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RESEARCH ARTICLE

Evaluation of plastic crate as replacement for raffia basket to prevent in-transit damage of packaged tomatoes

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ABSTRACT

In-transit damage of tomatoes packaged in plastic crate and raffia basket was evaluated in cross- regional transportation trials undertaken from Kwana Garfan (in Kano State) to Mile 12 market (in Lagos), Nigeria. Roma tomatoes were purchased from farmers and aggregated at a collection centre located at Kwana Garfan. There, two 25-tonne trucks were loaded with wholesome tomatoes differently packaged in plastic crate and raffia basket. Before departure to Lagos, samples of each filled container type were strategically positioned on the respective trucks. The commercial trips (from Kwana Garfan to Mile 12) covered a distance of 998 km, taking two (2) days. At Mile 12 market (Lagos destination), in-transit damage in delivered tomatoes was evaluated by sorting and separating damaged fruit within sample lots of each container type. Weights of damaged fruit in each sample container were determined for each truck. Baskets incurred high in-transit damage of 34.72% to 49.78% (with 41.12% average). The use of plastic crate reduced this damage to a level of 4.69 to 5.24% (with 4.92% average), thereby reducing damage in crates by 88%. In trucks, loaded in 5 basket layers, high levels, 49.78% and 45.70%, of the total damage occurred at the bottom and topmost layers (first and fifth layers respectively) of tomato baskets while lower damage levels of 37.4%, 36.72% and 37.9% occurred at the three middle layers (second, third and fourth layers) respectively. A follow-up trial with a 20-tonne truck carrying baskets of tomatoes from Kaduna showed the same trend of fruit damage.

Keywords: Plastic crate, raffia basket, packaging, Roma tomatoes, in-transit damage, transportation

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INTRODUCTION

The tomato (*Lycopersicon esculentum* Mill.) is one of the most widely cultivated and consumed fresh vegetables in Nigeria. The country is second largest producer of tomato in Africa, second only to Egypt and 13th in the world, producing about 1.5 million tons of tomatoes in a year (FAO, 2013). The vegetable is consumed as complementary foods, forming the most common vegetable crop in the country diet. Tomato is important also because of its unique commercial value as both a fresh vegetable and as concentrated processed products.

Because the greatest concentration of production is in the northern part of the country, there exists an active local trade in the vegetable fruit largely between the cities in the north and those in the south. Nearly all the harvested tomatoes are bulk packaged in raffia woven baskets for transportation, by road, to the southern parts (Idah et al., 2007a). This follows interstate roads over a long distance for different production areas and wholesale markets, such as about 998 km from Kano to Lagos and about 912 km from

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Kaduna to Lagos. The Roma variety is highly favoured in commercial production and transportation in the country in consideration of its relative firmness.

Various authors have undertaken simulated transit studies on of Nigerian tomato fruit to investigate the effect of compressive load, container, vibration and maturity on mechanical damage (Olorunda and Tung, 1985). Idah et al. (2009) specifically studied the resonance frequency as related to prevention of damage during transportation. These workers (Raji and Oriola, 2007; Idah et al., 2007) have identified that most of the large losses encountered during distribution from farm to consumer are due to poor postharvest handling. In particular, the fruit is highly susceptible to transportation spoilage due to poor packaging (Idah et al., 2007a). In Nigeria, therefore, tomatoes present special problems of both transportation and packaging because they are much more perishable than other fruits and vegetables types (Mohammadi-Aylar et al., 2010) like oranges and mangoes. Packaging thus presents special problems of quality deterioration in tomato more than other transported fruits and vegetables because it is more perishable and tender (Mohammadi-Aylar et al., 2010). For internal trade in Nigeria after harvest, the raffia baskets used in packaging tomatoes are woven of strips of raffia ribs, and are carried in open trucks. This conventional packaging material does not effectively protect the fruit en route but frequently causes tomato spoilage. Considerable mechanical damage is inflicted, due to compression, on the packaged fruits in the distribution system (Babarinsa and Nwangwa, 1987; Chepngeno et al., 2015). This in-transit damage (such as bruising, collision and impact) results in produce loss and low quality products at the destinations (Shirmohammadi, et al., 2011, Raji and Oriola, 2007; Idah et al., 2007) with consequent financial losses. Losses occur at handling stages emphasizes the need to focus on packaging solutions required at these stages of the tomato value chain. Accordingly, selection of suitable and appropriate package types is desirable to minimize postharvest losses during transportation of tomatoes. There is therefore the need for practical evaluation of the extent of the form of damage and quantify the losses incurred in transit with tomatoes packaged in raffia basket through the distribution phase in the postharvest system. Subsequent improvement of tomato packaging will have a very significant economic impact by enhancing higher financial returns to all stakeholders - the transporters, dealers and retailers.

The aim of the present study was to investigate the extent of mechanical damage inflicted on tomatoes during transportation due to use of raffia baskets. This is with a view to evaluating intended gain from using plastic crate as replacement for the basket to prevent the in-transit damage of tomatoes. In-field transportation trials were undertaken between northern Nigeria (Kano and Kaduna) collection centres and southern Nigeria wholesale market at Lagos (Mile 12 Market).

MATERIALS AND METHODS

Plant materials

Freshly harvested tomatoes of the Roma variety were purchased from farmers and were aggregated at the collection centres located at Kwana Garfan (in Kano State). The tomatoes, mostly at the table ripe stage, were slightly sorted to separate fruit with surface injury from sound fruit. Tomatoes that were deformed, damaged, decayed, or cracked were discarded promptly.

Packaging containers

The two packaging materials used for tomato packaging for the interstate trips were raffia basket and nestable plastic crate.

***Raffia Basket*:** The basket used for tomato transport trial was the normal hand-woven basket (made of raffia) that was commonly used for packaging of fruit and vegetables for commercial transportation in Nigeria. Weaving material for making the basket consisted of sets of raffia strips cut to thickness of about 0.5cm and width of 1cm. The basket was about 45-55 cm deep and 60cm in diameter, capable of holding 50 kg of tomato fruit.

Plastic crate: The crate used and tested as substitute for raffia basket was a nestable plastic crate designed with the potential to totally protect contained fruit from compression. The plastic crates were those manufactured by Celphas Plastic Industries

Ltd. for tomato packaging. It was the nest/stack type described by Thompson (2003). The crate is capable of holding about 25 kg of tomato fruit.

This plastic container had inset features that facilitated stability of the filled crates when stacked without subjecting the top-loaded fruits to compression. This includes features for nesting of successive crates when empty. By this, the empty crates can be partly nested (one inserted into another) in order to conserve space for the return trip. With the empty crates, however, a crate fittingly received another crate when rotated ninety degrees. By this, several empty crates were inserted one in another in a pile, thereby saving carrying space.

Field transportation trials

The transportation trials were undertaken during the growing season in Kano for onward transportation to Lagos. These were conducted with trucks loaded with consignments of freshly harvested tomatoes sampled for damage analysis at the delivery ends of the trips.

Study areas and locations: The field trips, involving commercial transportation of tomatoes, were undertaken from a take-off collection centre which was a primary market located at Kwana Garfan (in Kano state). This area is in the north of the country where tomatoes are grown in large quantities and transported to the south. The destination for the trips was a wholesale tomato market located at Mile 12 Market (Lagos) in the south of the country (Figure 1). The trip from Kano covered a distance of 998 km.

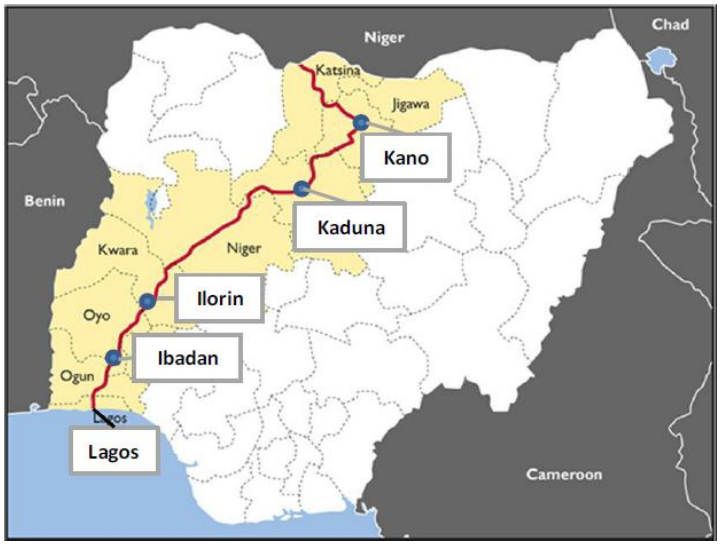

Figure 1: Travel route from Kano (in north) to Lagos (in south) (Source: USAID 2013;15)

Truck loading: The trucks that were used in the main trips were 5-layered, Mercedes 911 lorry, which was 6m long, 2.3m wide and 3.4m high, with holding capacity of 25-tonnes. This was conventionally used for commercial transportation by the tomato dealers. The loading compartment lorry carried 10 or 15 crates lengthwise, 5 crates across the floor and 9 crates high.

Tomatoes were purchased from the wholesale market at Kwana Garfan in the afternoon when brought from the farm. Fruits used for tests were randomly selected and loaded on the trucks to ensure that they represented the real loading pattern of the marketers in their commercial haulage. The trucks were loaded, one with 420 filled baskets amounting to 21,000 kg of tomatoes and, the other, with 560 filled crates amounting to 14,000 kg of tomatoes (Plate 1). A follow-up field trial transportation was also undertaken with a 20-tonne capacity truck loaded with 320 filled baskets containing 16,000 kg of tomatoes. This trip was undertaken from a collection center located at Dutsen Wai (at Kaduna state) to Mile 12 market (at Lagos).

Sampling of tomatoes: Sample containers of tomatoes from the two different packaging containers were randomly picked and tagged for identification at the time of loading the trucks for take-off. For each truck, 8 sample containers were drawn for each of five basket layers on the truck to provide a representative bulk sample. Each set of the sample containers were distributed and located strategically at 8 sample points on each of the five layers of baskets. The sampling points (on each layer) in the truck were located at the middle and approximately 2 baskets from the sides of the truck.

Colourful tags were attached to all sample baskets prior to loading to clearly identify them for easy spotting within the bulk upon delivery at the destination market. Field workers were however allowed to handle the sample containers in line with their normal commercial practice of loading and off-loading.

Evaluation of in-transit damage in tomatoes

In-transit damage of tomatoes was assessed at the delivery market at Mile 12 (Lagos) using assessment sheets. Evaluation of damaged produce (in %) was made by sorting and separating damaged fruit within each sample lot from each sample container in the respective consignments. At this point of delivery, tomatoes from each sample basket were sorted to assess the condition of the contained lot of fruit. Mechanical damage to tomatoes was assessed as cracks, breakage or bruising observed on the skin of the fruit. Physical injury (such as body distortion) with or without cracks was also categorized as damage. By this, the respective numbers and weights of fruit having mechanical damage were determined using a top-loading balance.

Plate 1: Rear view of truck load with crate packaged tomatoes

RESULTS AND DISCUSSION

Comparison of in-transit damage losses by basket and crate

Possible sources of tomato damage incurred between collection center (in the north) and the delivery market (in the south) was the totality of those encountered at the stages of handling (comprising truck loading and off-loading) and in-transit (during transportation).

Damage losses: During handling of fresh tomatoes transport and packing operations, the fruit are subjected to different mechanical stresses causing mechanical damage. Bruises and impact damage resulting from compression destroy the integrity of cellular structure and induce rapid deterioration during subsequent handling.

The movement of packaged tomatoes from Kano to Lagos took two days are spent. Results show that level of damage in the basket packaged tomatoes was very high on arrival at Lagos as only about 58.80% of the consignment appeared marketable in wholesome form. Other tomatoes in baskets suffered different levels of damage thereby reducing the marketing quality of the fresh fruit. Findings on the damage assessment of delivered tomatoes indicated that after the 998 km travel with the 25-tonne truck, raffia basket had 34.15% - 46.08% fruit damage (Figures 2 and 3) showing as bursts, bruises or fresh skin cracks. This gave an average of 41.12% damage losses of tomatoes sampled at the top, middle and bottom layers (layers 1, 3 and 5 respectively in Figure 4). In crates, this huge damage was reduced to 4.69 to 5.24% (average of 4.92%). This implies that the use of crates achieved 88% reduction in average damage losses caused by use of basket in the truck. In the 25-tonne truck, damage value in basket was 36.72 to 49.78% (Figure 3). Poor packaging methods are a common sources of mechanical damage in tomatoes during transportation (Raji and Oriola, 2007). Simulated transit studies of Olorunda and Tung (1985) on tomatoes have shown that compressive load, poor container and vibration contribute considerably to mechanical damage in the fruit.

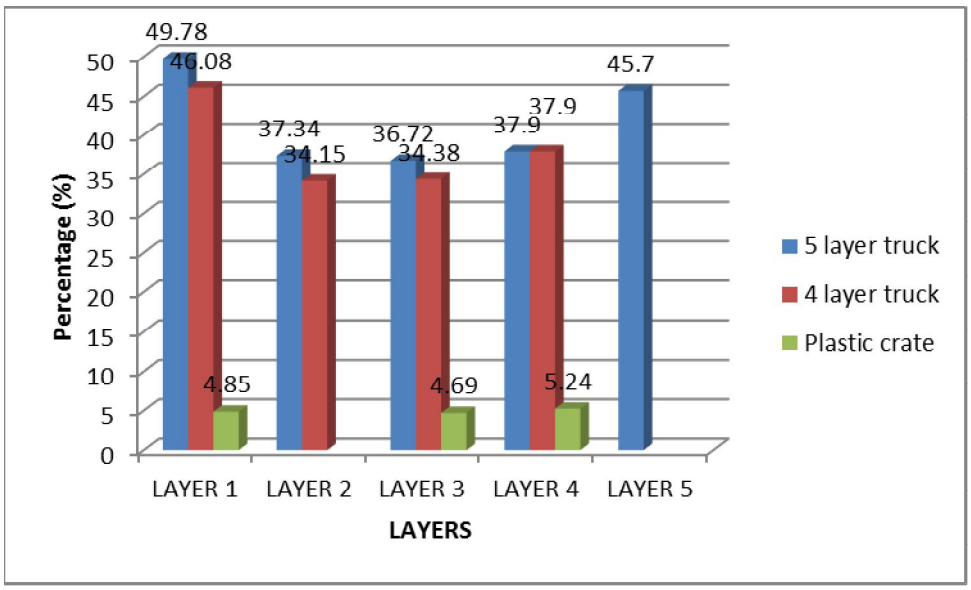

Figure 2: Level of damage to tomatoes in basket and crate on different layers in truck.

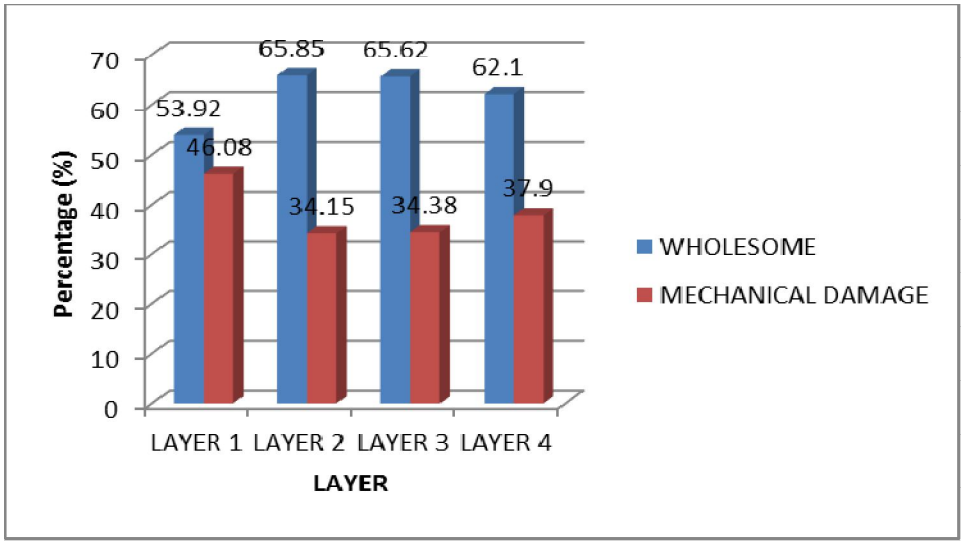

Figure 3: Level of damage to tomatoes in basket on four layered truck.

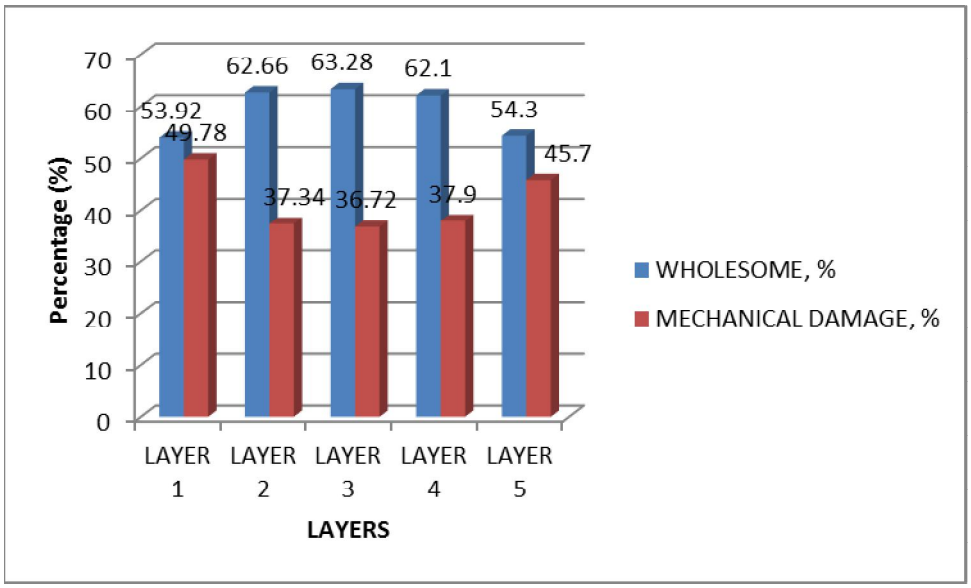

Figure 4: Level of damage to tomatoes in basket on five layered truck.

Baskets: The high mechanical damage encountered in tomato packaged in raffia baskets during haulage can be mainly attributed to compression, abrasion and vibration damage to the packaged tomatoes during when road transportation. This damage particularly leads to crushing of the fruit due to compression from overlaying stack of baskets and squeezing of the contents of the baskets. The external (surface) mechanical damage of tomato observed in this study represents fracture, deformation at break (Babarinsa and Ige, 2012a) and rupture, deformation at peak (Babarinsa and Ige, 2013). This form of damage to tomatoes usually constitutes huge losses to transporters after haulage.

The considerable damage to tomato fruit herein recorded while using baskets during the long distance haulage from the north to the south results from certain defects in the local baskets. Babarinsa and Nwangwa (1987) highlighted the major problems arising from defect of the traditional baskets in handling fruits. These include mechanical injury imparted to fruits through numerous sharp edges within the baskets and low durability of the baskets due to structural failure and breakage of the wall. Others are instability of stacks and subjection of contents to excessive compression, which leads to physical spoilage when stacked. The rough surface of the traditional basket facilitated damages to tomatoes. The weak edges in raffia basket could be damaged to handlers when loading and unloading crates to trucks.

Crates: The use of plastic crate prevents major causes of damage to packaged tomatoes, thereby cutting down losses in the produce during transportation. The plastic crates achieved the recorded 88% reduction in average damage losses caused by use of basket in the truck by protecting the packaged fruit. In the comparative data from this study, comparing baskets with plastic crates, the stackable crate had demonstrated ability to reduce considerable the damage that is encountered in tomatoes packaged in baskets for commercial transportation in trucks.

The reduction of damage in plastic crate is due to several functional features that make it more suitable for packaging tomatoes for transportation. It facilitates ventilation and is easy to handle and clean. All surfaces are smooth and water proof. Another contributory factor to the suitability of the crate to reduce mechanical damage in packaged tomatoes is its rigidity which makes it stackable. The crates retained their stacking strength and structural integrity throughout the trip and thereafter. There was no damage to the crates during loading with the usual drops in either the straight or angular movement.

It is worth noticing that all forms of visible external (surface) damage of tomato are always preceded by invisible internal damage called bioyield deformation occurring as cell and tissue damage (Babarinsa and Ige, 2012b). However, an assessment of this internal damage of tomato developing during transportation has not been achieved because such damage cannot be visualized non-destructively (Li and Thomas, 2014). A reliable criteria for studying the deformation (damage) process in tomato under the application of compressive load is the energy absorption capacity of the fruit and the applied vibration during compression (Babarinsa and Ige, 2012c)

Benefits derived in using Crates

The loss assessment study has revealed that the use of crates for tomato packaging for long distance transportation has great benefits for fruit and vegetable marketers in reducing mechanical damage to transported tomatoes. Thus the vision about finding alternative to raffia basket on long distant haulage of the produce was substantiated.

With the 25-tonne truck (Mercedes 911 lorry), the 560 crates containing 14,000 kg of tomatoes yielded 95.08% wholesome fruit, amounting to 13,311.2 kg of the fruit. On the other hand, the 420 baskets containing 21,000 kg yielded only 58.88% wholesome fruit, amounting to 12,364.8 kg wholesome fruit. Hence, even though there was a decrease of 33.3% in transported quantity of tomatoes with the use of the plastic crates instead of raffia baskets, the reduction in tomatoes damage compensated more than adequately for this reduction in take-off quantity. Having reduced damage occurring in basket by 88.0% in crate, the use of crates in tomato packaging yielded a 7.7% increase in wholesome fruit delivered at Mile 12 market. The reduced mechanical damage would ensure that fresh tomatoes get to the consumers and processors in wholesome state. It became apparent that better packaging would be needed to enable growers to send tomato safely over longer distances. All cohorts in the scheme of the reusable plastic crate must collaborate to take full advantage of the container use, and a categorical link is essential for harmonisation and control.

Effect of Layers

In the 25-tonne truck (with 5-loading layers of baskets), It was observed that most of the severely damaged fruits were those contained in the baskets which were in direct contact with floor (bottom layer) of the truck loading compartment. These are areas where impact between the packaging containers and surface of the floor was occurred more frequently and severely. The filled baskets at the bottom layer (first layer) suffered the highest level of damage, being 49.78% of the total damage (Figures 2 and 3). The proportion of damage reduced to 37.4%, 36.72% and 37.9% in the middle layers (second, third and fourth layers) respectively. The proportion of damage losses however increased to 45.7% in the top layer (the fifth layer).

The highest level damage observed on the floor layer of baskets in the loaded truck might have been further caused by the effect of imparted shocks from the vehicle suspensions. On the other hand, the high magnitude of damage observed on the topmost layer (the fifth layer) may be attributed to vibration occurring at the surface where the baskets were moving freely and impacting on each other. The free movement of the filled baskets were in response to the induced vehicular vibration. This is in agreement with the findings of Singh and Singh (1992). The damage distribution pattern over the layers for the 20-tonne truck followed the same trend as observed in the 25-tonne (5-layered) truck. Tomatoes that were packaged in plastic crates remained almost equally wholesome irrespective of layers position on the 25-tonne truck (Figures 5). The nominal relative reduction of wholesome fruit on the top layer was perhaps caused by slipping of some crates at the top right corner as seen in the figure.

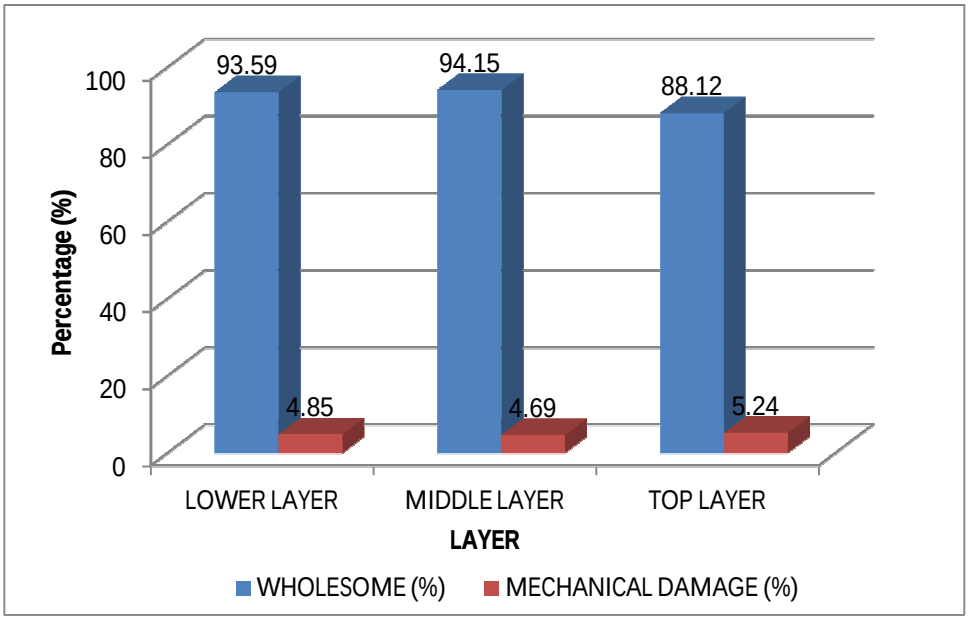

Figure 5: Level of damage to tomato in crate on four layered truck.

CONCLUSION

In-transit damage in packaged tomatoes represents a considerable component of the losses occurring in the supply chain from the collection centre (in the north) to the consumer (in the south) in Nigeria. Nestable plastic crate was compared with the traditional raffia baskets for packaging tomatoes for interstate road transportation from Kano state to Lagos. In-transit mechanical damage incurred in the tomato haulage from the north to south of Nigeria when using raffia baskets was high and

evaluated to an average of 41.12%. This high in-transit damage was greatly reduced, on an average, to 4.92% in nestable plastic crates.

The high tomato damage encountered in raffia baskets was attributable to certain defects such as presence of sharp edges. However the plastic crate has better smoothness compared to traditional raffia basket used by marketers and transporters. The smoothness of inner surface of nestable plastic crates minimizes damages to tomatoes during handling and transportation of tomatoes. Strength of the nestable plastic crate stabilize stacks well during transportation and reduced damages. The plastic crate is, thus, a more suitable package type than the raffia basket for handling and transportation of tomatoes in terms of technical feasibility. Consequently, the use of the plastic crates for handling and transportation of tomatoes could be beneficial to increase the profit gain for farmers as well as wholesalers.

The results of the investigation suggest that the tested plastic crate is a good alternative to the raffia basket. Plastic crate, being a new packaging material comparable to international standards, is suitable for use in long distance distribution of tomatoes. This will support systemic change in markets on the expectation of the handlers looking forward to improved packaging container. Thus, on a commercial scale, the current improved method of tomato packaging, using the tested plastic crate, is meeting the handling needs of interstate transportation demand.

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