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Effect of harvesting stage and storage condition on post-harvest quality and sensory acceptability of mango fruit in Gamo Zone, Southern Ethiopia

Wasihun Wale Eyese*, Ermias Dureto Badebo and Melese Lema Tessema

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A B S T R A C T

The effect of harvesting stages (mature green, half-ripe and full ripe) and storage conditions (zero energy cool chamber, wooden box and underground storage) on post-harvest quality and sensory acceptability of mango fruit was evaluated. Three harvesting stages of mango fruit were harvested and 10 kg of mango fruit was stored in three storage conditions until the end of the storage period. Spoilage and weight loss of mango fruit were recorded from storage in three-day intervals. All samples were analyzed for Post-harvest quality of mango fruit before and after storage at Arba Minch University, Abaya Campus Chemistry laboratory, and sensory acceptability was evaluated by using untrained 45 panelists at the end of the storage period. Completely Randomized Design in factorial arrangement with three replications was used to evaluate the shelf life and postharvest quality of mango fruit. Weight loss, spoilage, firmness and total soluble solids of mango fruit were increased while vitamin C, moisture content and titratable acidity were decreased with increased storage time. The vitamin C content of mango fruit was highest at half ripe in a zero energy cool chamber and was lowest at full ripe harvested in a wooden box after the end of the storage period. The highest overall acceptability of mango fruit was observed at the half-ripe harvested stage in zero energy cool chambers while the lowest was observed at the mature green harvested stage mango fruit in a wooden box after the end of the storage period. Based on the current study, half ripen mango fruit in zero energy cool chamber storage recorded the least percent of weight loss, spoilage amount, maximum shelf life and quality, especially vitamin C content and higher overall acceptability. Further study will be needed on the microbial quality of mango fruit in different harvesting stages and storage conditions during storage periods.

Keywords: Harvesting stage, Mango fruit, Post-harvest quality, Sensory acceptability, Storage conditions

South Agricultural Research Institute, Arba Minch Agricultural Research Center, Arba Minch, Ethiopia

*Corresponding author's email: wasihunwale2011@gmail.com (Wasihun Wale Eyese)

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Introduction

Mango (*Mangifera indica* L) is known as one of the most popular tropical fruit in the world and Mangoes belong to genus Mangifera. Mango is a climacteric fruit, generally harvested at mature green stage and ripens up during the marketing process (transport, storage etc.). Due to its popularity and importance, *M. indica* is often named "King of fruits" for its luscious flavor, taste and high nutritive value (Moula Sab *et al.*, 2017) that makes the crop valued for both food and nutritional security especially for developing countries like Ethiopia where the realization of food and nutritional security is still a challenge.

Due to the application of conventional technology for the transfer of the produce and an irregular storage period, more than 30% is wasted (Shahbaz *et al.*, 2009). The postharvest losses of mangoes have been estimated in the range of 25-40 % from harvesting to consumption stage (FAO, 2001). Once fruits are harvested, these processes along with other bio-chemical deterioration, and decrease the fruit quality very quickly which affects its marketability, becomes highly susceptible to postharvest losses (Wills *et al.*, 2007).

However, postharvest losses in this important fruit crop are always a topic of concern for various mango growing countries worldwide (Patil *et al.*, 2013, Luo *et al.*, 2015), as this directly affects its trade and availability to consumers (Chattopadhyay, 2014). The major reason of high postharvest loss, less postharvest quality and short shelf life of mango fruits are improper harvesting stages and storage condition that affect the shelf life and post-harvest quality of mango fruit. Until today there is still existence of lack in systematic study on effect of harvesting method on mango postharvest loss and its quality, which is need of hour for mango trade (Pacheco *et al.*, 2017).

Mango fruit production areas in developing countries such as Ethiopia, South region, Gamo Zone was faced a problem of less postharvest quality and shelf life of mango fruit which were caused by lack of storage conditions and improper harvesting stages. The increasing post-harvest quality and shelf life of mango fruit through suitable harvesting stages and storage conditions have not been practiced and did not conducted any research in area. Therefore, this study was conducted to evaluate harvesting stages and storage conditions that provide better post-harvest quality and shelf life of mango fruit in study area.

Materials and Methods

Source of study materials

Good quality mango fruits were selected from farmer's field at different locations such as Chino Mille kebele. The mango fruits were harvested by three different stages mature green, half ripen and full Ripen with stalk length of 3-5 cm. Three stage harvested mango fruits were precooled to remove field heat, cleaned and well-dried mango fruits were stored separately at three different storage materials.

Experimental design

Experiment were carried out by using completely randomized design (CRD) in factorial arrangement with three replications, having 10 kg of three maturity stage of mango fruit at each storage conditions.

Post-harvest quality of mango fruit

The moisture contents were calculated by taking 10 g of fruit pulp and drying in an oven up to constant weight at 76°C and calculating the loss in weight (AOAC, 2005). The total titratable acidity was determined by titrating 100 mL of juice against (0.1 N) sodium hydroxide. The estimation of total solid soluble (TSS) was determined using hand refracto-meter (Atago-Palette PR 101, Atago Co. Ltd., Itabashi-Ku, Tokyo, Japan). A drop of mango juice was used to record the TSS and values were expressed as ^{o}brix. Vitamin C content (ascorbic acid) of mango fruit was determined by the indophenols method as reported by in Onwuka (2005).

Sensory acceptability of mango fruit

Sensory acceptability of mango fruit was evaluated after the end of storage periods by using untrained 45 farmers. Prior to the sensory evaluation, mango fruit samples from each storage condition were individually coded and served to the panelists in plastic dishes. Clean water was provided to the judges to rinse the mouth in between testing of the mango fruit samples to avoid residual effects. The judges were instructed to evaluate and score the mango fruit samples based on the degree of likeness and acceptance by using a five-point hedonic scale with 1, 2, 3, 4 and 5 representing dislike very much, dislike, neither dislike nor like, like, and like very much, respectively.

Data analysis

The collected data were subjected to Analysis of Variance (ANOVA) by using SAS version9.0 computer software. Least Significance Difference (LSD) was used to establish mean values Separation. Mean values were considered at 5% significance level ($p<0.05$).

Results and Discussion

Weight loss of mango Fruit

The results of weight loss and shelf life of mango fruits stored in different storage conditions were presented in Table 1. Day three, the weight loss score (6.47) of mango fruit was highest in wooden box at full ripen harvesting stage while least weight loss score (0.16) was recorded at green matured harvesting stage in under-ground storage. The mean weight loss scores of mango fruit had not shown significant difference ($p<0.05$) in zero energy cool chamber and under-ground at full matured harvesting stage, zero energy cool chamber at half harvesting stage and under-ground storage at matured green harvesting stage. In wooden box at green matured and half ripen harvesting stages had not shown significant different in mean scores of weight loss.

Table 1. Weight loss of mango fruit in three storage conditions.

Treatment	WL Day 3	WL Day 6	WL Day 9	WL Day 12	Shelf life (days)
MGUG	0.20e	6.86d	21.92f	35.93g	17
MGWB	4.90b	9.79b	24.92e	37.92e	14
MGZEC	2.57c	5.88e	27.90d	38.93d	19
HRUG	0.80d	8.87c	28.92c	39.97c	15
HRWB	4.92b	9.19c	29.78b	41.89b	14
HRZEC	0.16e	4.98f	17.92i	34.937i	20
FRUG	0.19e	6.99d	20.89g	36.90f	14
FRWB	6.47a	14.56a	30.83a	44.94a	15
FRZEC	0.38de	5.86e	18.89h	35.09h	18
LSD(0.05)	0.43	0.37	0.25	0.16	

Where, WL= Weight loss, MGUG= mature green in under-ground, MGWB= mature green in wooden box, MGZEC= mature green in zero energy cool chamber, HRUG= half ripe in under-ground, HRWB= half ripe in wooden box, HRZEC= half ripe in zero energy cool chamber, FRUG= fully ripe in under-ground, FRWB= fully ripe in wooden box, FRZEC= fully ripe in zero energy cool chamber,

Day six, mean weight score (14.56%) of mango was highest in wooden box at full ripen harvesting stage while least mean weight score was recorded (4.98%) at half ripe in zero energy cool chamber. The weight loss of mango fruit at half-ripen harvesting stage in under-ground and wooden box storage had not shown significant different ($p<0.05$), and had not shown significant different ($p<0.05$) at mature green and full ripe in zero energy cool chamber storage.

Day nine, mean weight score(30.83%) of mango was highest at full ripen harvesting stage in wooden box while least mean weight score was recorded (17.92%) at half ripe harvesting stage in zero energy cool chamber. The results of spoilage percent of mango fruits stored in different storage conditions were presented in Table 2.

Zero energy cool chamber storage, day nine storage periods, the mean weight score of mango fruits had shown significant difference ($p<0.05$) in all storage conditions and harvesting stages. Day twelve, the mean weight loss score (44.94%) of mango fruit was highest in wooden box at full ripen harvesting stage while least mean weight loss score (34.93) was recorded at half-ripe in zero energy cool chamber storage. Day twelve, the mean weight score of mango fruits had shown significant difference ($p<0.05$) in all storage conditions and harvesting stages.

Spoilage percent of mango fruit

The results of spoilage percent of mango fruits stored in three different storage conditions were presented in Table 2. The spoilage percent of mango fruit had not shown significance difference ($p<0.05$) in harvesting stages and storage conditions at three days storage time except full ripe mango fruit in wooden box storage.

Table 2. Spoilage percentage of mango fruits in three storage conditions.

Treatments	Spoilage (%) day 3	Spoilage (%) day 6	Spoilage (%) day 9	Spoilage (%) day 12
MGUG	0.00b	0.67c	5.18c	31.50a
MGWB	0.00b	1.83b	5.20c	15.36f
MGZEC	0.00b	1.15c	5.16c	10.53g
HRUG	0.00b	1.06c	2.23d	22.16d
HRWB	0.00b	1.14c	2.30d	22.76d
HRZEC	0.00b	1.13c	2.13d	10.33g
FRUG	0.00b	1.83b	12.13b	19.90e
FRWB	2.96a	2.86a	13.32a	29.50b
FRZEC	0.00b	1.90b	5.24c	25.50c
LSD ($p<0.05$)	0.030	0.516	1.167	0.903

The spoilage percent of mango fruit had not shown significance difference ($p<0.05$) at mature green in underground and zero energy cool chamber, at half ripe in underground, wooden box and zero energy cool chamber storage. Spoilage percent had not shown significance difference ($p<0.05$) at mature green in wooden box, at full ripe in underground and zero energy cool chamber storage at day six storage periods. The spoilage percent of mango fruit had not shown significance difference ($p<0.05$) at mature green in all storage conditions and at full ripe in zero energy cool chamber, and also spoilage percent of mango fruit were not shown

significance difference ($p<0.05$) at half ripe harvesting stage in all storage conditions until day nine storage periods. Day nine storage periods, highest spoilage percent of mango fruit was recorded at full ripe harvest in wooden box storage and lowest spoilage percent was measured in Zero energy cool chambers.

The spoilage percent of mango fruit had shown significance difference ($p<0.05$) in harvesting stages and storage conditions but had not significance difference ($p<0.05$) at half ripe harvesting stage in underground storage and wooden box storages, and were not shown significance difference ($p<0.05$) at mature green and full ripe harvesting stage in zero energy cool chamber until day twelve storage time. Day twelve storage periods, highest spoilage percent was evaluated at full ripe harvesting stage in wooden box storage and least spoilage was recorded at half ripe harvest mango fruit in zero energy cool chambers.

Post-harvest quality of three harvesting stages of mango fruit before storage

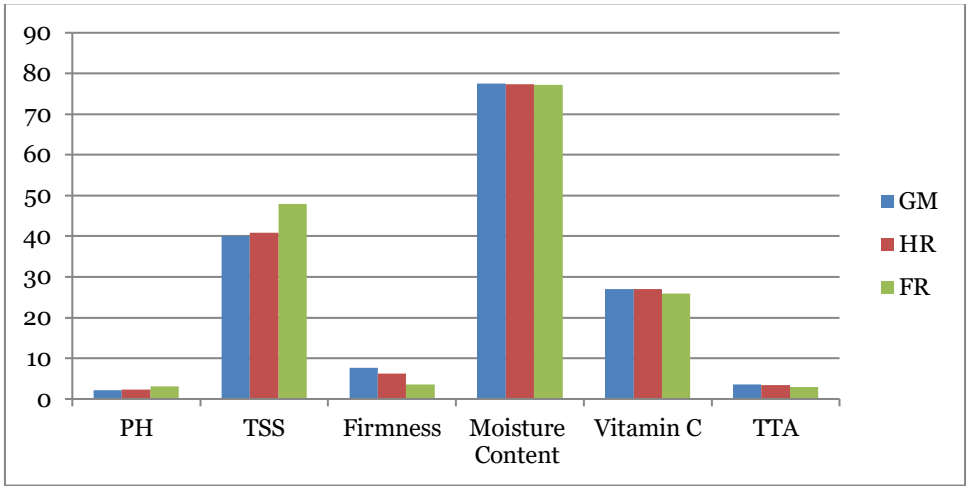

Chart 1. Quality of three harvesting stages of mango fruit before storage.

Where, GM: Green mature, HR: Half-ripe, FR: Full ripe, TTA: Titretable acidity and TSS: Total soluble solid

Post-harvest quality of mango fruit in three storage conditions at the end storage periods

Total soluble solids

The results of total soluble solids, firmness, moisture content, vitamin C and titratable acidity of mango fruits stored in three different storage conditions were presented in Table 3.

Table 3. Post-harvest quality of mango fruit in three storage conditions after the end of storage periods.

Treatment	TSS	Firmness	Moisture	Vitamin C	TTA
MGUG	60.54^{g}	4.21^{ab}	74.62^{a}	18.67^{c}	0.77^{a}
MGWB	61.40^{f}	3.30^{c}	72.58^{c}	18.23^{d}	0.52^{b}
MGZEC	60.36^{g}	4.26^{a}	73.35^{b}	19.167^{b}	0.76^{a}
HRUG	63.61^{e}	3.83^{b}	73.33^{b}	17.43^{f}	0.55^{b}
HRWB	64.20^{c}	3.36^{c}	71.79^{d}	16.60^{f}	0.41^{c}
HRZEC	63.90^{d}	3.34^{c}	70.48^{e}	20.63^{a}	0.56^{b}
FRUG	65.53^{b}	3.83^{c}	74.43^{a}	14.80^{g}	0.36^{e}
FRWB	66.60^{a}	2.61^{c}	68.75^{f}	13.36^{h}	0.32^{f}
FRZEC	65.50^{b}	3.40^{c}	71.47^{d}	14.63^{g}	0.35^{e}
LSD($p<0.05$)	0.583	0.42	0.43	0.33	0.02

The TSS value of mango fruit at various storage conditions and harvesting stages were ranged from 60.36-66.60. The mean TTS values of mango fruits had shown significant difference ($p<0.05$) in storage conditions and harvesting stages but TTS value of mango fruits in under-ground and zero energy cool chamber at green mature, and in under-ground and zero energy cool chamber at full ripen harvest stage had not shown significant difference($p<0.05$). The total soluble solids (TSS) were increased with the ripening process as the storage periods increased. The increase in TSS was the outcome of conversion of carbohydrates into simple sugars through a complex mechanism during the storage and the conversion rate was increased with the increase in storage period and temperature. This conversion is also considered to be one of the important indexes of ripening process in mango and other climacteric fruit (Doreyappy-Gowda and Huddar, 2001; Kittur *et al.*, 2001).

Firmness

The firmness of mango fruit at three storage conditions and harvesting stages were ranged from 2.61-4.26. The mean firmness score (4.26) of mango fruit was highest in zero energy cool chamber at green mature harvesting stage while least mean firmness score (2.61) was recorded in wooden box storage at full ripen harvesting mango. The firmness of mango fruit was decreased to the fact that the ripening of mango fruit is characterized by loss of firmness due to cell wall digestion by pectin esterase and other enzymes and this process was increased the storage period.

Moisture Content

The moisture content of mango fruit at three storage conditions and harvesting stages were ranged from 68.75-74.62. The moisture content that were high at the harvest time, were decreased with the ripening process and increased storage period. In addition, the moisture contents move from the inner side of the fruit to outer side for the escape purpose and it takes place through diffusivity phenomenon, which is enhanced with the ripening of the fruit (Dissa *et al.*, 2011).

Vitamin C

The vitamin C content of mango fruit at various storage conditions and harvesting stages were ranged from 13.36-20.63. The vitamin C content(20.63) of mango fruit was highest in zero energy cool chamber at half ripen harvesting mango while least vitamin C content (13.36) was recorded in wooden box storage at full ripen harvesting mango. The vitamin C value was decreased with the ripening of the fruit or with the increase in storage period as compared with vitamin C content of mango fruit during harvesting time. This trend was due to conversion of acid into sugars and their further utilization in metabolic process of the fruit and that the chemical and biological process was increased with the increase in storage (Rathore *et al.*, 2007).

Titratable Acidity

The acidity of mango fruit at various storage conditions and harvesting stages were ranged from 0.32-0.77. The titratable acidity (0.77) of mango fruit was highest in zero energy cool chamber at green mature harvesting mango while least titratable acidity (0.32) was recorded in wooden box storage at full ripen harvesting mango. Acidity of mango fruit was decreased as compared with the acidity of mango fruit at harvest time. The decrease in acidity of mango was attributed towards the conversion of citric acid into sugars and their further utilization in metabolic process of the fruit (Rathore *et al.*, 2007; Srinivasa *et al.*, 2002).

Sensory acceptability of mango fruit

The results of sensory acceptability of mango fruits stored in three different storage conditions were presented in Table 4. The color of mango fruit had not shown significance difference($p<0.05$) at mature green, half ripe and full ripe in zero energy cool chambers, mature green in wooden box, half ripe in underground and wooden box, full ripe in underground and wooden box storage. In addition, color of mango fruit had not shown significance difference ($p<0.05$) at mature green and half-ripe in underground and mature green in wooden box storage. The smell of mango fruit had not shown significance difference ($p<0.05$) at three harvesting stages and storage conditions after the end of storage period.

Table 4. Sensory acceptability of mango fruit in three storage conditions after the end of storage periods.

Treatments	Color	Taste	Smell	Overall acceptability
MGUG	3.80^{b}	3.73^{b}	4.43^{a}	4.43^{a}
MGWB	4.20^{ab}	4.00^{ab}	4.41^{a}	3.67^{b}
MGZEC	4.40^{a}	4.26^{ab}	4.40^{a}	4.06^{ab}
HRUG	4.13^{ab}	4.13^{ab}	4.42^{a}	3.80^{b}
HRWB	4.41^{a}	4.40^{a}	4.43^{a}	3.73^{b}
HRZEC	4.40^{a}	4.40^{a}	4.41^{a}	4.53^{a}
FRUG	4.42^{a}	4.40^{a}	4.42^{a}	4.40^{a}
FRWB	4.40^{a}	4.13^{ab}	4.40^{a}	4.42^{a}
FRZEC	4.40^{a}	4.40^{a}	4.13^{a}	4.41^{a}
LSD	0.52	0.55	0.54	0.49

Taste of mango fruit had not shown significance difference ($p<0.05$) at three harvesting stages and storage conditions except mature green in underground storage after the end of storage period, and taste of mango fruit had not shown significance difference ($p<0.05$) at mature green in underground, wooden box and zero energy cool chamber, half ripe in underground and full ripe in wooden box storage. The overall acceptability of mango fruit had not shown significance difference ($p<0.05$) at full ripe in underground, wooden box and zero energy cool chamber, at half ripe in zero energy cool chamber, at mature green in underground and zero energy cool chamber storage after the end of storage period while the taste of mango fruit also had not shown significance difference ($p<0.05$) at mature green in wooden box and zero energy cool chamber, at half ripe mango in underground and wooden box storage after end of storage time.

Conclusion and Recommendation

Based on current results, half ripen mango fruit at zero energy cool chamber storage was observed least percent of weight loss, waste amount, maximum shelf life (20 days) and better post-harvest quality especial vitamin C content and higher overall acceptability. Full ripen mango fruit at wooden box storage was recorded high percent of weight loss, waste amount, minimum shelf life (13 days) and less vitamin C content. Half-ripe harvesting stage of mango fruit with zero energy cool chamber storage was recommended for mango producer and retailor for purpose of mango fruit storage. Further study will be needed on the microbial quality of mango fruit in different harvesting stage and storage conditions during storage periods.

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Competing Interest

The authors declare no competing interest in this research work that could bias the collection, analysis and publishing of this paper.

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