growth and yield of cucumber (*Cucumis sativus* L.). *Science World Journal*. 2019;14(1):156-163.
2. Mandey JS, Wolayan FR, Pontoh CJ, Sondakh B. Phytochemical characterization of cucumber (*Cucumis sativus* L.) seeds as candidate of water additive for organic broiler chickens. *J. Adv. Agric. Technol*. 2019;6(6410.18178).
3. Shittu SK, Bello M, Dangora ND. Development of a motorized tomato (*Solanumly copersicum* l.) Slicer. *Arid Zone Journal of Engineering, Technology and Environment*. 2017;13(2):197-208.
4. Khurmi RS, Gupta JK. A textbook of machine design. S. Chand publishing; 2005.
5. Uche AG, Nwabueze AS, CHIBUIKE MJ, JOSEPH MC. Energy requirements for cutting of selected vegetables: A review. *Agricultural Engineering International: CIGR Journal*. 2018;20(4):139-148.
6. Kamaldeen OS, Arowora KA, Abioye JS, Awagu EF. Modification of Manually Operated Tomato Slicing Machine. *International Journal of Engineering Science and Computing*. 2016;6(7):1983-38.
7. Samaila RS, Olowonibi MM, Adgidzi D. Design, Construction and Performance Evaluation of a Manually Operated Vegetable Slicer. *J. Agric. Eng. Technol*, 2008. 16(1), 48-52
8. Behera G, Rayaguru K. Development and performance evaluation of manually operated star fruit slicer. *Journal of Agricultural Engineering*. 2016;53(3):10-18.

Recommended Citation

Jibril AN, Mashi AA, Shu'aibu SM. Design, construction and performance evaluation of a cucumber slicing machine. *Alger. J. Eng. Technol. 2022*, 7;70-74.