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Design and development of a tomato manual slicing machine

Kamaldeen O. S[1*]. and Awagu E. F.[2]

Nigerian Stored Products Research Institute, Kano Station, PMB 3032, Hadeija Road, Kano, Nigeria
**Corresponding author E-mail: contactnsprikano@yahoo.com*

Abstract

Principle of slicing was reviewed and tomato slicing machine was developed based on appropriate technology. Locally available materials like wood, stainless steel and mild steel were used in the fabrication. The machine was made to cut tomatoes in 2cm thickness. The capacity of the machine is 540.09g per minute and its performance efficiency is 70%.

Keywords: *Slicing, Machine, Formability, Ductility*

1 Introduction

Tomato which is referred to as plant (selenium lycopersicum) or the edible is very nutritionally essential in body as a fruit or vegetable. It is believed to benefit the heart, among other organs. It contains the carotene lycopene, one of the most powerful natural antioxidants. In some studies, lycopene especially in cooked tomatoes has been found to help prevent prostate cancer but other research contradicts this claim. Lycopene has also been shown to improve the skin's ability to protect against harmful Ultra violet-rays. A study done by researchers at Manchester and Newcastle university revealed that tomato can protect against sun burn and help keeping the skin youthful. With these nutritional benefits of the perishable tomatoes, it is very important to be processed and preserved to ensure its availability during off season. One of the major methods of tomato preservation is drying before storage. Tomatoes are best dried when sliced and slicing of tomatoes had been considered difficult operation as it is usually done manually. The manual means of slicing tomatoes is energy and time consuming and off course prone to injury when not done carefully. To solve the problems encountered in slicing of tomatoes, a tomato slicer has been developed which is capable of slicing up to hundred tomatoes at a time thereby conserving human energy, reducing time spent in slicing, providing safety to the users and serves as a source of income to individual.

1.1 Statement of Problems

After careful study of indigenous way of slicing tomatoes, it was observed that it involves a lot of physical labor and material wastage. Therefore, to improve the processing method and enhance its hygienic level, there is need of mechanization of the slicing method.

1.2 Significance of the research

i. The tomato slicer is very important because of the relief it will bring to those who had been slicing their tomatoes manually.
ii. This design would provide opportunity for easy part replacement without recourse to importation or total abandonment.
iii. It's simplicity in operation will make it user-friendly.

2 Objectives

1. To conserve human energy and reduce time spent in slicing tomato.
2. To increase the amount of tomatoes to be sliced at a load.
3. Using locally available materials and technology to produce an affordable machine to local populace

4. To ease the problem of slicing especially for commercial consumption.

3 Methodology

The tomato slicer comprises of wooden frame, stainless knife, ball bearing, wooden stand, bolt and nut of different sizes. Ball bearing is used for easy shearing of the blade which in turn will enhance slicing of tomato. Blades are also arranged in such a away to allow easy shearing since cutting basically involves shearing force with minimum applied force. Wood is selected due to its availability, corrosion resistance, relatively low cost and minimum strength needed to withstand fatigue. Below is isometric view of the tomato slicer.

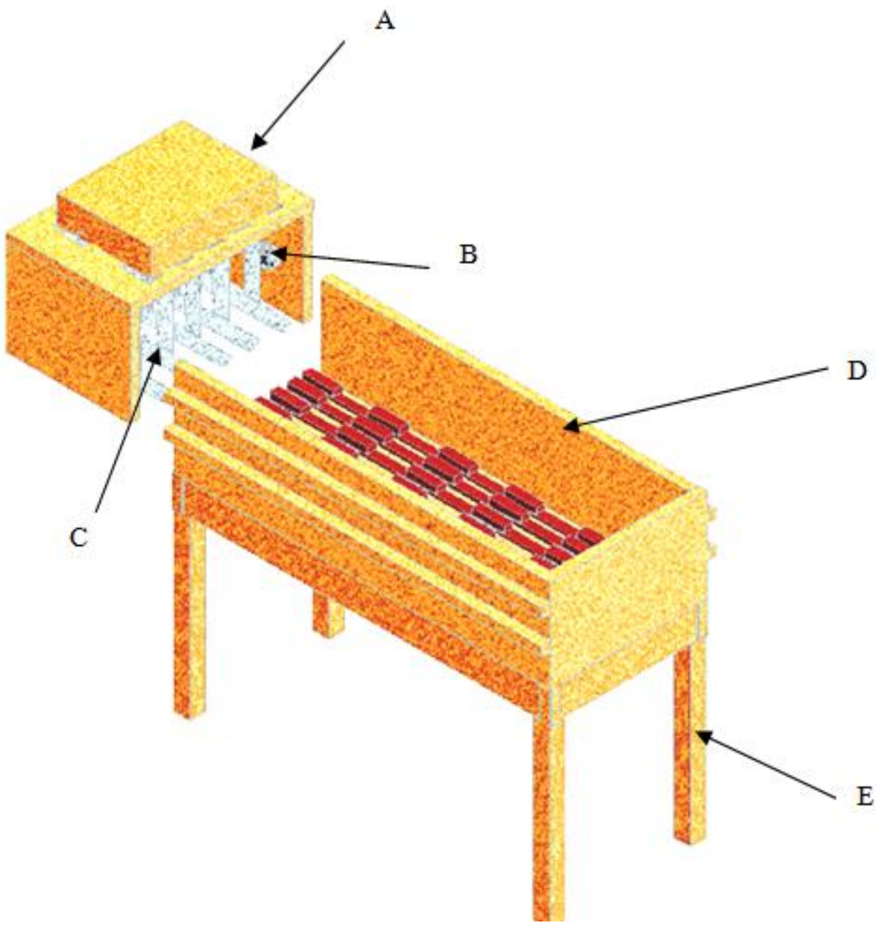

Fig.1: Isometric View of tomato slicing machine

[A] = Knife compartment
[B] = Ball bearing
[C] = Stainless knife
[D] = Slicing compartment
[E] = Siler stands

4 Literature review

Slicing is the process of cutting through an item using sharp-edge object. Because of the importance of slicing of food items in our day-to-day life, there is the need to employ the use of simple mechanical device to ease the process. This mechanical device is called slicer which is either manually or electrically powered. In any of the cases, the machine consists of a knife or set of knives arranged in a particular pattern to meet the need of the operation(s) intended to perform.

4.1 Principle of cutting

Cutting involves principally the application of shearing force on an item with the help of a knife. The knife could be stationary or on translational or rotary motion. Slicing could be achieved in any of the following ways

i. A knife moving against a stationary one while getting the food cut in-between.
ii. Two knives or cutting elements moving in opposite directions against one another and thereby getting the food item sliced in the process.
iii. A knife moving against a stationary part of the machine

The third principle was chosen to develop my slicing machine.

5 System design and material selection

System Design: The following design criteria were used

i. Mechanical properties which include strength , rigidity, toughness and ductility
ii. Machineability or formability.
iii. Available of Material.
iv. Wear resistance of Material.
v. Cost of material

5.1 Design consideration

The following are considered

i. Reactions on the slicer stands
ii. Average weight of the tomatoes in the slicer
iii. Average human effort exacted by hand
iv. Average weight of slicer component on the stands
v. Weight of knives used
vi. Weight of knife compartment.

The entire above are important to select the length and thickness of the slicer stands putting the slender ratio in consideration.

A. Weight of the planks on which tomatoes will be arranged is given

$$W = M \times g \quad (1)$$

Where M is the mass of the wood used for the construction and g is acceleration due to gravity
But

$$M = v \times Þ \quad (2)$$

Where v is the volume
Þ is density

$$V = length \times breadth \times height \quad (3)$$

If L=0.23m, B=0.18 and thickness =0.015m
$V = 0.23 \times 0.18 \times 0.015$
$V = 621 \times 10^{-6}\ m^3$
Þ(density of plywood) = $290 kg/m^3$
$M = 621 \times 10^{-6}\ m^3 \times 290 kg/m^3$
$g = 9.81\ m/s^2$
$W = 621 \times 10^{-6}\ m^3 \times 290 kg/m^3 \times 9.81 m/s^2$
W = 1.77N
Three of this plank was used
Then total weight is 1.77N ×3 = 5.31N

B. Weight of knives

L = 0.22m, width = 0.015m, thickness (t) = 0.0006m density Þ =8000kg/m3 and g =9.81m/s2

Wkn = 0.22× 0.035×0.006×8000×9.81
= 0.155N
Since we used ten knives then the total weight is 0.155×10
W_{kn} (total) = 1.55N

C. Knife compartment

V = 0.3×0.015× 0.18
= 81×10-5
Þ (density of plywood) = 290kg/m3
g = 9.81m/s2
W = 81× 10-5 × 290 × 9.81
= 2.304N
Also V = 0.18 × 0.13 × 0.015
= 3.51 × 10-4 m3
Þ (density of plywood) = 290kg/m3
g = 9.81m/s2
W = 3.51 × 10-4 × 290 × 9.81
= 0.999
Two of this plank was used then total weight is 2 × 0.999 = 1.998
W = 1.998N

D. Weight of metal handle attached to knives

V = 0.1× 0.000003 × 0.02
= 6×10-7m3
Density of mild steel = 7880kg/m3
g = 9.81m/s2
Whandle = 6×10-7 × 9.81 × 7880
= 0.046N
Ten of the handles were used, then total weight = 0.046 × 10
W_{handle} = 0.46N

E. Weight of tomato box (slicing compartment) on the stands

V = 0.75 × 0.13 × 0.015
V= 14.63 × 10-4m3
Þ (density of plywood) = 290kg/m3
g = 9.81m/s2
Wplank = 14.63 × 290 × 9.81
= 4.2N
Two of this plank were used then total weight becomes 4.2 × 2 = 8.4N
Also V= 0.15 × 0.13 × 0.015
= 2.93 × 10-4 m3
Þ (density of plywood) = 290kg/m3
g = 9.81m/s2
W = 2.93 × 10-4 × 290 × 9.81
= 0.83 N

Plank used for bearing slot
V = 0.73 × 0.03 × 0.015
= 3.29 × 10-4
Þ (density of plywood) = 290kg/m^3
g = 9.81m/s^2

$W = 3.29 \times 10^{-4} \times 9.81 \times 290$
$= 0.94N$
Four of this plank was used then total weight here is 4 × 0.94
W = 3.74 N
Plank used for other side of knife compartment
L =0.18m, B = 0.13m t= 0.015m
Volume (V) = 0.18× 0.13 ×0.015
$= 3.51 \times 10^{-4}$ m3
Þ (density of plywood) = 290kg/m^3
g = 9.81m/s^2
$W = 3.51 \times 10^{-4}$ m3×290kg/m^3×9.81m/s^2
W = 0.99N
Two of this plank was used
Then W_t =0.999× 2
= 1.998N

Note: average human effort exerted by hand is taken as 12.38N by K.H Bernhard K Roemer, 1969
0verall weight on the stands will the total of all weights calculated from the beginning
W_T = 5.31+5.84 +0. 46 + 8.4 + 0.83 + 3.74 + 1.10 + 1.55 +12.38 + 0.883
= 40.49N
Assuming uniform distribution each of the four stand is 40.49/4
A vertical load on each load = 10.12N.

F. Calculating the thickness of each stand

The principle of slenderness ratio is applied

$$F = (\pi^2 EI)/ (KL)^2 \qquad (4)$$

Where F = maximum or critical force (vertical load on column)
F = 11N
E = Modulus of elasticity of wood E = 13- 50 (where compression is taking place)
E = 35N/m^2 were taken for this project
I = Area moment of inertia

$$I = bd^3/12 \qquad (5)$$

Where b = d, $I = d^4/12$
K = column effective length factor whose value depends on the condition of end support of the column this can be shown as follows

- Both ends pinned k = 1
- Both ends fixed k = 0.5
- One pinned and other end fixed k = 0.699
- One fixed and the other end is free k = 2

But for this slicer both ends are fixed therefore k = 0.5
$\pi = 3.142$
From above equation (4) above $I = F(KL)^2/\pi^2 E$
$I = 11\times (0.5\times0.56)^2/(3.142)^2\times35$
I = 0.8624/345.53
I = 0.00250 but $I = d^4/12$
$d^4 = 12\times 0.00250$
= 0.02995
$d = {}^4\surd(0.02995)$
d = 0.041m
4.5cm thickness of 56cm long of 4 wooden stands were selected

5.2 Machine Output

Machine output = total mass of tomatoes sliced/total time taken (6)

Number of tomatoes cut at a time is 20 tomatoes for 10seconds and the number of firm tomatoes got from small basket of tomatoes is 250 tomatoes
Therefore time taken to cut all tomatoes = (250×10)/20 = 125s = 2.08min
Also Average weight of tomatoes is determined to be 4.5g
Therefore total weight of tomatoes = 4.5g × 250 = 1125g

Output of the slicer = 1125g/2.08min =540.9g/min

5.3 Efficiency of the slicer

Efficiency = Number of right slice of tomato/total Number (7)

Out of 20 tomatoes fed into the slicer at a load only 6 tomatoes at the side of slicer were not cut (2cm set) accurately, therefore in the whole 250 tomatoes we have only 75 tomatoes that were wrongfully cut.
Number of right slice = 250 – 75 = 175
Efficiency = (175/250) × 100 = 70%

6 Conclusion

The slicer has been successfully developed and tested. The performance efficiency is 70% and the output per minute is determined to be 540.9g/min.

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