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DEVELOPMENT OF A TOMATOES (*Solanum Lycopersicum*) COMPACTING MACHINE

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ABSTRACT

A manually operated tomato compactor was designed and fabricated capable of compacting 3600 g of tomato in ten minutes into sizable cubes for easy drying, storage and accessibility. Due to the current practices of preserving fresh tomatoes and the increasing demand for dry tomato at homes and industries, there is a need to develop a machine capable of compacting and drying the tomatoes to increase the quantity that can be stored, packaged and transported. The compacting of tomatoes is done by the densification of the fresh tomatoes by the removal of its fluid to reducing the volume the product occupies when fresh .The machine presses the tomato and rids it of any fluid and then compacts it into cubes to be dried. The design of the compactor ensures that the machine requires only one operator and is very time efficient and hygienic. The tomato is compacted by the application of force exerted from the rotational movement of a screw handle, these force is then converted into the downward movement of the presser which in-turn compacts the tomatoes into the partitioner. The screw handle is turn reversely to off load the compacted tomatoes in the partition. After the compacting of the tomato, the partitioner can then be removed and the compacted tomato fruits transferred into crates to be dried and stored. The machine has a time saving efficiency which is 80 percent greater than the slicing and thumb compacting method alternative. The general efficiency of the machine is 51 percentage greater when compared to the traditional method of slicing and thumb compacting.

Keywords: Design, Compacting, Densification, Tomatoes

1. INTRODUCTION

Tomato (*Solanum Lycopersicum*) is one of the most important fruits/vegetables grown in a wide range of climates, mostly in open-field but also under protection in plastic green houses and heated glass houses (Henry and John,2018).Vegetables are of great nutritional importance since they make a significant contribution in supplying wealth of essential vitamins, minerals, antioxidants, fibers and carbohydrates that improve the quality of the diet. Tomatoes are also rich in health valued food components such as carotenoids (Lycopene), ascorbic acid (Vitamin C), vitamin E, folate and dietary fiber (Davies and Hobson, 1981).

Many vegetables are highly seasonal in nature, they are available in plenty at a particular period of time in specific regions that many times result in market glut (Habibiasi, *et al*.,2017) Tomatoes fruits are commercially important crop both for fresh fruit market and for the food processing industries (Vishal, *et al.*, 2016), therefore, the food processing sector can play a vital role in reducing the post-harvest losses by processing and value addition of vegetables which will ensure better remuneration to the growers. (Isaac, *et al*., 2016)

The annual worldwide production of tomatoes has been estimated at 125 million tonnes in an area of about 4.2 million hectares. The global production of tomatoes (fresh and processed) has been increased by 300% in the last four decades and the leading tomato producers are in both tropical and temperate regions (FAO, 2005). Canada is also an important producer of tomato (USDA, 2004) with an annual production of about 0.6 million tones both for processing and fresh fruit consumption (Statistics-Canada, 2006).

The post-harvest loss in vegetables has been estimated to be about 30-40% due to inadequate post-harvest handling, lack of infrastructure, processing, marketing and storage facilities (Hawlader and Karim, 2005).

In Nigeria, production is carried out during the rainy season in the southern part with improved indigenous variety such as Ibadan local, Ife-1, while in northern part of the country, production is carried out mostly in the dry season using exotic varieties such as roman VF (Adeleke and Onoriode, 2019) . Production in Nigeria takes a total of 1 million hectares annually, making it about 18% of the average daily consumption of vegetables in Nigerian homes (PWC, 2018). However, an alarming 45% of tomatoes harvested in the country is lost due to poor food supply chain (FSC) management; price instability resulting from seasonal fluctuation in production and supply preference of farmers and middle man for the urban market than processors due to low farm gate prices (Ugonna, *et al.*, 2015).

Data obtained from (PWC, 2016) shows that Nigeria is the world's 14th largest producer or tomatoes fruit and 13th largest importer of tomato paste. In African, Nigeria is the 2nd largest producer of tomato after and the 3rd largest importer.

Cold storage of large volume of dried products for a long period of time is another alternative method of preserving the tomatoes but it is expensive and energy consuming. This means that is quite out of reach of most local farmers. Moreover, the storage medium conventional used by farmers is not fully hygienic, as dry products are left in sacks which can easily be attacked by microorganisms. Furthermore, Food frozen at -18 degree celcius and below is preserved indefinitely and the quality of the food will deteriorate if it is frozen over a lengthy period. The United States Department of Agriculture, Food Services and Inspection Services published a chart showing the suggested freezer storage time for common food (Coles, 2003).

A research team at Jomo Kenyata University of Agriculture and Technologist (JKUAT) Kenya has constructed a fruit compacting machine that compact tomatoes, orange and mango. The machine compacts these vegetables and allow them to dry for storage and accessibility (JKUAT, 2018) . Their idea is to increase the shelf life of these vegetables, but his work is to compact and mix both the water and the fleshes together.

Due to the current practices in preserving fresh tomatoes and the increasing demand for dry tomato at homes and industries, there is a need to develop a means to increase the quantity that can be stored, packaged and transported. This can only be achieved by densification of the dried product at the same time reducing the volume product.

2. METHODOLOGY

The machine is designed to have a 350 by 350 mm compacting frame giving it a compacting capacity of 3600kg of tomatoes, a force floor, four legs stand, two holding hooks are provided at adjacent sides of the compaction frame body to hold the screw handle that controls the vertical movement of the presser. The component parts of the machine include the presser, force floor, stand, power screw, holding hook, partitioner, screw guide, compacting frame, bottom plate.

2.1 Component parts of the machine

2.1.1 Presser

The presser is a flat square plate that compresses the tomatoes against the force floor. In between the screw handle and the presser is a bearing that facilitates rotational movement of the screw handle about the center of the presser. It is situated below the screw handle and above the force floor.

2.1.2 Stand

A four legs stand welded up to support the machine body in position, it is made of an angled steel for strength and rigidity.

2.1.3 Screw handle

The screw handle is always held to position with the help of a horizontal screw guide placed just under the hooks attached to the compactor frame.

2.1.4 Force floor

The force floor is also an angular plate where the compressive force is being sustained during compaction. It is attached to the compaction frame welded in position at adjacent sides. After the false floor has been fixed to the compactor frame, the dried tomatoes (with little moisture) is weighed and then poured into the compactor frame, with the rotating effort of the screw handle clockwise, the Presser is forced to compress the tomatoes against the false floor. The screw handle is turned to compress and compact the tomato into cubes within the petitioner till it cannot be turned anymore. It is then left to stay for a minimum of 10 minutes before the petitioner is being removed from the compaction chambers

2.1.5 Compaction frame

It serves as the body of the machine under which the compacting action take place in. The compaction frame supports all the mechanisms of the machine.

2.1.6 Partitioner

The compaction of tomato take place in the partitioner, it is a nine (9) boxes partitioner in which tomatoes placed for compaction.

2.1.7 Power screw

Power screw is an interposed between the screw handle and the presser to transmit power from the screw handle to the presser.

2.1.8 Holding hooks

These are two hooks at adjacent to each other so as to holds the screw guide in a horizontally position, which in turn supports power screw.

2.1.9 Screw guides

A horizontally shaft, threaded across its length to accommodates power screw in position.

2.1.10 Bottom plate

The water removed from the tomatoes is trapped here and drained away through one exit channel.

2.2 Design theory

2.2.1 Maximum applicable load below the screw:

This is the maximum load that can be applied on or below the screw to avoid failure during service. It is expressed as: (Khurmi, 2008).

$$P = \sigma \left[\frac{\pi}{4} \left(\frac{d_p + d_c}{2} \right)^2 \right] \quad 1$$

Where

$P = the\ maximum\ applied\ load\ (N)$

$\sigma = maximum\ permissible\ stress\ of\ the\ material\ (N/m^2)$

$d_p = pitch\ diameter\ of\ the\ screw\ (m)$

$d_c = core\ or\ minor\ diameter\ of\ the\ screw\ (m)$

2.2.2 Net weight of a part:

The weight of any material/part is expressed as: (Rajput, 2010).

$$W = \rho V g \quad 2$$

Where:

$W = weight\ of\ the\ material\ (N)$

$\rho = mass\ density\ of\ the\ material\ (kg/m^3)$

$V = volume\ of\ the\ material\ (m^3)$

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

2.2.3 Stresses on the screw

These are stresses generated within the threads and the shaft of the screw when in service

Shear stress on the screw:

It is expressed as: (Khurmi, 2008)

$$\tau_s = \frac{P}{\pi d_c b n} \quad 3$$

Where

$\tau_s = shear\ stress\ on\ the\ screw\ (N/m^2)$

$P = the\ maximum\ applied\ load\ (N)$

$d_c = core\ or\ minor\ diameter\ of\ the\ screw\ (m)$

$b = width\ of\ the\ thread\ section\ at\ the\ root\ (m)$

$n = number\ of\ the\ threads\ in\ engagement$

2.2.4 Crushing stress on the screw:

It is expressed as: (Khurmi, 2008)

$$\sigma_c = \frac{P}{\pi (d^2 - {d_c}^2) n} \quad 4$$

Where

$\sigma_s = crushing\ stress\ on\ the\ screw\ (N/m^2)$

$d = major\ diameter\ of\ the\ screw\ (m)$

2.2.5 Strength of the welded joint

a) Bearing/Crushing strength of the joint (P_c):

The crushing strength of the link joint is expressed as: (Rajput, 2010)

$$P_c = ndt\sigma_c \quad 5$$

Where

$n = number\ of\ rivets\ per\ row$

$d = diameter\ of\ the\ joint\ hole\ (m)$

$t = depth\ of\ the\ plate\ (m)$

$\sigma_b = maximum\ allowable\ bearing\ stress\ (N/m^2)$

b) Shearing strength of the joint (P_s):

The shearing strength of the joint is expressed as: (Rajput, 2010)

$$P_s = n_1 \frac{\pi d^2}{4} \tau \qquad 6$$

Where

$n_1 = number\ of\ plates\ in\ the\ joint$

$\tau = maximum\ allowable\ shearing$

$stress\ (N/m^2)$

c) Tearing strength of the joint (P_t):

The tearing strength of the joint is expressed as: (Rajput, 2010)

$$P_t = (p - d)t\sigma_t \qquad 7$$

Where

$p = distance\ from\ the\ joint\ hole\ to\ the$

$end\ of\ the\ plate\ (m)$

$\sigma_t = maximum\ allowable\ tearing$

$stress\ (N/m^2)$

d) Strength of a single joint (P_t):

The strength of a single joint is expressed as: (Rajput, 2010)

$$P = \sigma_t \times p \times t \qquad 8$$

e) Efficiency of the joint (η_{joint}):

The efficiency of the joint is expressed as: Rajput (2010)

$$\eta_{joint} = \frac{least\ of\ the\ strength}{pt\sigma_t} \qquad 9$$

f) Strength of the weld joint

$$F = A \times Q \qquad 10$$

Where

$F = weld\ strength$

$A = weld\ area$

$Q = allowable\ stress\ of\ the\ material$

2.4 Material selection

Most parts of the machine are made out of mild steel because of its special properties (such as ease to machine, ductility, medium density and low cost) it is also available. The presser and partitioner are however plated with stainless steel for corrosion resistance.

2.5 Fabrication Process

Material selection, machining and fabrication were conducted in other to produce a machine capable of providing sufficient strength, durability and cost efficiency.

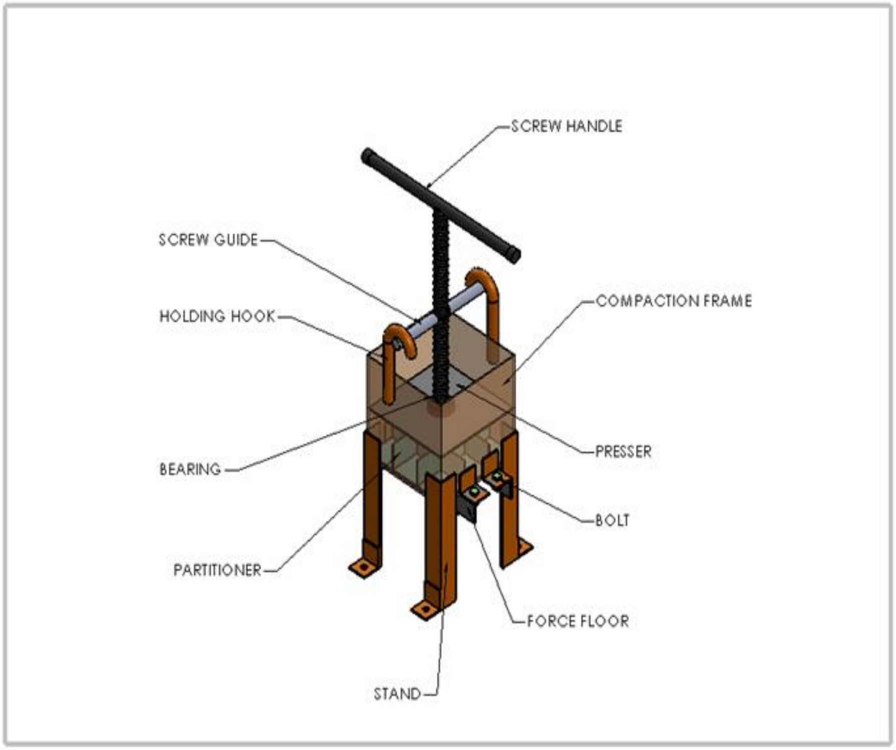

Figure 1: CAD view of the tomatoes compacting machine assembly.

All joints were welded together using arc wielding and the strength of the joints tested against the maximum expected stresses. Mild steel of sufficient quality was used for most part of the machine such as the force floor, stand, power screw, holding hook, screw guide, compacting frame, and bottom plate.

Plate 1: Fabricated tomato compacting machine

2.5.1 Fabrication Method

S/N	Component	Materials used	Process and description	Equipment
1.	Force Floor	Two (2) angular steel of 50 x 450 mm and 5mm thickness	Two angular steel 5mm thickness and 50 x 450mm were cut and joined to form the force floor	Shearing machine, hacksaw, welding machine, steel rule, scriber, try square
2.	Stand	Angular steel 50 x 350mm and 5mm thickness	The angular steel 50 x 350mm were cut into 4 and welded in position to form a squared supporting legs. The stand was then welded to the edges of the force floor.	Shearing, welding, drilling machines, steel rule, scribed and tape try square
3.	Power Screw	Steel of circular cross section with 20mm diameter and length of 450mm	Steel of circular cross section was threaded across its entire length and drilled 5mm at one end accommodate the presser	Hacksaw, lathe, drilling, machine and scriber and tape.

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4.	Holding hook	Two (2) cylindrical steel 30mm in diameter and 450mm in length	Two (2) Steel bar of 30mm diameter and 450mm in length were cut, folded and welded to accommodate screw guides, and then welded on the compacting frame.	Hacksaw, welding, machines, steel rule and tape.
5.	Presser	Mild steel plates of dimensions 95 x 95 x 100mm, Stainless steel plates of dimensions 97.5 x 97.5x 100mm.	The steel plates was cut and formed into a boxes of steel after welding, The stainless steel plates was also cut and formed into a boxes of stainless steel with dimensions 5mm greater than that of the steel plate.	Hacksaw, welding machines, Vanier caliper, steel rule and scriber.
6.	Partitioner	Steel plates of dimension 105 x 105 x 100mm Stainless Steel of dimension 102.5 x 102.5 x 100mm	The steel plates were cut and formed into nine (9) little boxes. The stainless steel plates were cut and formed into nine (9) boxes with dimensions 2mm smaller than that of the steel plate boxes so they can fit into the nine (9) smaller steel boxes.	Hacksaw, welding, machine steel rule scriber, and vanier caliper
7.	Screw guide	Cylindrical steel bar of 40mm diameter, and 400mm in length	The cylindrical steel bar of 40mm diameter, 400mm length was cut and a hole of 30mm diameter was drilled at its center. The entire steel bar was then threaded and welded on the holding hook.	Hacksaw, drilling, lathe machines, tapper tools.
8.	Screw handle	Cylindrical steel of 23mm diameter and 500mm length	The steel bar of 23mm diameter and 500mm length was cut and welded on the power screw.	Shearing, welding grinding, machines steel rule and scriber

9.	Compacting frame	Four (4) steel plates of dimension 350 x 350mm and 2mm thickness.	The steel plate was cut to form a box 30x350x350mm and 2mm thickness.	Hacksaw, welding machines, hack saw Vanier caliper try square
10.	Bottom plate	A steel sheet plate of dimension 350 x 350mm and 1mm thickness.	The steel plate was cut 1x350x350mm and deformed to form fairly squared cups which are welded on the stand.	Hacksaw , welding machine hacksaws Vanier caliper

2.6 Performance Evaluation

2.6.1 Procedure

The quantity by volume of tomatoes compacted at once are;

$$97.5 \times 97.5 \times 9\,(mm) = 8.55m^3$$

The quantity by mass of tomatoes compacted at once are;

$$200\,(g) \times 9 = 1800(g) = 1.8\,Kg$$

The performance evaluation of the machine or its efficiency is given by;

$$Efficiency = \frac{Weight\ of\ compacted}{Weight\ before\ compacting} = \frac{Output}{Input} \times 100$$

From the tomatoes compacting test, the following values were recorded as:

a) Mass of tomatoes before compacting $= 200 \times 9 = 1800\ g = 1.8\,Kg$
b) Mass of tomatoes after compacting= $102 \times 9 = 918g = 0.918\,Kg$

3. RESULT AND DISCUSSION

Table 1: Masses of compacted and un-compacted tomatoes

Mass of Tomatoes	Test 1	Test 2	Test 3
Before compacting	200g	400g	800g
After compacting	91.8g	190g	420g

Mass of tomatoes before compacting = $200 \times 9 = 1.8\,Kg$

Mass of tomatoes after compacting = $918 \times 9 = 0.918\,Kg$

Efficiency = output/Input x100 = $\frac{0.918}{1.8} = 0.51 = 51\%$

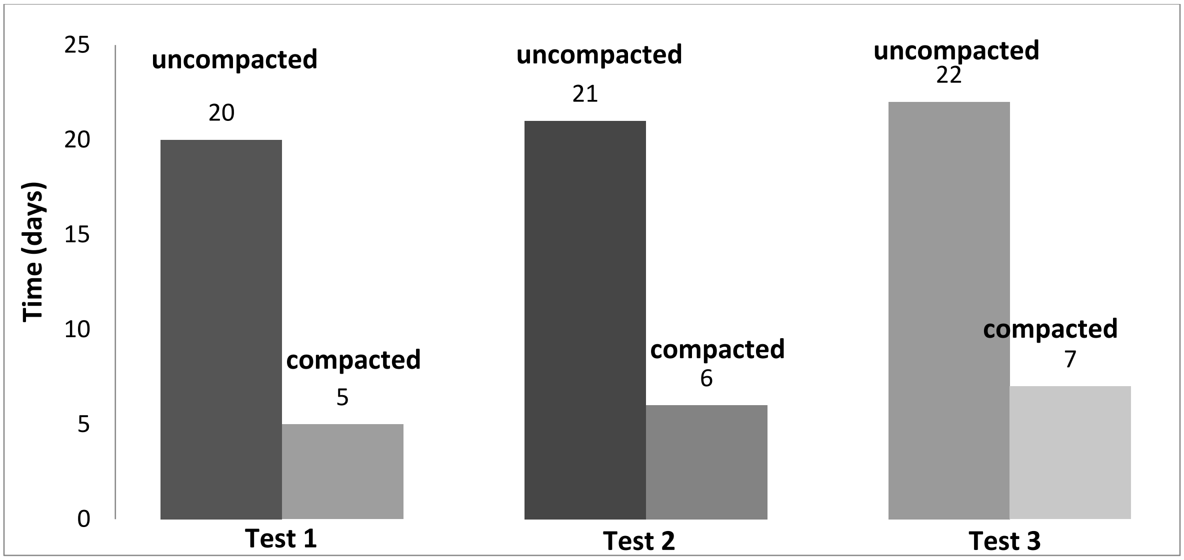

Figure 3: Drying time of compacted and un-compacted tomatoes

3.1 Discussion

The result of the tests on different masses of tomatoes compacted and that of the un-compacted shows consistently that it takes a much shorter time for the compacted tomatoes to dry as compared to the un-compacted.

It shows from the tests conducted that the drying period of compacted tomatoes is approximately six(6) days in comparison to the drying period of un-compacted which is twenty (20)days. This translates to 70% time saving.

It takes ten (10) minutes to compact 3600g of tomatoes against slicing of about thirty five (35) minutes which also translate to 80% time saving.

From the calculations the compacting machine has an efficiency of 51%.

4. CONCLUSION

Due to the current demand for tomatoes at homes and industries there is the need to store and preserve surplus so as to ensure its availability throughout the year. Considering all available methods of preserving the tomatoes fruits, compacting and drying is the most efficient and reliable method that would ensure it retains its quality and taste even after long periods of storage. From the performance evaluation of the machine designed, compacting of tomato into sizable cubes for drying, storage and ease to access is realizable. The cost advantage of using the machine for compacting large amount of tomatoes fruits is also one of the greatest advantages of the machine.

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