Modification of Manually Operated Tomato Slicing Machine

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Abstract:
Development of improved tomato slicing machine were carried out. The improved tomato slicing machine was constructed and the evaluation of both old and new slicing machines were carried out. The results from the evaluation were compared using t-test analysis. The results show that there is a significant achievement on the newly developed tomato slicing machine in terms of slicing efficiency while in terms of capacity, there is no significant difference. The slicing efficiency and output capacity of newly developed slicer was 90.10 % and 3.79 kg/hr. respectively. While that of old separating machine 66.07 % and 3.48 kg/hr. respectively

Key words: Tomato, Slicing, Machine, Modification, Knife,

Introduction
General background
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 (Tervell 1979). 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 (Tervell 1979).

Slicing operation is achieved by cutting, which involves moving, pushing or forcing thin sharp blade or knife through the materials resulting in minimum rupture and deformation of the materials (Raji and Igbeka, 1994).

Statement Problem
Fruits and vegetable losses in Nigeria are high with annual tomatoes loss at an alarming rate of 50 -70% due to poor processing and preservation culture (Okunoya, 1996). In Kano State, 500kg of Tomato being a seasonal crop sells between N450 to N950 in its season and between N5000 to N10,000 at off season. Therefore, it is very important to process and preserve tomatoes 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.

Traditional Slicing of tomatoes involves using knife to cut through the tomato to desired thickness for faster and effective drying. This had been considered difficult operation as it is energy and time consuming and off course prone to injury when not done carefully (Raji and Igbeka, 1994).

Kamaldeen and Awagu (2013) developed a manually operated tomato slicing machine as shown in figure 1. The machine gave slicing efficiency of 70% and output capacity of 501g/min. Among the limitations of this machine are as follows:

1. Use of wood material for the machine. This do not give required strength needed due to water absorption
2. Wrong selection of knives. This directly affect the effectiveness of the slicer
3. No mechanisms for collection of sliced tomatoes

Figure 1: Tomato slicing machine developed by Kamaldeen and Awagu (2013)
Objective

The main objective of this study is to develop the existing tomato slicer by Kamaldeen and Awagu (2013) in order to solve problems associated with traditional methods of tomato slicing process.

Specific objectives

1. To redesign the existing tomato slicer.
2. To construct the designed slicer.
3. To evaluate the performance of the constructed slicer.

Justification

Slicing of tomatoes before drying is very essential as it aids fast and effective drying. Slicing of tomato opens the capillary tubes through which moisture flows to the surface of sliced tomatoes where vaporization of the moisture takes place and then being carried away by air flows during drying. Leo and Balogun (2009) reported that in drying of fruits and vegetables, the vegetables and fruits must be sliced into smaller pieces to facilitate heat transfer and removal of moisture from the pieces. For commercial slicing processes, mechanical slicer is needed. (Kamaldeen and Awagu, 2013). Development of this slicer will increase quantity of tomatoes sliced per unit time, conserve time and energy, and increase hygiene in the tomato slicing process. It will reduce the dependency on imported machines in Nigeria and as well serves as source of income to youth and peasant farmers.

Literature Review

Slicing and size reduction

Slicing is a form of size reduction and the general term “size reduction” includes slicing, cutting, crushing, chopping, grinding and milling. The reduction in size is brought about by mechanical means without change in chemical properties of the material and uniformity in size and shape of individual units of the end product (Leo and Balogun, 2009). Such processes as cutting of fruits or vegetables for canning, shredding sweet potatoes for drying, slicing onion for salad, chopping corn fodder, grinding grain for livestock feed and milling flour are size reduction operations. Reducing the size of food raw materials is an important operation to achieve a definite size range (Henderson and Perry, 1980). Size reduction may help in the extraction of desirable constituents from raw materials e.g. crushing palm fruits for extraction of palm oil, milling grains for the production of flour, crushing fruits for juice or for fermentation. Some other operations in food processing and preservation are facilitated by smaller size particles, for examples, when a food material such as yam is to be dried, it is cut into slices to expose more surface area to the drying medium. Similarly, in drying of okra or tomatoes, the vegetables and fruits are sliced into smaller pieces to facilitate heat transfer and removal of moisture from the pieces (Leo and Balogun, 2009).

Review of existing slicing machines

Several slicing and chipping machines had been designed and tested in various developing countries especially the Caribbean and South East Asian countries as reported by Clarke (1987). Various types of machines are manufactured from small hand-operated batch-types to large automatic continuous operation models. Some are petrol, diesel or electric motor operated. There are cassava chippers, tomato slicers, okra slicers and other root and vegetable choppers. Ukatu and Aboaba (1996) designed, constructed and evaluated a machine for slicing yam and it was reported that the machine’s thickness of cut can be varied from 2 mm to 20 mm and the slicing efficiency ranged from 82 to 93% and the rate of work is 45 cuts per minute. Raji and Igbeka (1994) designed, fabricated and tested a pedal-operated chipping and slicing machine for tubers and it was reported that the machine performed satisfactorily with production of slices of uniform thickness ranging from 1 mm to 13 mm thickness and a throughput of about 376 kg/h at an efficiency of about 83%. Olajide et al. (1997) evaluated an okra slicer and found out that there is higher loss in the traditional method of slicing than in the mechanical slicer. He reported that the machine gave 65% efficiency and 312 kg/hr. Teel, (1977) developed a belt cutting system for harvesting vegetation as an impact cutting device. However, he reported that the belt system’s nominal cutting speed of 40 m/s limited its usefulness for harvesting soybeans. Kamaldeen and Awagu (2013) design and developed a manual tomato slicing machine. It was made to cut tomatoes in 2cm thickness. The capacity of the machine is 540.09 g/min and its slicing efficiency is 70%.

Material and Methods

Materials

Materials used in the construction of this machine include mild steel, stainless steel and aluminum metal.

Design considerations

A number of factors were considered in the design of the slicing machine which include:

1. Functional requirement factor
2. Cost effective factor
3. Reliability factor
4. Resistance to environmental factors

3.2 Components of the tomato slicer

The tomato slicer comprises of various components each of which has specific function and they include the following:

A. Knife compartment
B. Ball bearing
C. Aluminum knives
D. Frame
E. Slicing compartment
F. Slicer stands

Design Calculation

Components Design for Tomato Slicing machine

Tomato compartment design

The volumetric capacity of the tomato compartment was calculated in relation to the volume of material it occupies. The compartment was designed to contain 25 kg of tomato per unit operation.

The volume of the any material was calculated as given by Khurmi and Gupta (2005):
\[ V_1 = \frac{M}{\rho} \] (1)

Where \( V_1 \) = volume of material in m\(^3\)

\( M \) = mass of the material in kg

\( \rho \) = bulk density of tomato (kg/m\(^3\)) = 897 kg/m\(^3\) (Measured)

\[ \frac{25}{897} \]

\[ V_1 = 0.028 \text{ m}^3 \]

In the designing of compartment volumetric capacity, the shape of the compartment was designed to be cuboid. Lengths and height of the compartment were selected to be 0.6m and 0.3m respectively, as shown in Figure 1.

\[ V_2 = L \times B \times H \] (2)

\[ B = \frac{V_2}{L \times H} \]

Where,

\( L \) = compartment length

\( B \) = compartment breadth

\( H \) = compartment height

\[ V_2 = \text{volumetric capacity of the compartment} = 3 \times V_1 \]

\[ = 3 \times 0.028 \text{ m}^3 \]

\[ = 0.084 \text{ m}^3 \]

Volume of the tomato was multiplied by 3 to determine compartment volumetric capacity in order to allow for enough clearance and space in the compartment.

Therefore, to design for compartment breadth we have

\[ B = \frac{0.084}{0.6 \times 0.3} = 0.46 \text{m} \]

**Knife thickness design**

Selection of right thickness of slicing knife is very essential as it directly affects the slicing effectiveness. The thickness of slicing knife was calculated using expression as given by Khurmi and Gupta (2005):

\[ t = \frac{W_k}{L_k \times B_k \times g \times (\rho_k - \rho_T)} \] (3)

Where,

\( t \) = knife thickness (m)

\( W_k \) = knife weight = 1.55N measured

\( L_k \) = Knife length = 0.22 m selected due to its availability

\( B_k \) = Knife width = 0.015m selected due to its availability

\( g \) = acceleration due to gravity = 10m/s\(^2\)

\( \rho_k \) = knife density = 1682 Kg/m\(^3\) (Khurmi and Gupta 2005):

\[ \rho_T = \text{tomato density} = 897 \text{ kg/m}^3 \] (measured)

\[ t = \frac{1.55}{0.22 \times 0.015 \times 10 \times (1682 - 897)} = 0.006 \text{m} \]

0.0006m thickness of knife was selected for this slicer.

**Slicer stand thickness design**

Since the slicer stand is a column therefore, its thickness was calculated using slender ratio formula as given by Khurmi and Gupta (2005):

\[ F = \frac{\pi^2 EI}{(KL)^2} \] (4)

Where \( F \) = maximum or critical force (vertical load on column)

\[ F = W_{Tc} + W_k + W_{kh} + W_{kc} + W_{hf} \] (5)

Where,

\( W_{Tc} \) = tomato compartment weight = 20 N (measured),

\( W_k \) = knife weight = 1.28 N (measured),

\( W_{kh} \) = knife holders weight = 0.82 N (measured),

\( W_{kc} \) = knife compartment weight = 8 N (measured),

\( W_{hf} \) = average human effort exerted by hand which is given as 12.38N by K.H Bernhard K Roemer, 1969

\[ F = 20 + 1.28 + 0.82 + 8 + 12.38 \]

\[ = 42.38 \text{ N} = 0.042 \text{kN} \]

\( E \) = Modulus of elasticity mild steel

\( E = 200 - 220 \text{ kN/mm}^2 \) (Khurmi and Gupta 2005)

\( E = 220 \times 100 \text{ N/mm}^2 \) were taken for this project

\( I \) = Area moment of inertia

\[ I = \frac{bd^3}{12} \] (5)

Where \( b \) = d,
\[ I = \frac{d^4}{12} \]

\( K \) = column effective length factor whose value depends on the condition of end support of the column. This is given by Khurmi and Gupta (2005) as:

- 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 \( k = 0.5 \)

\( L \) = length of the column (slicer stand) = 0.6m this was selected to certify the ergonometric factor in the design.

\[ I = \frac{F(KL)^2}{\pi^2 E} \] from equation (4)

\[ I = \frac{F(KL)^2}{\pi^2 E} = \frac{d^4}{12} \]

\[ d = \sqrt[4]{\frac{12 \times F(KL)^2}{\pi^2 E}} \]

\[ d = \sqrt[4]{\frac{12 \times 42.38 \times (0.5 \times 0.6)^2}{3.142^2 \times 220 \times 10^3}} \]

\( d = 42\text{mm} = 0.042\text{m} \)

0.045m thickness of 0.6m long of 4 steel stands were selected

Description of Tomato Slicing Machine Components

Modified tomato slicing machine had been designed and fabricated, the components of the machine are as follows:

![Modified manual tomato slicing machine](image)

Fig. 2: Modified manual tomato slicing machine
Knife compartment:
This is a form of box in which the slicing knives are arranged in such a way to ease slicing operation when in a linear motion. It contains two ball bearings to ease to and fro movement of the compartment. The dimension of the knife compartment is 0.1 m × 0.32 m × 0.5m.

Knife
The knife is the main part of the slicer purposely for slicing operation. The dimension of knife selected is 0.22 m × 0.015 m × 0.0006m

Knife holder
The knife holder is used to hold the knives firmly with knife compartment. It is 0.24 m long.

Tomato compartment
It is a form of box where tomatoes are arranged in such a way that each tomato sit on the base of the compartment. It contains a door at the base where sliced tomatoes are discharged. It is 0.6 m long × 0.46 m width × 0.3 m height

Collector
The collector is a container where the sliced tomatoes are collected for further process. It is 0.5m long by 0.3m width by 0.08m height

Frame
The frame was constructed using angle iron of 0.45 x 0.45 x 0.03 m and was selected based on the weights of various components of the whole system. It has dimension of 0.6 m x 0.3 m x 0.6 mm. The frame is a structure which gives support to all tomato slicing machine components.

Performance evaluation.
In evaluating the performance of the tomato slicing machine, performance of both newly developed slicer and the existing slicer were carried out. The same quantity (25 kg) of ripe tomatoes was separately fed into the two slicers in 9 replicates and mean value of slicing efficiency and output capacity were calculated. These results were compared using student t-test analysis to know the level of achievement on the new developed machine.

Performance indices for slicing machine
The performance indices used were slicing efficiency and output capacity

Slicing efficiency
The slicing efficiency measures how effective the tomatoes were sliced by the tomato slicing machine. It is calculated using expression given by Kamaldeen and Awagu (2013) as:

\[ S.E = \frac{W_{sliced}}{W_T} \times 100 \]

Where \( W_{sliced} \) = mean weight of tomato sliced correctly (kg)

\( W_T \) = total weight of tomato fed into the machine (kg)

Output capacity for
Output capacity of the slicer measures the quantity of tomatoes the slicer can handle per unit load of operation. It is calculated using expression given by Kamaldeen and Awagu (2013) as:

\[ OC = \frac{W_T}{T} \]

Where \( W_T \) = total weight of tomato fed into the machine (kg)

\( T \) = total average time taken to slice all the tomatoes fed into the machine (S).

Experimental Results from Evaluation of the Slicing efficiency for the Two Machines
The results for experimental evaluation on slicing efficiency of both new and old tomato slicing machine are as shown in Table 1.

<table>
<thead>
<tr>
<th>S/N</th>
<th>S.E for old Slicer (%)</th>
<th>S.E for New Slicer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>68.03</td>
<td>93.08</td>
</tr>
<tr>
<td>2</td>
<td>62.64</td>
<td>90.41</td>
</tr>
<tr>
<td>3</td>
<td>72.85</td>
<td>91.77</td>
</tr>
<tr>
<td>4</td>
<td>78.55</td>
<td>89.91</td>
</tr>
<tr>
<td>5</td>
<td>62.72</td>
<td>90.38</td>
</tr>
<tr>
<td>6</td>
<td>71.68</td>
<td>88.72</td>
</tr>
<tr>
<td>7</td>
<td>60.09</td>
<td>91.75</td>
</tr>
<tr>
<td>8</td>
<td>58.73</td>
<td>85.17</td>
</tr>
<tr>
<td>9</td>
<td>59.31</td>
<td>90.07</td>
</tr>
</tbody>
</table>

The results were analysed using t-test and the results of the analysis are as shown in Table 2. The results show that the mean slicing efficiency for old separating machine is significantly different from that of newly developed slicing machine. Mean slicing efficiencies of 66.07 and 90.10% were achieved for old and new machine respectively. This implies that there is a significant improvement in the newly developed tomato slicing machine.
### Table 2: t-test for comparison between old and new slicer based on slicing efficiency (SE)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean values</th>
<th>P(T&lt;=t) Calculated</th>
<th>P(T&lt;=t) Selected</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Old Slic</td>
<td>New Slic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separating</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>efficiency</td>
<td>66.07</td>
<td>90.10</td>
<td>0.001</td>
<td>0.05 **</td>
</tr>
</tbody>
</table>

** Significant

### Experimental Results from Evaluation of the output capacity for the Two Machines

The results for experimental evaluation on output capacity of both new and old tomato slicing machine are as shown in Table 3.

#### Table 3: Experimental results for output capacity

<table>
<thead>
<tr>
<th>S/N</th>
<th>OC for old Slicer (kg/hr.)</th>
<th>OC for New Slicer (kg/hr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.03</td>
<td>4.08</td>
</tr>
<tr>
<td>2</td>
<td>3.85</td>
<td>3.77</td>
</tr>
<tr>
<td>3</td>
<td>3.55</td>
<td>3.72</td>
</tr>
<tr>
<td>4</td>
<td>3.08</td>
<td>2.72</td>
</tr>
<tr>
<td>5</td>
<td>4.09</td>
<td>3.75</td>
</tr>
<tr>
<td>6</td>
<td>2.73</td>
<td>4.02</td>
</tr>
<tr>
<td>7</td>
<td>3.31</td>
<td>4.07</td>
</tr>
</tbody>
</table>

The results were analysed using t-test and the results of the analysis are as shown in Table 4. The results show that the mean output capacity for old separating machine is not significantly from that of newly developed separating machine. Mean output capacity of 3.48 and 3.79% were achieved for old and new machine respectively. This was expected anyway since both machines were operated manually even though the new slicer is bigger in size.

#### Table 4: t-test for comparison between old and new slicer based on slicing efficiency (SE)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean values</th>
<th>P(T&lt;=t) Calculated</th>
<th>P(T&lt;=t) Selected</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Old Slic</td>
<td>New Slic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separating</td>
<td>3.48</td>
<td>3.79</td>
<td>0.176</td>
<td>0.05 NS</td>
</tr>
</tbody>
</table>

NS= Not Significant

### Recommendation

1. The slicer is recommended to be motorized
2. Further research work should be done on the possibility of knives’ adjustment in order to slice in different thickness
3. The slicer should be evaluated on effect of tomato’s firmness on the slicing performance of the slicer
4. The slicer should also be evaluated on other fruits and vegetables such as okro, plantain, pepper, carrot etc. to make it more versatile thereby increasing its acceptability among end-users.

### Conclusion

The manual tomato slicing machine has been redesigned, fabricated and evaluated. The result of evaluation gave slicing efficiency and output capacity of the modified slicer as 92% and 3,012 kg/hr. respectively.

### Reference


