Nigerian Journal of Engineering Science Research (NIJESR). 3(1):41-47
Copyright@ Department of Mechanical Engineering, Gen. Abdusalami Abubakar College of Engineering, Igbinedion University, Okada, Edo State, Nigeria.
ISSN: 2636-7114
Journal Homepage: http://nijesr.iuokada.edu.ng

Design of a Multipurpose Slicing Machine

***[1]Ikimi, J.A., [2]Jewo, A.O., and [3]Sule, S**

[1]Department of Mechanical Engineering, Petroleum Training Institute, Effurun, Delta State (jefkim2000@yahoo.com)
[2]Department of Mechanical Engineering, Petroleum Training Institute, Effurun, Delta State Jewo_ao@pti.edu.ng
[3]Department of Mechanical Engineering, Petroleum Training Institute, Effurun, Delta State Salisu_s@pti.edu.ng

Corresponding Author: Ikimi J.A.; jefkim2000@yahoo.com (+2348033171609)

Manuscript History
Received: 20-03-2020
Revised: 25-04-2020
Accepted: 18-05-2020
Published: 10/06/2020

Abstract: *Agricultural products such as yams, potatoes, plantains, etc., are usually processed after harvesting in order to increase its shelf life. However, the human cost of such processing is enormous and impacts negatively on the economic benefits derivable from the plant production. Therefore, the development of appropriate, low-cost, easy to operate and maintain multipurpose slicer is long overdue. This research work presents efficient device that simulates the traditional method of slicing Agricultural produce for storage and preservation. The major components of the designed multipurpose slicing machine consists of a feed hopper, slicing chamber, shaft, bearings, discharge outlet and a 1 hp electric motor. A test was carried out with the designed machine using various masses of Agricultural produce such as yam, potatoes, plantain that weighed 6.55kg. The slicing efficiency, machine throughput capacity, slicing time was all evaluated. The results obtained shown that the machine has machine throughput capacity of 0.0771 kg/sec., slicing time of 85 seconds, and efficiency of 83.21%. From the test results, it was observed that the multipurpose slicing machine had a higher capacity and efficiency. Besides, the sliced products by the machine were finer when compared to manual method of slicing that is time consuming. Therefore, this design apart from increasing the shelf life of the abovementioned Agricultural produce, it will also increase the economic benefits for local processors and storage.*

Keywords: Multipurpose Slicing Machine, Efficiency, Processors and Storage, Machine Throughput Capacity

INTRODUCTION

According to World Health Organization (WHO) on world health dated 7th April 2015, "From farm to plate, make food safe". However before agricultural produce leave the farm to become edible food, tedious processes are involved in making this possible. This process is the transformation of raw ingredients, by physical means into food (Orhorhoro *et al.,* 2018S). The agricultural produce are usually present in range of sizes, often too large to be handle and must be reduced in size for easy handling to aid processing and storage (Agboola,1992; Igbeka and Olumeko,1996, Ikpe *et al.,* 2018). Crops such as yam, plantain, and potato are important dietary source of carbohydrate in the humid tropical zones of Africa, Asia and South America (Adesina *et al.,* 2015; Oyejide *et al.,* 2018). The aforementioned crops are rich in carbohydrate, vitamins A, C and B group as well as minerals such as calcium and iron (Yusuf and Abdullahi, 2007; Akinyemi *et al.*, 2010). The crops are useful as food to be consumed by human either as flour to be used in confectionaries or as jams and jellies; in chips etc. Their peels can be used as animal feed. All parts of the crops have medicinal applications; the flower is uses in bronchitis and dysentery and on ulcers, cooked flowers are given to diabetic patients etc. Their leaves especially plantain is useful for lining cooking pots and for wrapping food materials. Improved processes have also made it possible to utilize plantain fiber for ropes, table mats and handbag (Adewumi *et al.*, 2011).

They are commonly produced in West Africa especially Nigeria, Benin, Ghana and Nigeria (FAO, 1990; Yomeni *et al.*, 2004). They are also a basic food crop in developing countries, especially in Africa; they serve as one of the major foods for over 70 million people. In some part of Africa such as Nigeria and Ghana, yams just like potato are dried and made into flour (Arisa *et al.*, 2013). They are important export crop to industrialized countries, and it is therefore an important source of revenue for many small scale farmers in developing countries. However, as a result of poor storage facilities, substandard transportation network and high standard of exportation requirements, leading African yam and potato producing countries like Nigeria and Ghana, lost lots of tons of the crops to inadequate post-harvest handling and management practices (Zhou *et al.*, 2006; Sonawane *et al.*, 2011). Hence, most farmers are forced to sell their produce cheaply at meager prices to cut their losses. Processing of these harvested crops into various forms, most especially into chips, has not only proven to be a remedy to preventing post-harvest loses, but as a means of income and livelihood to the producers, thus this research work. Zhou *et al.* (2006) reported that, the fracture of a material, which is a result of the interaction between the blade edge and the material, depends both on the material properties and the knife geometry. Mahvash and Hayward (2001) formulated a relationship between the cutting force and depth of cut during slicing. Atkins *et al.* (2004) further clarified why there is a smaller cutting force required when pressing and slicing contrasted with the application of only pressing force while slicing. Another factor that influences the cutting forces is the blade sharpness. This is because it has direct impact on the cutting moments and the forces applied by the operator (McGorry *et al.*, 2005). Thus, there is a need to redesign a slicing machine that can serve several purposes.

MATERIALS AND METHODS

2.1 Materials and Equipment

The materials and equipment used for this research work include;

i. Mild steel sheet
ii. Weighing balance
iii. Arc welding machine
iv. Mild steel angle bar
v. Crops such as yam tubers, and potatoes
vi. Stainless steel sheet
vii. Stainless steel rod
viii. Drilling macine

2.2 Methods

The following methods were adopted.

A. *Design Specification*

The following design specifications were drawn:

i. 1hp will be required by the multipurpose slicing machine
ii. A minimum force not greater 300 N
iii. Distance between the driver and driven pulley of 0.4 m
iv. A shaft diameter of 20 mm
v. The machine should be able to accommodate up to 8 kg of products to be slice.

B. Description of the Multipurpose Slicing Machine

This design was carried out based on the problems associated with manual method and existing slicing machine. The machine consists of the following major components; cutting chamber, cutting blade, cutting disc, electric motor, feed hopper, machine frame, discharge outlet, slicing blade, V-belt, pulley, ball bearings, etc. Crops such as yam, potatoes, etc., are introduced into the machine through the feed hopper. A V-belt was used to transmit the power because of the distance between pulleys; its comparative advantages of increased frictional grip with the pulley to avoid slipping of belts. A 1 hp electric motor with a speed of 1440 rev/min was used to power the machine. The slicing process was carried out in the slicing chamber. The slicing chamber is connected to the feed hopper. It is designed to house the cutting disc and blade and equally to collect the sliced products. An inclined stainless steel was welded directly below the cutting disc to receive, and dispense the sliced crops. Perforated sheet metals are put at designated places on the cutting chamber to serve as air inlets, to avoid discoloration of the sliced crops. The machine works on shear cutting principle and has the capacity to slice large quantities of crops within a short period of time. Power is transmitted from electric motor to input shaft via a pulley system. The input shaft transmits power to the cutting mechanisms which consists of a disc with attached blades for cutting the crops fed in vertically from the feed hopper. Fig. 1 shows the isometric view of the multipurpose slicing machine.

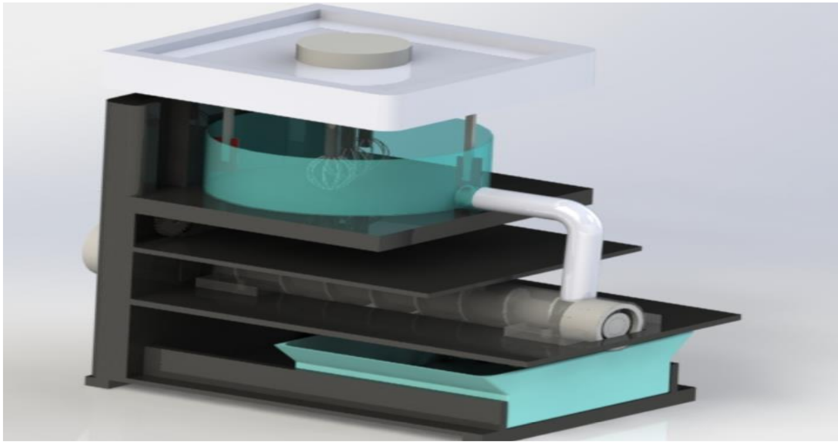

Fig. 1. Isometric View of Multipurpose Slicing Machine

C. Design Considerations

The following factors were considered in this design;

i. Size and weight of the machine
ii. Ease of operation
iii. Safety
iv. Maintenance
v. Cost

D. Design Calculation

The speed ratio of the belt drive is given by Equation (1)

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

where,

D_1 = Diameter of the driver = 50 mm

D_2 = Diameter of the driven = 100 mm

N_1 = Speed of the driver pulley = 1440 rpm

N_2 = Speed of the driven pulley =?

The angular velocity of slicing blade is given By Equation (2)

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

The slicing force was calculated using Equation (3).

$$F = ma \quad (3)$$

where;
m = Mass
a = Linear acceleration (m/s^2)
But, $a = rw^2$ (4)
where, w = Angular velocity of rotating disc
r = Radius of the cutting disc = 30 mm = 0.030 m
Substituting Equation (4) into Equation (3)

$$F = mrw^2 \quad (5)$$

The power required to slice is given by Equation (6)

$$P = FV \quad (6)$$

where,
P = Slicing Power
V = Linear velocity required to slice
F= Slicing Force
But,

$$V = rw \quad (7)$$

Thus,

$$P = Frw \quad (8)$$

The centre to centre distance between driver and driven pulley is given as:

$$C = 2D_1 + D_2 \quad (9)$$

where,
D_1 = Diameter of the driver = 50mm = 0.05m
D_2 = Diameter of the driving = 100mm = 0.10m
C= Centre to centre distance between driving pulley and driven pulley
The belt length was determined using Equation (10)

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) + \frac{D_1 + D_2}{4C} \quad (10)$$

The angle of lap was obtained using Equation (11)

$$\alpha = 180 \pm 2\sin^{-1}\left(\frac{D_2 - D_1}{2C}\right) \quad (11)$$

where,
α_1 = Angle of lap for driving pulley (rad)
α_2 = Angle of lap for driven pulley
C = Centre to centre distance between driving pulley and driven pulley
However, for open belt, angle of lap is given as;

$$\alpha = 180 - 2\sin^{-1}\left(\frac{D_2 - D_1}{2C}\right) \quad (12)$$

The torque is obtained from the Equation (13)

$$T = Fr \quad (13)$$

where,
T = Torque
F = Force
The belt tension is given by Equation (14)

$$2.3 log\left(\frac{T_1}{T_2}\right) = \mu\alpha \quad (14)$$

where, α = angle of wrap of an open belt
μ= coefficient of friction = 0.47
T_1= Tension in the tight side of the belt
T_2= Tension in the slack side of the belt
Also;

$$P = (T_1 - T_2)V \quad (15)$$

$P = (T_1 - T_2)rw$ (16)

Where T_1 and T_2 are tension on the tight and slack sides respectively (N)

The shaft diameter was calculated from Equation (17)

$d^3 = \frac{16}{\pi S_S}\sqrt{(K_b M)^2 + (K_t T_d)^2}$ (17)

where,

M=Bending moment

For suddenly applied load (heavy shock), the following values are recommended for K_b and K_t

K_b= 2 to 3

K_t= 1.5 to 3

Selecting material of shaft SAE 1030

S_{ut}= 527MPa

S_{yt}=296MPa

K_L= Load factor=1.75 for line shaft

$\tau_{max \leq 0.30 S_{yt}}$

$\tau_{max \leq 0.18 S_{ut}}$

S_{ut}= Ultimate yield strength

RESULTS AND DISCUSSION

Table 1 shows the results of detailed design of the multipurpose slicing machine. The slicing force, Torque, power required were calculated as 250.00N, 20 Nm, and 1 hp respectively. The diameter of the driver, diameter of the driven speed of the driver pulley, speed of the driven pulley, and angular velocity of slicing disc were obtained as 50.00mm, 100.00mm, 480rpm, and 50.272rad/s.

Table 1. Results of Detailed Design

S/N	Design Parameters	Units	Value Obtained
1	Diameter of the driver	Mm	50.00
2	Diameter of the driven	Mm	150.00
3	Speed of the driver pulley	Rpm	1440
4	Speed of the driven pulley	Rpm	480
5	Angular velocity of slicing disc	rad/s	50.272
6	Slicing force of the crop	N	254.370
7	Power required to slice crop	hp	1
8	Distance between the driver and driven pulley	m	0.4
9	Belt length	m	1.24
10	Lap angle	Rad	2.89
11	Required torque	Nm	0.2133
12	Tension in the tight side of the belt	N	1,608.36
13	Tension in the slack side of the belt	N	972.407
14	Diameter of shaft	mm	20.00

Several samples of yams and potatoes measured to be 6.55 kg using a weighing balance was used to evaluate the machine for performance. The samples were sliced for 85 seconds using machine and 800 seconds using manual method via knife and hand; the mass of the properly sliced samples and broken sliced samples were 6.00 kg and 0.55 kg respectively.

Mass of collected samples = 6.55 kg

Mass of properly sliced samples= 6.00 kg

Mass of broken sliced samples= 0.55 kg

Time required to sliced samples mechanically = 85 seconds

Time required to sliced samples manually = 800 seconds

The machine throughput capacity was calculated using Equation (18) (Orhorhoro *et al.*, 2018).

$M_C = \frac{M}{T}$ (18)

where,

W = Mass of fresh plantain fingers (kg)
T = Slicing time (seconds)
Using machine;
$M_C = \frac{6.55\ kg}{85} = 0.0771\ kg/seconds$
Using manual method;
$M_C = \frac{6.55\ kg}{800} = 0.00819\ kg/seconds$
The efficiency of the machine is calculated using Equation (19).

$$Eff. = \frac{M_1 - M_2}{M} \times 100 \quad (19)$$

where,
M_1 = Mass of properly sliced samples
M_2 = Mass of broken sliced samples
$Eff. = \frac{6.00-0.55}{6.55} \times 100 = 83.21\ \%$
The slicing time for collected samples by machine and manual were determined to be 85 seconds and 800 seconds respectively. Thus, the machine sliced faster than the manual method of using hand and knife. The machine throughput capacity and efficiency of the machine were obtained as 0.0771 kg/seconds and 83.21%. Therefore, the machine is efficient and when commercialized, it can solve the laborious, time wasting, and inefficient manual method of slicing harvested crops that is currently practice in average Nigerian homes.

CONCLUSION

The multipurpose slicing machine was designed, and evaluated for performance. With this design, the problems of safety, quality and quantity of sliced harvested crops associated with manual slicing have been eliminated. The slicer is environmental and user friendly and does not require any special skill to operate. The slicing efficiency of the machine was calculated to be 83.21 %. Besides, the slicing time of 85 seconds against 800 seconds of manual slicing were obtained for slicing 6.55kg of harvested crops.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Adesina, A. O., Ajiboshin, I. O., Adedeji, W. O., and Adelana, S. O., (2015). Design, Development and Performance Evaluation Of Plantain Slicing Machine, *International Journal of Emerging Trends in Engineering and Development*, Issue 5(1), pp. 204-216

Adewumi, B. A., Adejumo, O., Famurewa, J. A. (2011). Motorization of a plantain slicer for improved capacity and efficiency. Manuscript prepared for publication in the International Journal of Food Science and Technology, UK

Agboola, S., (1992). Technologies for Small-scale Storage of Grains in Nigeria, proceedings of 3rd CODRI seminar on Food Storage, Processing and Utilization. CODRI 1(1), pp.22-27

Akinyemi, S. O., Aiyelaagbe, I. O., & Akyeampong, E. (2010). Plantain (Musa spp.) Cultivation in Nigeria: a Review of Its Production, Marketing and Research in the Last Two Decades, Acta Horticulturae, 1, 879, pp. 211-218.

Arisa, N.U., Adelekan, A.O., Alamu, A.E., and Ogunfowora, E.J. (2013). The effect of pretreatment of plantain (Musa Paradisiacal) flour on the pasting and sensory characteristics of biscuit”. International Journal of Food and Nutrition Science, vol. 2(1), pp. 10-12

Food and Agricultural Organization of United Nation (1990): Root tubers, plantains and banana in human nutrition series, 24, Rome-Italy, pp. 37-45

Igbeka, J. and Olumeko, D., 1996. An Appraisal of Village Level Grain Storage Practices in Nigeria, *Journal of Agricultural Mechanisation in Asia, Africa and Latin America,* 27(1), pp.29-33

Ikpe, A.E., Orhorhoro, E.K., Erhinyodavw, O. (2018). Design of a Multi-Purpose Crushing Machine for Processing of Food Grains in Nigeria. *International Journal of Research Publications*, 9(1), pp. 1-9

Mahvash, M., and Hayward, V., (2001). Haptic Rendering of cutting: A fracture Mechnics Approach, Haptics-e, 2(3), pp. 1-12

Marriott, J., and Lancaster, P.A. (1983). Bananas and Plantains, In: Chan, H.T. (ed.): Handbook 6 of Tropical Foods. Marcel Dekker, New York, USA. pp. 85-143

McGorry, R. W., Dowd, P.C., and Dempsey, P.G., (2005). The effect of blade finish and blade edge angle on forces used in meat cutting operations, *Applied Ergonomics*, 36(1), pp. 71– 77

Orhorhoro, E.K., Odinikuku, E.W., and Salisu, S., (2018). Performance Evaluation of an Improved Roasted Groundnut Seeds Decorticating Machine, *Nigerian Journal of Engineering Science Research, (NIJESR)*, 1(1), pp.30-39

Orhorhoro, E.K., Oyejide, J.O., and Salisu, S. (2018). Design and simulation of continuous melon fruit depodding machine, *Nigerian Journal of Technological Research (NJTR),* 13(2), pp.51-57

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), pp. 656 – 662

Sonawane, S.P., Sharma, G.P., and Pandya, A.C., (2011). Design and development of power operated banana slicer for small scale food processing industries, *Res. Agr. Eng.,* 57, pp.144–152

Yomeni, M. O., Njoukam, J., and Tchango, T. J. (2004). Influence of the stage of ripeness of plantains and some cooking bananas on the sensory and physicochemical characteristics of processed products. *Journal of the Science of Food and* Agriculture, 84(9), pp.1069-1077.

Yusuf A. O., and Abdullahi I., (2007). Development of Potato Slicing Machine, *Continental Journal of Engineering Sciences* 2, pp. 49 - 57