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SIMULATION OF A CONCEPTUAL FRESH TOMATO FRUITS PACKAGING CONTAINER FOR TRANSPORTATION

[*1]Olanrewaju, T.O., [2]Idah, P.A., [2]Osunde, Z.D. and [3]Kovo, A.S

[1]*Department of Agricultural Engineering and Irrigation,*
National Agricultural Extension and Research Liaison Services (NAERLS),
Ahmadu Bello University, Zaria, Nigeria
[2]*Department of Agricultural and Bioresources Engineering, School of Engineering and Engineering Technology,*
Federal University of Technology, Minna, Nigeria
[3]*Department of Chemical Engineering, School of Engineering and Engineering Technology,*
Federal University of Technology, Minna, Nigeria

***Corresponding Author:** *taofiqolanrewaju@naerls.gov.ng; toolanrewaju@abu.edu.ng*

ABSTRACT

Tomato is a tender and compression-sensitive fruit. It is a viscoelastic material that mostly experience compressive stress when packaged in unit loads, resulting in deformation, bruising and/or complete failure of the fruit. Harvested tomato fruits in Nigeria are packaged in traditionally woven raffia baskets and transported in open trucks making them highly susceptible to mechanical damage. An inefficient packaging system is a disadvantage to tomatoes marketing due to its direct influence on cost, quality and overall post-harvest losses. The need for an effective tomato packaging container that could ameliorate post-harvest losses becomes expedient, hence, in this study, a packaging container for fresh tomato fruits was conceived. The container was developed in automated computer aided design (AutoCAD) and verified with a computer simulation using 2016 3-Dimensional solid works software. The static analysis, solid mesh, and free body forces were set and the simulation installed and attached. The material properties used was Acrylonitrile Butadiene Styrene (ABS) of linear elastic isotropic, tensile strength of 4 X 10^7 *N/m*^{2}*, elastic and shear modulus of 2.41 X* 10^9 *N/m*^{2} *and 8.622 X* 10^8 *N/m*^{2} *respectively with a mass density of 1070 kg/m*^{3}*. The simulation was run assuming a normal force of 200N exerted on the weight of the tomatoes, and a corresponding reactive force considered. Stresses on the container base and handles, ability to stack, drop and buckling tests were simulated. Simulation results revealed that the conceived container when developed can withstand the transportation rigor with insignificant damages to the packaged tomato.*

Key words: Tomato, simulation, stresses, packaging container, Solid works

1 INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a staple fruit vegetable, a member of the *Solanaceae* family (Abdullah *et al.,* 2004). It is one of the most important vegetables worldwide (Saeed Awan *et al.,* 2012) Tomato is a compression-sensitive fruit (Babarinsa and Ige, 2014), being a viscoelastic tender material that experiences compressive stress when packaged in unit loads, resulting in deformation, bruising and/or complete failure of the fruit. Food losses are on the increase in recent times. About 1.3 billion tons of food is predicted to be lost each year (Gustavsson *et al.,* 2011). In Nigeria where the agriculture sector contributes more than 30% of the GDP and employs about 70% of the labor force (Olayerni *et al.,* 2012), high post-harvest losses has continued to be observed in food supply chains of perishable agricultural commodities like fruits and vegetables (Idah *et al.,* 2007a; Parfit *et al.,* 2010).Conservatively, 90% of food supply from developing nations like Nigeria is wasted as a result of deterioration (Onifade *et al.,* 2013); another estimated loss of 40 – 50% of tomatoes are at post-harvest stages (Olayemi *et al.,* 2010). Furthermore, Idah *et al.* (2007b) stated an estimated loss of fruits and vegetables commonly in the tropics occurred between production areas and consumption points to be between 50 – 70% (Olanrewaju *et al.*, 2018). In Nigeria, freshly harvested tomato fruits are packaged in traditionally woven raffia baskets and transported in open trucks making them highly susceptible to mechanical damage due to poor packaging container and inappropriate transport system (Babarinsa and Ige, 2012; Ebimieowei and Ebideseghabofa, 2013). An inefficient packaging system is a disadvantage to tomatoes marketing as it has direct influence on cost, quality and overall post-harvest losses.

Verbal interviews conducted by the researcher received significant percentage of complaints from tomato marketers and consumer. Post-harvest losses was generally traced to packaging failure resulting from poor design or inappropriate selection and use.However, a well-designed tomato container is expected to contain, protect, and identify the produce, satisfying everyone from grower to consumer. Containers should be designed to protect tomato against damage during transportation and distribution and as well provide enough venting for rapid and uniform heat transfer during transportation and distribution (Clément *et al.,* 2009). It became expedient to have an effective tomato packaging container that could ameliorate post-harvest losses, hence, the conceived tomato packaging container that was subjected to simulation in this study, to ensure an effective tomato packaging container that could reduce post-harvest losses when developed.

Tomato packaging from time immemorial started with the use of broad green leaves, graduated to gourd and earthen pots, then weaved baskets, wooden crates, cardboard crates and boxes (Shankara *et al.,* 2005). Interestingly, among the mentioned packaging containers, only weaved baskets are still commonly used today because they are readily available, easy to produce and cheap. However, the damages inflicted on tomato fruits from the use of weaved baskets are numerous, resulting in tomato damage that forces farmers to sell their products at throw away prices. Girja *et al.* (2009) developed a corrugated fiberboard cartons for long distance transport in India. The specifications of the boxes were capacities 15 and 20 kg, bursting strength 11±1, number and diameter of ventilations 8 and 24.5 mm. Compression-drop and vibration tests were done on the peti box to determine its strength and weakness for long truck journeys. The boxes were generally acceptable by its users despite its deficiency of use during rain resulting in transporting products in covered van. Moreover, Pathare *et al.* (2012) reviewed the design of packaging vents for cooling fresh horticultural produce. Also, Abubakar, (2009) developed and evaluated the performance of an improved packaging for mass transportation of tomato. He developed a 15 kg rectangular wicker basket and transported fresh tomato fruits with it. His results were quite impressive. Idah *et al.* (2012) simulated transport damage on fresh tomato fruits by subjecting packaged tomato fruits in basket and plastics to some level of vibration in the laboratory. The simulation assumed that packaged tomato fruits travelled a distance of not less than 1000 km, considering vibrations subjected to the tomato fruits as a result of bad roads and vehicles transporting them.

2 METHODOLOGY

The concept of the packaging container was adapted from the conventional commonly used wicker baskets for packaging fresh tomato fruits with weight intervals of 20 – 40 kg. A sketch was made and developed into drawings using automatic computer aided design (AutoCAD) as shown in Figure 1. Design calculations was done considering appropriate plastic materials, weight, durability, ergonomics and other techno-economic factors.

The workability of the conceptual drawing was verified by subjecting the auto-cad drawing to a computer simulation using 2016 3–Dimensional solid works software. The 3D component was fully designed (the choice of material proposed for the design, the static and dynamic stresses to be applied) with high dimension accuracy and specific material choice. The components were placed within the simulation environment after setting the static analysis, solid mesh, and free body forces (Figure 2) on the computer and the simulation were installed and attached.

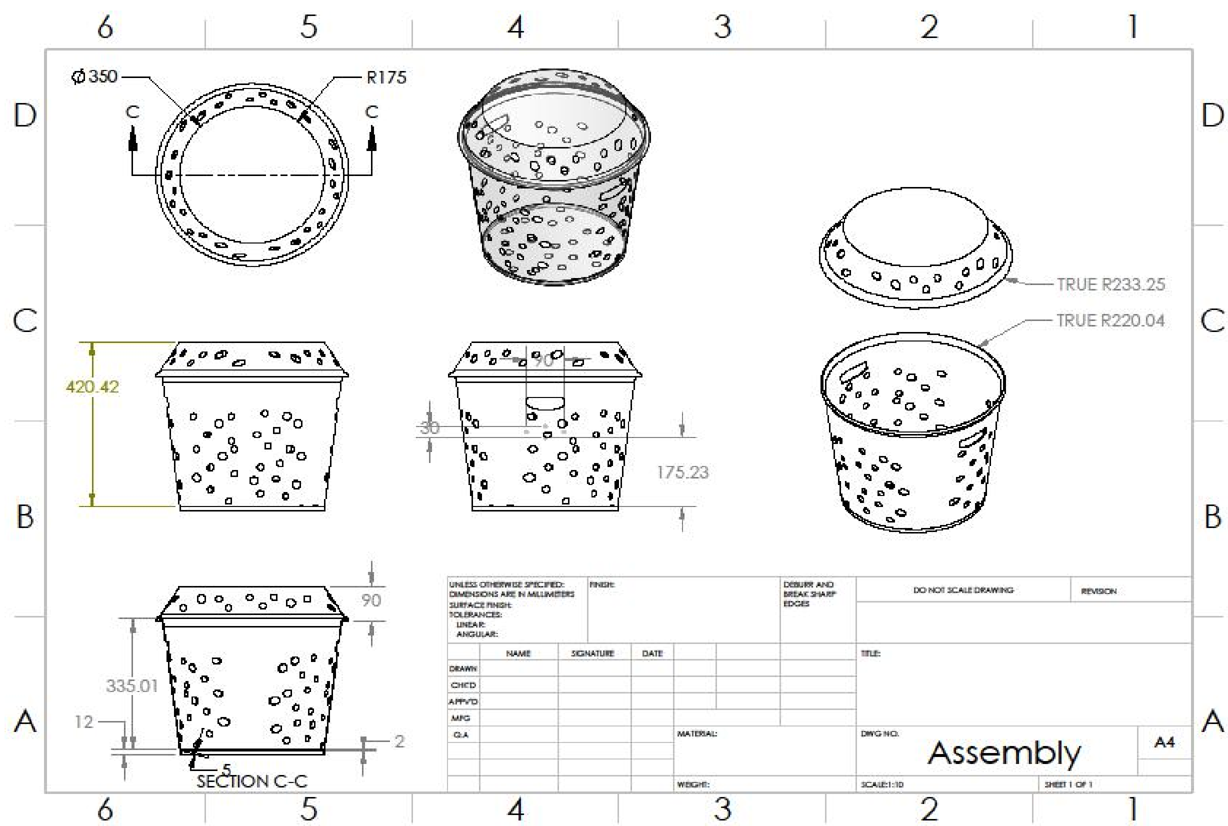

Figure. 1: Isometric, orthographic and plan Projections of the proposed packaging container

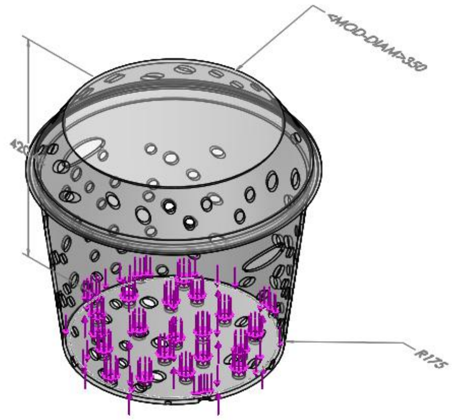

Figure 2: Initial installation of simulated components on the software

In running the simulation, an assumption of a single large tomato as presented in Figure 3 was made to reduce the processing workload of the simulation which would have taken several days if multiple normal size tomatoes were to be used. Each tomato would have been analyzed one after the other but since a single tomato was used, the simulation only lasted few hours. The material properties were ABS of linear elastic isotropic, tensile strength of 4 X 10^7 N/m^2, elastic and shear modulus of 2.41 X 10^9 N/m^2 and 8.622 X 10^8 N/m^2 respectively and a mass density of 1070 kg/m^3 (Olanrewaju, *et al.,* 2017). The simulation was run with a normal force of 200N exerted on the weight of the tomatoes, and a corresponding reactive force taken.

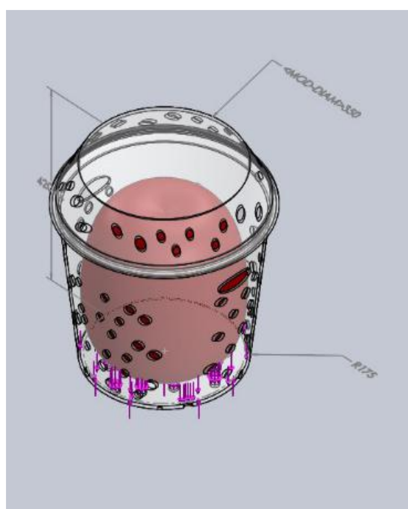

Figure 3: A single large tomato size

In simulating the base test; the container loaded with tomato was placed inside the simulation environment, gradual force was exerted on top of the container until it reaches 200N. The stress distribution on the container was observed especially on the base as presented in Figure 4. The container handles was subjected to a tensile stress when loaded and placed in the simulation environment. The stress subjected on the handle was from a gradual force applied on each of the handle towards different direction. The reaction of the handles and the entire container to this stress is seen in Figure 5. More so, the stack-ability test was done by placing 10 containers filled with tomatoes on top of one another inside the environment of the simulation. The containers placed on top of one another was assumed to be 30 kg each when filled with fresh tomato fruits.

The effects of the stack was observed on the bottom most container and presented in Figure 6. A drop test was done by placing a loaded container in the simulation environment, then dragged up to a height of 1 meter before it was abruptly dropped. The effect of the drop was studied as presented in Figure 7. Finally, the buckling test was done by subjecting the loaded container inside the simulation environment with a compressive force. A gradual force was applied at the top and bottom of the container. The behavior of the container was studied and presented in Figure 8. The responses of the test from the simulation was explained using coloration.

3 RESULTS AND DISCUSSION

The results of the simulation were interpreted using the color scale on the right side of each chart. The blue color designates the lowest value on the scale while red represents the highest, hence, within a stress test; blue areas indicate areas with least stress, while red are areas with the highest stress with reference to the scale. Though, red does not actually mean bad, but merely highest stress experienced.

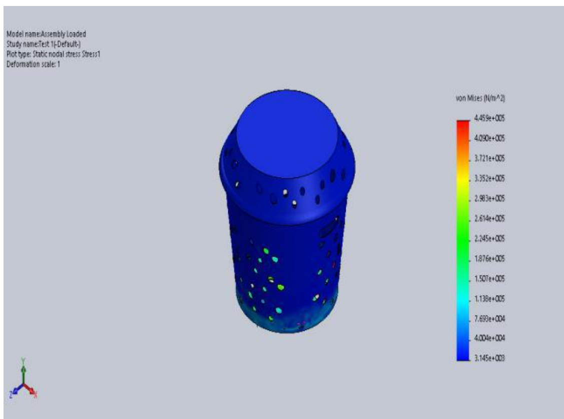

Figure 4: Stresses on base

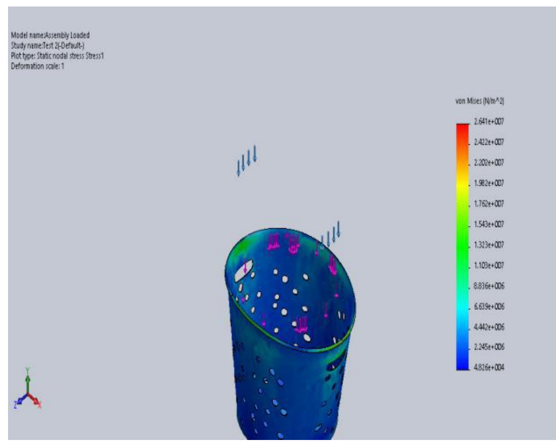

Figure 5: Stress on handles

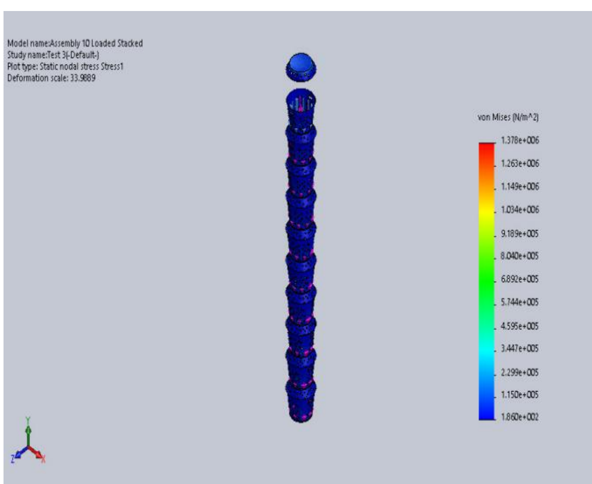

Figure 6: Stack ability test (Stack of 10)

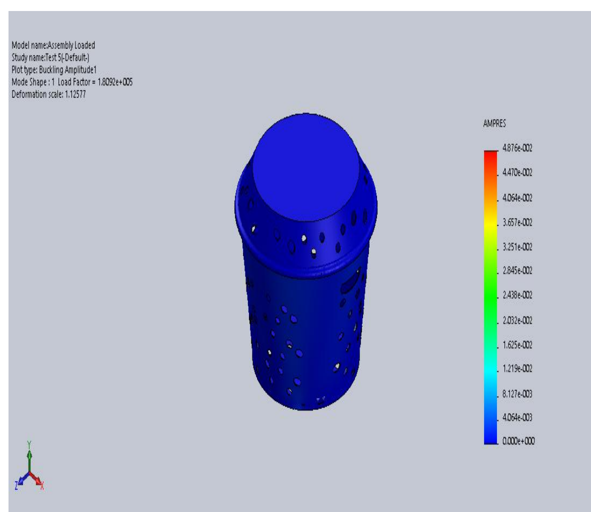

Figure 7: Drop test

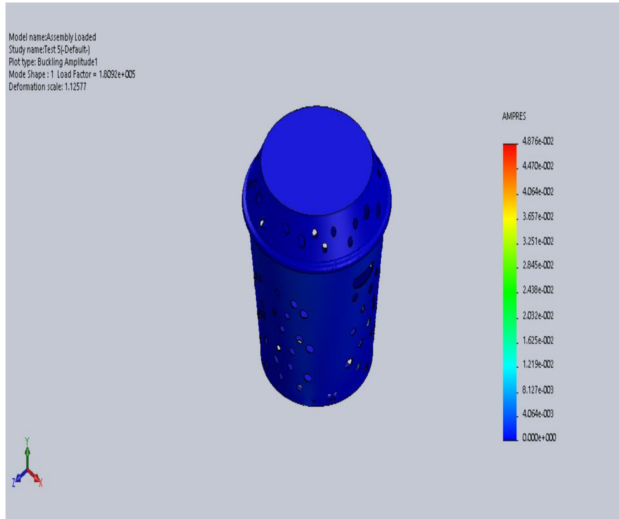

Figure 8: Buckling test

4 DISCUSSIONS

As observed from Figure 4, the stress chart showed that the container base is stressed between 1.507 X 10^5 N/m^2 to 2.983 X 10^5 N/m^2. The stressed experienced was a normal one, due to the fact that the base of the packaging container receives bulk of the load (dead and applied load). However, the stress experienced poses no threats to either the container or, the tomato fruits packaged in it. The handles of the packaging container as presented in Figure 5 was found to have stresses between the values of 6.639 X 10^6 N/m^2 to 8.836 X 10^6 N/m^2. Such high values were recorded as a result of the flexibility of the material selected; causing the handle slots to bulge when it is lifted. This effect is not a deficiency, rather, an advantage that results from the flexural properties of the chosen material as explained by Rachida and Ismahane (2011) in their study. Also, Figure 6 revealed that the base of the first seven containers from below were stressed between 1.149 X 10^6 N/m^2 to 1.263 X 10^6 N/m^2, a relatively smaller stress when compared with studies conducted by Babarinsa and Ige (2014). The first bottom 3 containers bears the highest stress while the top 3 containers were least stressed. Stresses on the bottom most 3 containers were basically as a result of the collective dead and applied load when stacked on top of one another. It is normal for the bottom most container to bear the highest stress during stacking, however, it is recommended that the stack height should be 5 containers. This is to maintain the minimum allowable stress and ensure longevity of the packaging container.

Moreover, Figure 7 was found to have concentrated stresses between 3.883 X 10^6 N/m^2 to 7.765 X 10^6 N/m^2 around the centroid of the packaging container; such stress concentration was an indication of a uniformly distributed stress along the circular walls of the container when accidentally or intentionally dropped from a height not more than 1 m without causing serious damage to the tomatoes. This result agrees with the study of Idah *et al.,* (2007b). Figure 8 was found to have a least buckling value of not more than 4.064 X 10^3 N/m^2. These values were found to be adequate for the rigor of the intended use as a result of the material selected. These study results are in agreement with the study of Idah *et al.,* (2012); Venus *et al.*, (2013) and Girja *et al.,* (2009).

A Summary of the simulated results is tabulated and presented in Table 1.

Table 1: Summary of Computer Simulation Results

Test	**Purpose of Test**	**Observation**	**Inference**	**Remarks**
Stress on base	Determine the ability of the container to hold the tomatoes for an extended period while placed on a floor.	The analysis reveals an even distribution of the weight along the base and low stress on the edges of the unit. Despite the thin thickness of the material the maximum displacement observed was still very low.	The modified basket will maintain its structure even when fully loaded with tomatoes	Good
Stresses on Handles	Determine the ability of the container to maintain its structural integrity while lifted and being held by the handles	The container bulges to accommodate the stress caused by the weight of the full load of tomatoes, but the bulge does not result in a permanent deformation of the container.	The bulge experienced was temporary and is expected to occur when the basket is fully loaded. Though, the Elastic limits are exceeded. The shape of the handle grip ensures a longer,gentler distribution of the stresses	Good
Stack-ability Stack of 10	Determine the filled tomato containers can be loaded on top of each other without causing failure.	The strain is distributed from the highest container down to the lowest and the design ensures the effect of it is spread throughout the container body.	The container body is easily capable of being stacked in rows of 10. The design ensures the load is stable and will not deform. But for reasons of safety and practicality, it is advised the stacked rows be limited to 5.	Good
Drop test	Determine how dropping a fully loaded container of tomatoes will affect the container when dropped from a height of 1 meters upon a hard surface.	The bottom rim of the container experiences very little stress, and little strain is experienced across the entire container and it is gently spread through the middle.	The design allows any stress from the impact to be evenly spread across the structure, no failure is expected to occur upon impact.	Good
Buckling test	Calculate the critical failure load of the container under compression to predict possible failure modes.	A very low amplitude is experienced by the container during the buckle experiment.	The design of the container can withstand whatever forces it will be subjected to within the wide range of possible tomato loading situations.	Good

5 CONCLUSION

Studies conducted on the simulated conceived packaging container for fresh tomato fruits was found to be appropriate for tomato packaging and transportation in Nigeria. When the container is eventually developed, it is expected to address the post-harvest challenges as related to fresh tomato fruits packaging and transportation. Moreover, the simulation information that this study provided has added to the data bank for developing an appropriate fresh tomato fruits packaging container for transportation.

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