# DEVELOPMENT OF A TOMATO SLICING MACHINE

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## ABSTRACT

In many parts of Nigeria, post-harvest and storage spoilage losses are enormous because of poor handling facilities for agricultural produce. This problem leads to undue scarcity of agricultural produce immediately after harvesting season. In order to address this problem, a tomato slicing machine was designed, fabricated and tested. This machine is intended to add value to ripped tomatoes by slicing and exposing the water cells for easy drying in a dryer on an industrial scale. The sliced dried tomato chips gotten will be packaged for storage in order to improve its shelf life. The performance evaluation of the fabricated machine was carried out to be very efficient. Several quantity of measured tomatoes were fed into the machine in a given time taking about 2kg in a minute under a continuous feeding. The feed and slicing time were observed and measured. The results of the tests were tabulated and analyzed. The machine provides a lasting solution to the drudgery associated with tomato slicing.

**KEYWORDS**: Design, fabrication, testing, tomato slicing, processing.

## 1. INTRODUCTION

Tomato (*Solanum lycopersicum*) is one of the most important vegetable plants in the world. A major vegetable crop that has achieved tremendous popularity over the last century. It is grown in practically every country of the world - in outdoor fields, greenhouses and net houses. It is said to have originated in western South America, and domestication is thought to have occurred in Central America. (Zvi H. W 2000). Because of its importance as food, tomato has been breed to improve productivity, fruit quality, and resistance to biotic and a biotic stresses. Tomato has been widely used not only as food, but also as research material.

Tomato is a major agricultural crop cultivated in Nigeria especially in the Northernpart. Oyeniran (1988) reported that in Nigeria, figures like 6 million tonnes of tomatoes have been given as annual production level. During harvesting period, several tones of this tomato fruit are produced. Unfortunately, they are not only seasonal but highly perishable and deteriorate very fast loosing almost all the required attributes and some may likely result to total waste because they cannot be stored for longer duration. It has been shown that as high as 50% of these produce are lost between rural production and town consumption in the tropical areas (Oyeniran, 1988). Due to perishability, farmers are losing a bulk of produce each year. Although much is consumed locally and a little exported to other neighbouring African countries, yet large wastages is still incurred during each harvesting season. This reason coupled with the fact that tomato is a seasonal produce, causes the scarcity of this fruit to step in immediately the harvesting period is over. Tomato is a very nutritive fruit with moisture content of about 90% (Akpinar et al., 2003).

Tomatoes, aside from being tasty, are very healthy as they are a good source of vitamins A and C. It also helps maintain capillaries, bones and teeth and aids in the absorption of iron. It is grounded and used for several food preparations. It can be eaten raw. Also, it can be sliced and be used for salad and confectioneries. Tomato could be sliced and dried for storage purposes to take care of the non-harvesting seasons and also to reduce wastage. In developing countries the tomato is becoming a more important part of the food basket but the goal of the farmer is to produce quantity not quality so that people can eat. (Zvi H. W 2000). It is estimated that 45 million tonnes of tomatoes are produced each year from 2.2million hectares excluding the large amount grown in home gardens.(Villareal,1980)

The essence of the slicing before drying is to expose the water cells of the tomato fruit for easy drying. After drying and cooling, the tomato could be packaged for storage. Furthermore, it could be milled to dust and packaged as grounded dried tomato for easy cooking. The objective of this project work is therefore, to design, produce and test a tomato slicing machine as one of the equipment that will facilitate the drying and packaging of dry tomato in order to reduce wastage incurred during harvesting period and also make the tomato fruit last longer during storage in order to take care of the scarcity periods of this particular fruit.

## 2. MATERIALS AND METHOD

### 2.1 Description of the Tomato Slicing Machine

The tomato slicing machine is shown in Fig. 1.

The main components of the machine: Sleeve with knives; Slicing chamber; Discharge chamber; Feed hopper; Structural frame; Slicing bed; Discharge spout; Transmission shaft; Knives carrier; Ball bearings; Pulleys; Belts; Dividing strips; Electric motor; Main casing with reinforcement.

Sharp strips of flat plates are arranged on long sleeve in opposite direction as knives. The sleeve is bolted at the centre of the transmission shaft. The shaft is mounted at the inside centre of the slicing chamber via bearings at the outside of the chamber. The exterior of the shaft on one side is connected to the driven pulley. The driver and the driven pulleys are then connected with a v-belt.

The slicing bed acts as a support for the tomatoes for easy slicing. The slicing bed is a rectangular formation with bolting points at the four edges. The inside of the bed is divided with strips of metals giving gaps for the rotation of the knives in between the gaps. The division is according to the number of knives. The gap between a knife and the bed strip is reasonable enough to allow for the passage of sliced tomatoes. The inlet hopper is arranged to direct and spread the incoming unsliced tomatoes to the slicing beds. One tomato can be split into about four pieces depending on the size.

### 2.2 Mechanics of Operation of the Tomato Slicing Machine

All the components of the machine are systematically arranged on the structural stand. The mechanics of operation of this machine is purely based on the dynamics of the components namely pulleys, belt, shaft, bearings etc. The electric motor provides the primary motion which is transmitted via pulleys, bearings and belt to the shaft and sleeve carrying the knives. The rotational motion of these components, gravitational motion of the tomato fruit through the hopper outlet channel are employed in order to achieve the desired slicing operation. The knives rotate at a medium speed of (1440) rpm in between the dividing stripes on the bed. Slicing of the tomatoes is achieved on the bed with this speed.

The rotary knives are carried on a sleeve which is bolted on a shaft. There are thirty two (32) number of knives. The dimension of one knife is shown in Fig. 2. The thickness of the knife is 2mm. The edges are sharpened to aid slicing.

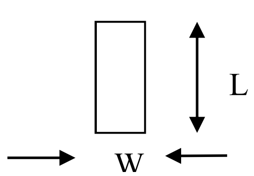



Fig 2. Knife Dimensions

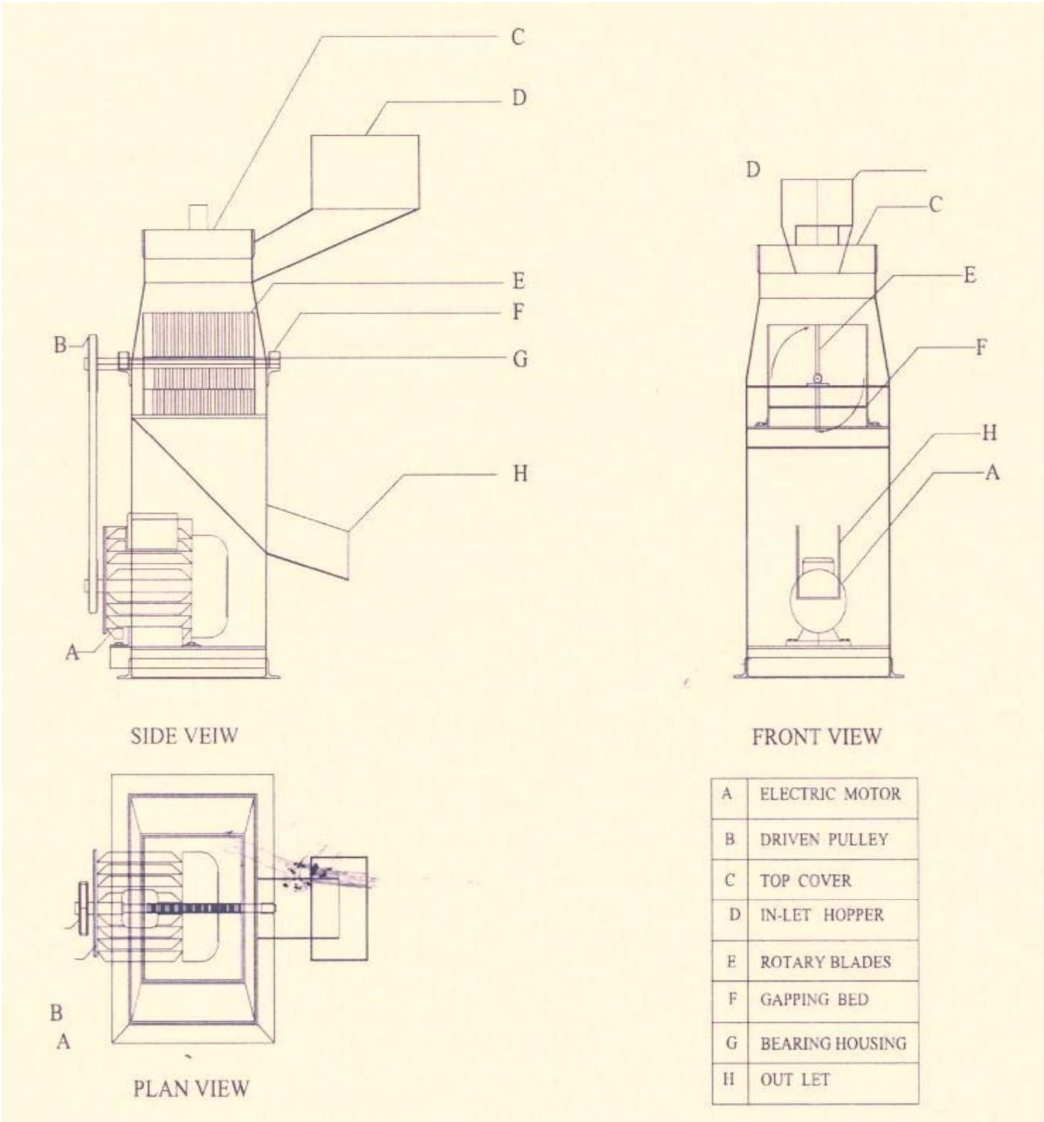
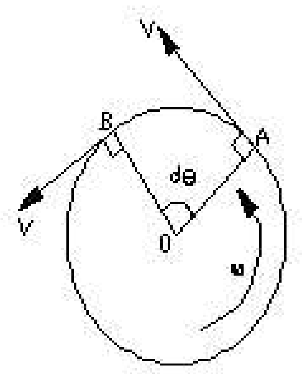


Fig. 1. The Tomato Slicing Machine

### *2.2.1 Rotational Motion and Centrifugal Force (Fc)*

The rotational motion from the shaft of the prime mover (electric motor shaft) is transmitted to the input shaft carrying the driven pulley and knives. For any object of mass M moving in an circular motion, its acceleration is directed towards the centre of the body and its linear velocity is tangential to the radius of the object. The displacement which starts from point A, then to B and continues is in terms of θ. The angular velocity is designated ω. The acceleration (a) of the rotary body is given as (Fig. 3):

$a=\omega^2 r$………………………………………………….. (1)




(J. Hannah & R. Stephens, 1984)
Fig 3. Centrifugal Force

Where r = radius of the object. The acceleration is centripetal. The radially inward, or centripetal force required to produce acceleration is given as

$F_c = Ma = M_{\omega}{}^2 r = MV^2/r$ ………………………………………...(2)

(John Hannah &R.C. Stephens 1984)

If the body rotates at the end of an arm, this force is provided by the tension on the arm, the reaction of this force acts at the centre of rotation and is centrifugal force. It represents the inertia of the body resisting the change in the direction of the motion. A common concept of centrifugal force in engineering problems is to regard it as radially outward force which must be applied to a body to convert the dynamical condition to the equivalent static condition.

### *2.2.2 Rotational Torque (T)*

The value of torque developed by a rotational body is given as the product of the force causing the motion multiplied by the radius of rotation (John Hannah &R.C. Stephens 1984)

$T = F_C \times r$ ……………………………………………………………………….(3)

Where: $F_C$ = Centrifugal Force, R = radius

### *2.2.3 Work Done by a Torque*

If a constant torque T moves through an angle θ

Work done $= T * \theta$ ……………………………………………………………… (4)

If torque varies linearly from zero to a maximum value T

Work done $= \frac{1}{2} T * \theta$ ……………………………………………………………(5)

In general case where $T = f(\theta)$

Work done $= \int f(\theta) de$ …………………………………………………………… (6)

The power (p) developed by a torque T(N.M) moving at ω rad/sec is

$P = T\omega = 2\pi$(watts) ……………………………………………………………… (7)

Where N is the speed in rev/min and

$\omega = \frac{2\pi N}{\epsilon o}$

### *2.2.4 Pulley and belt drive*

The schematic representation of the pulley system is shown in Fig. 4.

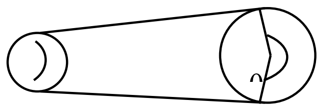


Fig 4. The Pulley System

The velocity ratio between two pulleys transmitting torque or power is given as

$$\frac{W_1}{W_2} = \frac{N_1}{N_2} = \frac{D_2}{D1}$$

i.e. $D_2 = (\frac{N_1}{N_2})\, D_1 = n\, D_1$ ……………………………….(11) (Avallone E.and Baumeister T.,1997)

where: $W_1$ = angular velocity of driver; $W_2$ = angular velocity of driven; $N_1$= rpm of driver; $N_2$ = rpm of driven

$D_1$ = diameter of the driver; $D_2$ = diameter of the driven; θ = angle of lap between the belt and the pulley; n = $N_1/N_2$ = speed ratio

### *2.2.5 Tension on Belt Driver ($T_1$ and $T_2$)*

For belt transmission between two pulleys (Hall et al.,1961)

$$\frac{T1}{T2} = e^{\mu\theta} \quad \text{……………………………………………………………….…………..(8)}$$

Also

$$\frac{T_1 - T_c}{T_2 - T_c} = e^{m\theta} \quad \text{…………………………………………………………………...(9)}$$

And $T_c = mv^2$ ……………………………………………………………..……..(10)

### *2.2.6 Power Requirement (P) of the Slicing Machine*

The power requirement of the slicing machine is given as:

$P = (T_1 - T_2)\, v$…………………………………………………………………….(11)

In this equation, the power (P) is in Watts, when $T_1$ and $T_2$ are in Newton and belt velocity is in meter per second. When the tensions are in pounds and the velocity in feet per minutes, the horse power(Hp) transmitted is given as

$$Hp = \frac{(T1 - T2)v}{33000}$$ ……………………………………………………………..…..(12) (Hall et al.,1961)

Where: $T_1$ = tension on tight side of belt; $T_2$ = tension on slack side of belt; $T_c$ = centrifugal tension; $W_1$= angular velocity of driver; $W_2$ = angular velocity of driven; θ = angle of lap between belt and pulley; v = linear velocity of belt

### *2.2.7 Belt Length (L)*

This is given as

$L = \frac{\pi(D_{1+D_2})}{2} + \frac{(D_{1-D_2}}{4c} + (2c)$ ………………………….(13) (Avallone E. and Baumeister T.,1997)

C = centre distance of two pulleys

### *2.2.8 Shaft Design*

The shaft with the forces acting on it is represented schematically in Fig. 5.

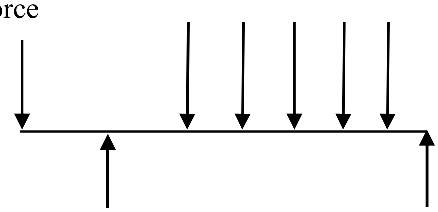



Fig 5. Force analysis

From the evaluation of the forces and determination of bearing reactions, the maximum bending moment of the shaft is evaluated ($M_{max}$).

The shaft diameter (D) is calculated using ASME code standard for shafting. The standard equation for shafting is stated below

$D= \{\frac{5.2}{\tau_d}[(C_m \times M_{max})^2 + (C_T \times T)^2]^{1/2}\}^{1/3}$ ……………………………………(14)

For ASME code standard

$\tau_{d=0.3\delta_y \text{ or } 0.18\delta_u}$ ………………………………………………….(15)

The smaller of the two is chosen as $\tau_d$. The presence of key sit on the shaft reduces the value of $\tau_d$ by 75%. For rotating shafts $C_m$ 1.5, $C_r$ = 1

Where: D = diameter of shaft; $\tau_d$ = allowable shear stress; $C_m$ = moment factor; $C_T$ = Torque factor; $M_{max}$ = maximum bending moment; T = rotational torque; $\delta_y$ = yield stress of shaft material; $\delta_u$ = ultimate stress of shaft material.

Material used for shafting is stainless steel

### *2.2.9 Bearing Selection (Loading)*

Bearing selection was carried out using the following equations by Shigley and Mtscake (1961)

$P_b = XVF_r + YF_a$ …………………………………………………………………….(16)

$L_{10} = [C/P_b]^3$ ………………………………..……………………………………..(17)

Where: $P_b$ = bearing load; $F_r$ = radial load; $F_a$ = axial load; X = radial load factor; C = basic load rating; V = Inner ring rotation factor; $L_{10}$ = bearing life in million revolution.

### *2.2.10 Slicing Bed*

The designed tomato slicing machine has a rectangular slicing bed with metal partitions. The knives rotate in these partition. The tomatoes to be sliced fall from the hopper of the machine by gravity to this bed. The bed supports the tomatoes and makes for easy slicing. The sketch of the bed is shown in Fig.6.

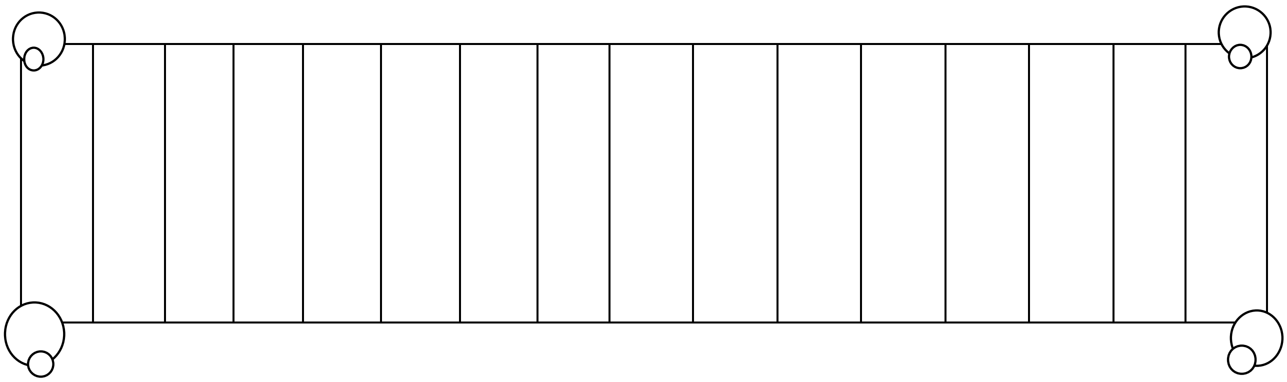


Fig 6. The Slicing Bed

## 2.3 Testing of the Slicing Machine

### *2.3.1 Free Test Run of the Machine*

The machine was tested in the Department of engineering research and development projects, (ERDP) Fabrication Workshop PRODA, ENUGU. The test was carried out in two different stages. Stage (1), the free test run (without load) and stage (2), testing with varied loads (i.e fresh tomatoes) with different weights of (5.0kg, 8.0 kg, 12kg, 15kg to 58kgrams) respectively. A stop watch and a weighing balance were used to ascertain the feed time in seconds, duration of slicing and measuring the weight of tomatoes to be sliced, receptively. Analyses of the results were made.

### *2.3.2 Actual Test on Load*

The tomato that was used for the test running of the Slicer was gotten from an open market at Ogbete main market Enugu state of Nigeria. Also, some tomato fruit of long shelf-life hybrid, were obtained from a commercial farm in the area of Obinagu located less than 2km south of the Institute. Fruits were harvested early in the morning and transported to the laboratory for the experimentation. Fruits were sorted and washed. There was no treatment given to the tomatoes before slicing. Fresh selected tomatoes were used. The samples of the tomatoes used and sliced are shown in Fig. 7.below:

Fig 7. Sample of whole and sliced tomatoes

## 2.4 Performance Evaluation of the Tomato Slicing Machine

The tomato slicing machine was tested by feeding several quantity of measured tomato into the machine in a given time. The feed and slicing period (time) were observed, measured and tabulated.

## 3. RESULTS AND DISCUSSION

The results of the performance evaluation are shown in Table 1 and Figs 8 – 11.

Table 1: Performance Evaluation of Tomato Slicing Machine.

| S/N | Weight of tomato (kg) | Feed time (s) | Feed rate (kg/s) | Slicing time (s) | Slicing rate (kg/s) | Difference between feed and slicing time (s) |
|---|---|---|---|---|---|---|
| 1 | 5 | 3 | 1.67 | 4 | 1.25 | 1 |
| 2 | 8 | 4 | 2.00 | 5 | 1.60 | 1 |
| 3 | 12 | 5 | 2.40 | 7 | 1.71 | 2 |
| 4 | 15 | 6 | 2.50 | 9 | 1.67 | 3 |
| 5 | 19 | 8 | 2.38 | 12 | 1.58 | 4 |
| 6 | 26 | 12 | 2.17 | 17 | 1.53 | 5 |
| 7 | 30 | 15 | 2.00 | 20 | 1.50 | 5 |
| 8 | 40 | 22 | 1.82 | 28 | 1.43 | 6 |
| 9 | 50 | 28 | 1.79 | 36 | 1.39 | 8 |
| 10 | 58 | 34 | 1.71 | 44 | 1.32 | 10 |
| Total | 263 | 137 | 20.44 | 182 | 14.98 | 45 |
| Mean | 26.3 | 13.7 | 2.044 | 18.2 | 1.498 | 4.5 |

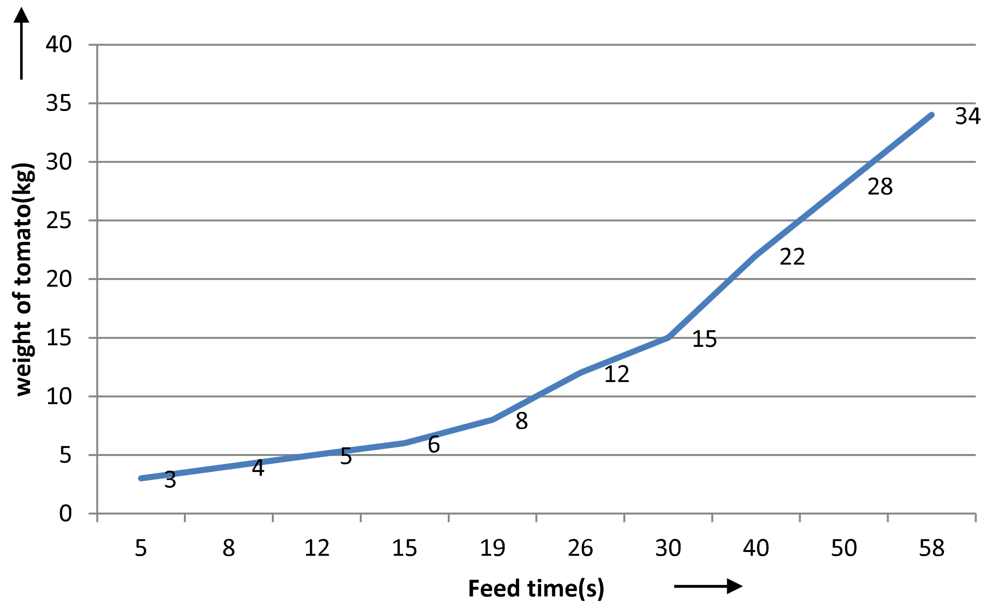



Fig 8. Effect of weight of tomato on seed time

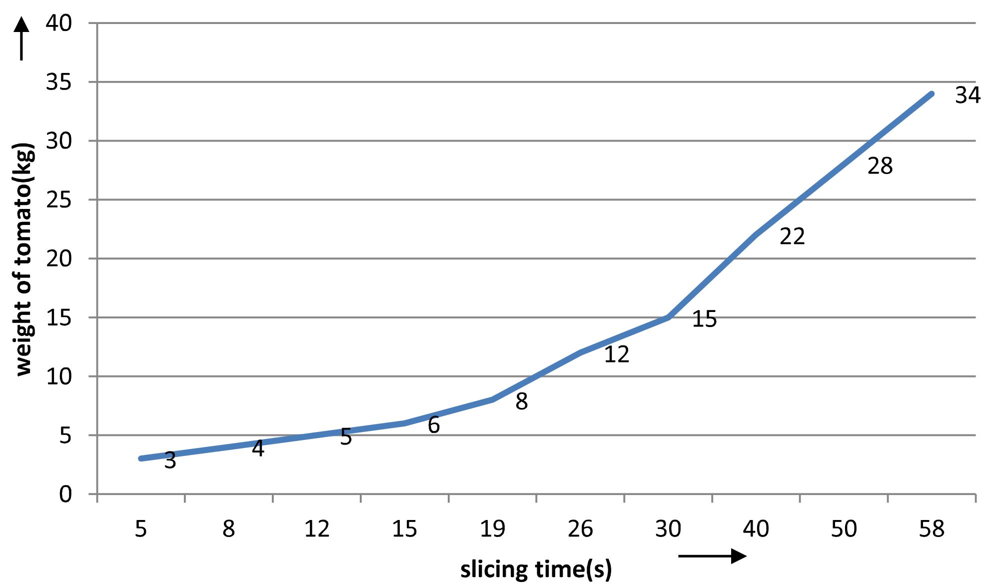



Fig 9. Effect of weight of tomato on slicing time

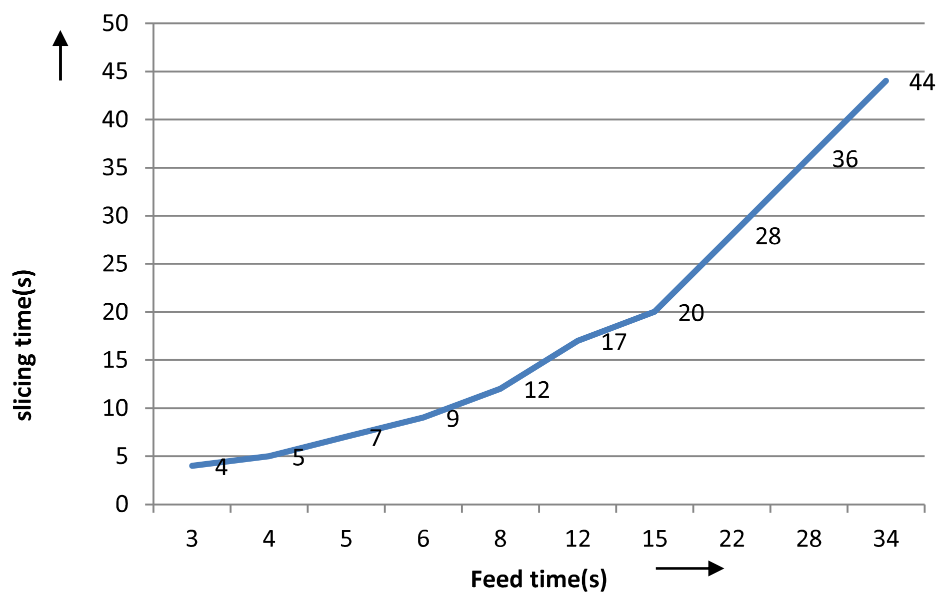



Fig 10. Relationships between slicing time and feed time

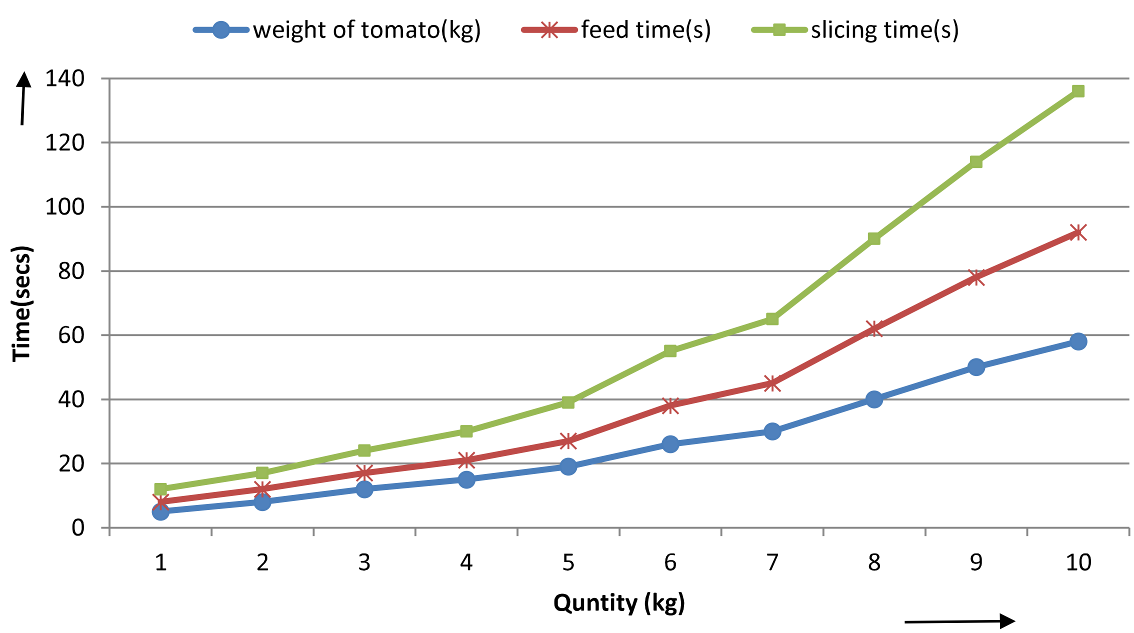



Fig 11. Relationships among weight of tomato, the feed time and the slicing time

From the above graph, it shows that the feed rate calculated from the mean value

= 26.3 / 13.7 = 1.91kg/min which is approximately 2kg/min

The mean slicing rate per minute is given as 26.3/ 18.2= 1.44kg/min

From the table and graph of performance analysis of the tomato slicing machine on different loads, the following inferences can be drawn.

I) There is progressive increase in slicing time as the load increases.
II) There is progressive increase in the difference between feeding time and slicing time
III) From calculation of the feed rate and slicing rate based on the mean value of load, the slicing rate is close to the feed rate. There is only a 0.47kg difference between the two (2) values.
IV) Based the calculated slicing rate, the machine capacity in slicer is put at 2kg per minute.

## 4. CONCLUSIONS

The ripped tomatoes after slicing, will no doubt reduce waste of labour and resources if merged with efficient means of drying and packaging to prolong storage. Based on the slicing rate by the machine, high productivity in slicing is achieved and the slicing efficiency is very high and to upward of 90%. The machine is actually useful in minimizing wastage and improving the shelf life of ripped tomatoes.

This machine is recommended to all agricultural and food processing industries of the contemporary society since tomato slicing as a unit in tomato preservation and processing operations requires a mechanized means.

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