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DEVELOPMENT OF ENVIRONMENTAL FRIENDLY MULTI-CROP SLICING MACHINE TO ERADICATE UNHYGIENIC MANUAL PROCESSING FOR HEALTH SAFETY

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ABSTRACT

Background: Human health safety is very important and considered as the number one criterion in the design and fabrication of any food processing machine. Manual slicing methods are unhygienic, risky, stressful and inefficient while the use of an internal combustion engine as prime mover in the food processing machine is not environmental friendly due to the emission of gases.

Objectives: The aim of this study was to design, fabricate and evaluate for performance an environmental friendly and hygienic multi-crop slicing machine.

Methods: The major components of the machine include the hopper, mainframe, driving pulley, belt, driven pulley, shaft, main bearings, crank plate, connecting rod, slicing unit, groove bearings, spacers, electric motor and outlet. The machine is powered by a variable speed, three-phase 0.75 kW electric motor with rotational speed ranging between 284 and 800 rpm. The performance of the machine was evaluated in slicing six different crops namely yam, carrot, sweet potato, onion, plantain and cucumber at three machine speeds of 190, 362 and 533 rpm while the slice thickness was also varied as 3, 5 and 8 mm. The parameters that were investigated include functional efficiency (FE), slicing efficiency (SE), percentage mechanical damage (MD), percentage materials lost (ML), percentage materials retained (MR), throughput (TP), slicing capacity (SC) and quality performance efficiency (QPE).

Results: Major performance criteria obtained for yam were 90.4% FE, 93.7% SE, 156.7 kg/h TP, 84.8% QPE and 11899 slices per hour. 88% FE, 93.7% SE, 120.7 kg/h TP, 82.4% QPE and 9365 slices per hour were obtained for sweet potato. 85% FE, 95.8% SE, 138.5 kg/h TP, 81.5% QPE and 31300 slices per hour were obtained for the carrot. 78% FE, 98.3% SE, 68.4 kg/h TP and 77% QPE were obtained for onion. 89% FE, 92.5% SE, 83.5 kg/h TP, 82.5% QPE and 15876 slices per hour were obtained for plantain. 93.5% FE, 94% SE, 128 kg/h TP, 88% QPE and 13790 slices per hour were obtained for cucumber. The result of the study shows that the machine can slice any fruit as well as root and tuber crops satisfactorily.

Conclusion: The performance evaluation revealed that any of the speed and thickness range can be used without a significant side effect.

Keywords: multi-crop; functional efficiency; percentage materials retained; throughput; quality performance efficiency

INTRODUCTION

A machine is a mechanical or electromechanical device or contrivance having two or more relatively constrained component parts which are actuated by a power source to transmit or modify force and motion required to accomplish some tasks or get some work done. The multipurpose crop slicing machine is a machine designed purposely for slicing different types of crops irrespective of the mechanical properties of such crops. Some of the crops in this category include plantains, bananas, cucumbers, carrots, okra, cocoyam, cassava, yams, etc. In designing such a machine knowledge of the mechanical properties of various crops which have been established by various researchers is very paramount (Kolawole *et al.*, 2007; ASAE, 2003; Schott, 2003; Altuntas *et al.,* 2005).

Plantain, bananas, cocoyam and yams are popular staples in Africa and in many other countries of the world. They contain ash, protein and the vitamins and are used in the human diet. It was also reported by Kachru *et al.* (1995) that unripe plantain is a major source of iron. This set of crops can be taken in fried, boiled, roasted and baked form. They can also be processed into chips. Through slicing, drying and grinding operation, they can be transformed to flour which is also consumed when baked. The flour can be reconstituted in boiled water to form dough which is taken with different kinds of delicious soup in many African countries. Various travellers, office workers and school children demand for banana, plantain and yam slices in form of fried chips greatly. In an effort to make these readily available, several means have been devised in cutting them into slices before being processed into chips and flour.

Cucumbers, carrots and okra are very good source of vitamin and minerals in human diet. They can be eaten raw or processed into salad which is taken as part of daily meal. Cucumbers are best harvested when they are about 2 inches long up to any size before they begin to turn yellow. Okra has remained a very popular soup in many countries of the world til date. Processing of this set of crop is very advantageous because it makes storage easier due to the reduction in bulkiness and increase in their shelf life. This can be achieved through the process of slicing, drying and grinding.

The kitchen knife method remains a primitive way of slicing crops in large quantities in small, medium and the large scale industries. In this case, a sharp knife is used to slice the crops on a wooden cutting board. The problems associated with this method are fatigue, a low speed which leads to poor output and low income generation, too many staff, hand injury, poor uniformity of chip thickness, high productive time and much energy consumption. The manually operated wooden platform crop slicer is another slow method employed in small scale industries. The crop is pressed and moved against the sharp blades of the machine. The major risk is that when it misses a cut, the machine operator gets his/her finger cut by the exposed sharp blades. It is also time consuming since the operator will be operating in a slow rate to avoid injury. Manually operated cutting knives are also another method in which the crops to be sliced are placed on top of a sharp blade on the base frame of the machine, and the upper handle on which sharp blades are contained is pressed down thereby crops into slices. The major problem here is that when off-loading, one gets his hands injured because of the slices stocked in-between the sharp blades. Due to the slow nature of off-loading, this method has also been considered to be time consuming.

Therefore there is the need to design and develop a more efficient multipurpose crop slicing machine fit for the current commercial challenge. It is an indisputable fact that the disadvantages associated with the aforementioned methods limit the farmers' output with little or no profit margin. However, various researchers across the world have developed machines to cater for each of the crops of concern in this project. In addition to improving the efficiency of these existing machines, there is a need to combine two or more functions in a single machine for better efficiency and productivity. Therefore, the design and development of multipurpose crop-slicing machine is the solution that crop processing industries across the world need to embrace.

2. MATERIALS AND METHOD

2.1 Conception of the Machine

Conception of this machine began from the consideration of the stress, difficulty and hazard involved in the conventional slicing method and the fact that many small and medium scale chips producers are unable to afford the expensive foreign slicing machines. Moreover, the capacity in term of feed per unit operation and the efficiency of those few available locally made slicing machines are not enough. Also, a lot of cost will be saved by employing a single slicing machine for many crops instead of buying different machines to handle various individual crops differently.

2.2 Design Considerations

The following are the considerations employed in the course of carrying out the design

(i) The cost of the multipurpose slicer should be affordable;

(ii) Minimum labour requirements;
(iii) The design should be simple, easy to maintain and should be able to eliminate the limitations of other methods; and
(iv) The materials required to fabricate the machine should be locally available.

2.3 Description and Operation of the Slicing Machine

As shown in the annotated diagram of the multipurpose crop slicing machine contained in Figure 2.1, it is made up of cutting device, support frame, hopper assembly, shaft, bearings, covering guards and electric motor as a source of power. The cutting mechanism consists of the stainless steel blade, blade frame, groove, groove bearings, pulleys, two connecting rods and crank mechanism meant to convert rotary motion of shaft to reciprocating motion of the cutting unit. The blade is orientated such that it is parallel to the hopper assembly and perpendicular to the crops meant to be sliced.

Moreover, the cutting mechanism of the machine is provided with adjustable spacers separating the cutting blade from the base plate with which various uniform slicing thicknesses can be achieved. The hopper assembly is made of stainless steel so as to avoid contamination of processed crops by corrosion.

Power is transmitted from electric motor to input shaft via belt and pulley drive system. The crank plates hinged by the shaft on both ends transmit the motion of the shaft to the cutting unit through the connecting rods. Concurrently, the rotary motion of the shaft is converted to the reciprocating motion of the blade by the action of the crank mechanism. The crops loaded vertically in the hopper are fed automatically into the cutting chamber by gravity. As they drop on the base plate by gravity against the motion of the blade, uniform slices as predetermined are picked up by the blade at each reciprocating horizontal stroke of the blade. The operation continues by feeding the hopper with more crops continuously as its content is being exploited. The sliced crops drop inside the collector positioned at the discharge end of the machine. The facts that no stress is involved and no expertise is required in feeding the machine with crops are parts of the major advantages of this design.

2.4 Materials Selection

Materials of fabrication were carefully selected to ensure high quality standard. The following were carefully considered in selecting the materials of construction.

i. Physical and mechanical properties of the material
ii. Chemical property of the materials
iii. Reliability of the material
iv. Availability
v. Maintainability, and
vi. Cost effectiveness

Stainless steel was chosen as the appropriate material for those components that are having direct contact with the crops to avoid contamination by corrosion. Those components that were made of stainless steel include hopper, cutting blades, discharging tray and pressure plate. Spacers were made of aluminum while the remaining components were made of mild steel and galvanized metal sheet.

2.5 Design Calculations

2.5.1 Calculation of shaft and pulley speed

Let the diameter of driving or motor pulley be = d = 8 cm

The rotational speed of driving pulley = n = 284 rpm

The diameter of driven pulley = D = 12 cm

The rotational speed of driven pulley = N

The speed of the driving pulley was measured as 284 rpm using digital Tachometer.

$$\frac{N}{n} = \frac{d}{D} \tag{2.1}$$

$$\frac{N}{284} = \frac{8}{12}$$

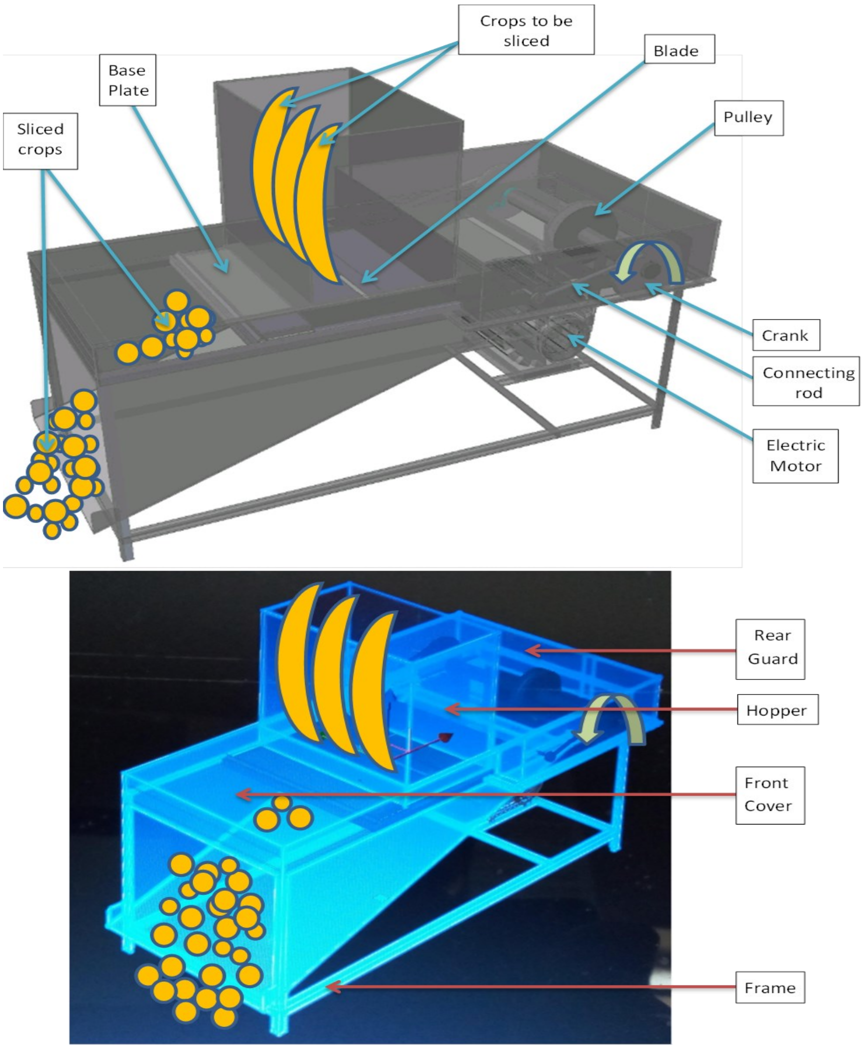

Figure 2.1: Annotated diagram of the multipurpose crop slicing machine

$$N = \frac{284 \text{ x } 8}{12}$$
$$N = 189.3rpm$$
$$N = 190rpm$$

2.5.2 Belt length design

(1) Length (L) of the belt

The length of the belt is given by;

$$L = \frac{\pi}{2}(D + d) + 2C + \frac{(D-d)^2}{4C} \quad (2.2)$$

Where ; L = Length of the belt

D = Diameter of driven pulley = 0.12 m

d = diameter of driving pulley = 0.08 m

C = Centre distance = 0.51 m

$$L = \frac{\pi}{2}(0.12 + 0.08) + 2 \text{ x } 0.51 + \frac{(0.12 - 0.08)^2}{4 \ x \ 0.51}$$
$$L = \frac{\pi}{2}(0.2) + 1.02 + 7.843 \ x \ 10^{-4}$$
$$L = 1.335 \ m = 1335 \ mm$$

(2) Length of belt that passes over the driving pulley in one minute

$$L_d = \pi dn \quad (2.3)$$
$$L_d = \pi \ x \ 0.08 \ x \ 284$$
$$L_d = 71.377 \ m/min$$

(3) Length of belt that passes over the driven pulley in one minute

$$L_D = \pi DN \quad (2.4)$$
$$L_D = \pi \ x \ 0.12 \ x \ 190$$
$$L_D = 71.628 \ m/min$$

(4) Speed of the belt on the driving pulley

$$v_1 = \frac{\pi dn}{60} \quad (2.5)$$

$$v_1 = \frac{\pi\ x\ 0.08\ x\ 284}{60}$$

$$v_1 = 1.1896 \text{ m/s}$$

$$v_1 = 1.19 \text{ m/s}$$

(5) Speed of the belt on the driven pulley

$$v_2 = \frac{\pi DN}{60} \quad (2.6)$$

$$v_2 = \frac{\pi\ x\ 0.12\ x\ 190}{60}$$

$$v_2 = 1.1938 \text{ m/s}$$

$$v_2 = 1.194 \text{ m/s}$$

2.5.3 Torque transmitted by electric motor

$$T_{motor} = \frac{P\ x\ 60}{2\pi n} \quad (2.7)$$

$P = 1.08$ hp $= 1.08 \times 746 = 805.68$ Watt

$$T_{motor} = \frac{805.68\ x\ 60}{2 \text{ x } \pi\ x\ 284}$$

$$T_{motor} = \frac{48340.8}{1784.425}$$

$$T_{motor} = 27.09 \text{ Nm}$$

$$T_{motor} = 27.1 \text{ Nm}$$

2.5.4 Torque transmitted by shaft

$$T_{shaft} = \frac{P\ x\ 60}{2\pi N} \quad (2.8)$$

$$T_{shaft} = \frac{805.68\ x\ 60}{2 \text{ x } \pi\ x\ 190}$$

$$T_{shaft} = \frac{48340.8}{1193.805}$$

$$T_{shaft} = 40.493 \text{ Nm}$$

$$T_{shaft} = 40.5 \text{ Nm}$$

2.5.5 Angle of lap or angle of contact of the belt (ϴ)

The angle of lap is given by;

$$\Theta = 180^0 - 57.3\frac{(\text{d}-\text{D})}{C} \quad (2.9)$$

Recall; D, d and C have been defined in the equation above

$$\Theta = 180^0 - 57.3\frac{(0.08 - 0.12)}{0.51}$$

$$\Theta = 180^0 - (-4.494)$$

$$\Theta = 180^0 + 4.494)$$

$$\Theta = 184.5^0$$

$$\Theta = 185^0$$

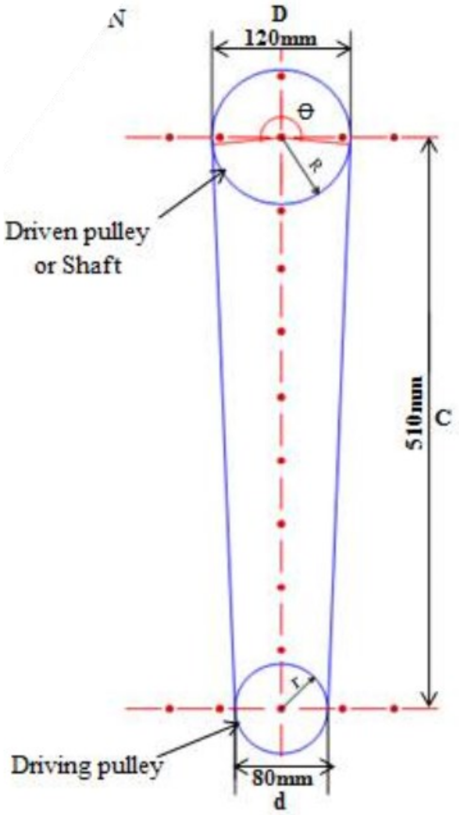

Figure 2.2: Belt design

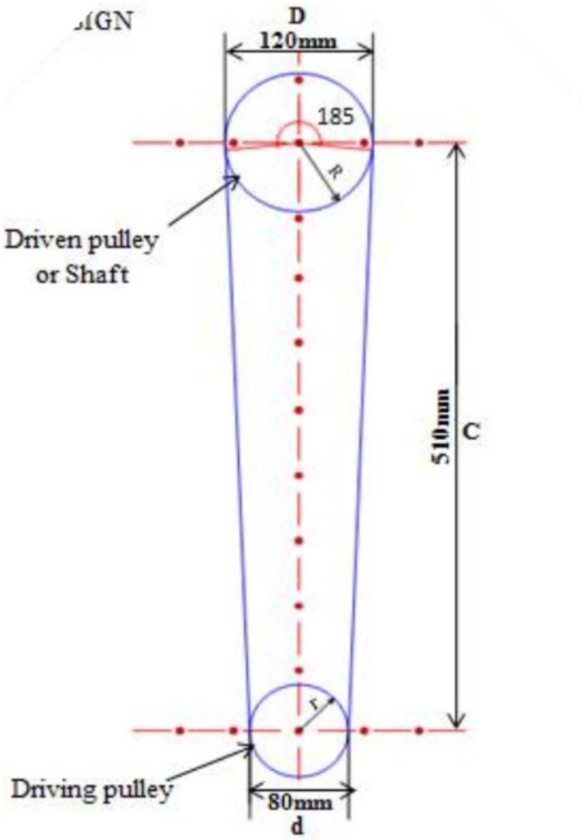

Figure 2.3: Angle of wrap (Θ)

2.5.6 Tension on tight and slack sides of the belt

Let :- T_1 = Tension on the tight side and

T_2 = Tension on the slack side

The tensile ratio is given by;

$$\frac{T_1}{T_2} = e^{\theta k} \qquad (2.10)$$

Where:- e = base of natural logarithms = 2.71828

K = A constant for Vee-belt design = 0.5123

θ = Arc of contact in radian

$$\theta(\text{radian}) = \theta^0 x \ \frac{\pi}{180} \qquad (2.11)$$

$$\theta(\text{radian}) = 185^0 x \ \frac{\pi}{180}$$

$$\theta(\text{radian}) = 3.2289 \ rad$$

Therefore,

$$\frac{T_1}{T_2} = 2.71828^{(3.2289 \ x \ 0.5123)}$$

$$\frac{T_1}{T_2} = 2.71828^{1.6541}$$

$$\frac{T_1}{T_2} = 5.2286$$

$T_1 = 5.2286T_2$

Torque (T) transmitted by the driving pulley is given as

$$T = (T_1 - T_2)r \qquad (2.12)$$

$27.09 = (T_1 - T_2)0.04$

$27.09 = (5.2286T_2 - T_2)0.04$

$27.09 = 4.2286T_2 \, x \ 0.04$

$4.2286T_2 = 677.25$

$T_2 = \frac{677.25}{4.2286}$

$T_2 = 160$ N

Recall:- $T_1 = 5.2286T_2$

$T_1 = 5.2286 \ x \ 160$

$T_1 = 837$ N

2.5.7Determination of loads on the shaft

The masses of the two cranks together with the attached connecting rod and the mass of pulley were determined using weighing balance. Their values were recorded as 1.245 kg, 1.245 kg and 1.173 kg respectively. Their weights were calculated in Newton (N) as shown below by multiplying their masses with acceleration due to gravity which is 9.81 m/s^2. Moreover, the tension T_1 and T_2 exerted by the belt on the shaft were also calculated as shown below in order to calculate the total force acting at point (C) on the shaft. Vertical load acting on the shaft at (A) = 1.245 kg = 1.245 x 9.81 = 12.2 N

Weight of pulley (W_p) = 1.173 kg = 1.173 x 9.81 = 11.5 N

Vertical load acting on the shaft at (E) = 1.245 kg = 1.245 x 9.81 = 12.2 N

Total vertical load acting on the shaft at (C)

$$TVL_C = W_p + T_1 + T_2 \qquad (2.13)$$

$TVL_C = 11.5 + 160 + 837$

$TVL_C = 1008.5$ N

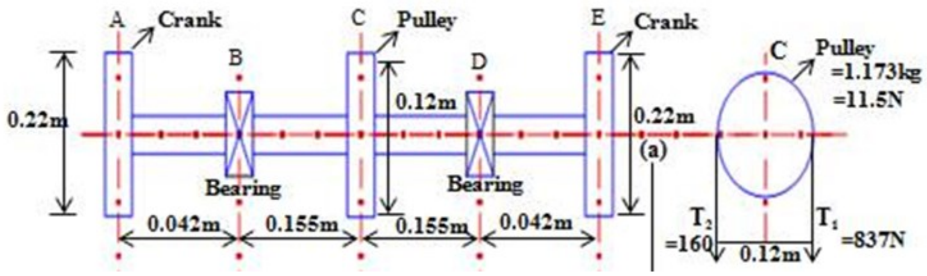

Figure 2.4 Determination of belt tension (T_1 and T_2) on the shaft

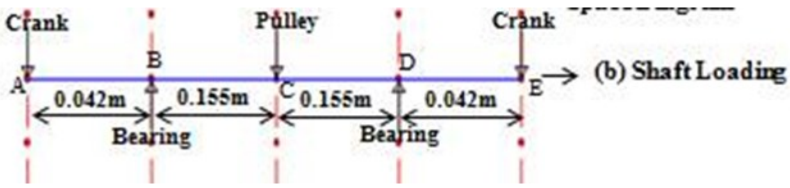

Figure 2.5 Shaft loading

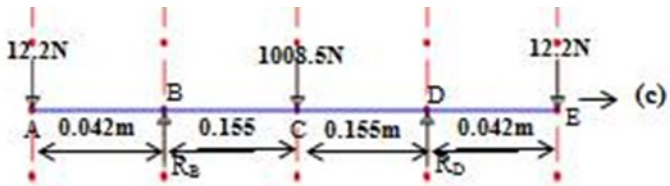

Figure 2.6: Free body diagram of the loaded shaft

2.5.8 Determination of bending moment (M) of the shaft

Having determined the loads acting on the shaft, it became easy to calculate the reactions on bolt bearings by summing up the forces.

$R_B + R_D = 12.2 + 12.2 + 1008.5$

$R_B + R_D = 1032.9$ N (2.14)

Taking moment about (B)

$\sum^{\frown} M_B = 0$

$-12.2 \times 0.042 + 1008.5 \times 0.155 - R_D \times 0.31 + 12.2 \times 0.352 = 0$

$-0.5124 + 152.3175 - 0.31R_D + 4.2944 = 0$

$160.0995 = 0.31R_D$

$$R_D = \frac{160.0995}{0.31}$$

$R_D = 516.45$N

Recall:- $R_B + R_D = 1032.9$ N

:- $R_B = 1032.9 - R_D$

$R_B = 1032.9 - 516.45$

$R_B = 516.45$ N

Bending Moment at (A)

$M_A = 0$

Bending Moment at (B)

$M_B = 12.2 \times 0.042 = 0.5124 = 0.51$ Nm

Bending Moment at (C)

$M_C = 12.2 \times 0.197 - 516.45 \times 0.155 = 2.4034 - 80.0497 = -77.6464 = -77.65$ Nm

Bending Moment at (D)

$M_D = 12.2 \times 0.352 - 516.45 \times 0.31 + 1008.5 \times 0.155$

$M_D = 4.2944 - 160.0995 + 156.3175$

$M_D = 0.5124 = 0.51$ Nm

Bending Moment at (E)

$M_E = 12.2 \times 0.394 - 516.45 \times 0.352 + 1008.5 \times 0.197 - 516.45 \times 0.042$

$M_E = 4.8069 - 181.7904 + 198.6745 - 21.6909$

$M_E = 203.4813 - 203.4813$

$M_E = 0$

2.5.9 Determination of shaft diameter (d)

The diameter of the shaft can be estimated using the equation below;

$$\sqrt{(K_m \ x \ M)^2 + (K_t \ x \ T)^2} = \frac{\pi}{16} \text{ x } \tau \text{ x } d^3 \tag{2.15}$$

$$d^3 = \frac{16}{\pi\tau}\sqrt{(K_m \ x \ M)^2 + (K_t \ x \ T)^2} \tag{2.16}$$

Where:- d = diameter of shaft

τ = maximum allowable shear stress

= 56 MPa for shaft without keyway

= 42 MPa for shaft with keyway

T = maximum torsional moment

M = maximum bending moment

K_t = combined shock and fatigue factor for torsion

= 1.0 for gradually applied or steady load

K_m = combined shock and fatigue factor for bending

= 1.5 for gradually applied or steady load in rotating shaft

From the design calculation above,

T = 40.5 Nm

M = 77.65 Nm

K_t = 1.0

K_m = 1.5

τ = 56 MPa

$$d^3 = \frac{16}{\pi \ x \ 56 \ x \ 10^6}\sqrt{(1.5 \ x \ 77.65)^2 + (1.0 \ x \ 40.5)^2}$$

$$d^3 = 9.0946 \ x \ 10^{-8}\sqrt{13566.42563 + 1640.25}$$

$$d^3 = 9.0946 \ x \ 10^{-8} \ x \ 123.3153503$$

$$d^3 = 1.121499861 \ x \ 10^{-5}$$

$$d = \sqrt[3]{1.121499861 \ x \ 10^{-5}}$$

d = 0.02238 m

d = 2.24 cm

d = 22.4 mm

Therefore 30 mm diameter shaft was chosen

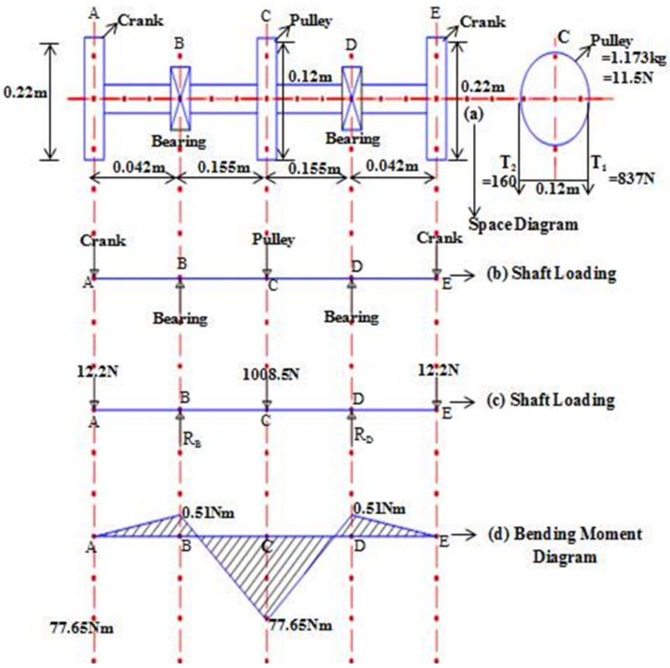

Figure 2.7: Bending moment diagram

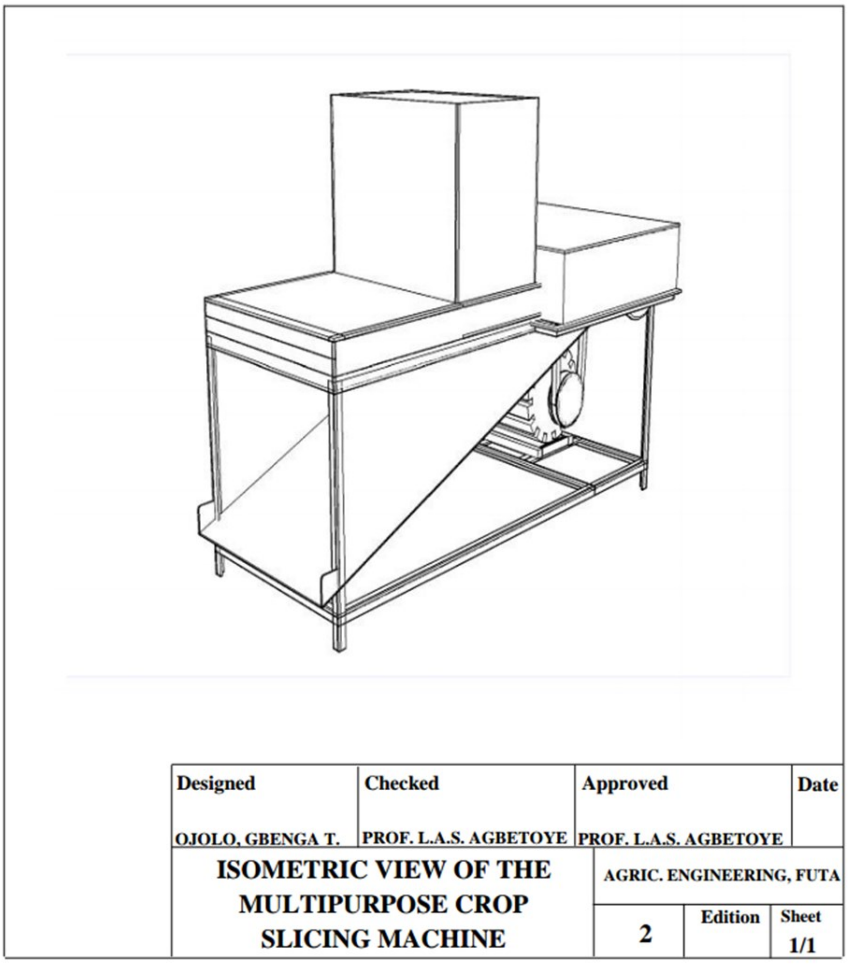

Figure 2.8: Isometric drawing of the multipurpose crop slicing machine

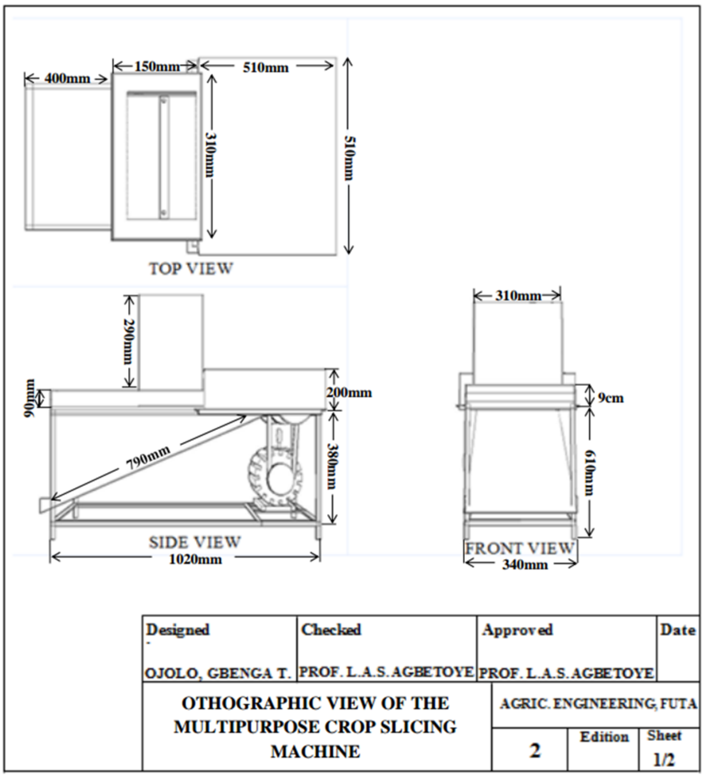

Figure 2.9: Autographic projection of the multipurpose crop slicing machine

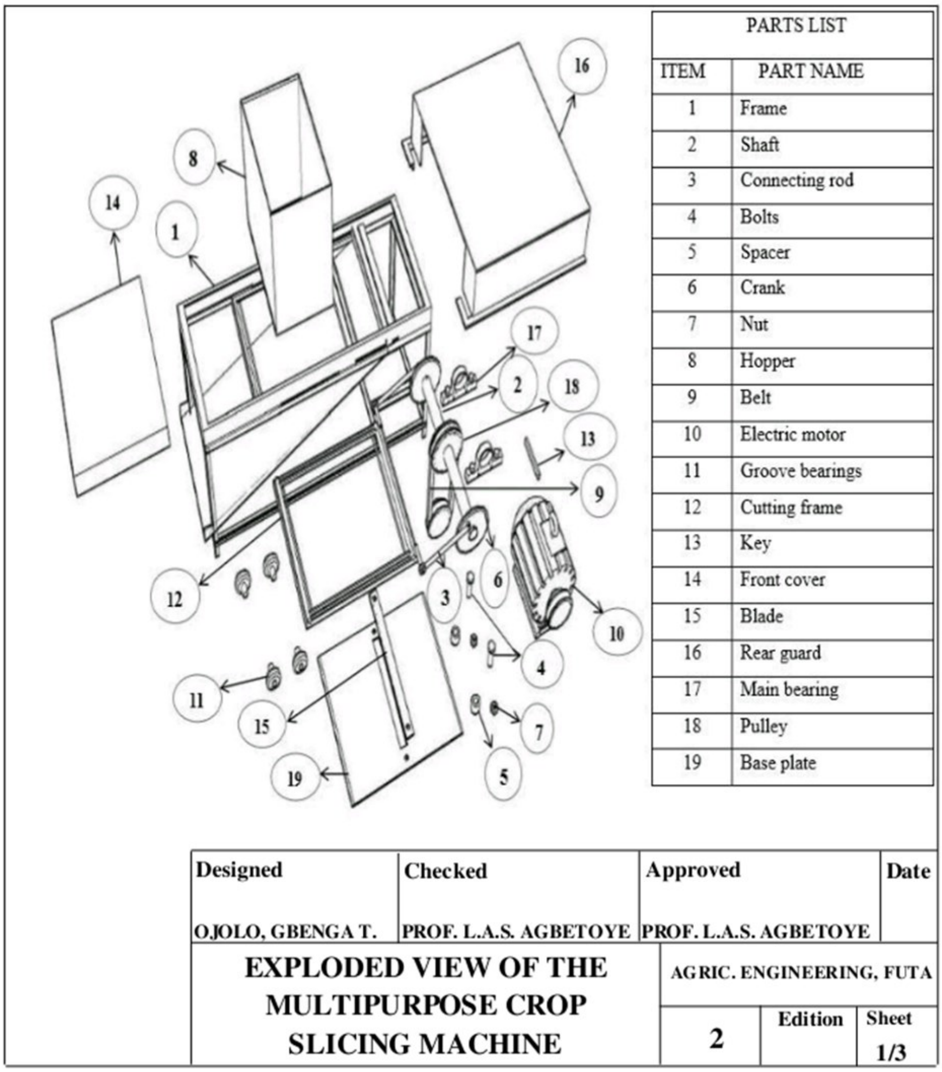

Figure 2.10: Exploded view of the multipurpose crop slicing machine

2.6 Estimate of the Cost of Production of the Machine

The cost of production of the machine was estimated in stages by calculating cost of bought out components, fabricated components, machining jobs, non-machining jobs, testing materials and miscellaneous items such as machinery overhead, cost of labour, transportation, call cards, hiring of weighing balance and tachometer.

2.7 Performance Evaluation of the Machine

2.7.1 Sourcing and preparation of test samples

Six different crops namely; Yam, Plantain, potato, Carrot, Onion and Cucumber used for tests were purchased from a local market in Akure, Ondo State, Nigeria. The yam and potato tubers among the test crops were peeled and cut into samples. Plantains and onions were peeled and cleaned concurrently with carrot and cucumber in readiness for the performance test. A digital weighing scale was used in determining the mass of all the samples.

2.7.2 Test variables and experimental design

Many factors which could affect the performance of the machine include cutting resistance of the crop, age of the crop, orientation of the hopper, moisture content, machine speed, size of crops, type of crops and variety of crops (Agbetoye and Balogun, 2009).
Kachru (1996) developed a plantain-slicing machine and evaluated its performance with respect to parameters such as cutting velocity, orientation of hopper, shear angle, level angle, number of blades of the machine.

The factors considered critical to the performance of the multipurpose crop slicing machine which were investigated in the present work include thickness of crop slices, mass of crop, machine speed and type of crop. Tests were conducted at 190 rpm, 362 rpm and 533 rpm to slice yam, carrot, potato, onion, plantain and cucumber respectively. The slicing thickness of 3 mm, 5 mm and 8 mm were investigated. The experiment was arranged in a Randomized Block Design.

2.7.3 Experimental procedure

A tachometer was employed to ensure correctness of operating speeds as determined in the design calculation. The tachometer was also used to ascertain variation in the speed of the machine through a variable speed electric motor. The output materials obtained from the machine outlet was collected and separated into two groups, that is, good slices and damaged slices. The mass of each category was determined by an electronic weighing balance while the mass of materials left in the machine was also determined. The time taken for each test run was recorded with stopwatch while the number of slices produced per unit time was counted for each sample.

3. RESULTS AND DISCUSSIONS

3.1 The Fabricated Multipurpose Crop Slicing Machine and its Performance Test Data

Plate 3.1 shows the picture of the fabricated multipurpose crop slicing machine and Plate 3.2 shows the pictures of crops sliced by the machine during testing. The performance of the machine was evaluated with carrot, cucumber, onion, plantain, sweet potato and yam at various machine speeds and slice thicknesses following the experimental procedure elucidated in chapter two. Table 3.1 shows the summary of the data obtained from the evaluation. Test parameters that were measured in evaluating the performance of the machine as contained in Table 3.1 are throughput, functional efficiency, percentage materials loss, percentage mechanical damage, percentage materials retained, slicing capacity, slicing efficiency and quality performance efficiency. The data obtained were subjected to statistical analysis using ANOVA and Duncan's Multiple Range Test. Test of significance was also conducted at 5% reliability level.

Ideally, the effective and efficient functionality of a slicing machine is confirmed by comparing its slicing efficiency, functional efficiency and quality performance efficiency. These parameters for an excellent slicing machine are supposed to follow hierarchical order. That is to say the value of slicing efficiency should be greater than that of functional efficiency while functional efficiency should be greater than quality performance efficiency. In other word, the value of quality performance efficiency should be the least of all the three efficiencies while that of slicing efficiency should be the highest. Table 3.1 shows clearly that these three parameters follow the normal hierarchical order for all the crops tested. This result confirms the accuracy of this research as well as the effective and efficient functionality of this multipurpose crop slicing machine.

4. CONCLUSIONS

An environmental friendly and hygienic multipurpose crop slicing machine suitable for slicing various agricultural produce into regular slices for the purpose of drying, roasting, frying, handling, consumption, better analysis, storage, packaging, marketing, transportation, extracting desirable constituents, fermentation and flower production has been designed, fabricated and evaluated for performance. Test results with the machine in slicing samples of onion, carrot, yam, sweet potato, plantain and cucumber indicated satisfactory performance. Since the statistical analysis carried out showed that the variation of speed does not have significant effects on most of the performance criteria examined, the machine will give satisfactory performance within the designed speed range of 190-533 rpm. Furthermore, the fact that variation of slice thickness does not have so much significant effects on most of the performance criteria considered for each crop sliced is also another desirable advantage. The end users can vary slice thickness at will within the tested range (3-8 mm) and beyond depending on his/her desire without any fear. The result of the study shows that the machine can slice any fruit as well as root and tuber crops satisfactorily.

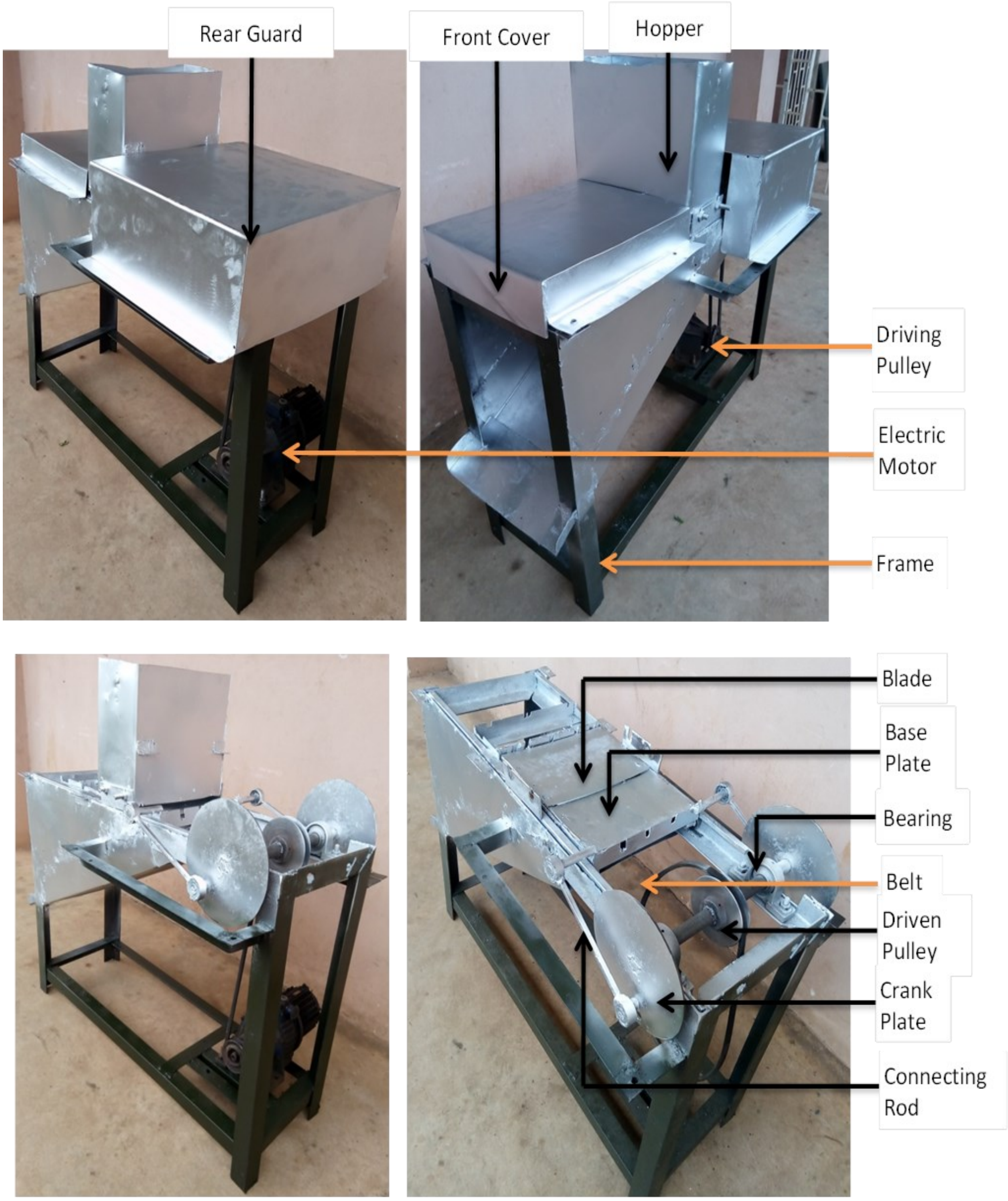

Plate 3.1: Pictures of the multipurpose crop slicing machine

(a) Cucumber (b) Plantain

(c) Sweet potato (d) Onion

(e) Carrot (f) Yam

Plate 3.2: Pictures of different crops sliced by the multipurpose crop slicing machine

Table 3.1: Optimum performance criteria for the selected crops

Crops	FE (%)	SE (%)	TP (kg/h)	SC(NỌ S/h)	ML (%)	MD (%)	MR (%)	QPE (%)
Carrot	85.02	95.82	138.49	31299.67	4.49	3.51	10.49	81.49
Cucumber	93.54	94.03	128.02	13789.89	3.43	5.52	3.03	88.02
Onion	78.05	98.24	68.38		8.39	1.42	13.57	76.62
Plantain	89.22	92.53	83.54	15876.22	4.73	6.75	6.04	82.48
Potato	87.98	93.72	120.73	9364.67	5.07	5.56	6.95	82.41
Yam	90.44	93.75	156.68	11899.11	3.87	5.63	5.69	84.82

*FE = Functional Efficiency; SE = Slicing Efficiency; TP = Throughput; SC = Slicing Capacity; ML = Materials Lost; MD = Materials Damaged; MR = Materials Retained; QPE = Quality Performance Efficiency

REFERENCES

Agbetoye, L. A. S and Balogun, A. (2009). Design and Performance Evaluation of a Multi -Crop Slicing Machine; International Symposium on Food Processing, Monitoring Technology in Bioprocesses and Food Quality Management. Potsdam, Germany. CIGR Section VI

Altuntas, E, Ozgoz, H. And Taser, O.F. (2005): Some Physical Properties of Tubers. *Journal of food engineering,* 58: 42 - 47.

ASAE Standards. (2003): Moisture Measurement – Root and Stem Tubers. S352.2. ASAE. St Joseph, Mich, USA.

Kachru, R. P. D., Nachiket, K. C. and Balasubramaniam, D. (1995). Physical and mechanical properties of green banana fruit. *Journal of Food Engineering, 26*: 369–378.

Kachru, R. P. D.; Balasubramania, D. and Nachiket, K. C. (1996). Design, Development and Evaluation of Rotary Slicer for Raw Banana Chips. *Agricultural Mechanisation in Africa, Asia and Latin America,* **27**(4): 61 – 64.

Kolawole, O.P., Agbetoye, L.A.S. & Ogunlowo, A.S. (2007). Strength and elastic properties of cassava tuber. *International Journal of Food Engineering*, 3(5): 1-12.

Schott, L. (2003): Mechanical and Physical Properties of Flour Extracted from Taro *Colocasia esculenta,* 16: 12 – 14.