



DEVELOPMENT OF AN NCAM TUBER-SHAPED VEGETABLE SLICING MACHINE

O. B. Asamo*, F. B. Olotu, R. O. Jimoh, R. A. Alade, S. C. Obiakor, N. A. Okoro and
Y. S. Ademiluyi

Department of Crop Processing and Storage Engineering
National Centre for Agricultural Mechanization (NCAM), Km. 20, Ilorin-Lokoja Highway, Idoian, Kwara State, Nigeria

*Corresponding author's email address: asamoolaoluwa@gmail.com

ARTICLE INFORMATION

Submitted 4 February, 2023
Revised 18 March, 2023
Accepted 24 March, 2023

Keywords:

tuber - shaped vegetable
slicing machine
design
fabricate
evaluation

ABSTRACT

Generally, most agricultural products are not stable immediately when freshly harvested, while their preservative nature varies accordingly especially, vegetables and fruit crops. The need to process and preserve them in a stable form is very important. In processing of some tuber -shaped vegetable crops such as carrot, plantain, cucumber, eggplant, etc., slicing/chipping is usually done traditionally with the aid of knives and other manual methods which are time consuming, thereby exposing processors to dangers of injury, increases drudgery and overall reduces productivity. In respect of these, an NCAM tuber - shaped vegetable slicer was designed, fabricated and evaluated. The performance parameters used for the evaluation are slicing efficiency, slice thickness and percentage damage. IBM SPSS 2.0 was used to analyse the result obtained from the performance evaluation of the tuber – shaped slicer. It was observed that blade thickness had a significant effect on percentage damage and slice thickness, and no effect on slicing efficiency at $p \leq 0.05$. 94.74% and 90.99% efficiency was observed at 1.5 mm and 1 mm blade thickness for plantain and cucumber respectively. Furthermore, the highest mean value for percentage damage for plantain was 44.08% at 1.0mm blade thickness, while the highest mean value of percentage damage for cucumber was 24.88% at blade thickness of 1.0mm. This shows that the tuber – shaped vegetable slicing machine performed efficiently. Therefore, tuber-shaped slicing machine is recommended for use by processor of tuber – shaped crops into other stable form.

© 2023 Faculty of Engineering, University of Maiduguri, Nigeria. All rights reserved.

1.0 Introduction

Root vegetable and fruits crops make up a majority of the common staple food consumed in Nigeria. In 2018, the combined global production data for onion bulbs, plantain, cucumbers, Irish potatoes and carrots was above 108 million tonnes (FAO, 2019). The preservative prospects of various root vegetables and fruit crops vary, but in general, these crops are perishable and moving them from the farm to the market is often very expensive due to their bulkiness. Processing them into essentially non-perishable produce provides an alternative to storage in fresh form as they are best preserved in the dried form by processing into flour, chips and pellets for both human and livestock ingestion (Oyejide *et al.*, 2018).

Traditionally, slicing is done with the aid of knives or other manual methods which takes a longer time to slice, expose the operator to dangers of injuring themselves, increases drudgery and overall productivity is lower (Awoluyi 2003; Obeng 2004). Indigenous methods of cutting and slicing root vegetables and fruit crops into chips is associated with drudgery and susceptible to finger injury, time wastage, un-uniform size of sliced chip and unavoidably, leads to low output by farmers with diminutive or no income margin.

Ezugwu et al. (2019) investigated the design and fabrication of a motorized operated plantain slicer for optimum chips production. The machine produced chips of uniform sizes in a short time of 3 seconds and had a slicing efficiency of 96.84% and could effectively slice a 70 mm diameter of unripe plantain. Okafor et al. (2013) investigated plantain chip slicing machine that was designed, fabricated and tested to use a carrier spring return mechanism to achieve both the feeding option and the slicing operation. A slicing efficiency of 74% was recorded. Adesina et al. (2015) designed and developed a plantain slicing machine that was tested and evaluation with its performance for machine capacity of 52Kg, slicing efficiency of the machine was at 80% and the value of the length of the belt was calculated at 1039.85mm. The machine solved the problem of non-uniformity of chip thickness associated with traditional slicing methods as the time of slicing plantain for mechanical slicing was shorter but longer for traditional slicing method. However, percentage damage reported in the aforementioned research work was large. Against this background there is the need to design a vegetable slicing machine to solve the problem mentioned above.

The specific objectives of this study is to develop a tuber shaped vegetable slicer and evaluate its performance in order to produce quality chip, reduce time of operation, increase slicing efficiency and achieve a relatively noise free operation and vibration with low power consumption.

2. Material and Methods

2.1 Description of the Machine/ Mode of Operation

The major parts of the machine include the frame, slicing unit and the power unit. The slicing unit consist of the hopper, feeding chute, cutting disc, blades and discharge outlet. Stainless material was selected for the above-mentioned parts. The frame was constructed with mild steel angle iron to provide rigidity and support to the machine, while the power unit consist of the shafts, bearings, belt, pulley and 1Hp electric motor which powers the machine. Tuber-shaped vegetables are placed in the feeding chute vertically, the power transmitted from the electric motor through the shaft makes the cutting disc move in a rotary motion. The movement of the cutting disc in contact with the vertically placed material results in the slicing of the crop.

2.2 Design Calculations

2.2.1 Pulley Speed and Size

The pulley was designed by taking into account the power to be transmitted between the electric motor and the shaft connected to the cutting disc. The diameters of the pulley are calculated as employed by Khurmi and Gupta (2004.)

$$VR = \frac{N_1}{N_2} = \frac{D_1}{D_2} \quad (1)$$

where:

N_1 = Speed of the pulley on the motor, rpm N_2 = Speed of the pulley on the shaft, rpm
 D_1 = Diameter of the pulley on the motor, mm D_2 = Diameter of the pulley on the shaft, mm
and VR = Velocity Ratio

$$VR = \frac{2552}{638} = \frac{D_1}{D_2} = 4$$

If a pulley of diameter 70 mm was used on the motor, a pulley of 280 mm is required for the shaft.

$$D_2 = D_1 * 4 = 70 * 4 = 280 \text{ mm}$$

2.2.2 Length of the Belt

As explained by Khurmi and Gupta (2004) and Akande and Onifade (2015) the length of an open belt could be calculated by

$$L = 2c + \frac{\pi}{2} (D_1 + D_2) - \frac{(D_2 - D_1)^2}{4c} \quad (2)$$

L = Length of an open belt, mm

C = Centre distance of belt, mm

D₂ = Diameter of the pulley on the motor, mm D₁ = Diameter of the pulley on the shaft, mm

Given C = from the design, L is calculated as,

$$L = 2(395) + \frac{\pi}{2} (280 + 70) + \frac{(280-70)^2}{4(395)}$$

$$L = 790 + 550 + 28 = 1.37\text{m}$$

V-belts are designated by its type and nominal inside length. A V-belt of type A which can transmit power between the ranges of 0.7- 3.5KW, the standard inside length nearest to 1368 mm is 1600mm (Khurmi and Gupta 2004.), (Najeem et al, 2015).

2.2.3 Tension in the Belt

The relation between tight side and slack side tension, in terms of co-efficient of friction (μ) and the angle of contact is given by Khurmi and Gupta (2004.) as;

$$2.3 \log \left(\frac{T_1}{T_2} \right) = \mu \theta \quad (3)$$

where;

T₁ = Tension in the belt on the tight side, N
N and

T₂ = Tension in the belt on the slack side,

μ = the coefficient of friction between the belt and pulley = 0.25 Khurmi and Gupta (2004)

$$\log \left(\frac{T_1}{T_2} \right) = \frac{0.25 * 2.48}{2.3}$$

$$\log \left(\frac{T_1}{T_2} \right) = 0.27$$

$$T_1 = 0.27 * T_2 \quad (4)$$

The expression which shows the relationship between the powers transmitted, belt tension and linear velocity is given as;

$$P_M = (T_1 - T_2) \quad (5)$$

P_M = Power of the electric motor

Where;

V = Belt velocity, m/s

$$V = \frac{\pi D_1 N_1}{60} \quad (6)$$

$$V = \frac{\pi * 0.07 * 2552}{60} = 8.25 \text{ ms}^{-1}$$

$$(T_1 - T_2) = \frac{P_M}{v} = \frac{746}{8.25} = 90.42 \text{ N}$$

2.2.4 Determination of the Power required by the Electric Motor

The power required by the electric motor was obtained from Equation (7)

$$P_M = P_C * P_F \quad (7)$$

where:

$$\begin{aligned} P_M &= \text{power of electric motor} & P_F &= \text{power factor} = 2 \\ P_M &= 211.55 * 2 & &= 423\text{watt} \\ &= 0.423 \text{ kW} & &= 0.57 \text{ hp} \end{aligned}$$

Electric motor of capacity 950W (1hp) with speed of 1550 rpm was selected based on safety and availability of the motor.

Auto-Cad software was used to develop the proposed design of the machine to show the orthographic and isometric view of what the machine would look like before and after fabrication as shown in Figures 1, 2 and 3, respectively.

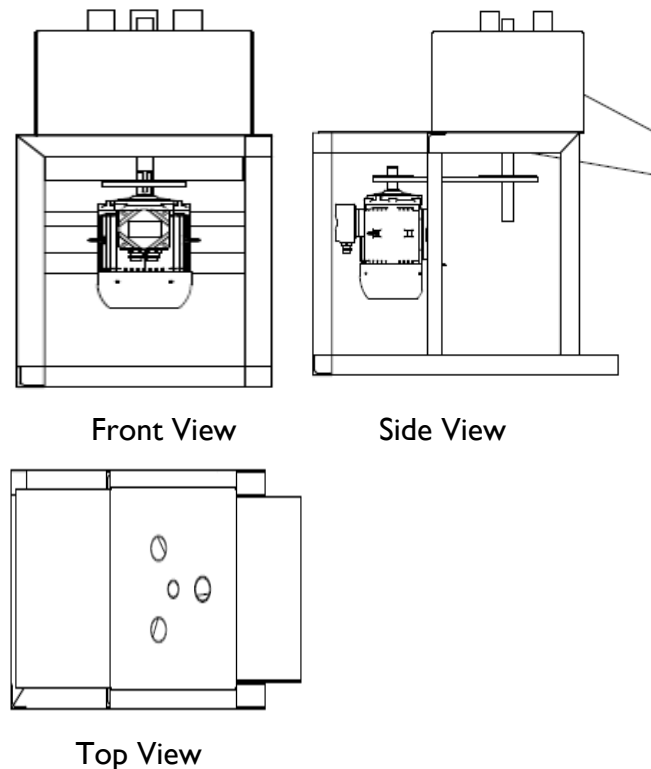


Figure 1: The Orthographic View of the Tuber-Shaped Vegetable Slicer

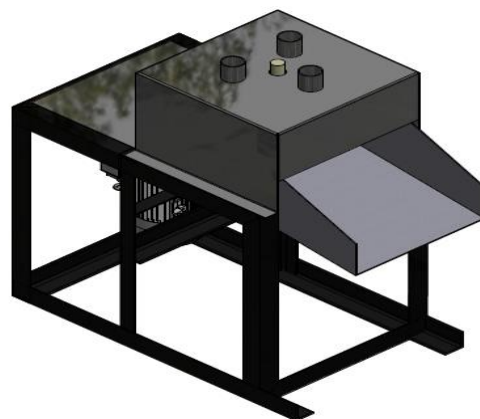


Figure 2: Isometric View of the Tuber-Shaped Vegetable Slicer



Figure 3: Pictures of the Developed Tuber-Shaped Vegetable Slicer

2.3 Performance Test and Evaluation

2.3.1 Experimental Procedure

The performance evaluation of the root vegetable slicer was carried out in the processing and storage department (PSED) of the National Centre for Agricultural Mechanization (NCAM) Ilorin, Kwara State. Plantain tubers and Cucumber used for the experiment were cleaned and sorted into various sizes. Three cutting disc with blade thickness of 1mm, 1.5mm and 2mm was used to determine which blade thickness is best suited for slicing the available crops. A 24S-D ADC cammy industrial table top scale was used to measure the weight of plantain tubers and cucumber in three (3) batches of 1kg each, other laboratory apparatus used in carrying out the experiment include; digital photo/contact tachometer of model number DT2236B with accuracy $\pm (0.05\% + 1 \text{ digit})$ produced by BepEdu World in Kodhawa, Pune, Maharashtra, India, which was used by placing the photo contact point of the tachometer on the pulley while the machine was in operation to determine the operating speed of the machine. Vernier calliper and clock/stop watch were used to measure the thickness of the sliced, unsliced and damaged products and time taken to slice the plantain and cucumber respectively. After weighing the plantain tubers, the first batch of 1kg plantain and cucumber was fed through the hopper and sliced using the cutting disc with blade thickness of 1mm while the second and third batches were sliced using the cutting disc with blade thickness of 1.5mm and 2mm thickness respectively and the entire process was replicated three (3) times. The weight of the sliced product, damaged product at the outlet of the machine and weight of the unsliced product which was remaining in the hoppers were weighed after each operation to determine the performance parameters of the slicing machine which are, slicing efficiency, percentage damage and percentage recovery.

Analysis of variance (ANOVA) and New Duncan Multiply Range Test (NMDRT) of IBM SPSS 30.0 statistical package was employed to analyse how the operational conditions affect the performance of the root vegetable slicer.

2.3.2 Performance Parameter

2.3.2.1 Slicing Efficiency; SE (%)

This is the weight of the sliced product at the machine outlet divided by the total weight of both the sliced product and the unsliced product in percentage. It is expressed as in Equation (8)

$$SE = \frac{W_2+W_4}{W_0} \times 100 \quad (8)$$

where: W_0 = Weight of the sample before slicing W_1 = Total weight at discharge outlet (g)

$W_1 = W_2+W_4$ W_2 = Weight of the sliced product at the machine outlet (g)

W_3 = Weight of unsliced product (g)

W_4 = Weight of the damaged product at machine outlet (g)

2.4.2.2 Percentage Damage; P.D (%)

It is the weight of the damaged product during slicing over the total weight of unsliced product and damage product after slicing operation in percentage. It is expressed as in Equation (9).

$$PD = \frac{W_4}{W_3+W_4} \times 100 \quad (9)$$

2.4.2.3 Slice' Thickness; ST (mm)

It is the average thickness of slices produced at the end slicing operation in mm. It is measured with the use of digital venial calliper.

3. Results and Discussion

The tuber-shaped vegetable slicer has been designed and fabricated, its Performance was evaluated to ascertain its effectiveness. The summary of the performance evaluation of the Tuber-Shaped Vegetable slicer is presented in Table 1. The average values performance parameters of the slicer such as slicing efficiency, percentage damaged and slice thickness were obtained at 113 rpm at difference blade thickness of 1.0mm, 1.5 mm and 2.0 mm using plantain and cucumber.

It is observed that the highest mean value of slicing efficiency of 94.74% was noted at 1.5 mm blade thickness when plantain was used with the least mean value of slicing efficiency of 93.91% at blade thickness 2.0 mm. When cucumber was used for evaluation, the slicer had it highest mean value of slicing efficiency of 90.99% at 1.0 mm blade thickness with the least mean value of slicing efficiency of 90.24% at 2.0 mm blade thickness.

The result of Analysis of Variance (ANOVA) conducted showed that the blade thickness had no significant effect on slicing efficiency of the slicer at $p \leq 0.05$ as shown in Table 2. The levels at which the slicer's blade thickness affects the slicing efficiency of the tuber- shaped vegetable slicer is shown in NDMRT Tables 3 which shows all levels of the blade thickness were not significantly different from each other at $p \leq 0.05$. This means that the blade thickness is similar to each other in term of their effectiveness in slicing the tuber-shaped vegetables which might be that the selected levels of blade thickness used are sharp enough to slice the tuber-shaped vegetable. The independence sample test was also conducted on slicing efficiency of slicer between plantain and cucumber as presented in Table 4. The results showed that there were significant different between the slicing efficiencies of the machine using plantain and cucumber at $p \leq 0.05$. This means that plantain and cucumber do not have similar effects on the slicing efficiency of the slicer. These

differences in slicing efficiencies could be because of the difference in morphology of the crop as cucumber has a firm exocarp than plantain. This is also in line with research findings conducted on the slicing of carrot, plantain, onions and banana as reported elsewhere (Sonawane et al., 2011; Rajesh et al., 2016; Ezeanya et al 2020).

The highest mean value of percentage damage of 44.08% of plantain chips was observed at blade thickness of 1.0 mm with least mean value of 28.05% at blade thickness 2mm. The lowest mean value of percentage damage of sliced cucumber 15.10% obtained at 2.0 mm blade thickness and it highest mean value of percentage damage 24.88% was obtained at the blade thickness of 1.0mm. The ANOVA results shows that the blade thickness (BT) and the crop type (CT) had significant effects on the percentage damage of the slices as well as their combination at $p \leq 0.05$ as shown in Table 2. The levels at which the slicer's blade thickness affects the percentage damage of the slice are shown in NDMRT Tables 4 which shows all levels of the blade thickness were significantly different from each other at $p \leq 0.05$. The highest percentage of damaged slices observed at 1mm blade thickness for both plantain and cucumber slices could be that cutting action was faster at 1 mm blade thickness with incomplete slicing operation on the crop because it is the sharpest blade thickness.

The result of the slice thickness in relation to the blade thickness used in slicing was shown in Table 1. It can be observed that the highest mean value of slice thickness 1.75mm of plantain chips was obtained at blade thickness of 2.0 mm with least mean values of 0.71mm at blade thickness 1.0mm was obtained after slicing operation. The lowest mean value of cucumber slice thickness 0.81mm given at 1.0mm blade thickness and it highest mean value of 0.90mm was obtained at the blade thickness of 1.0mm. The ANOVA results shows that the blade thickness and the crop type had significant effects on the slices of tuber – shaped vegetable as well as their combination at $p \leq 0.05$ as shown in Table 2. The levels the slicer's blade thickness that led to the differences slices' thickness are shown in NDMRT Tables 3 which shows all levels of the blade thickness were significantly different from each other at $p \leq 0.05$. The independence sample test was conducted on slices thickness of plantain and cucumber as presented in Table 5. The results showed that there were significant different between the slices' thickness of plantain and cucumber at $p \leq 0.05$ as indicated in Table 3. This means that the slicer does not have similar effects on the slice thickness of plantain and cucumber.

Table 1: Summary of the Performance Evaluation of the Tuber-Shaped Vegetable Slicing Machine

Crop	Operating Speed (rpm)	Blade Thickness (mm)	Thickness of the slice (mm)	Slicing Efficiency (%)	Percentage Damage (%)
Plantain	113	1	0.71	94.60	44.08
	113	1.5	1.28	94.74	35.56
	113	2	1.75	93.91	28.05
Cucumber	113	1	0.81	90.99	24.88
	113	1.5	0.86	90.51	19.88
	113	2	0.90	90.24	15.10

Mean Values of Three Replicates

Table 2: Analysis of Variance (ANOVA) for Performance Parameters of Tuber-Shaped Vegetable Slicing Machine

Performance Parameters	Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
	Corrected Model	76.153 ^a	5	15.231	17.589	.000*
Slicing Efficiency (%)	CT	73.609	1	73.609	85.005	.000*
	BT	1.394	2	.697	.805	.470
	CT * BT	1.150	2	.575	.664	.533
	Error	10.391	12	.866		
	Total	153858.638	18			
	Corrected Model	1673.210 ^a	5	334.642	138.968	.000*
Percentage Damage (%)	CT	1144.014	1	1144.014	475.079	.000*
	BT	499.745	2	249.873	103.766	.000*
	CT * BT	29.450	2	14.725	6.115	.015*
	Error	28.897	12	2.408		
	Total	15739.166	18			
	Corrected Model	2.285 ^a	5	.457	464.836	.000*
Slice Thickness (mm)	CT	.650	1	.650	660.814	.000*
	BT	.988	2	.494	502.379	.000*
	CT * BT	.648	2	.324	329.305	.000*
	Error	.012	12	.001		
	Total	22.353	18			

*Significant at $p \leq 0.05$; CT = Crop Type; BT = Blade Thickness

Table 3: New Duncan Multiply Ranged Test (NDMRT) for Performance Parameters of Tuber-Shaped Vegetable Slicing Machine

S/N	Levels of Blade Thickness (mm)	Performance Parameters		
		Mean Thickness of Slices (mm)	Mean Slicing Efficiency (%)	Mean Percentage Damage (%)
1	1.00	0.76 _a	92.80 _a	21.57 _a
2	1.50	1.07 _b	92.13 _a	27.72 _b
3	2.00	1.34 _c	92.36 _a	34.48 _c
Sig	0.05			

Mean with the same alphabet are not significantly different from each other

Table 4: Independent Sample Test on Performance Parameters of Tuber-Shaped Vegetable Slicing Machine using Plantain and Cucumber

		Independent Samples Test					t-test for Equality of Means	
		Levine's Test For Equality of Variances					95% Confidence Interval of the Difference	
		t	df	Sig (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
	Equal variances assumed	2.512	16	.023	.38000	.15127	.05933	.70067
Slice Thickness	Equal variances not assumed	2.512	8.195	.036	.38000	.15127	.03262	.72738
	Equal variances assumed	9.542	16	.000	4.04444	.42385	3.14592	4.94297
Slicing Efficiency	Equal variances not assumed	9.542	15.068	.000	4.04444	.42385	3.14138	4.94795
	Equal variances assumed	5.727	16	.000	15.94444	2.78411	10.04239	21.84650
Percentage Damage	Equal variances not assumed	5.727	13.065	.000	15.94444	2.78411	9.93277	21.95612

Significantly Different at $p \leq 0.05$

4. Conclusion

An NCAM Tuber-Shaped vegetable slicer was designed, fabricated and evaluated. The result of the evaluations presented shows the highest mean value of slicing efficiency to be 94.74% and the lowest mean value for percentage damaged was 24.88% for plantain while highest efficiency for cucumber was 90.99% and percentage damage was 15.10%. The percentage damage values shows that the machine will not only serve as an improvement the use of knives to slice but also increase the productivity of small-holder farmers and small scale processing industries.

References

- Adesina, AO., Ajiboshin, IO., Adedeji, WO. and Adelana, SO. 2015. Design, Development and Performance Evaluation of Plantain Slicing Machine. *International Journal of Emerging Trends in Engineering and Development*, 1(5):204-216.
- Akande, FB. and Onifade, TB. 2015. Modification of a plantain slicing machine. *Innovation System Design and Engineering*, 6(10): 41-53.
- Awoluyi, OO. 2003. Design and construction of plantain slicer. MSc. Thesis, Department of Design and Fabrication, Federal Institute of Industrial Research Organization, Oshodi, Nigeria, pp 72.

Ehiem, J.C., Irtwange, S.V. and Obetta, S.C. 2009. Design and Development of an Industrial Fruit and Vegetable Dryer. *Research Journal of Applied Sciences, Engineering and Technology*, 1(2): 44-53.

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

Ezugwu, C.A. 2019. Design and fabrication of a motorized power operated plantain slicing machine. *Research Journal of Agriculture and Biological Sciences*, 4(6): 624-635.

FAOSTAT, 2019. World crop production indices for 2018. FAO, Rome.

www.fao.org/faostat/en/#search/crop%20production%20in%20nigeria%202018 accessed on 8 August, 2022.

Khurmi, R.S. and Gupta, J.K. 2004. A text book of Machine Design. Eurasia Publishing House LTD. Ram Nagar, New Delhi, pp.1096.

Khurmi, R.S. and Gupta, J.K. 2010. Theory of Machines. Eurasia Publishing house, New Delhi, India.

Kingsley-Omoyibo, Q.A. 2020. Design and Fabrication of an Improved Continuous Plantain Slicing Machine. *Nigerian Journal of Engineering Science Research (NIJESR)*. 3(1): 17-26

Najeem, S., Daniel, A., Okanlawon, H., Orilade, M., Abioye, P. and Adekanmi, S. 2015. Construction of locally made plantain slicer. B.Tech. Thesis, Department of Agricultural Engineering, LAUTECH, Ogbomoso, Nigeria.

Obeng, G.Y. 2004. Design and fabrication and testing of a mechanized plantain and carrot slicer. *Journal of science and technology*, 24(2):126-133.

Okafor, B.E. and Okafor, V.C. 2013. Design of a Plantain Chips Slicing Machine. *International Journal of Engineering and Technology*, 3(10):26-40.

Olutomilola, E.O. 2019. Theoretical design of plantain peeling machine, *International Journal of Scientific and Engineering Research*, 30(1):234-244.

Onifade, T.B. 2015. Energy and Exergy Analyses of the thin layer of drying of physic nuts (*Jatropha curcas*). Ph.D Thesis, Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

Oyejide, J.O., Orhorhoro, E.K., Afoegba, S.C. and Olaye, M. 2018. Design and fabrication of an improved plantain processing machine. *Nigerian Journal of Technology (NIJOTECH)*, 37(3): 656 – 662.

Rajesh, G.K., Pandiselvan R. and Indulekshmi, A. 2016. Development and performance evaluation of plantain peeler cum slicer. *Scientific Journal of Agricultural Engineering*, (2): 41-50.

Sonawane, S.P., Sharma, G.P. and Pandya, A.C. 2011. Design and development of a power operated banana slicer for small scale food processing industries. *Journal of Research in Agricultural Engineering*, 7(04): 144-152