Journal of Sustainable Development in Africa (Volume 19, No.4, 2017)
*ISSN: 1520-5509*
*Clarion University of Pennsylvania, Clarion, Pennsylvania*

# EVALUATION OF THE SUSTANIBILITY OF SWEET ORANGE POSTHARVEST HANDLING TECHNOLOGIES IN OYO AND OSUN STATES, NIGERIA

[1]Mufuliat Oladuntan Olatilewa, [2]Olubunmi Abayomi Omotesho, [2]Abdul-Azeez Mohammad-Lawal

[1]Nigerian Stored Products Research Institute, Ilorin, Nigeria.
[2]Department of Agricultural Economics and Farm Management, University of Ilorin, Ilorin, Nigeria

## ABSTRACT

Sustainable postharvest handling technologies are necessary for reduction in wastages associated with Nigerian agricultural sector. Two experiments were conducted on the usage of improved and traditional postharvest handling technologies. Data were analyzed using Percentage weight loss, ANOVA and Net Marketing Margin. The first experiment compared transportation of oranges using Stackable-Ventilated-Plastic Crates, Polypropylene Sack and Direct Pouring into Vehicle. The second was storage of coated sweet orange in Wall-in-wall, Pot-in-pot, Metal-in-Wall, Tin-in-Pot; and Local Storage Media for four weeks, using Randomized Complete Block Design.

The results showed that Polypropylene sack has highest orange weight loss during transportation (5.93%), whileLocal-Storage-Media recorded 44.23% among the storage technologies; it also indicated that only Aloevera Gel and Vaccine in both improved and local storage technologies had imputed positive Net Marketing Margin ranging between ₦5,336.07 and ₦26,562.07 per tonne($p<0.05$). The effect of the improved storage technologies in loss reduction necessitates its adoption.

**Keywords:** Postharvest technologies, Coating materials, Stackable-Ventilated-Plastic-Crate, Direct- Pouring-into Vehicle, Wall-in-Wall, Pot- in-Pot

## INTRODUCTION

The problem of food loss in Sub-Saharan Africa is acute. More than 30% of the food produced for human consumption across the continent is lost because of inadequate postharvesthandling technologies. Across Africa, fruits and vegetables feature the highest rate of losses as a proportion of production—approximately 50% (World Bank, 2015). This has resulted in malnutrition and stunting among children who are the most vulnerable to the impact of decreased availability of fruits and vegetables.

Citrus is one of the most important fruit crops grown all over the world. The commonly grown citrus species belong to the family Rutacceae, with about 150 genera (Opeke, 2005).The different species of citrus includes; grapefruits, tangerines, oranges, tangelos, limes and lemon (Oyedele, 2005). The products' economic importance as industrial materials is well known which includes the production of single strength juice, frozen concentrate, pectins used in the production of jams and jelly pulp. (Liu, (2003) and Bakhru, (2000) noted that regular intake of orange prevents frequent attacks of common cold, influenza and bleeding and also contributes to healthy living and longevity. Also, the peel serves as an insecticide against mosquitoes; the dried pulp as cattle feed; while the rinds produce essential oils used broadly as pharmaceutical components, in supplements and in cosmetic industry and aromatherapy (Maria et al., 2012). Orange peel was shown to contain more amount of essential oil than lemon and lime (Njoku and Evbuomwan, 2014).

The worldwide production estimate of citrus as at 2012 shows that it has increased to over 115 million metric tons (FAO, 2012) with more than half of this being sweet oranges (FAO, 2008).This steady rise in global citrus production was due to increase in cultivation areas, consumer preference for more healthy food and rising incomes (UNCTAD, 2010).

Citrus production yield in Nigeria shows steady rise from 2003 to 2010 and later experienced fluctuation till 2013(FAO, 2015)as shown in Table 1.0

**Table 1.0: Nigeria Citrus Production Yield**

| Year | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yield | 43,464 | 45,287 | 47,898 | 58,504 | 44,156 | 45,424 | 47,655 | 48,718 | 48,101 | 47,799 | 48,750 | 47,799 |
| Change (%) | | 4.19 | 5.77 | 22.14 | -24.53 | 2.87 | 4.91 | 2.23 | -1.27 | -0.63 | 1.99 | -1.95 |

Source: FAO, 2015

At production season, the excessesproduced are neither stored nor adequately preserved; to take care of scarcity at off-season due to poor storage facilities. Apart from the obvious losses incurred,the integration or otherwise ofimproved storage technologies have deep-rooted effects and impacts on the economic, social and environmental frontiers of nations. Ranging from the minor to the major, several activities, many of which are overlooked, contribute to the current state of sustainability in societies. One of such is agricultural produce handling techniques. Intergenerational equity recognizes the long-term scale of sustainability in order to address the needs of future generations (Dernbach J.C. 1998; Stoddart, 2011)

The use of refrigeration and controlled atmospheric storage or a combination of both to extend the shelf life is expensive to install, costly to maintain, as well as impractical for use with small quantities of production.In order to minimise losses, farmers and traders dispose their products at "give away" prices and sometimes leave fruits on trees to rotten, when handling costs could not be recouped by the ruling market price, leading to high wastage. The extent of food loss, orange inclusive, at every stage of postharvest handling, reduce the initial total output for consumers and this contributes to food insecurity in the country. With more than 70% of Africans drawing their livelihoods from agriculture, finding sustainable solutions for postharvest losses holds tremendous promise for enhancing regional economic growth and well-being (RockefellerFoundation, 2015).

Though,many research studies identified some improved postharvest technologies in the area of storage and packaging of fruits in transit to minimize wastage and improve the income of traders, the level of their efficiency need to be determined to know how viable they are.Along with the level of efficiency, sustainability of the methods need to be carefully considered. Furthermore, since marketing efficiency of sweet orange is not likely correlated with the technology used, there is need to relate the contribution of technology used to the net marketing margin.The aims of the research are to examine the percentage weight loss during transportation and storage, and also to determine the net marketing margin of coated sweet orange stored using various both local and improved storage technologies.

## METHODOLOGY

### Materials for Experiments

The study areas are Osun and Oyo States, South-western part of Nigeria (Figure 1). Sweet orange fruits (Citrus sinensis) were used for the experiments. Three methods of packaging during transit were used namely; Stackable Ventilated Plastic Crates (SVPC), Polypropylene sacks and Direct Pouring into Vehicle (DPV); four improved storage technologies, which include; Wall-in-wall, Metal-in-wall, Pot-in-pot and Tin-in-pot available at NSPRI demonstration plot, and local storage media, such as; Baskets, Polypropylene Sacks and Open store were used. Seven edible coatings were also used namely; Aloe-vera gel, Moringa Oil, Sesame Oil, Chitosan, SMA (combination of Sesame oil, Moringa oil and Aloe-vera gel in equal proportion), CSMA (combination of Chitosan, Sesame oil, Moringa oil and Aloe-vera gel in equal proportion) and Vaccine made from spoilt sweet orange fruits; obtained from Chemistry Laboratories in University of Ilorin and Food Quality Control in NSPRI Ilorin. Though these technologies were available but traders have not been using them. This prompted the assessment of these improved technologies; by evaluating them through on-station experiments.

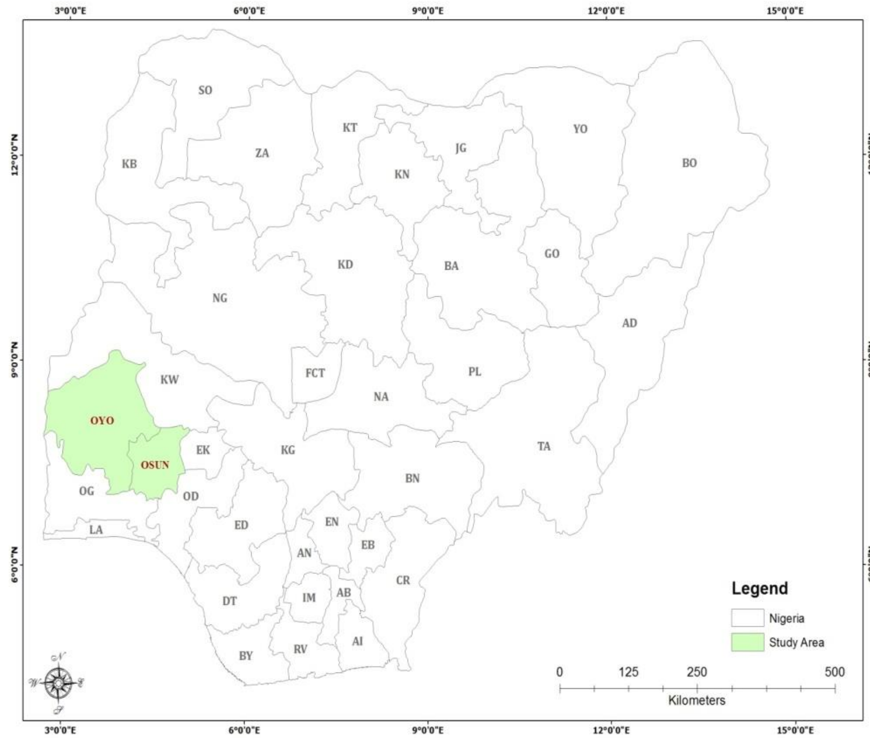


Figure 1: Map of Nigeria showing the study areas (Oyo and Osun States)

## Experimental Set-up

Matured Sweet oranges (Citrus sinensis) fruits were harvested in July 2015 in Apoti-village, Ipetu-Ijesha, Osun State, packed under shade for cooling, culled to separate spoiled and damaged fruits. One tonne (1000kg) of sweet orange fruits were loaded per bus and transported, using three different packaging methods which include; Stackable Ventilated Plastic Crates (SVPC), Direct Pouring into Vehicle (DPV) and Polypropylene sacks to demonstration site of Nigerian Stored Products Research Institute's (NSPRI). Sweet oranges were carefully offloaded for handling activities, such as; cleaning, sorting of wholesome and defect free, and grading for sales. The spoiled and damaged orange fruits were separated and weighed for each packaging method used in transit. The percentage weight loss of each packaging methods was later determined and the sweet oranges were disposed.

For storage, sweet orange fruits were carefully harvested at physiological mature green stage from ECWA's farm, along Oke-Oyi in Ilorin East LGA, Kwara State. The fruits were transported in SVPC as packaging material, during transit, to the NSPRI demonstration site the same day, where fruits were spread under shade, in Fruit shed, for cooling, to reduce fruits' heatand they are subsequently cleaned with wet handkerchiefs, coated and stored.

**Experimental layout of storage technologies with coated sweet oranges:**

The experiment was laid out in a randomized complete block design with split-split plots arrangement of 7 X 8 treatments i.e. the combination of storage technologies and edible coatings. Matured 960 wholesome sweet orange fruits that were without any visible blemish were sorted and divided into eight batches, each having 120 fruits. One batch serves as control (without any treatment) and divided into seven plots to take care of the seven storage technologies. The other seven batches were treated with different edible coatings {Aloe-vera gel (AG), Moringa Oil (MO), Sesame Oil (SO), Chistosan (CH), equal proportion of Sesame oil, Moringa oil and Aloe-vera gel (SMA), equal proportion of Chitosan, Sesame oil, Moringa oil and Aloe-vera gel (CSMA) and Vaccine (VA) made from spoilt sweet orange fruits. Each of the seven batches were also divided into seven plots (15 sweet oranges per plastic crate represented a plot) to take care of seven storage technologies (a plot per storage technology) totalling fifty-six (56) plots. The coatings were applied on fruits by spraying method and after treatment, fruits were stored at room temperature, in each of both local storage media and improved storage technology for four (4) weeks and data taken on various physical parameters were recorded for analysis. The marketable fruits were sold at prevailing market price and revenue generated was related to all marketing costs, involved in each storage technologies and net marketing margin was determined.

## RESULT PRESENTATIONS AND DISCUSSION

### The performance of Improved and Local Sweet Oranges Postharvest Technologies

The percentage weight loss of sweet oranges in different packaging materials in transit was shown in Table 1.
Extent of Quantitative Sweet Orange Losses in Packaging Material used in Transit

**Table 1: Percentage Weight loss in transit as related to Packaging Means**

| Packaging Material used in transit | Quantity packaged (kg) | Quantity Spoilt (kg) | Percentage spoilt |
|---|---|---|---|
| SVPC | 1000 | 3.21 | 0.32 |
| Sacks | 1000 | 59.29 | 5.93 |
| Direct pouring in Vehicle (DPV) | 1000 | 11.38 | 1.12 |

**Source: Computed from the Experiments (2015)**

It indicates that the usage of polypropylene sack had highest percentage weight loss of about 5.9 percent, followed by 1.12 percent spoilt in orange fruits, poured directly in bus and 0.32 percent weight loss was recorded of orange fruits packed, using SVPC in transit. This was due to the large air space available for the exchange of air within the surrounding. Otherwise, heat generated during respiratory activity of oranges in the package, during transit, could have increase spoilage. It is important that packaging system assists, rather than impedes this process. The high number of rotten fruits in the polypropylene sack could be as a result of condensation inside the packaging material due to poor or very low permeability of the package, to air flow, resulting to accumulation of heat. Transpiration is the major process leading to weight loss (Faasema*et al.*, 2011). The fruits packed in sack bags in transit, were more affected than fruits packed in SVPC and on the bus floor.

**Extent of Quantitative Losses of Sweet Orange in Storage Technologies**

The entries in Table 2.shows the percentage weight loss per week of coated and uncoated (as control) sweet orange fruits for consecutive four weeks of storage, in improved and local storage technologies.

**Table 2: Means Percentage Weight Loss of Coated Orange Fruits Stored in Storage Technologies**

| Storage Tech. | Week | AG | MO | SO | CH | CSMA | SMA | VA | Control |
|---|---|---|---|---|---|---|---|---|---|
| Wall in wall | 1 | 1.82 | 14.28 | 10.34 | 11.11 | 6.90 | 3.51 | 2.00 | 15.01 |
| | 2 | 4.55 | 21.43 | 42.24 | 13..89 | 12.07 | 10.66 | 6.39 | 36.32 |
| | 3 | 9.23 | 34.23 | 84.48 | 17.59 | 18.10 | 32.72 | 24.77 | 58.38 |
| | 4 | 15.27 | 55.56 | 94.82 | 18.52 | 21.55 | 54.65 | 38.77 | 60.75 |
| Metal in wall | 1 | 14.28 | 20.90 | 10.90 | 8.33 | 7.14 | 10.71 | 7.69 | 16.72 |
| | 2 | 16.08 | 48.51 | 32.12 | 12.50 | 11.61 | 18.75 | 8.76 | 38.41 |
| | 3 | 21.44 | 79.85 | 64.99 | 24.16 | 23.22 | 31.25 | 14.63 | 62.64 |
| | 4 | 32.16 | 91.05 | 81.66 | 40.00 | 36.61 | 41.96 | 27.14 | 68.20 |
| Pot in Pot | 1 | 1.02 | 3.57 | 15.52 | 6.78 | 1.75 | 3.64 | 1.89 | 9.98 |
| | 2 | 2.25 | 6.25 | 30..81 | 6.78 | 2.63 | 13.45 | 5.67 | 25.94 |
| | 3 | 6..79 | 19.65 | 66.82 | 10.17 | 6.15 | 25.99 | 10.39 | 38.23 |
| | 4 | 14.42 | 36.61 | 90.62 | 16.95 | 11.74 | 28.71 | 15.11 | 39.64 |
| Tin in Pot | 1 | 3.33 | 21.05 | 20.69 | 7.14 | 7.94 | 10.53 | 5.38 | 19.03 |
| | 2 | 5.83 | 40.88 | 43.97 | 8.04 | 11.76 | 14.04 | 6..27 | 42.90 |
| | 3 | 14.99 | 64.03 | 71.55 | 16.97 | 18.91 | 22.82 | 10.71 | 65.43 |
| | 4 | 24.66 | 69.38 | 77.46 | 28.57 | 26.20 | 28.96 | 22.32 | 83.26 |
| Local Storage Media (LSM) | 1 | 10.79 | 20.28 | 14.42 | 15.67 | 10.41 | 11.94 | 13.89 | 18.54 |
| | 2 | 17.37 | 33.54 | 26.77 | 27.70 | 17.37 | 18.77 | 21.69 | 46.80 |
| | 3 | 37.66 | 61.82 | 56.67 | 52.36 | 34.91 | 42.53 | 42.17 | 75.11 |
| | 4 | 64.98 | 82.22 | 81.14 | 74.01 | 61.23 | 69.33 | 69.13 | 86.99 |

**Source: Computed from the Experiments (2015)**

The result indicated that in both types of storage technologies orange fruits coated with MO and SO had the highest percentage weight loss from, week one to the end of the storage period compared to others. Considering the storage of uncoated sweet orange fruits in both storage technologies in the second week; it was shown that 44.23 percent weight loss was recorded for LSM while 36.32, 38.41, 25.94 and 42.90 percent weight loss were recorded for Wall-in-wall, Metal-in-wall, Pot-in-Pot and Tin-in-pot respectively. It indicated that losses were minimized with the use of Improved Storage Technologies (IST) (i.e. Evaporative Cooling Systems). This agreed with previous report by Dadhich, Dadhich and Verma (2008) that Evaporative Cooling System for agricultural commodities maintained their freshness and increase storage life, rather than in the ambient conditions; by reducing storage temperature and increasing relative humidity which is essential for maintaining freshness of produce and reduction of losses.

It also shows that in IST, low percentage weight losses were recorded in Pot-in-Pot and Wall-in-Wall with the use of AG(1.02), CSMA (1.75), VA(1.89) and AG(1.82) and VA(2.0) respectively in week one. In the second week of storage, low percentage weight losses recorded in coated sweet orange stored in Pot-in-Pot were AG (2.25), CSMA (2.63), and VA (5.67), AG (5.83) in Tin-in-Pot and AG (4.55) in Wall-in-Wall and others had above six (6) percent weight loss. CH had the minimum percentage weight loss of 6.15followed by AG (6.79) in Pot-in-Pot of the third week. LSM had its least to be10.41percent weight loss in week one with the use of AG, 17.37 percent in week two using AG and CSMA respectively, 33.91percent weight loss, in the third week with the use of CSMA. It was also indicated from the table that, though percentage weight loss in both storage technologies increases with storage period, they were much more reduced when fruits were coated. This was in agreement with the findings on strawberries coated with starch-based coatings and the extension of the storage life of avocado, both through a reduction in water loss and a modification of the internal atmosphere also, while studying Gala apple, coated with 10 percent of zein (natural corn protein) and as in chitosan and polyethylene wax (PE) coatings that also provide good protection for Hami melon (Bai *et al*.,2003 and Cong *et al*., 2007). Ochiki*et al.*, (2014) noted the potential of using Aloe vera gel at 50 percent as a coating for improved postharvest shelf life and maintaining quality of mango fruits hence reduced postharvest losses and also fruit firmness and total soluble solids concentration and pH were also maintained for longer periods. Study conducted by Arowora, *et al.*, 2013 also agreed with the lower weight loss for coated oranges (29.20+ 0.55%), while, that of uncoated oranges higher (53.30+ 1.17%) at the end of storage. Quantity of Coated and uncoated sweet orange fruits that would be available for sale per week is in the appendix 3. The prevailing market price at the time of study for 1.00kg of sweet oranges was ₦82.65 in the first two weeks of storage while it was ₦99.01 in the subsequent weeks.

**Profitability Analysis of Sweet Orange fruits Stored in Storage Technologies**

The entries in Table 3 presents the list of edible coatings used, cost per litre and cost of quantity of each edible coating used in coating one (1) tonne of sweet oranges

**Table 3: Cost of Edible Coatings used in coating 1 ton of Sweet Oranges**

| Coatings | Cost/litre (₦) | Cost of coating used (₦) |
|---|---|---|
| Aloe-vera Gel (**AG**) | 2,000.00 | 13,200.00 |
| Moringa Oil (**MO**) | 20,000.00 | 132,000.00 |
| Sesame Oil (**SO**) | 20,000.00 | 132,200.00 |
| Chitosan (**CH**) | 15,000.00 | 99,000.00 |
| CSMA | 14,250.00 | 94,050.00 |
| SMA | 14,000.00 | 92,400.00 |
| Vaccine | 250.00 | 1,650.00 |

**Source: Computed from the Experiments (2015)**

In appraising the improved postharvest technologies on storage of sweet oranges, computed costs and return were used to derive measures of profitability such as Net Marketing Margin (NMM). An average weight of a sweet orange fruit was found to be 0.202kg and one tonne (1ton) of sweet orange fruits were estimated to comprise of 4951 fruits. About 6.6 litres of each coating material were used to wax one tonne of sweet orange fruits in this study.

**Imputed Net Marketing Margin of Coated and Uncoated Sweet Oranges**

The Imputed Net Marketing Margin of Coated and Uncoated Sweet Orange in Storage Technologies was presented in Table 4.

The result indicated that only in Wall-in-Wall and Pot-in-Pot had positive imputed net marketing margin when sweet oranges were not coated; with the value of ₦3, 022.40 and ₦11, 187.12 respectively, at two weeks of storage. This agreed with the finding of Mogaji, et al. (2013) that the users of evaporative system in the preservation of tomato had higher return to their investment than those that used traditional preservative methods. It showed that holding sweet orange fruits beyond two weeks, resulted in negative imputed net marketing margin in all Storage Technologies used except Pot-in-Pot that had positive imputed NMM throughout the storage period. Among the IST used Tin-in-pot incurred more losses than others having negative imputed Net Marketing Margin of ₦-3,015.00 in the second week. Also, the result showed that among the edible coatings used AG and VA had positive imputed Net Marketing Margin, in both improved and local storage technologies, up to two weeks of storage. It also indicated that when sweet oranges were coated with AG and VA in WW and PP the shelf life was increased with positive imputed NMM. The use of VA in coating sweet oranges for storage was found to be more economical, with the fact that, it generated more than 50 percent increase in imputed NMM obtained in the use of AG. In the second week of LST; while AG had ₦5, 336.07; VA had ₦13, 524.96 as their imputed NMM respectively.

**Table 4: Imputed Net Marketing Margin of Coated Sweet Orange in Storage Technologies / Tonne (₦)**

| Treatments | Week | Improved Technologies | | | | Local |
|---|---|---|---|---|---|---|
| | | Wall in Wall | Metal in Wall | Pot in Pot | Tin in Pot | Technologies |
| AG | 1 | 18,905.56 | 12109.9 | 19,287.56 | 17,252.38 | 11338.75 |
| | 2 | 15422.57 | 8,303.92 | 17,562.07 | 14,751.93 | 5,336.07 |
| | 3 | 23362.91 | 9795.30 | 23560.93 | 11793.39 | -9477.50 |
| | 4 | 14049.95 | -5559.33 | 13672.95 | 4217.23 | -52717.29 |
| MO | 1 | -110,177.78 | -11,5606.76 | -101612.44 | -116,164.29 | -115294.59 |
| | 2 | -117310.76 | -138,987.77 | -104,571.27 | -133,340.07 | -126,602.87 |
| | 3 | -123657.07 | -169964.03 | -115219.07 | -152266.61 | -158317.50 |
| | 4 | -156290.05 | -180039.33 | -129102.05 | -160862.77 | -175619.29 |
| SO | 1 | -106,927.78 | -110140.1 | -111462.44 | -115864.29 | -110,461.25 |
| | 2 | -134,477.41 | -126,846.88 | -124,846.27 | -135,890.07 | -122,044.71 |
| | 3 | -178,257.07 | -160,144.03 | -171,819.07 | -160,686.61 | -159,357.50 |
| | 4 | -179,490.05 | -171,529.33 | -179,462.05 | -165,742.77 | -173,457.20 |
| CH | 1 | -74,561.11 | -72,223.43 | -71,262.44 | -71,697.62 | -86,144.59 |
| | 2 | -78,094.09 | -76,262.75 | -72,012.93 | -73,249.04 | -88,794.49 |
| | 3 | -69,697.07 | -82,584.03 | -65,579.07 | -77,326.61 | -116,197.50 |
| | 4 | -70,930.05 | -100,279.30 | -73,802.05 | -86,022.77 | -135,377.29 |
| CSMA | 1 | -66,144.44 | -66306.76 | -62162.44 | -67397.62 | -68820.51 |
| | 2 | -71,644.09 | -70,587.75 | -65509 | -75333.78 | -76,327.71 |
| | 3 | -65,187.07 | -82,584.03 | -65,579.07 | -77,326.61 | -91,967.50 |
| | 4 | -71,540.05 | -89,929.33 | -63,292.05 | -79,132.77 | -124,507.29 |
| SMA | 1 | -61,527.78 | -67590.1 | -62,062.44 | -67,880.96 | -68,811.25 |
| | 2 | -68,827.42 | -74,821.08 | -70,912.93 | -71,599.04 | -74,902.72 |
| | 3 | -91,917.07 | -80,004.03 | -73,979.07 | -73,766.61 | -104,157.50 |
| | 4 | -102,050.05 | -93,559.33 | -75,482.05 | -77,142.77 | -125,057.29 |
| VA | 1 | 30,305.56 | 25,643.24 | 30,720.89 | 27,135.71 | 20,546.17 |
| | 2 | 26,072.40 | 24,170.59 | 26,562.07 | 25,575.47 | 13,524.96 |
| | 3 | 7,592.93 | 26,865.97 | 33,970.93 | 30,643.39 | -8,827.50 |
| | 4 | -6,359.95 | 10,430.67 | 24,987.95 | 13,089.23 | -38,507.29 |
| CO | 1 | 18,872.22 | 19,843.24 | 22,621.02 | 18,652.38 | 18,138.95 |
| | 2 | 3022.40 | -1,345.59 | 11,187.12 | -3015.00 | -6173.05 |
| | 3 | -10,917.07 | -16,784.03 | 9,640.93 | -24,846.67 | -32,377.50 |
| | 4 | -15,330.05 | -23,979.33 | 4,037.00 | -29,842.77 | -47,037.29 |

**Source: Computed form the Experiments, 2015**

**Note:** 1st -2nd week; Prevailing Market Price of 1kg of oranges was ₦82.65 while it was ₦99.01 at 3rd -4th week of storage.

**Efficiency of Storage Technologies with Treatments**

In Table 5, the means percentage weight loss of treated and untreated sweet orange fruits stored, in both types of storage technologies was discussed.

**Table 5: Means Percentage Weight Loss of Coated Sweet Oranges in Storage Technologies/Tonne**

| Treatment | Improved Storage Technologies(IST) | | | | Local Storage Technologies (LST) | | | |
|---|---|---|---|---|---|---|---|---|
| Weeks | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| AG | 5.11$^{a}$ | 9.22$^{a}$ | 17.01$^{a}$ | 26.24$^{a}$ | 10.79$^{a}$ | 23.95$^{a}$ | 43.85$^{a}$ | 86.10$^{a}$ |
| MO | 14.95$^{bc}$ | 43.58$^{b}$ | 56.00$^{b}$ | 71.05$^{bc}$ | 20.28$^{a}$ | 46.79$^{ab}$ | 74.18$^{cd}$ | 90,25$^{a}$ |
| SO | 14.36$^{bc}$ | 60.21$^{b}$ | 83.71$^{c}$ | 88.63$^{c}$ | 14.42$^{a}$ | 39.12$^{a}$ | 74.22$^{cd}$ | 88.06$^{a}$ |
| CH | 8.34$^{ab}$ | 12.26$^{a}$ | 22.19$^{a}$ | 29.83$^{a}$ | 15.67$^{a}$ | 39.73$^{a}$ | 64.97$^{bcd}$ | 82.94$^{a}$ |
| CSMA | 5.93$^{a}$ | 13.10$^{a}$ | 20.08$^{a}$ | 27.97$^{a}$ | 10.41$^{a}$ | 24.31$^{a}$ | 45.50$^{ab}$ | 76.95$^{a}$ |
| SMA | 7.10$^{a}$ | 21.35$^{a}$ | 35.03$^{a}$ | 42.11$^{a}$ | 11.94$^{a}$ | 25.59$^{a}$ | 59.48$^{abc}$ | 79.18$^{a}$ |
| VA | 4.24$^{a}$ | 9.30$^{a}$ | 20.95$^{a}$ | 30.71$^{a}$ | 13.89$^{a}$ | 29.48$^{a}$ | 54.86$^{abc}$ | 83.41$^{a}$ |
| CO | 11.88$^{bc}$ | 52.48$^{b}$ | 58.47$^{b}$ | 62.17$^{b}$ | 25.21$^{b}$ | 69.91$^{b}$ | 80.30$^{d}$ | 93.70$^{a}$ |
| F-values | 4.301$^{*}$ | 10.245$^{*}$ | 13.500$^{*}$ | 12.159$^{*}$ | 11.341$^{*}$ | 3.886$^{*}$ | 5.064$^{*}$ | 0.854$^{*}$ |

$^{a,b,c,d,e}$ *Means with the same alphabets within columns are not significantly different from one another at* $p_{< 0.05}$

The efficiency of improved storage technologies was determined by comparing the percentage weight loss of coated sweet orange fruits, stored in both improved and local technologies on weekly interval.

Analysis of Variance (ANOVA) was used to compare their mean differences, using Duncan at $p_{\text{-value}} < 0.05$ in SPSS 16.0. The result indicated that in week 1, the mean of AG (5.11), CSMA (5.93), SMA (7.10), VA (4.24) and CH (8.34) were the same; also there was no significant different in means of MO (14.95), SO (14.36), and CH (8.34) under improved technologies (IST). Considering week 1 of local storage technologies (LST) there was no difference in all the treatment used. The means percentage weight loss of AG, CH, CSMA, SMA and VA had no significant difference in week 3 under IST with fair values of 17.01, 22.19, 20.08, 35.03 and 20.95 respectively but different from MO, CO and SO although MO and CO are the same but AG had the least of 5.11 as shown in the table. In the third week of LST there was significant difference in the means of percentage weight loss with treatments used but MO, SO CH, SMA, and VA are the same. Also, there is no difference in AG, CSMA SMA and VA while MO, SO, CH and CO is the same. Obviously, AG and CO are different. AG had the least mean percentage weight loss of 43.85. This shows that, AG, CSMA, CH and VA were effective in both storage technologies but the efficiency of IST was shown to be more than 100 percent when used with these edible coatings.

**Efficiency of Improved Storage Technologies**

The means percentage weight losses of Sweet Oranges in Improved Storage Technologies per week were presented in Table 6.

**Table 6: Means Percentage Weight Loss of Sweet Oranges in Improved Storage Technologies/Tonne**

| Improved Storage Technologies | Week 1 | Week 2 | Week 3 | Week 4 |
|---|---|---|---|---|
| Pot-in-pot (PP) | $5.52^{a}$ | $11.72^{a}$ | $23.02^{a}$ | $31.73^{a}$ |
| Wall-in-wall (WW) | $8.12^{a}$ | $17.94^{a}$ | $34.94^{a}$ | $44.97^{a}$ |
| Tin-in-pot (TP) | $11.89^{a}$ | $21.71^{a}$ | $35.68^{a}$ | $45.31^{a}$ |
| Metal-in-wall (MW) | $12.08^{a}$ | $23.34^{a}$ | $40.27^{a}$ | $52.35^{a}$ |
| F-value | 2.834 | 1.049 | 0.733 | 0.874 |

**Source: Computed from the Experiments (2015)**
*$^{a,b,c}$ Means with the same alphabets within columns are not significantly different from one another at $p_{< 0.05}$*

It was indicated in Table 6, that there was no significant difference in the mean percentage weight loss of coated sweet orange in PP, WW, TP and MW in week 1, 2, 3, and week 4. However, the least percentage weight loss was recorded in PP in all the weeks, thereby, preferred to be the most efficient among the improved storage technologies.

## CONCLUSION

Sustainable postharvest handling technology is necessary for reduction in postharvest losses, improving food security, promoting efficient resource utilization as well as securing the livelihood of small-scale farmers and other major stakeholders in agricultural value chain.Packaging systems such as wall-in-wall, metal-in-wall, pot-in-pot, tin-in-pot and local storage media were among the major postharvest technologies assessed for their effectiveness in reducing postharvest losses. Others were the use of edible wax for coating oranges.

The study concludes that the improved technologies are sustainablehad varying degree of impacts in reducing postharvest losses in sweet oranges. Using any of the three major postharvest technologies mainly coating with edible wax, wall-in-wall, and pot-in-pot enhances the shelf-life and net returns to sweet oranges beyond four weeks.

## REFERENCES

Arowora, K.A., Williams, J. O., Adetunji, C.O., Fawole, O. B., Afolayan, S.S,,Olaleye, O.O, Adetunji, J., &Ogundele, B.A., (2013). "Effects of Aloe-vera coatings on quality characteristics of Oranges stored under cold storage". *Greener Journal of Agric. Sci*ence 3:39-47.

Bai, J.H., Saftner, R.A., Watada, A.E., and Lee, S.Y.( 2003). Modified atmosphere maintains quality of fresh-cut cantaloupe (*Cucumismelo*L.). *Journal of Food Science*. 66(8): 1207-1211.

Bakhru, H.K. (2000). Foods that heal. Orient Paper Backs, New Delhi

Cong F, Zhang Y, Dong W. 2007. Use of surface coatings with natamycin to improve the storability of Hami melon at ambient temperature. *Postharvest BiolTechnol,* 46: 71-75.

Dadhich S.M, Dadhich, H.&Verma, R. (2008). Comparative study on storage of fruits and vegetables in evaporative cooling chamber and ambient. *India Journal of Food Engineering*,4 (1);Art 2

Dernbach, J. C. (1998). Sustainable development as a framework for national governance. *Case Western Reserve Law Review*, 1-103.

Faasema, J. Abu, J.O. &Alakali, J.S (2011). Effect of packaging and storage condition on the quality of sweet orange (*Sweet oranges cinesis*)**,** *Journal of Agricultural Technology* Vol. 7(3): 797-804 retrieved fromhttp://www.ijat-aatsea.comISSN 1686-9141

FAO (2008). Food and Agriculture Organization: The world vegetable centre newsletter (http://www.avrdc.org) site visited on 20/12/2012

FAO (2012). Food and Agricultural Organization of United Nations: Citrus Fruit: Fresh and Processed Annual Statistics: Citrus Bulletin. 46pg. Retrieved from http://www.fao.org/fileadmin/templates/est/COMM_MARKETS_MONITORING/Citrus/Documents/CITRUS_BULLETIN_2012.pdf

FAO (2015). Food and Agricultural Organization of United Nations: Citrus Fruit Statistics. 53pg. Retrieved from http://www.fao.org/3/a-i5558e.pdf

Liu, R.H. (2003). Health benefits of fruit and vegetables are from additive and synergistic combinations of phytochemicals1,2,3,4. *Am J ClinNutr* September 2003 vol. 78 no. 3 517S 520S

Maria, C. C. Rubria, E. R.; Jose E.B.; Gloria M. M.; Jose L.N.&Hugo, J., (2012). 'Characterization of volatile compounds in the Essential oil of sweet lime' Chilean *Journal of Agricultural Research* 72(2), Pg 275.

Mogaji T.S., Olufemi, A.D.,&Fapetu, O. P. (2013). Marketing performance and efficiency of evaporative-preservation cooling system for fresh Tomato marketing in Ondo State, *Nigeria.African Journal of Agricultural Research* Vol. 8(5), pp. 468-474.

Njoku, V.I. and Evbuomwan, B.O. (2014). Utilization of Essential Oil and Pectin Extracted from Nigerian Orange Peels. *Greener Journal of Chemical Science and Technology*: Vol. 1 (1), pp. 001-005.

Ochiki, S. &Wolukay, M.R.G (2014). Effect of various concentration of aloe vera coating on postharvest quality and shelf life on Mango (Magniferaindica L) *Africa Journal of Biotechnology* 13 (31) 3724-3729

Opeke, L.K. (2005). Tropical Commodity Tree crops. Spectrum Books Ltd, Ibadan. 503pp

Oyedele, O.O. (2005). Information and training needs of sweet oranges farmers in south western Nigeria Unpublished Ph.D. Thesis in the Department of Agricultural Extension and Rural Development, University of Ibadan, Nigeria

Rockefeller Foundation (2015). Perspectives to Reducing Post-harvest Losses of Agricultural Products in Africa Retrieved on 18/12/2017 fromhttps://www.afdb.org/fileadmin/uploads/afdb/Documents/Events/DakAgri2015/Agriculture_Industrialization_and_post-harvest_losses.pdf

Stoddart, H. (2011). *A Pocket guide to sustainable development governance.* Stakeholder Forum.

UNCTAD. (2010). United Nations Conference on Trade and Development. Retrieved fromhttp://www.Unctad.org/infocomm

World Bank, Annual Report 2015, The World Bank.

## ABOUT THE AUTHORS

MufuliatOladuntanOlatilewa: Nigerian Stored Products Research Institute, Ilorin, Nigeria.

OlubunmiAbayomiOmotesho: Department of Agricultural Economics and Farm Management, University of Ilorin, Ilorin, Nigeria

Abdul-Azeez Mohammad-Lawal: Department of Agricultural Economics and Farm Management, University of Ilorin, Ilorin, Nigeria.