Simulated transport damage study on fresh tomato (*Lycopersicon esculentum*) fruits

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Abstract: A simulated transport study under laboratory conditions was conducted to assess the performances of the current traditional basket which is the sole packaging container for tomato fruit handling and a plastic container which is currently not in use in the system. A developed vibrating table was used to excite vibrations and impact on the packaged fruits in these containers according to the ASTM D4169-08 International Standard, Assurance Level II. The results showed that 40%, 37.50% and 45% of the samples of tomato fruits from the top, middle and bottom of the traditional basket respectively were severely bruised after four hours of excitation. In the case of the plastic container, the corresponding values were 44.18%, 30.23% and 18.60% for the samples taken from the top, middle and bottom of the container, respectively. The average bruise width of the damage samples packaged in the traditional basket was 24.36 mm while the average length was 36.67 mm. In the case of the plastic container, the average bruise width was 15.18 mm and that of the length was 26.97 mm. The ANOVA shows that these mean values of bruise areas differed significantly ($p \leq 0.05$) between the two packaging containers. The plastic container which is currently not used by the handlers of these fresh produce performed better in reducing mechanical damage resulting from impact and vibration than the traditional basket solely used in the transportation of fresh tomato fruits in Nigeria.

Keywords: transport, damage, packaging containers, fresh tomato

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1 Introduction

In Nigeria, production of tomato (Lycopersicon esculentum), particularly Roma Vf variety in dry season is mainly by irrigation in the northern part, but the consumption is widespread throughout the country. Thus, transportation becomes very vital in the

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distribution process. Transportation and its associated problems therefore affect the quality and efficient distribution of the fresh produce.

Mechanical damage to fresh tomato fruits during transportation is quite significant. Generally, it is claimed that losses as high as 50% to 70% are common in fruit and vegetables between the points of rural production and urban consumption in the tropics (FAO, 1989; Osifo, 1995). It has been reported that losses up to 20% in some cases occurred in fresh tomatoes, pepper and onion transported from the production areas in northern Nigeria to an urban wholesale market in South West Nigeria, a distance of less than 1000 km (Olorunda and Aworh, 1983).

Evidence of severe problems of mechanical damage is on the increase and is affecting the trade in fruits and vegetables both locally and internationally (Altisent, 1991; Okhuoya, 1995). The high level of mechanical damage and diseases (often encouraged by mechanical damage) are clear indications of the need to improve the techniques of handling of perishable items like tomatoes. One likely means of achieving this is to explore alternative handling containers. However, a thorough investigation of the existing containers particularly the specific locations within the packaged fruits where damage is mostly concentrated requires investigation.

In particular, it has been reported that the basic mechanisms involved in the fresh fruit damage are impact and vibrations experienced by the individual items of the fruit as the vehicles traverse abrupt changes in road profiles (Jones, Holt and Schoorl, 1991; Olorunda and Tung, 1995; Singh and Singh, 1992). The vibrations due to transportation are influenced by road roughness, distance, traveling speed, packaging and some characteristics of the truck such as suspension and the number of axles (Vursavus and Ozguven, 2004).

Jones, Holt and Schoorl (1991) developed a road-vehicle-load model to predict the mechanical damage in loads of horticultural produce during transport. Results of the simulation of the model using predictor-corrector numerical solution techniques revealed that lightly loaded trucks cause more damage than the heavily loaded ones. It was recommended that since only selected values of some parameters were studied, investigations could be carried out on the effects of other parameters as well. These include road profiles, vehicle types and suspensions, different container types and load configurations which could provide important insights into the management of horticultural produce during transportation.

Understanding the behaviour of the produce under static and dynamic loads provides useful information in reducing mechanical damage and enhancing quality of the fresh produce during transportation, because damage to fresh produce due to mechanical forces is among the most important causes of losses of quality (Peters, 1996; Jones, Holt and Schoorl, 1991; Roudot, Duprat and Wenian, 1991; Jan, Vandewalle and Baedemaeker, 1997; Batu, 1998; Dewulf et al., 1999).

Reduced mechanical damage would ensure that fresh tomato gets to the consumers and processors in better state since it is believed that increase in food production is not the only goal in the food supply chain, but also how to get the food to the consumers in a desirable quality condition. Contrary to the general belief, the processors are just as much concerned about mechanical injury to fruits which they receive as the fresh fruits retailers and consumers (Altisent, 1991).

The present work simulates the road profiles, the vibration from these profiles under laboratory conditions and measures the mechanical damage to the fresh tomato packaged in two different containers with the view to ascertain the effects of these containers on the extent of bruising on the fruits.

2 Materials and methods

This study focused on simulating the factors of roads, vehicle and packaging systems and their effects on fresh tomato damage. Dimensions of road irregularities such as pot hole depths, bump heights and elevation profiles of the major roads used for fresh tomato haulage were carried out and the data collected were analyzed. The data collected were used to develop a vibrating table that was used in this study (Idah, 2010). Two packaging container types, the traditional basket woven from palm fronds (PM1) and plastic basket (PM2) were used to package the fresh tomato fruits. The tomatoes used in this study were the *roma* variety. This variety was selected because it is the most common variety that is usually hauled over long distances in Nigeria. The tomatoes were hand picked from a vegetable garden Chanchaga, in Minna Niger State, Nigeria.

The developed vibration table was used to simulate a typical road transportation condition in Nigeria under laboratory conditions. The sensor of the vibration meter (VI-100 from Quest Technologies) was mounted on the platform of the table. The AC output of the meter was connected to a Digital Storage Oscilloscope (GDS- 1000 Series, GDS 1062, 60 MHz from GWINSTEK) where the output either in terms of displacement, velocity or acceleration (in g's rms) was displayed. The output signal were recorded on a memory card and transferred to PC. The experimental set up is as shown in Figures 1 and 2.

Figure 1 Set up with fresh tomato packaged in the traditional basket (PM1)

Figure 2 Set up with the fresh tomato fruits packaged in the plastic basket (PM2)

In this experiment, two packaging containers namely, the palm basket (traditional) and a plastic basket were used to study their effects on the mechanical damage of the fruits. The containers were packed with 20 kg of the fresh tomato fruits and fixed on the platform of the vibrating table. The ASTM D4169-08 International Standard by Michel Magendans (Kipp, 2000) was adopted for the test. This standard described the test procedure for transport simulation test using a single-packaging or a combination of pallet-packaging and where the truck simulation acceleration and vibration spectrum are specified depending on the assurance levels. Three assurance levels are specified in the standard and Assurance level II was adopted in this study.

Measurement of packaging transmissibility was carried out by placing the packaging containers on the vibrating table and subjected to vibration for specified durations of 4 hrs to simulate an average distance of 2100 km. The transmissibility of vertical vibration was measured at two stages. First stage, the vibration accelerometer was mounted on the vibration table and the vibration acceleration in the vertical direction was measured. Second stage, the accelerometer was attached to the containers of tomato and the acceleration was measured. Packaging transmissibility for the various packaging methods was computed using the equation (Vursavus and Ozguven, 2004):

$$P_T = \frac{a_b}{a_t} X 100 \quad (1)$$

where, P_T = packaging transmissibility (%), a_b = vibration acceleration on the container (g), a_t = vibration acceleration on the vibration table (g).

Tomato fruit damage was determined based on only mechanical injury. Damage in terms of bruising was assessed by taking 50 samples of the fruits from top, middle and bottom of the containers after subjecting the fruits to vibration for the four hours period. The samples that displayed signs of bruising were sorted out and the dimensions of the bruised areas were measured.

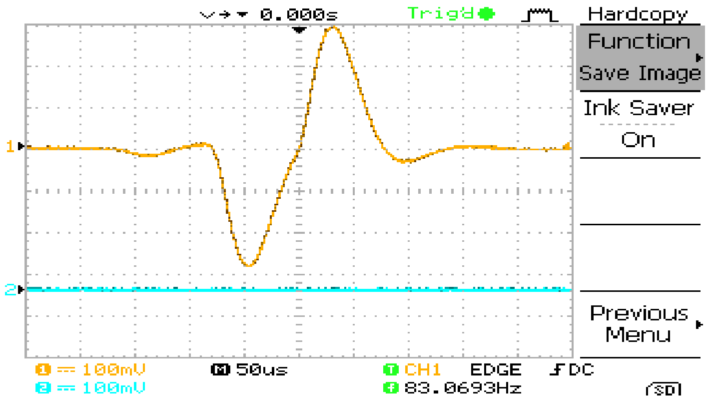
Control samples (unvibrated) were assessed alongside with the above to actually ascertain the effects of vibration. The samples were stored for two days during which the bruise damage and other forms of mechanical damage were assessed. The samples were weighed periodically during storage period to determine the weight loss in the stressed samples.

The data collected on the mechanical damage were subjected to statistical analyses. A complete randomized block design was used. The factors considered were the packaging containers, the depth of sampling and the interactive effect. The analyses of variance(ANOVA) was done in order to ascertain if there were any significant differences among the mean bruise dimensions on the damaged fruits from the various depths in the two containers. The statistical package MINITAB, release 14 (2003) was used for the analyses.

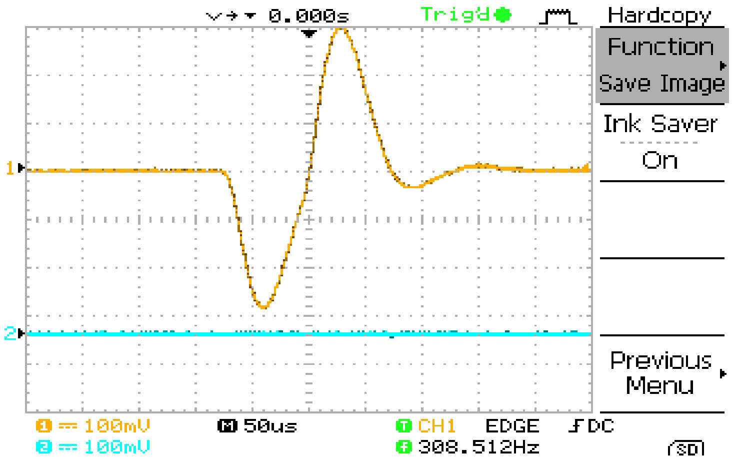
3 Results and discussion

The results of the laboratory simulation of transport damage due to vibration on the tomato fruits are presented thus:

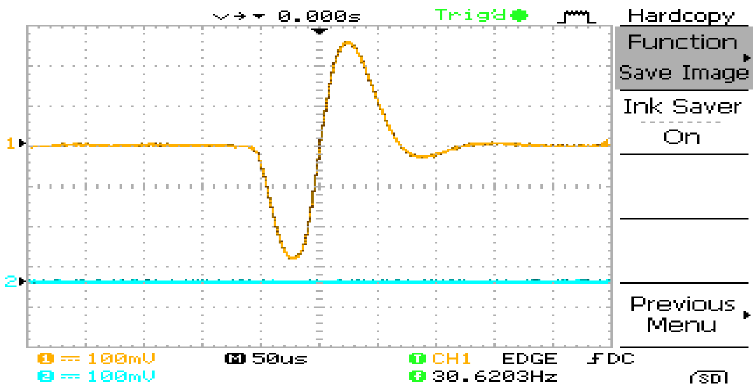
The average root mean square (r.m.s) value of the measured acceleration of the vibrating table during the exercise was 0.25 g on the table platform, 0.22 g and 0.20 g inside the traditional basket and plastic basket respectively. The packaging transmissibility for the two packaging containers was 88% and 80% for traditional basket and plastic basket respectively. The average r.m.s. value of the measured displacement (i.e. amplitude) read out from the vibration meter is 2.46×10^{-5} m. A sample of the displayed vibration output signal captured during the test is shown in Figure 3.



a: Vibration amplitude on the table top displayed by the digital storage oscilloscope during the laboratory simulation.



b: Vibration amplitude inside the traditional basket displayed by the digital storage oscilloscope during the laboratory simulation.



c: Vibration amplitude inside the plastic container displayed by the digital storage oscilloscope during the laboratory simulation.

Figure 3 Vibration amplitude during the laboratory simulation test.

The results of the damage assessments carried out on the samples of fruits from various depths of loading inside the two packaging containers (traditional basket PM1 and plastic basket PM2) are shown in Figure 4. The damage consisted of darkened streaks (bruises) on the skin with signs of water soaked underneath the skins.

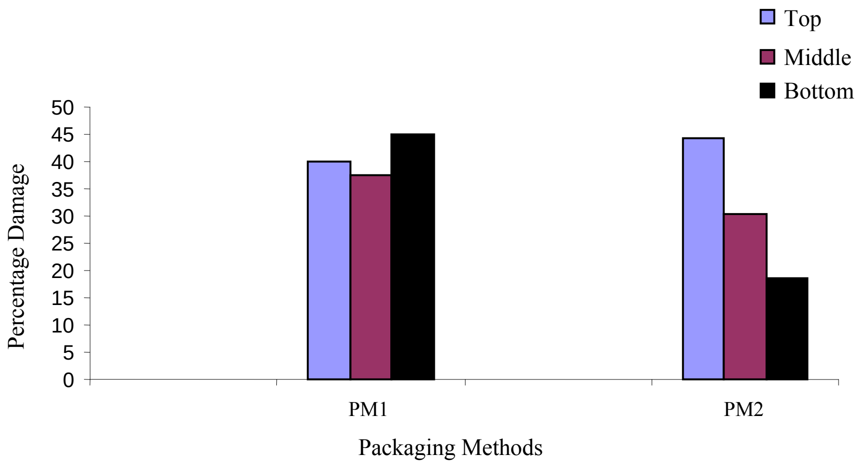


Figure 4 Percentage damage of tomato fruits after four hours of stressing using two packaging containers

The fruits were stored for two days in the laboratory at 23^{o}C and 67% relative humidity. The results of the assessments of the extent of damage of fruits are as presented in Figure 5 and Figure 6.

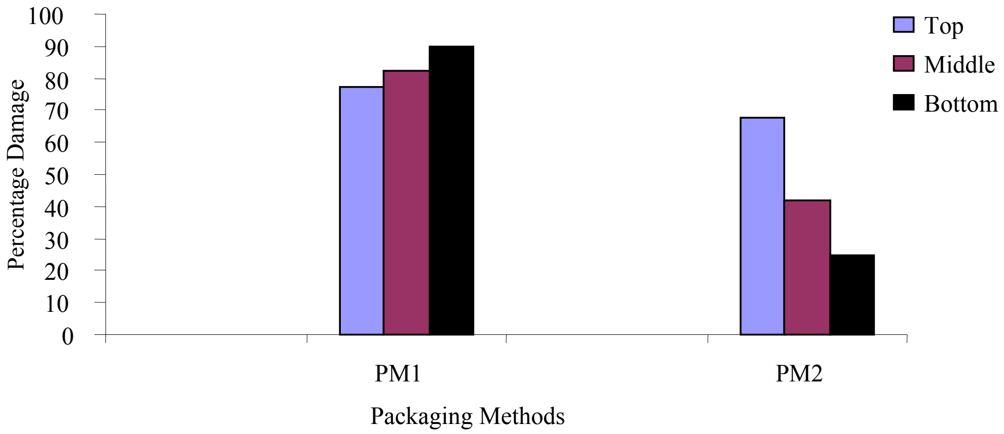


Figure 5 Percentage damage to tomato fruits 24 hours after stressing for four hours using two packaging methods

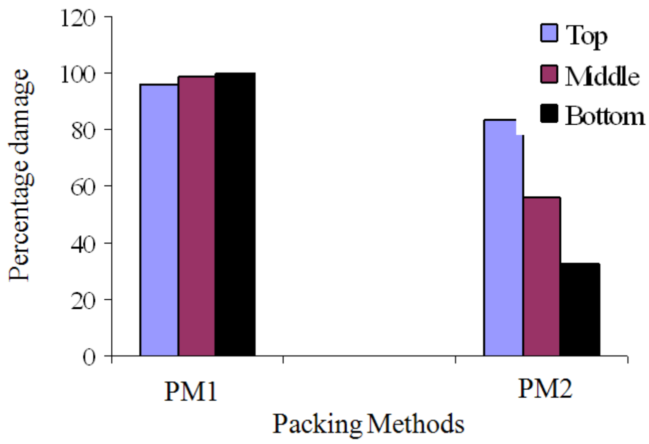


Figure 6 Percentage damage to fresh tomato fruits 48 hours after four hours of stressing using two packaging methods

Figure 7 shows the percentage weight loss from the samples of the stressed fruits. Some samples of the damaged tomato fruits are as shown in Figure 8 and Figure 9.

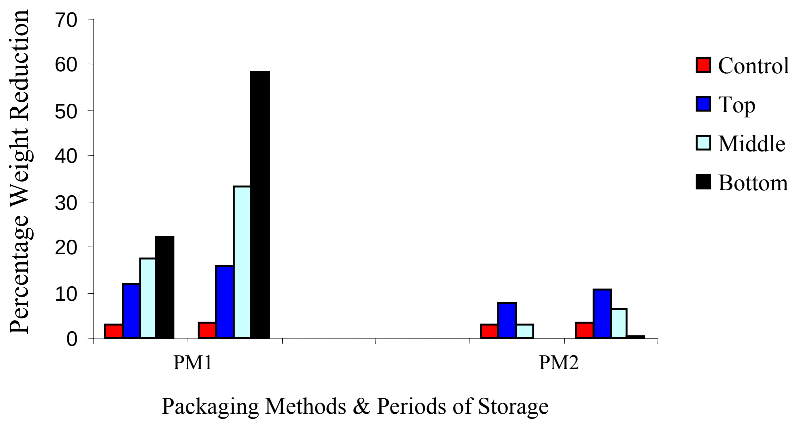


Figure 7 Percentage weight loss in the fresh tomato fruits during the period of storage after vibration

Figure 8 Some samples of the stressed tomato fruits using the traditional basket

Figure 9 Samples of the stressed tomato fruits packaged in plastic container

4 Discussion

A simulated transport study under laboratory conditions was conducted to assess the performances of the current traditional basket which is the sole packaging container for tomato fruit handling and a plastic container which is currently not in use in the system. The developed vibrating table was used to excite vibrations and impact on the packaged fruits in these containers.

The results (Figure 4) showed that in the traditional basket (PM1), 40%, 37.50% and 45% of the samples of tomato fruits taken from the top, middle and bottom of the basket respectively were severely bruised after 4 hours excitation which according to the ASTM D4169 truck. Assurance Level II stimulates an average distance of 2100 km. With regards to the plastic basket (PM2), the corresponding values were 44.18%, 30.23% and 18.60% for the samples taken from the top, middle and bottom of the basket respectively after 4 hours of stressing. It was observed that most of the severely bruised fruits in the traditional basket were those in direct contact with wall and floor of the basket. These are areas where friction between the fruits and surface of the packaging container was more. In the case of the plastic container, it was observed during the exercise that the magnitude of vibration at surface was greater as the fruits were moving freely and impacting on each other and this is responsible for higher percentage of damage at the top or surface of the packaged fruits. These results agree with other studies (Jones et al., 1991; Ran et al., 2007). Unlike the traditional basket, samples of the fruits at the bottom of the plastic container suffered the least bruises. The overall results indicate that samples of the fresh tomato fruits packaged in the traditional basket suffered more damage (40.83%) than those packaged in the plastic basket (30.98%).

After 24 hours of storage, the percentage of damaged fruits increased to 77.50%, 82.50% and 90% for samples from the top, middle and bottom positions respectively in fruits packaged in the traditional baskets (Figure 5). For the samples in the plastic container, the values were 67.44%, 41.86% and 25.00% for those from top, middle and bottom positions respectively. It was observed that the samples of fruits that showed signs of bruises on the first day of the experiment became rotten or decayed.

After 48 hours of storage most of the fruit samples that were packaged in the traditional baskets had become completely decayed. The opening of the bruised areas led to release of moisture from the damaged fruits. This also exposed the fruits to infestation by other spoilage organisms thus accelerating the rate of decay. Those that were not rotten showed signs of shrinkage and this led to decrease in weight as can be seen in Figure 7. The results showed that the samples packaged in the traditional basket suffered greater weight losses than those packaged in the plastic container. The control sample (unvibrated) showed less reduction in weight during this same period of storage. Some of the samples are shown in Figure 8 and Figure 9.

The dimensions of the damaged (bruised areas) were assessed. The results of the assessment are presented in Table 1. The average bruise width of the damage areas in the samples packaged in the traditional basket was 24.36 mm and the average length was 36.67 mm. With regards to the samples packaged in the plastic basket, the average width of damage was 15.18 mm and that of length was 26.97 mm. The measured bruise dimensions were subjected to statistical analysis to ascertain whether the mean values of this damage sizes differ significantly between the samples from the two packaging materials and also the samples from the various depths in the package. The summary of the results of the ANOVA on the assessed damaged fruits are shown in Table 2. The average bruise dimensions obtained in this study for fresh tomatoes agreed with other earlier studies (Berardinelli et al., 2005). The results also showed that the average dimensions of damage in the samples packaged in the traditional basket differed significantly ($P \leq 0.05$) from those packaged in the plastic basket. The average bruise dimensions obtained in this assessment for the samples packaged in the traditional basket fall into the category of severe damage according to the classification given by Vursavus and Ozguven (2004), while those of samples packaged in the plastic container fall within the medium category of damage.

Table 1 Characteristics of damaged fresh tomato fruits, mean values and standard deviation (SD, in Brackets) of the bruise sizes in damaged fruits from each depth.

Packaging Method	Position in the container	Damaged fruits %	Mean width of bruises (SD) mm	Mean Length of bruises (SD) mm	Overall mean dimensions	
					Width (SD) mm	Length (SD) mm
Traditional Basket(PM1)	Top	40	23.30 (1.05)	34.80 (1.02)	24.36 (1.37)	36.67 (1.24)
	Middle	37.50	24.52 (1.15)	36.40 (1.05)		
	Bottom	45.00	25.30 (1.26)	38.80 (1.39)		
Plastic Basket (PM2)	Top	44.18	18.70 (1.32)	28.60 (1.04)	15.18 (1.15)	26.97 (1.22)
	Middle	30.23	13.85 (1.25)	26.80 (1.34)		
	Bottom	18.60	13.33 (1.19)	25.50 (1.52)		

Note: The mean values were calculated only on the damaged samples.

Table 2 Summary of the ANOVA results on the assessed damaged fruits

Source of variation	DF	F-values (length of bruise)	F-values (Width of bruise)
Packaging method(PM)	1	10.826**	18.514**
Depth in package(D)	2	0.887ns	0.363ns
PM x D	2	3.839**	4.917**
Error	66		

** Significant at 0.05 level, ns = not significant ($p \leq 0.05$)

The essence of the simulated transport study in this research is to ascertain the effects of the road-vehicle-packaging system on the mechanical damage of the fresh tomato fruits during transportation. The assessment of the two packaging containers in this study is to investigate the possibility of improving on the packaging methods that will minimize the losses. Since the vehicles and the roads in the distribution system are already in place and cannot easily be influenced, the only available alternative is to improve on the packaging containers. The results of the assessment carried out here had revealed some positive indications in this regard. The extent of mechanical damage measured using this simulated study and under the specified conditions conformed to the ASTM Standard D4169-08 (Kipp, 2000) and so the performances of the containers used are indications of their suitability or otherwise in quality maintenance during transportation.

The effects of these packaging containers had been investigated in this study. The traditional baskets recorded more severe mechanical damage in the fruits samples packaged in it than the plastic basket. Majority of the severely bruised samples in the traditional basket were those in contact with the wall and the floor due to its rough surfaces. Earlier studies (Kra and Bani, 1988) suggested that the rough internal walls of the palm baskets should be turned outwards. Implementing this recommendation will however make it difficult to handle the baskets during loading and unloading because of injuries that will result from rough surfaces.

Currently, it is only the traditional baskets woven from the palm backs that are being used in the distribution of tomato fruits in Nigeria. Studies have shown that these baskets are not suitable for handling delicate fruits like tomatoes (Kra and Bani, 1988; Oyeniran, 1988, Daramola and Okoye, 1998). However, no alternative containers have been tried along with the palm baskets. The results from this study showed that the plastic containers can perform better especially in reducing the incidences of mechanical damage during transportation resulting from the robbing of fruits on the walls of the containers. Abubakar (2009) designed a rectangular plastic basket as an alternative to the current traditional basket but the designed plastic container could not be fabricated due to the cost of mould.

Since the traditional baskets currently being used are in different sizes which form the basis of pricing the product (Idah, Ajisegiri and Yisa, 2007), the new plastic containers can be designed and fabricated in line with the traditional baskets shapes and sizes for easy acceptance and adaptation by the handlers and transporters. Unlike in the past when plastic industries were scarce in the country, several of these companies now exist in the country. Also, since the high cost of these containers are some of the reasons for their non-usage in the fresh fruits and vegetable distribution system (Idah, Adeoti and Oje, 1999), adequate collaborative work can be embarked upon between the universities and the plastic companies in the country in this regard. Introduction of the plastic containers into the distribution system of the fresh tomato transportation in Nigeria will greatly enhance the delivery of high quality product to the consumers.

5 Conclusions

Comprehensive assessments of the effect of road-vehicle-packaging system on the quality of fresh tomatoes during distribution in Nigeria had been carried out with a view to minimizing mechanical damage and reduce losses. From the results the following conclusions could be drawn:

The plastic container which is currently not in use in the system performed better in reducing mechanical damage resulting from vibration and impact than the traditional baskets currently being used to package fresh tomatoes and should therefore be exploited.

The results obtained from these investigations form a data bank which handlers, packaging containers and processing equipment designers and those involved in the management of post harvest distribution of fresh tomatoes can use to provide appropriate handling methods that will reduce losses in the distribution of fresh products in the country.

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