ASUU JOURNAL OF SCIENCE
A Journal of Research and Development
Vol. 6, No. 1 & 2, December, 2019; pp 143-18

Effect of Harvesting Methods and Fruit Size on Physiological quality of Mango (*Mangifera indica* L.) Fruits During Storage

[1]Ahmed, M., [2]Gungula, D.T. and [3]Tame, V.T.

Abstract

Postharvest management of mango fruits is generally poor in developing countries, Nigeria inclusive. The fruits are not properly harvested, sized and graded which lead to a high level of postharvest loss to the farmers and retailers. This study was aimed at investigating the effect of fruit size and harvesting methods on the storage life of mango fruits. The experiment was laid in a Split Plot Design and the treatments consisted of two factors, fruit sizes (big and small) and three harvesting methods (ground, picker and foam). Data were collected on percentage change in fruit girth; physiological weight loss; deterioration and speed of deterioration were subjected to Analysis of Variance (ANOVA). The results of which showed that storage life is significantly ($P < 0.05$) affected by fruit size and harvesting methods likewise significantly ($P < 0.05$) interaction occurred between fruit size and harvesting method on fruit's percentage change in fruit girth, percentage physiological weight loss and percentage deterioration. In conclusion, fruit harvested using ground method had shorter storage life of less than six days while fruits harvested with picker had longest shelf life of 18 days of storage. Big fruits had lesser percentage change in fruit girth, physiological weight loss and deterioration than small fruits. The study therefore recommended big fruit size and harvesting with picker for farmers in the study area.

[1]Ahmed, M., [2]Gungula, D.T. and [3]Tame, V.T.
1 Crop Science Department, Adamawa State University, Mubi, Adamawa State – Nigeria
2 Crop Production and Horticulture Department, Modibbo Adama University of Technology, Yola - Nigeria
Corresponding author's email: mohmash68@yahoo.ca GSM +2347030952535

Key words: Fruit size, Harvesting Methods, Deterioration, Storability,

Introduction

Mango (*Mangifera indica* L.) is one of the most popular tropical fruits that generate high foreign exchange for some developing countries such as India, Pakistan and Mexico. As at 2013, developing countries accounted for more than 98 % of the total World production with Nigeria placed among the largest mango fruits producing nations (Anon., 2015). The bulk of the mango fruits are produced mostly in Northern Nigeria (Avav and Uza, 2002). The volume of trade in mango fresh fruits and juices has sky rocketed to more than 5,000,000,000.00 US dollars annually (Anon., 2015) in recent years with major exporters consisting mostly of tropical and subtropical countries.

Postharvest management of mango fruits in Nigeria is generally poor due to low level of technological development, poor harvesting methods where the fruits are harvested by either hitting with stick or shaking the tree violently thereby shading the fruits and dropping on the ground with high impact, packing without cleaning, sizing, sorting and other pre storage postharvest treatments (Ugese *et al*., 2012). Consequently, these improper harvesting methods and other poor postharvest operations are responsible for the low quality and large postharvest losses of mango fruits in the country. In addition, injured mango fruits during harvesting couple with wrong fruit size can easily cause deterioration due to infection by pathogens, infestation by pests, latex flow; water loss and decay (Lalel *et al*., 2003; Yahia, 2006; Ahmed *et al*., 2016).

Despite the large production of mango fruits in Nigeria, the country couldn't export fresh mango fruits or processed products caused by poor postharvest management and as such a large quantity of the fruits is wasted annually resulting to poor standard of living among the farmers and marketers (Yahia, 1999; FAOSTAT., 2007; Ugese *et al*., 2012; Ahmed *et al*., 2019). This research was conducted with the main objectives of determining the effects of fruit sizes and harvesting methods on the quality characteristics of mango fruits during storage and the interaction between harvesting methods and fruit sizes on its storability.

Materials and methods

The experiment was carried out in the Laboratory of the Department of Crop Production and Horticulture of Modibbo Adama University of Technology (MAUTECH), Yola (latitude 9^0 23'N and longitude 12^0 46'E), Adamawa State. The treatments consisted of two factors, fruit size and harvesting methods which were factorially combined and laid in a Split Plot Design (SPD), fruit size was assigned to the main plot and harvesting method was assigned to the subplots. All treatments consisted of 10 fruits, replicated three times and were packaged in a corrugated fibre cardboard carton.

The following three harvesting methods were used to harvest the fruits: ground (control), picker (plate I) and soft surface (foam). The mango fruits were harvested in the morning from the same tree at an approximate height of 5m.Two fruit sizes were used namely: big fruit (weighing 320 - 750 gm with a length $\geq$ 7.5 cm and girth of $\geq$ 5.5cm) and Small fruit (150 - 319 gm, and length $<$ 7.5 cm and a girth of $<$ 5.5cm).

The fruits were stored under ambient condition within the temperature range of 30 - 36^{0}C and the relative humidity lies between 45 - 51% throughout the storage period inside the laboratory. Data were collected periodically after every two days on the following parameters:

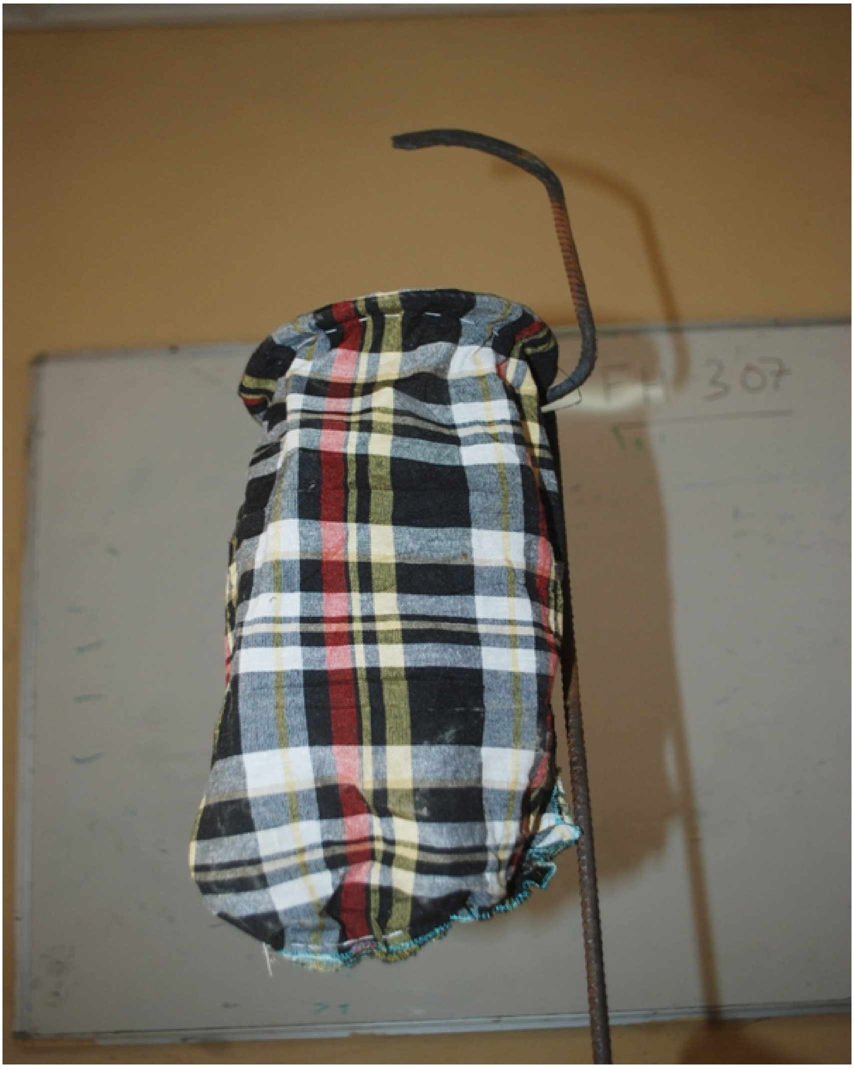

Plate I: Locally Fabricated Mango Fruit Picker

1. Percentage change in fruit girth or diameter: The fruit diameter or girth refers to the width of the fruit midway between the nose and the stem ends of the fruit, it was determined by measuring the diameter at the middle of the fruit using Vernier caliper (plate II).

The fruit percentage change in diameter or girth was obtained by finding the difference between original and final diameter, divided by the original diameter and then expressed in percentage after every two days during the study (Ahmed, 2016).

Percentage change in fruit girth was calculated using the expression:

$$\text{Percentage Change in fruit diameter or girth} = \frac{\text{original diameter} - \text{new diameter} \quad \times 100}{\text{original diameter}}$$

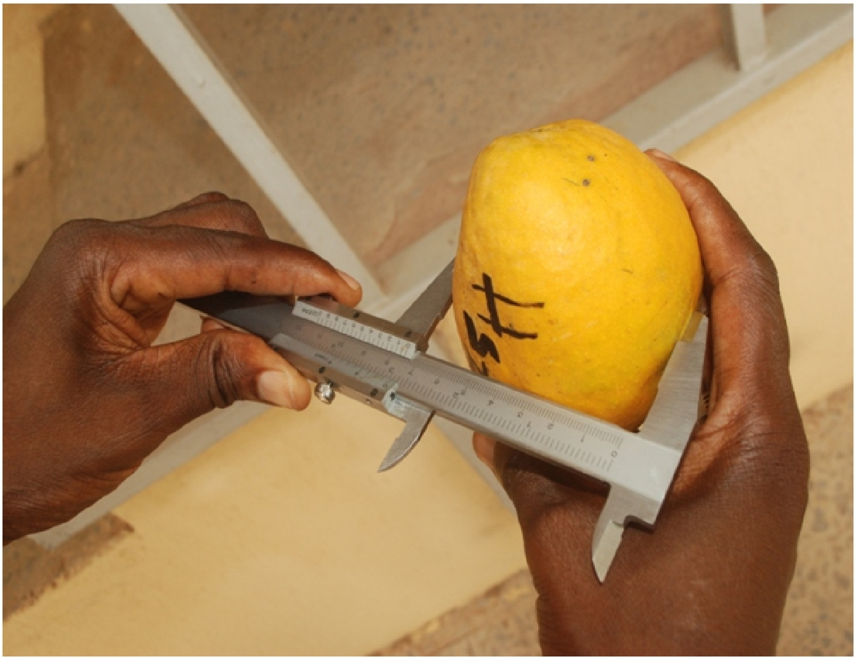

Plate II: Measuring Fruit Diameter at 14th Days of Storage with Vernier caliper (Fruit Harvested with Picker)

2. Percentage deterioration: Percentage deterioration of fruits was calculated by counting the deteriorated fruits out of the total fruits in each treatment after every two days of storage and expressed in percentage. Fruits with visibly infected surface area which were not edible were considered as deteriorated (plate III and IV). The percentage deterioration was calculated according to Jawandha *et al.* (2012); Ahmed *et al.* (2016); Ahmed et al. (2019) as follows:

$$Percentage\ Deterioration = \frac{number\ of\ fruit\ rotten \times 100}{total\ number\ of\ fruits}$$

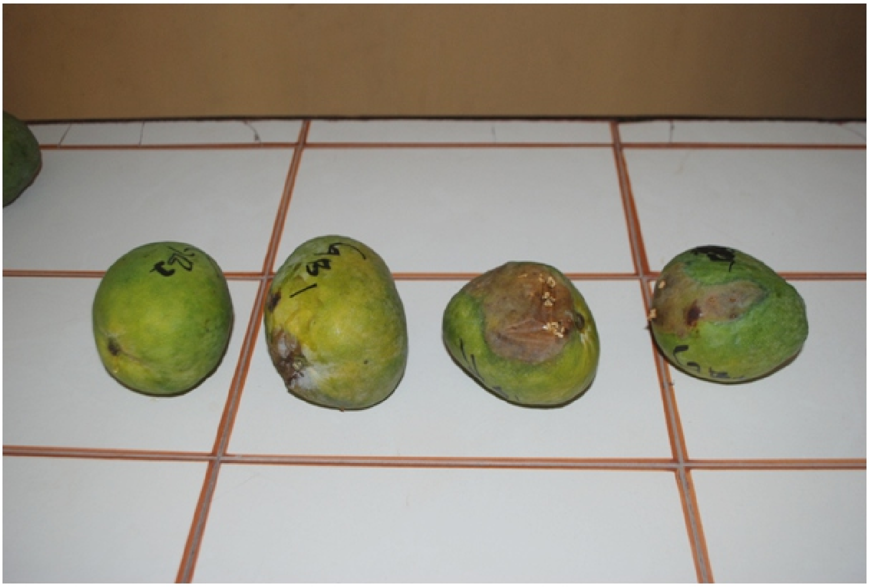

Plate III: Deteriorated Mango Fruits after 6 Days of Storage (Fruits Harvested on the Ground)

Plate IV: Flesh of Deteriorated Mango Fruit after 6 Days of Storage (Fruits and fell on the Ground)

3. Speed of Fruit Deterioration: The time taken for a fruit to deteriorate during storage is the rate of deterioration of the fruit. Speed or rate of deterioration was obtained by dividing number of deteriorated fruits by the number of days taken each mango fruit to deteriorate from initial day of storage to the final day of spoilage (Ahmad *et al*., 2007; Ahmed *et al*., 2016; Ahmed *et al* 2019).

$$\textit{Speed of Fruit Deterioration} = \frac{number\ of\ rotten\ fruits}{days\ taken\ to\ rot}$$

4. Percentage physiological weight loss: Percentage physiological weight loss was obtained by weighing individual fruit from initial day of storage to the final day (Ahmed, 2016). Measurements were taken using Ohaus triple bar chemical balance model 700/800 (plate V), the difference between original and final weights were calculated then divided by the original weight and expressed in percentage after every two days during the study. Percentage weight loss was calculated using the expression.

$$\text{Percentage physiological Weight loss} = \frac{\text{original weight} - \text{new weight} \times 100}{\text{original weight}}$$

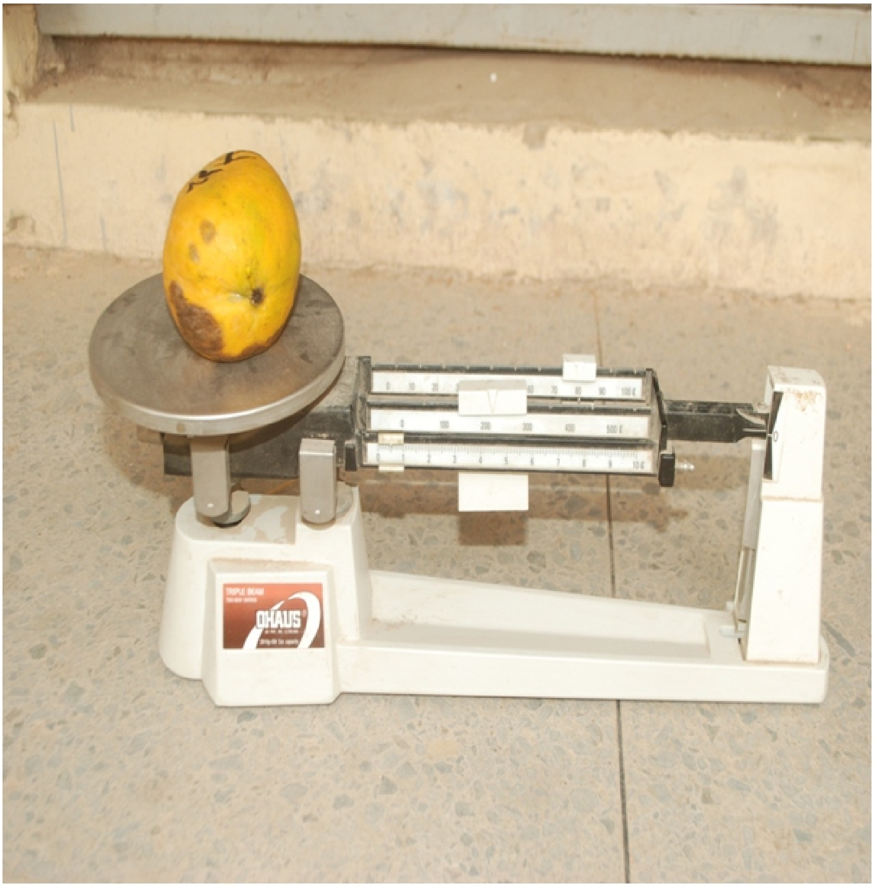

Plate V: Measuring Fruit Weight at 16^{th} Days of Storage (Fruit Harvested with Picker)

Data Collection and Analysis

Data collected from the above enumerated parameters were subjected to Analysis of Variance (ANOVA) using generalized linear model (SAS system for windows v8, 2000) and values having significant effect were separated using Least Significant Difference (LSD)

Results

The results in Table 1 shows that harvesting methods had highly significant ($P<0.01$) effect on percentage change in fruit diameter or girth at the 10th ,12th and 14th days of storage but at the 16th day of storage, the level decreased to significant ($P<0.05$) effect. A highly significant ($P<0.01$) interaction between fruit size and harvesting method was observed at the 2nd, 4th and 6th days of storage. However, at the 10th and 12th days of storage the level of interaction reduced to significant ($P<0.05$) interactions as indicated that Table 1.

During 18 days of mango fruits storage, fruit size had significant ($P<0.05$) effect on mango fruit percentage deterioration only at the 16th and 18th days as shown in Table 2. Harvesting methods also had significant ($P<0.05$) effect on mango fruit percentage deterioration only at the 16th day of the storage as presented in Table 2. Similar trend was observed in terms of interaction, significant ($P<0.05$) interaction occurred only at the 16th day of storage between fruit size and harvesting method on mango fruit percentage deterioration (Table 2).

The speed of fruit deterioration was significantly ($P<0.05$) influenced by harvesting method at the 8th and 16th days of storage but at the 18th day the level of influence of harvesting method on speed of fruit deterioration raised to highly significant ($P<0.01$) level (Table 3). There were also significant ($P < 0.05$) interactions between fruit size and harvesting methods at the 10th and 16th days of storage with respect to speed of fruit deterioration during storage as depicted in Table 3.

The physiological weight loss of mango fruits was highly ($P<0.01$) affected by fruit size at all the sampling periods except at the 2nd, 12th, and 14th days in storage (Table 4). Likewise also, harvesting method highly ($P<0.01$) affected the physiological weight loss of mango fruits at all days of the storage periods except at the 2nd day where it was significantly ($P<0.05$) affected. In case of interaction, there were also highly ($P<0.01$) interaction between fruit size and harvesting method at the 8th, 10th, 16th and 18th days of the storage period.

Discussion

The highly significant effect of harvesting methods on percentage change in mango fruit diameter or girth might be attributable to increased respiration rate and subsequent water loss from the fruits that were harvested using ground method due to mechanical injury sustained by the fruits. The rough harvesting method increase physiological disorder thereby increased respiration and water loss. The finding of this work concurred with earlier works by Ajayi and Nyisir (2006); Jawadha *et al.* (2012); Ahmed *et al.* (2016) who reported that careless harvesting practices cause mechanical damages to the fruits which significantly increases water loss, shriveling due to high respiration and susceptibility to infection by postharvest pathogens.

Both the highly significant and significant interactions observed between fruit size and harvesting method during the storage period in terms of percentage change in fruit girth might be because of the high respiration rate and injury arising from bad harvesting method and small fruits, which increase fruit physiological disorder due to mechanical injury and infection on the fruits. This result is in conformity with Yahia (1999); Abu-Ghoukh and Mohammed (2004); Panhwar (2005); Paltrinieri (undated); Ahmed *et al.* (2019) who asserted that harvesting method and fruit size influences mango fruits storage.

The significant effect of harvested fruit size on percentage deterioration of mango fruits during storage recorded at day eight of storage might be due to high rate of respiration associated with small fruits caused by surface-area-to-volume-ratio phenomena coupled with high temperature and low relative humidity during storage. Similar findings were reported by Gosbee and Jessup (2000); Ahmad et al. (2007); AgrInfo (2011); Ahmed *et al*. (2016); Ahmed *et al.* (2019) who stated that mango fruits are affected by temperature, relative humidity and harvested fruit size during storage. The significant effect of harvesting method on percentage deterioration that occurred at the 16th and 18th of storage may be due to the shock and mechanical injury suffered by the fruits harvested on the ground. This finding is in agreement with Yahia (1999) and Savikumar *et al* (2011) who reported that poor harvesting method causes rapid decay, pest attack and physiological breakdown.

The significant interaction between harvested fruit size and harvesting methods on fruit percentage deterioration at the 16th and 18th days of storage might be due to the bruised and cuts that provide avenue for attack by pathogens, this result is in agreement with the findings of Eckert and Eaks (1989); Anwar and Malik (2007); Ladaniya (2008); Iqbal *el at.* (2012) who reported that fruit size and harvesting method are some of the major factors that affect postharvest life of mango fruits.

The significant effect at the 8th, 16th and the highly significant effect at the 18th days of storage caused by harvesting method on speed of deterioration could be as a result of impact which led to elevated respiration and injuries that provide entry points for rotting agents that fasten deterioration during storage. This finding is in line with the outcome of the studies conducted by Slaughter (2009) and Singh et al (2014) who asserted that wounded mango fruit due to poor harvesting lead to rapid quality loss through rotting.

The significant interaction of fruit size and harvesting method recorded at the 10th and 16th of the storage on speed of deterioration may be due to the manifestation of infection and physiological disorder associated with improper harvesting and natural ripening or senescence process. This result is in tandem with Singh *et al.* (2014) who reported that fruit senescence, physiological disorder, insect infestation, pathological infection, physical or mechanical injury are major causes of postharvest losses in mango fruits.

The significant effect of fruit size on fruit physiological weight loss that occurred during storage might be attributed to high water loss, latex flow, respiration and transpiration rate by smaller fruits because smaller fruits have high level of respiration during storage due large surface area to volume ratio phenomena, this outcome is congruent with the results reported by Day (1993), Ahmad *et al.* (2007) and AgriInfo (2011) ; Ahmed *et al.* (2016); Ahmed *et al.* (2019) who reported small fruit experience high respiration due to surface area to volume ratio.

The Significant effect of harvesting methods on physiological weight loss could be due to the high ambient temperature (33 ± 30 C) and low relative humidity (48 ± 3%) recorded during the storage periods which enhances respiration, transpiration and thus further aggravated water loss by the fruits that are subjected to harvesting on the ground. The result is in harmony with Day (1993); Gosbee and Jessup (2001); Abu-Goukh and Mohammed (2004); AgriInfo (2011); Singh *et al* (2014); Anon. (2015); Ahmed *et al.* (2016); Ahmed *et al.* (2019) who observed that high temperature, low humidity, mechanical damage, surface-area-volume ratio, nature of skin and maturity are the factors that affect respiration and transpiration in fruits in storage.

The significant interactions of fruit size and harvesting methods recorded throughout the storage period might be due to small harvested fruit size and careless harvesting method which influences shelf life of the fruit during storage. This assertion is further reaffirmed by Bhattarai and Gautam (2006); Ahmad *et al* (2007) AgriInfo (2011); Singh *et al* (2014); Ahmed *et al.* (2016); Ahmed *et al.* (2019) who acknowledged both fruit size and harvesting method directly affect mango fruits during storage.

Conclusion and recommendations

In conclusion, fruit harvested using ground method had shorter storage life of less than six days while fruits harvested with picker had longest shelf life of 18 days of storage. Big fruits had lesser percentage change in fruit girth, physiological weight loss and deterioration than small fruits. The study thus, recommended big fruit size and picker method of harvesting for farmers in the study area. Therefore, mango fruits should be harvested carefully without falling on the ground and big mango fruits should be sorted for fresh market and long storage, thus ensuring high quality

Table 1: Effects of Harvesting Methods and Fruit Size on the Mango Fruit Percentage Change in Diameter during Storage

Treatment	Storage period (days)								
	2	4	6	8	10	12	14	16	18
Fruit size									
Big	7.68	7.37	7.04	6.04	4.43	3.00	2.32	1.87	1.19
Small	7.88	7.62	7.32	7.03	5.92	4.44	3.52	0.73	0.00
LSD	0.299	0.191	0.048	2.822	3.564	2.530	3.422	3.157	2.561
Probability of F	0.408	0.349	0.385	0.220	0.057	0.076	0.211	0.197	0.116
Harvesting Methods									
Ground	8.03	7.70	6.77	5.40	1.95	0.00	0.00	0.00	0.00
Picker	7.33	7.10	7.37	7.03	6.68	6.67	6.40	3.90	1.78
Foam	7.97	7.68	7.42	7.18	6.90	4.50	2.37	0.00	0.00
LSD	0.601	0.819	0.968	2.315	1.919	2.060	2.745	2.494	2.023
Probability of F	0.103	0.183	0.232	0.173	0.003	0.002	0.007	0.019	0.11
Interaction (H×S)	0.015	0.018	0.029	0.164	0.049	0.020	0.083	0.208	0.11

Table 2: Effects of Harvesting Methods and Fruit Size on Percentage Deterioration of Mango Fruit during Storage

Treatment	Storage period (days)								
	2	4	6	8	10	12	14	16	18
Fruit size									
Big	0.11	0.33	2.22	8.89	0.00	0.00	0.00	0.00	0.00
Small	0.33	0.78	4.44	8.89	0.33	0.78	6.67	1.11	11.00
LSD	0.96	1.27	9.56	37.95	14.34	17.24	16.57	12.65	19.12
Probability of F	0.69	0.78	0.84	1.00	0.44	0.12	0.16	0.02	0.05
HarvestingMethods									
Ground	0.33	1.00	6.67	0.00	0.00	0.00	0.00	0.00	0.00
Picker	0.00	0.00	0.00	0.00	0.00	0.00	10.00	16.67	16.67
Foam	0.33	0.67	3.33	26.67	5.00	11.67	0.00	0.00	0.00
LSD	1.20	2.95	17.72	29.99	11.33	13.62	13.09	9.99	15.11
Probability of F	0.69	0.66	0.62	0.11	0.44	0.12	0.16	0.02	0.05
Interaction (H×S)	0.69	0.78	0.84	1.00	0.44	0.12	0.16	0.02	0.05

Table 3: Effects of Harvested Fruit Size and Harvesting Methods on speed of Fruit Deterioration of Mango Fruit during Storage

Treatment	Storage period (days)								
	2	4	6	8	10	12	14	16	18
Fruit size									
Big	0.22	0.44	0.67	1.78	1.11	1.33	1.56	1.89	2.00
Small	0.56	1.00	0.67	2.44	2.22	1.33	3.11	5.33	6.00
LSD	0.83	1.72	0.00	9.22	9.56	9.94	6.69	8.17	7.90
Probability of F	0.61	0.65	1.00	0.66	0.37	1.00	0.56	0.14	0.09
HarvestingMethods									
Ground	0.67	1.33	1.00	5.33	1.67	0.00	0.00	0.00	0.00
Picker	0.00	0.00	0.00	0.00	0.00	0.00	2.33	8.00	12.00
Foam	0.50	0.83	1.00	1.00	3.33	4.00	4.67	2.83	0.00
LSD	2.07	3.83	3.93	4.72	3.78	7.85	8.36	6.46	6.24
Probability of F	0.68	0.65	0.73	0.05	0.160	0.360	0.391	0.05	0.009
Interaction (H×S)	0.76	0.80	0.44	0.80	0.05	1.00	0.17	0.02	0.09

Table 4: Effect of Fruit Size and Harvesting Method on the Percentage Physiological Weight Loss of Mango Fruit during Storage.

Treatment	Storage period (days)								
	2	4	6	8	10	12	14	16	18
Fruit size									
Big	0.67	4.02	3.72	2.70	2.48	1.78	1.59	0.00	0.00
Small	1.13	5.47	5.11	3.42	3.17	1.79	1.62	1.49	0.38
LSD	2.76	0.38	0.27	0.38	0.38	2.02	1.83	0.34	0.39
Probability of F	0.77	0.001	0.003	0.001	0.007	0.98	0.94	0.001	0.01
Harvesting method									
Ground	1.33	5.88	5.48	2.03	1.88	0.00	0.00	0.00	0.00
Picker	0.25	3.08	2.82	2.57	2.33	2.12	1.87	0.67	0.57
Foam	1.12	5.27	4.95	4.58	4.25	3.23	2.95	1.57	0.00
LSD	2.49	0.59	0.74	0.52	0.46	1.52	1.38	0.42	1.28
Probability of F	0.50	0.001	0.001	0.001	0.001	0.01	0.01	0.001	0.01
Interaction (H×S)	0.97	0.13	0.21	0.003	0.002	0.39	0.38	0.001	0.01

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ASUU Journal of Science
A Journal of Research and Development
Vol. 6, Nos. 1 & 2, December, 2019

ISSN: 2276-9595

ASUU Printing Press, National Secretariat, Abuja