# Evaluation of different packaging types for adoption in safe handling and transportation of fresh tomato fruits in Nigeria

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**Abstract:** This work evaluated plastic, wooden and carton crates and compared the best of them to traditional basket for possible adoption in safe handling and transportation of fresh tomato fruits in Nigeria. This was achieved through laboratory experiments and analyses involving static tests that involve loading the crates and storing them in static condition for a period of time, simulating storage conditions (at average temperature and humidity of 28.92ºC and 62.08% respectively) and dynamic tests, simulating handling and transportation conditions involving dropping from different heights and vibration at different amplitudes and frequency. Based on experimental results and economic considerations, carton crate was adjudged the best and a new modified design of it was developed. The performance of the designed crate and the traditional basket presently in use in Nigeria was compared. Results of comparative predictive analysis between the carton and the traditional basket revealed that losses that can be incurred using traditional basket while on transit is about 6.25%-7.08%; which can be reduced to an average of 5.71% when carton crates are used. In case of accident, the traditional method can incur an average loss of 51.59%, which can be reduced to an average of 37.88% when carton crates are used. In case of delay in travel (2-3weeks), the traditional method may lose an average of 23.81%-88.10%, but this can be reduced to 14%-67% when carton crates are used. Based on the findings of this study, tomato fruit postharvest handlers should be enlightened on the importance and benefits of using carton crates for handling and transportation of fresh tomatoes in Nigeria.

**Keywords:** fresh tomato fruits, packaging types, handling, transportation, post-harvest losses

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## 1 Introduction

The incidence of fruit postharvest losses and waste due to physical and mechanical damages caused by poor packaging and handling is a major problem in Nigeria. There is need for a systematic study to select and adopt a new packaging for tomatoes in order to minimize postharvest losses arising from poor packaging and handling methods. During handling and transportation of

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tomato fruit, both the packaging and contents experience a range of force conditions which include compression and vibration resulting to bruises and other forms of damage. Gebeyehu (2018) reported that the major factors influencing postharvest damages on fresh tomatoes resulting in losses incurred in Ethiopia include the nature of packaging material, lack of storage facility and mode of transportation of the produce. In Nigeria, as high as 10%-50% postharvest losses occur due to poor handling, delays in transport arrangements and long distances to urban markets (Odemero and Ngozi, 2014; Sibomana et al., 2016).

A good and suitable packaging material for fresh tomato fruit in Nigeria should be able to protect tomato fruits against mechanical damages, carry same volume of the produce as the current traditional method, sell the produce, and inform the buyers about the produce. These are the basic functions of a packaging material according to Esguerra et al.(2018). Haile and Safawo(2018) stated that packaging materials have significant effect on physiological weight loss, decay percentage, color score, overall acceptability and marketability of tomato fruits. The common packaging materials used in most developing countries include wooden crates, cardboard boxes, woven palm baskets, nylon sacks, jute sacks, and polythene bags. In Nigeria, the most prevalent of the crates are woven palm basket, wooden crate and nylon sacks.

The abovementioned packaging materials do not give all the protection required by tomato fruits. Nylon sacks do not allow good aeration within its packaged tomato fruit leading to heat build-up as a result of respiration. Woven palm basket and wooden crate have rough surfaces and edges which cause mechanical injuries to the produce(Okonkwo and Onu, 2018). Their height leads to compressive force that causes internal injury on tomato fruits placed at the base of the crates (Arah et al., 2015). From literature (Raji and Oriola, 2007; Rolle et al., 2011; Jayathunge et al., 2011; Esguerra et al., 2018) the commonly used packaging types and materials for tomato handling and transportation all over the world were identified as nestable plastic crate, plastic baskets, polyethylene sacs, cardboard box, wooden crate, steel collapsible crate and traditional woven palm basket. Analysis of many different literature information(Bank et al., 2011; Jayathunge et al., 2011; Kiaya, 2014) further revealed that the most commonly used packaging material in the countries that mostly produce tomatoes all over the world such as China, India, USA, Spain, Egypt, Turkey, Iran, Italy, Brazil and Mexico include the plastic, wooden and cardboard box (carton) crates. Esguerra et al.(2018) recommended the use of plastic crate as packaging material for tomato because of its rigidity which can provide adequate protection against compression force, smooth inside finishing, ease to clean and its reusability.

The shortcoming of this package material is that it is expensive when compared to other packaging material used in Nigeria and its return cost after use due to its stack ability and maintenance cost is high. Haile and Safawo(2018) recommended perforated low density polyethylene bag that resulted in longer shelf life with better-quality of tomato produce in their study for use as packaging of tomato fruit. The issue with this package material is that it cannot contain a sufficient quantity of tomato fruit and its not rigid to protect its content against vibrational force. Idah et al. (2007) simulated the extent of damage between the traditional basket and plastic basket, their result showed that the plastic baskets minimized mechanical damage on tomato than the traditional basket. Abubakar and El-Okene(2015) designed a rectangular shaped woven basket and compared its performance with the traditional conical woven basket. The rectangular shaped woven basket reduced the postharvest losses of tomato on transit from 13.22% recorded in the conical shaped woven basket to 3.58%. This study focused on identifying different packaging types available for tomato handling and transportation in Nigeria, evaluating the effects of each packaging type and material on the quality and shelf life of tomato, selecting the most suitable type and material, redesigning it and comparing the performance of the new design and the traditional baskets presently in use in Nigeria.

## 2 Materials and methods

### 2.1 Tomato harvest

Fresh tomato fruits (Derica tomato fruits) were harvested from a commercial farm located in Nsukka, Enugu state Nigeria (latitude 06052N and longitude 07024E), at the early hours in the morning based on visual maturity determination, with the aid of experienced personnel. The fresh tomato fruits were harvested on May, 2017 at exactly three months of age. Harvesting was carried out manually with maximum care to minimize mechanical damage. Fruits were selected for uniformity of color, size, shape and freedom from defects. Immediately after selection, fruits were washed with clean water to remove field heat, soil particles and to reduce microbial population.

### 2.2 Material selection

Based on analysis of literature information and experimental results; plastic crate, wooden crate and carton crate were selected used in this study. These materials are the most commonly used for handling and transportation of tomatoes all over the world.

### 2.3 Determination of the effect of different tomato packaging types and materials on the quality and shelf life of tomato

The effect of different packaging types and materials on the quality and shelf life of tomato were determined by two classes of tests: static and dynamic tests.

### 2.4 Static test

The different packaging types and materials were loaded with fresh tomato fruits and left in a static condition for a period of four weeks (28 days) in a room typical of where such crates are stored while in transit from the farm to the final consumer, with average room temperature and humidity of 28.92$^o$C and 62.08% respectively. At the end of every week (7 days), the extent of damage/deterioration on the tomato fruits in each packaging type leading to losses were determined. The quantity of tomato fruits lost in each crate were noted and recorded. A tomato fruit was considered lost if there was a crack on the fruit, if the fruit was infected by warm, pest or disease. Also, mass of fruits, major, minor and intermediate diameters of each fruit were measured and recorded each week and losses in mass of each tomato fruit were determined. The deterioration metrics determined included percentage mass loss and rate of mass loss in each crate. Randomly selected tomato samples were used to carry out lycopene content test at the beginning and at the end of the static test.

### 2.5 Determination of lycopene content of tomato

One gram of tomato sample was dissolved with 10mL of acetone in 50mL conical flask and allowed to stand for 20mins which was shaken gently at 4min interval to extract the colour substance in the sample. After agitation, the conical flask content was allowed to settle and then decanted to obtain a clear solution in a test tube. Five mL of benzene was added and shaken gently. Two distinct layers were observed, the upper layer was obtained by separation with separating funnel and collected in a glass ware and read off in the absorbance at 487nm. The lycopene content (mg100g$^{-1}$) as shown in Table 1 was calculated using the Equation ):

$$\text{Lycopene content} = \frac{Abs \times 10^5}{3370} \quad (1)$$

Where, Abs is the absorbance reading at 487nm(Berra, 2012).

### 2.6 Dynamic test

Dynamic tests included the vibration and drop tests respectively.

### 2.7 Vibration test

The vibration test was used to simulate what happens during transportation of the fresh tomato fruits loaded inside the crates and conveyed in haulage vehicles; this was carried out using Haver and Boecker Model 59302 Vibrator, following the ASTM D4169-09 and ISTA 2A Standards Test series. The different packaging types and materials were loaded with fresh tomato fruits and set up with a suitably constructed holder on the Vibrator. Vibration was carried out at two amplitudes: 1mm and 3mm, and each at frequencies of 2, 5, and 8 Hertz respectively, according to the procedure by Fadiji et al. (2016) and Chaiwong and Bishop (2015). The amplitudes and frequencies of vibration were chosen by preliminary studies, based on possible vibration levels and frequencies at each gallop during transportation.

**2.8 Drop test**

The drop test investigated what happens when any of the crates fall from a height while loading or unloading in and out of haulage vehicles. The drop test was done using a constructed drop test rig. The different packaging types and materials were loaded with fresh tomato fruits and set up on the drop test rig; and the crates were dropped at three different heights 1.5, 2.45 and 3m respectively, according to the ASTM D4169 and ISTA 2A Standards Test series with slight modification based on the height of common trucks used for transportation of tomatoes in Nigeria. 1.5m height was chosen based on possibility of fall from a standing position of workers involved in manual hand loading, 2.45 m height was chosen to simulate a fall from a standing position of workers on a truck while 3m height was chosen to simulate a fall from the utmost height of the truck during loading and unloading of the crates in and out of haulage vehicles or in cases of accident. The extent of damage on the fresh tomato fruits after each test were determined by visually checking and counting the number of fruits that were either broken or bruised.

**2.9 Design and construction of crate for safe handling and transportation of tomato fruits**

After subjecting the packaging types to static and dynamic tests as already described, carton crate (boxlike) was selected as the most suitable packaging type and material (i.e. the packaging type with overall minimum tomato loss). The carton box crate was therefore redesigned to determine the optimum geometry and economic capacity based on the determined engineering properties of the fresh tomato fruit specie.

**2.10 Design considerations**

The following were taken into consideration in the design of the crate: the crate should be able to reduce drudgery associated with the traditional systems for tomato handling and transportation, strength of crate should withstand the forces acting on the various components and also suitable to prevent bruises on the fruits, the crate as tomato handling and transportation system should suit the intended users and cause no side effect on him and his environment, the crate should carry same quantity of tomato fruits as the traditional basket can carry in one haulage vehicle, its tonnage must be within the capacity of the haulage vehicle.

**2.11 Optimum capacity design of crate**

**Determination of crate height:** A study of the Engineering properties (physical and mechanical) of the fresh tomato fruits and the physical dimensions of the common haulage vehicle in Nigeria was reported by Onu (2017); results of the hardness tests revealed that each of the tomato fruits could withstand an average compressive force of 31.65N before braking and could carry a load of 4.91N without deformation.

From Table 2, average mass of tomato fruits is 74.91g, thus average weight of the tomato fruits is 0.73N. If a tomato fruit can carry a load of 4.91N without deformation, therefore

A tomato fruit could carry an average,4.91/0.73=6 layers of tomato fruits without deformation.

However, for stability and to minimize the effect of self-load, it was assumed that the tomatoes were arranged stem end facing down and one crate will carry a maximum of three layers. For the purpose of this design, all physical and mechanical property values for the fresh tomato fruits were gotten from Onu (2017).

Average major diameter of tomato = 55 mm

For a maximum of three layers of fruits inside the crate, the average height of fruits standing on each other inside the crate = 3×55 = 165mm

Giving an allowance of 15mm, the crate was designed to have a height of 180mm = 0.18m

**Determination of crate length:** Assuming seven tomatoes were arranged across the length of the crate, average minor diameter of tomato = 60.5mm

Length of crate =60.5×7=423.5 mm

The length of the crate was therefore approximated to 430mm for ease of measurement and construction.

**Determination of width of crate:** Assuming five tomatoes were to be arranged across the width of the crate, where average minor diameter of tomato = 60.5mm

Width of crate = 5×60.5 = 302.5mm

The width of crate was therefore approximated to 310mm for ease of measurement and construction.

Crate dimensions were therefore determined as 430mm×310mm×180mm as length × width × height respectively.

## 3 Results and discussions

The experimental results and analytical results carried out to determine the best packaging type for adoption in safe handling and transportation of tomato fruits in Nigeria are presented below:

### 3.1 Performance of crates during static test

Averages losses of tomatoes in each packaging type are presented in Figures 1 and 2. Figure 1 shows the cumulative loss of tomato fruits in plastic, wooden and carton crate weekly (7 days). It was observed that plastic crate had the minimum loss of 78.33%, followed by wooden crate 83.33% and carton crate had the maximum loss of 90.48% at the end of week four. One factor which may have influenced losses in the carton crate could be that carton crates had no vent holes at the bottom which led to the carton crate absorbing and retaining most of the moisture lost by some decomposing fruits on top and middle layers. This situation plus the nature of carton as paper resulted in the carton crate becoming soaked with moisture and this enhanced the spread of pests (tomato worm) and diseases in the crate. Also the experiment was conducted during rainy season, a season when infestation of pests and diseases for tomato fruit is at its peak.

Figure 2 shows the average mass loss in percentage of the tomato samples in each crate per week. It was observed that the tomato samples in the wooden crate were losing moisture averagely faster compared to the samples in carton crate and plastic crate. Samples in plastic crate had minimum average mass loss. It was also observed that the average dimensions of the samples in each crate were reducing at the end of each week.

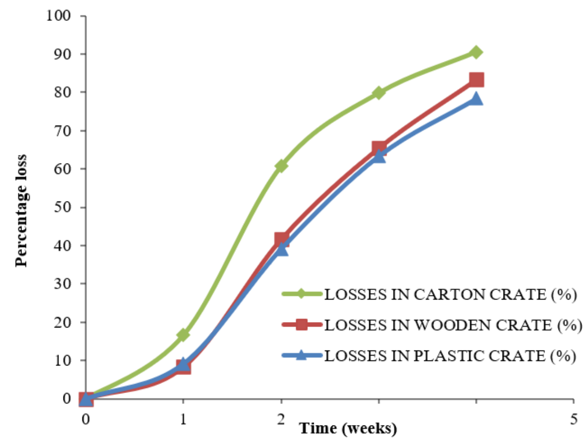


Figure 1 Percentage quantity loss of tomato fruits per week in different crate materials

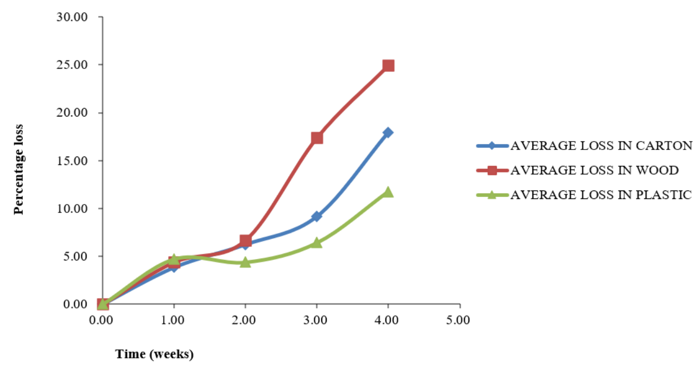


Figure 2 Percentage mass loss (%) of tomato samples per week

### 3.2 Lycopene test

Result of lycopene test is presented in Table 1. It was observed that ripe tomatoes have the highest lycopene content of 60.24mg100g$^{-1}$ followed by unripe tomato 45.55 mg 100 g$^{-1}$, then half ripe tomato 41.16 mg 100 g$^{-1}$ at harvest, after four weeks, ripe tomatoes have highest lycopene content of 81.40mg100g$^{-1}$ followed by half ripe tomato of 29.50 mg 100 g$^{-1}$ then unripe 16.20 mg 100 g$^{-1}$. This means that lycopene content of tomato fruit reduces as it changes from green unripe fruit to pink then red and increases as the fruit turns from light red to dark red as it ripens more. At harvest, the lycopene content of unripe tomato fruit was higher than the half ripe tomato fruit but lower than the ripe tomato fruit. It could also mean that no two tomato fruits have the same lycopene content even when tested at same maturity stage as lycopene test is a destructive test.

**Table 1 Lycopene test result**

| Maturity Stage | *Abs* | | Lycopene content (mg100g$^{-1}$) | |
|---|---|---|---|---|
| | At harvest | After 28days | At harvest | After 28days |
| Unripe | 1.54 | 0.42 | 45.70 | 12.46 |
| Half ripe | 1.39 | 0.77 | 41.24 | 22.85 |
| Ripe | 2.03 | 2.11 | 60.24 | 62.61 |

## 3.3 Performance of crate during dynamic test

### 3.3.1 Vibration test

Result obtained from vibration test is presented in Table 2. Table 2 shows the tomato losses (in number and percentage) in the three crates after being subjected to vibration test at amplitude 1mm and 3mm and frequency intervals of 2hertz, 5hertz and 8hertz. From Table 2, it can be observed that carton crate recorded minimum loss of tomato fruit when vibrated at both amplitude 1mm and 3mm when compared to plastic and wooden crates which might be as a result of the cushioning nature of carton crate.

**Table 2 Vibration test result**

| Amplitude | Frequency (Hertz) | Material | | | | | |
|---|---|---|---|---|---|---|---|
| | | Plastic | | Wood | | Carton | |
| | | Loss (pcs) | Loss (%) | Loss (pcs) | Loss (%) | Loss (pcs) | Loss (%) |
| Amplitude 1 | 2 | 3 | 2.86 | 6 | 5.56 | 1 | 1.04 |
| | 5 | 8 | 7.62 | 8 | 7.41 | 3 | 3.13 |
| | 8 | 10 | 9.52 | 12 | 11.11 | 6 | 6.25 |
| Amplitude 3 | 2 | 6 | 5.71 | 4 | 3.70 | 0 | 0.00 |
| | 5 | 7 | 6.67 | 6 | 5.56 | 5 | 5.21 |
| | 8 | 11 | 10.48 | 10 | 9.26 | 6 | 6.25 |
| Total quantity of tomatoes in each crate | | 105 | | 108 | | 96 | |

Eissa et al.(2013) concluded in their study that packaging fruit by cushioning material may move thenatural frequencies of the fruit out range of that thetransport vehicle resulting in reduced resonant vibrationand vibration bruising for fruit. Sharan et al. (2009) in India developed a corrugated fiber board cartons for long distance transport of tomatoes; they conducted a vibration test on the developed carton crates of 20kg and 15kg capacity and vibrated at 15mm amplitude, their carton crate lost between 3.2% to 6.2% of the tomatoes after 1hour of vibration. The losses experienced in the work of Sharan et al. (2009) is a bit similar with that of this work 0% to 6.25% losses as shown in Table 2 except that the duration of vibration and amplitude differ. This difference may be due to the specific specie of tomato used for the experiment, the specific characteristics of the vibrator used or other experimental details not mentioned. Also Seydim and Dawson (1999) simulated the effect of shell egg package during transportation; they simulated a vibration test in plastic and carton crates, and carton crate similar to the result of this work, recorded minimum loss of 9.03%compared to the plastic crate with loss of 16.28%.

### 3.3.2 Drop test

The results obtained during the drop test are presented in Table 3. It can be observed that on the average, carton crate protected its tomato fruits more resulting in minimum losses 20.56%, 38.61% and 54.17% at heights of 1.5m, 2.45m and 3m respectively, compared with plastic crate and wooden crate. This suggests that the cushioning nature of carton crates might have contributed to better absorption of the impact force due to fall more than the other crates with harder and rougher surfaces.

**Table 3 Drop test result**

| Height | Replications | Material | | | | | |
|---|---|---|---|---|---|---|---|
| | | Plastic | | Wood | | Carton | |
| | | Loss (pcs) | Loss (%) | Loss (pcs) | Loss (%) | Loss (pcs) | Loss (%) |
| 1.5 meter | 1 | 28 | 27 | 26 | 22 | 19 | 16 |
| | 2 | 37 | 35 | 33 | 28 | 24 | 20 |
| | 3 | 42 | 40 | 39 | 33 | 31 | 26 |
| **Average** | | **35.67** | **33.97** | **32.67** | **27.22** | **24.67** | **20.56** |
| 2.45 meter | 1 | 48 | 46 | 56 | 47 | 53 | 44 |
| | 2 | 22 | 21 | 53 | 44 | 46 | 38 |
| | 3 | 51 | 49 | 58 | 48 | 40 | 33 |
| **Average** | | **40.33** | **38.41** | **55.67** | **46.39** | **46.33** | **38.61** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 64 | 61 | 68 | 57 | 62 | 52 |
| 3 meter | 2 | 46 | 44 | 62 | 52 | 62 | 52 |
| | 3 | 66 | 63 | 76 | 63 | 71 | 59 |
| **Average** | | **58.67** | **55.87** | **68.67** | **57.22** | **65.00** | **54.17** |

### 3.3.3 Cost of crate materials

Table 4 shows the unit cost of each of the crate types, and this reveals that carton crate is the cheapest with $0.79 unit cost which may be improved when mass produced for commercial purpose.

**Table 4 Unit cost of the different packaging types in local currency**

| S/N | Crate types | Amount ($) |
|---|---|---|
| | Plastic crate | 6.84 |
| | Wooden crate | 9.21 |
| | Carton crate | 0.79 |
| | Traditional basket | 1.32 |

### 3.3.4 Material selection

The results of all the analysis carried out on the different types of crates are summarized in Table 5 and a bar chat in Figure 3 was used as a decision tool to select the best packaging material for the tomato crate.

**Table 5 Comparison of the performance of the three packaging types during various tests**

| Test | | Plastic | Wood | Carton |
|---|---|---|---|---|
| Unit cost | | $6.84 | $9.21 | $0.79 |
| Average coefficient of static friction | | 0.27 | 0.26 | 0.25 |
| Percentage loss during Static test | | 78.33% | 83.33% | 90.48% |
| | Percentage loss at 1.5m | 33.97% | 27.22% | 20.56% |
| Drop | Percentage loss at 2.45m | 38.41% | 46.39% | 38.61% |
| | Percentage loss at 3m | 55.87% | 57.22% | 54.17% |
| Vibration | Average percentage loss at 1mm amplitude | 6.67% | 8.02% | 3.47% |
| | Average percentage loss at 3mm amplitude | 7.62% | 6.17% | 3.82% |

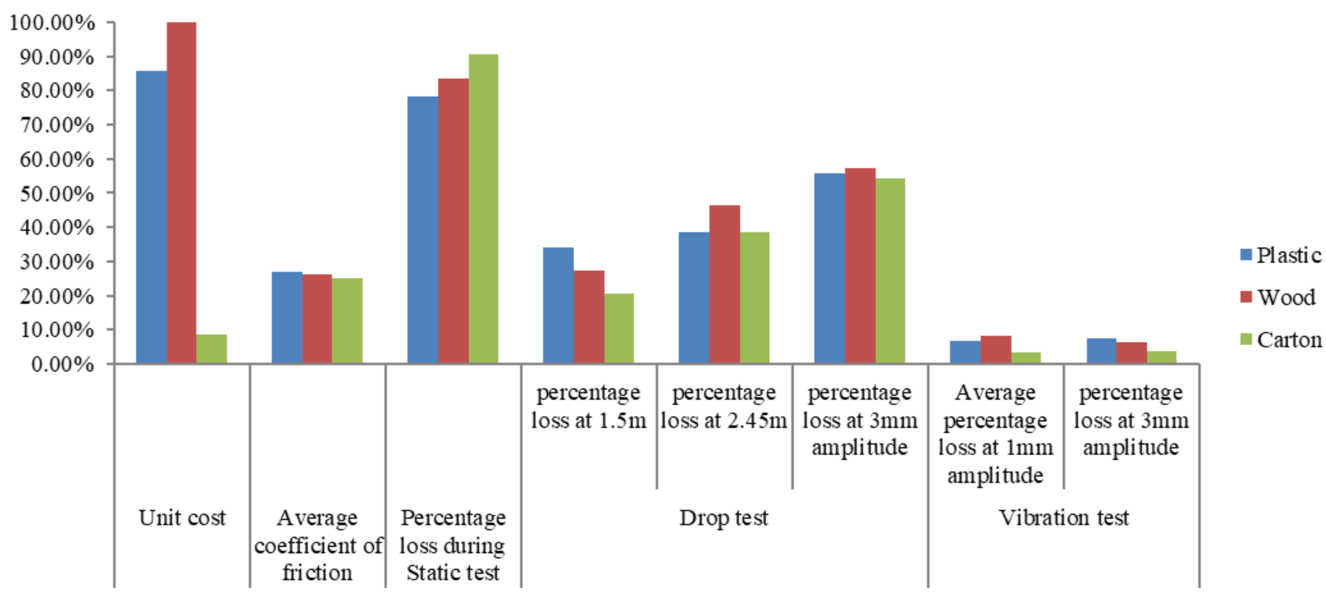


Figure 3 Comparison of the performance of the three crate materials for the various tests

In this study, carton crate was selected as the best crate for safe handling and transportation of fresh tomato fruits in Nigeria for the following reasons:

From Figure 3, carton crate performed best in all the dynamic tests except for static test which was as a result of the carton crate not having vent holes at the bottom like the wooden and plastic crates thereby absorbing all water lost by the tomato fruits in it and creating an enabling environment for pest and diseases. And this can be reversed with more vents and either controlled atmosphere or dry season period.

Carton crate recorded the lowest frictional force compared to plastic and wooden material (Onu, 2017).

The technology and energy involved in the design and manufacture of carton crate is low compared to wooden and plastic crates.

Carton crate is cheaper compared to the other materials.

3.3.5 Result of optimum capacity design of crate

The result of optimum capacity design of crate is presented in Table 6.

**Table 6 Properties of the optimized design**

| Parameter | Crate Dimension (mm) |
|---|---|
| Length | 430 |
| Width | 310 |
| Height | 180 |

## 3.4 Performance of traditional basket and the designed crate in dynamic test

3.4.1 Vibration test

The result of performance tests of the traditional basket compared with the designed carton crate are presented in Table 7.

**Table 7 Vibration test result for the designed carton crate and traditional basket**

| Amplitude | Frequency (Hertz) | Material | | | |
|---|---|---|---|---|---|
| | | Carton | | Traditional basket | |
| | | Loss (pcs) | Loss (%) | Loss (pcs) | Loss (%) |
| Amplitude 1 | 2 | 1 | 0.95 | 5 | 2.08 |
| | 5 | 3 | 2.86 | 7 | 2.92 |
| | 8 | 6 | 5.71 | 15 | 6.25 |
| Amplitude 3 | 2 | 0 | 0.00 | 2 | 0.83 |
| | 5 | 5 | 4.76 | 12 | 5.00 |
| | 8 | 6 | 5.71 | 17 | 7.08 |
| **Total Quantity of Tomatoes in Each Crate** | | **105** | | **240** | |

The result shows that the designed carton crate reduced loss of tomato fruits as a result of vibration during transportation by an average of 0.785% when compared to traditional basket. Lost tomato fruits from traditional baskets were observed to have experienced bruises, puncture damages and breakages; while lost tomato fruits from the designed carton crate only experienced breakages. The breakages were due to self-load of the tomato fruits, therefore traditional baskets may have lost more of its tomato fruits possibly because of its rough surface.

3.4.2 Drop test

The drop test results for the traditional basket and the designed crate are presented in Table 8. It was observed that the designed carton crate reduced loss as a result of drop from heights below 3metre by an average of 41.14% when compared to traditional basket. This observation is attributed to higher capacity of the carton crate to withstand impact compared to that of traditional basket. Also, the smoother surface area of the carton crate might have had less tendency to introduce puncture on the tomato fruits thereby minimizing rupture and bruises.

**Table 8 Drop test result for designed carton crate and traditional basket**

| Height | Replications | Material | | | |
|---|---|---|---|---|---|
| | | Traditional basket | | Carton | |
| | | Loss (pcs) | loss (%) | Loss (pcs) | Loss (%) |
| 1.5 meter | 1 | 62 | 26 | 17 | 16 |
| | 2 | 41 | 17 | 21 | 20 |
| | 3 | 98 | 41 | 27 | 26 |
| **Average** | | **67.13** | **27.97** | **21.67** | **20.63** |
| 2.45 meter | 1 | 144 | 60 | 46 | 44 |
| | 2 | 125 | 52 | 40 | 38 |
| | 3 | 149 | 62 | 35 | 33 |
| **Average** | | **139.33** | **58.06** | **40.33** | **38.41** |
| 3 meter | 1 | 132 | 55 | 55 | 52 |
| | 2 | 173 | 72 | 55 | 52 |
| | 3 | 190 | 79 | 62 | 59 |
| **Average** | | **165.00** | **68.75** | **57.33** | **54.60** |

3.4.3 Comparison based on static test result

Results for the comparison of losses during static test for both carton crate and the traditional basket are presented in Tables 9 and 10. Results show that carton crate preserved tomato fruits inside it for four weeks before losing 90.48% of the fruits while traditional basket preserved tomato fruits inside it for four weeks and lost100%. This means that traditional basket lost all the tomato fruits inside it in four weeks while carton crate may lose almost all after four weeks. Table 10 reveals that tomato fruits inside both packaging materials lose mass almost at the same rate; after two weeks traditional basket lost an average mass of 6.22% and carton crate lost an average mass of 6.23%. Similarly, after three weeks the traditional basket lost an average mass of 9.61% while carton crate lost an average mass of 9.17%.

**Table 9 Losses measured in pieces of fruits damaged for carton crate and traditional basket during static test**

| Week | Carton Crate | | Traditional Basket | |
|---|---|---|---|---|
| | Loss (pcs) | Loss (%) | Loss (pcs) | Loss (%) |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | 14.00 | 16.67 | 20.00 | 23.81 |
| 2 | 51.00 | 60.71 | 54.00 | 64.29 |
| 3 | 67.00 | 79.76 | 74.00 | 88.10 |
| 4 | 76.00 | 90.48 | 84.00 | 100 |

**Table 10 Average mass, mass loss, major, minor and intermediate diameter of tomatoes in carton crate and traditional basket during static test**

| Crate material | Week | Average mass (g) | Average mass loss (%) | Dimensions (mm) | | |
|---|---|---|---|---|---|---|
| | | | | Major | Minor | Intermediate |
| Carton | 0.00 | 74.28 | 0.00 | 49.75 | 53.52 | 54.10 |
| | 1.00 | 71.43 | 3.84 | 49.66 | 53.40 | 54.43 |
| | 2.00 | 69.60 | 6.23 | 49.57 | 52.33 | 54.00 |
| | 3.00 | 67.42 | 9.17 | 49.35 | 51.70 | 54.03 |
| | 4.00 | 60.48 | 17.94 | 47.85 | 50.65 | 52.51 |
| Traditional basket | 0.00 | 49.98 | 0.00 | 46.56 | 44.98 | 48.35 |
| | 1.00 | 48.43 | 4.10 | 45.92 | 44.10 | 47.83 |
| | 2.00 | 46.86 | 7.22 | 45.92 | 44.00 | 47.67 |
| | 3.00 | 45.18 | 9.61 | 45.43 | 43.47 | 47.48 |
| | 4.00 | - | - | - | - | - |

## 4 Conclusion and recommendation

(I) Among the crates evaluated in the study, namely plastic crate, wooden crate and carton crate, the carton crate was the most suitable packaging type for handling and transportation of fresh tomato fruits, in terms of both technical and economic feasibility.

(II) The durability of the plastic crate and wooden crate were higher than that of the carton crate but the damage to tomato fruits in the former packages were high as compared to the latter.

(III) The damage recorded in plastic and wooden crate were higher, due to presence of sharp hard edges.

(IV) The costs of transportation of these crates were higher when compared to carton crate because they occupy larger truck space on return of empty crates to the point of production, which is not applicable with carton crate.

(V) When carton crate was compared with traditional method of packaging namely traditional woven basket, the loss occurring in the traditional method when on transit is 6.25%-7.08%. But this loss could be reduced to an average of 5.71% when carton crates are used. In cases of accident, traditional method incurred an average loss of 51.59%, this could be reduced to an average of 37.88% if carton crates are used. In case of long distance travel (2-3weeks), traditional method lost an average of 23.81%-88.10%, which could be reduced to 14%-67% if carton crates are used.

Based on the findings of this study, the following recommendations are made:

(I) Farmers and tomato postharvest handlers should be educated and enlightened on the importance and benefits of using carton crates for handling and transportation of fresh tomatoes.

(II) Haulage vehicles for fresh fruits especially tomatoes, with some kind of controlled temperature, perhaps through hydro-cooling, should be implemented and popularized in Nigeria

(III)Further study should focus on the design of appropriate size, shape and position of vent holes on the designed carton crate in order to improve heat and mass transfer process in the carton crate, as is the practice in some advanced countries of the world.

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