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Research Article

Effect of Harvesting Stage and Types of Storage on the Quality and Shelf-Life of Tomato Fruit

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ABSTRACT

The study was conducted to undertake the effect of harvesting stage and types of storage on the quality and shelf life of tomato fruit. Three harvesting stages (mature green, half ripen and red /fully ripen and three types of storage (wooden box (control), zero energy cool chamber and aerobically underground storage) were used as treatment and laid out in factorial arrangements in complete randomized design with three replication. During the storage period percentage weight loss, decay, moisture content, vitamin C and total soluble solids were increased in all storage types irrespective of harvesting stages, while fruit firmness decreased accordingly. Vitamin C and shelf life of tomato were highest in zero energy cool chamber than aerobically underground and wooden box storage. Decay and weight loss percentage were highest in wooden box than aerobically underground and zero energy cool chamber storage. At end of storage period due to starch degradation TSS was increased in all types of storage and it was highest in aerobically underground storage than zero energy cool chamber and wooden box. Tomato moisture and firmness were highest in aerobically underground storage and wooden box storage than the rest respectively. Significant difference ($p<0.05$) was observed for the parameters from harvesting stages and storage types. Results indicated that, irrespective of harvesting stage percentage weight loss(2.3-30,12.5-51.5,12.3-71.7), decay(1.38-63.9,1.36-76,1.3-88.9), shelf life(17-21,11.3-15.3,4.3-7.3), firmness(2.13-6.2,1.79-6.14,1.93-6.22), total soluble solids(3.06-4.88,3.23-5.2,2.94-4.14), moisture(83.52-87.18,83.53-91.4,82.07-86.76) and vitamin C(17.33-18.67,16.81-18.43,15.53-18.32) contents were ranged from first day to end of storage in zero energy cool chamber, aerobically underground storage and wooden box respectively.

Keywords: Zero energy; Cool chamber; Shelf life; Post-harvest loss; Maturity stage; Vitamin C; Content; Ripening

INTRODUCTION

The tomato (*Solanum lycopersicum* L.) is one of the most widely consumed fresh vegetable in the industrialized world. Botanically, tomatoes are fruits (berry), but they are commonly referred to as vegetable. Fresh-market tomatoes are a popular and versatile fruit vegetable, making significant contributions to human nutrition throughout the world [1]. It plays a vital role in human diet [2]. These are consumed whole peeled or in salads, cooked into soups or processed into juice, ketchup, paste and puree (Adedeji et al., 2005). Tomatoes are rich source of vitamins, minerals, sugars, essential amino acids, iron, dietary fibers and phosphorus [3]. Fruits also contain higher amounts of lycopene, a carotenoid with anti-oxidant properties beneficial in reducing incidence of chronic diseases like cancer and other cardiovascular disorders [4].

It is highly perishable fruit that needs care during its harvesting, storage and transportation from one place to another. Inappropriate storage materials and harvesting stage in the study area was one of the major factors that affect both qualitative and quantitative loss of tomato. At Gamo zone of southern Ethiopia, farmers were unaware of post-harvest handling practices and they have no storage facilities, while the transport and marketing channels also lack storage facilities. Due to absence of proper cold

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storage facilities the harvested tomatoes are stored in the open wooden box and exposed to high temperatures and low relative humidity and then the farmers have no choice but to sell their produce at lower prices to middlemen, whole-seller or retailer without making profit from the fruit. The working principle of zero energy cool chambers is by using water evaporation to obtain cooling effect and the faster the evaporation the greater is the cooling. This evaporative cool chamber fulfills all these requirements and is helpful to small farmers in rural areas [5].

Improper maturity/harvesting stage are also the major factor that affects both qualitative and quantitative loss of tomato. Maturity stage of tomato fruit at harvest is an important determinant of many quality traits [6]. Commonly practiced harvesting stage of tomato at the Gamo zone, southern Ethiopia for home consumption is full ripened whereas mature green and half ripened are harvested for commercial purpose in order to reduce the damage. Maturity at harvest is most important quality parameter for processors as it directly affects composition, quality, losses and the storage potential of the plant produce [7]. Tomato is generally harvested at edible maturity, characterized by attaining pink-reddish color and maximum size [8]. Tomato fruit when harvested at edible maturity is prone to post-harvest losses [9]. Harvesting tomato fruit at an improper maturity stage causes post-harvest losses such as decay and external damage [10]. There was limited research on the fields of post-harvest handling technology of highly perishable fruits such as tomato, because it is newly emerging agricultural field of study and lack focus for the effect of post-harvest loss in Ethiopia. Except common wooden box storage of tomato after harvest, the low cost and ecofriendly storages are not evaluated in the study area. Hence, the aim of this study was to evaluate the effect of harvesting stage and types of storage on the quality and shelf life of tomato fruit.

MATERIALS AND METHODS

Description of the study area

The study was conducted under simple shade constructed before conducting this study in order to prevent tomato from direct sun light and other damaging factors. The study was undertaken at Arbaminch Agricultural Research Centre, Chanomile crop research sub trial station. Laboratory analysis was carried out by carefully packaging and transporting tomato to the Arbaminch University, College of computational science which is seven kilometers away from experimental site. The daily minimum and maximum temperature, relative humidity and rain fall during the study period were indicated as follows (Table 1).

Sampling techniques and treatments

The fruit used for the study was harvested from tomato planted near the experimental site. Total of 10 kg tomato with similar size and shape was harvested at three different harvesting stages (mature green, half ripen and fully ripen). For laboratory analysis three fruits (0.5kg) per harvesting stage and types of storage were used and analysis was done three times within four days gap.

Construction of zero energy cool chambers

To construct the zero energy cool chamber an-upland having a nearby source of water supply was selected and the trial was placed out in three Complete Randomized Designs (CRD).The dimensions (L×W×H) of both the outer and inner brick walls were 200cm × 100 cm × 50 cm and 180 cm × 80 cm × 50 cm, respectively. The 10 cm gap left between the outer and inner wall was filled with sand as the use of a porous sand material for a special type of evaporative cooler could reduce ambient temperature by as much as 15°C. Water was carefully supplied to sand through manual sprinkling of water on sand. The chamber was closed with top cover made with bamboo (210 cm x110 cm) frame and dry grass. Simple shed was constructed with galvanized roof sheets to protect the zero energy cool chambers from heavy rains and direct sun light. Aerobically underground storage is similar to zero energy cool chamber by its construction design but it was put under the pit of depth 50cm and width 100cm. Wooden box storage is common storage material immediately used as the tomato harvested in study area. To construct wooden box storage simple locally available trees such as bamboo was used in similar size with above mentioned one.

Treatment setting

The experiment consisted of two main factors, Factor-A (harvesting stage stages) and Factor-B (types of storages). The three harvesting stages: (A) Matured green tomatoes (B) Half ripen tomatoes (C) and full ripen tomato were three levels of factor A. The levels of factor B were (1) Control: wooden box (2) aerobically underground storage and (3) Zero energy cool chambers in factorial arrangements with three replications at room temperature (25°C-28°C)

Table 1: Daily minimum and maximum temperature and relative humidity of storage room recorded at ambient condition.

Weather condition	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D13	D14	D15	D16	D17
Maximum(°C)	29.8	30.7	28.7	26.7	26.4	24.8	25.5	26.84	28.68	27.86	28.62	28.94	26.6	28.7	29.3	27.4
Minimum (°C)	15.8	15.8	17.9	17.3	17.9	17.0	18.4	18.3	17.7	17.9	16.7	17.3	14.3	18.5	17.9	18.2
RH(%)	35.8	39.3	58.7	66.1	64.1	50.6	44.1	63.35	69.11	60.34	57.45	16.34	65.4	60.5	56.8	63.3

Design of experiment

The experimental designed in a Randomized completely design (CRD) with three replications. 10 kg of uniform size tomato fruits were kept in each storage with three replication.

Measuring tomato quality parameters

Total soluble solids (TSS): Total soluble solids were determined using hand refractometer (Atago-Palette PR 101, Atago Co. Ltd., Itabashi-Ku, Tokyo, Japan) with range of 0-32°Brix. A drop of tomato juice was used to record the TSS and values were expressed as °brix [11].

Percent weight loss: For determining the physiological loss in weight, fruits were weighed before putting tomato into types of storage which served as the initial fruit weight. The loss in weight was recorded at 4 days interval until 16 days which served as the final weight. The physiological loss in weight was determined by the following formula and expressed as percentage.

%Weight loss = (WI-WF) × 100

WI Where, WI= Initial weight, WF= final weight

Shelf life in days: The shelf life was calculated by counting the days required to attain the last stage of ripening, but up to the stage when fruit remained still acceptable for marketing and home consumption

Moisture content (%): Moisture was determined by taking 10 g of sample in petri dish and dried in a Blue M lab oven with temperature range of 10°C above ambient to 260°C, Control ≤ ±1°C, Uniformity ≤ 3°C, run up time to maximum temperature ≤100min oven was used at 105°C till the weight of the petri dish with its content was constant (AOAC, 2000). Each time before weighing, the petri dish was cooled in desiccators. Moisture content of the sample was expressed in g/100 g of sample.

Moisture content (%)=initial weight (g)-observed weight (g)/ weight of the sample × 100

Percentage decay: For the determination of % decay, decayed fruits were isolated and weighed at each data collection date and removed from the storage. The percentage decay was calculated by using the weight of decayed tomato and initially stored weight of tomato as follow:

%decay= (decayed weight/initial weight) ×100%

Ascorbic acid (vitamin C content): The ascorbic acid content of the tomato fruits was determined at Arbaminch University by the indophenols method as reported by Onwuka [12]. The fruit was pulped using domestic juice extractor (Master Chef Model MC-J2101). Two grams of the blended pulp was weighed and 100 ml of distilled water added to it in a volumetric flask. The solution was filtered using a filter paper to get a clear solution. Fifty milliliters of unconcentrated juice was then pipetted into 100 ml volumetric flask in triplicate. Twenty five milliliters of 20% Metaphosphoric acid was added as a stabilizing agent and diluted to 100 ml volume. About 10 ml of the solution was then pipetted into small flask and 2.5 ml of acetone added. The solution was titrated with 2, 6. dichlorophenol indophenols to a faint pink color which persisted for roughly 15 seconds The amount of ascorbic acid in the tomato fruit was calculated as follows:

Vitamin C (mg/100g)=20 × V × c, Where V=ml indophenol solution in titration and c= mg vitamin C/ml indophenols

Data analysis

All the collected data were subjected to analysis of variances (ANOVA) suitable for CRD in factorial arrangements with two factors (harvesting stage and types of storage) with three by three levels and replied three times to determine mean combined treatment effects and analyzed by using SAS software version 9.2. Least significance difference (LSD) between means were attained at p(<0.05)by using Fischer's LSD method.

RESULTS AND DISCUSSION

Weight loss (%)

Significant difference was attained (p≤0.05) for weight loss of tomato harvested at three different harvesting stages and each storage conditions from 4th to 20th day (Table 2). At 4th day, the highest percentage weight loss (20.2%) was recorded from mature green tomato stored in aerobically underground storage while the lowest weight loss (2.37%) was observed in mature green tomato stored in zero energy cool chambers. This may be due to harvesting at mature green stage was susceptible to moisture loss and shrink age led to physiological loss in weight as storage period increases. This result is in line with findings from mentioned that the moisture loss also induces wilting, shrinkage, and loss of firmness [13]. Among the all treatments and harvesting stages the best harvesting stage for zero energy cool chamber was mature green followed by half ripen and fully ripen stage of harvesting respectively. Storing tomato in both aerobically underground storage and common wooden box storage were exposure to weight loss of the fruit and there was no significant difference between two storages except mature green stored in aerobically underground storage. The findings from Moneruzzaman et al. [14] also suggested that total weight loss in mature green tomato was always higher during entire period of storage at ambient condition

Table 2: Mean percentage weight loss of tomato with different storage types and harvesting stages.

Treatment combination	Day 4	Day 8	Day 12	Day 16	Day 20
M1S1	4.3	12.64	16	15.4	30.2
M2S1	7.77	12.8	14.4	15.9	29.3
M3S1	2.37	12.64	16	21	28.7
M1S2	20.2	10.96	12	28.3	46.6
M2S2	12.5	9.76	10.4	26	43.3
M3S2	12.7	8.24	8	25	51.5
M1S3	12.37	14.16	24	32.2	54
M2S3	12.3	13.04	22.4	43.8	53.7
M3S3	13.2	12.88	20	44	71.7
LSD(0.05)	0.97	1.7	1.7	1.4	1.4
CV(%)	5.2	8.4	6.2	2.9	2.9

Day 8 was the second observation date of tomato after storage in three types of storage. The significance differences among the tomato stored was observed in half and fully ripe tomato stored in zero energy cool chamber and aerobically underground storage respectively (Table 2). In 8th day of storage the highest weight loss (14.16%) was recorded from mature green tomato stored in wooden box storage whereas the least (8.24%) was from fully ripe tomato stored in aerobically underground storage. Hassain et al. [15] reported similar result; maturity had the highest negative effect on weight loss. When the storage period increases, the weight loss of tomato also increased in almost all treatments and harvesting stages of tomato fruit. This result corresponds with that of [16]. There was reduction of weight loss as storage dates increased from 4th to 8th day in aerobically underground storage in three harvesting stages and fully ripe tomato stored in wooden box. This is contrary to findings from physiological loss in weight was progressively increased with an increase in the storage period, irrespective of the storage condition and the treatments This may be due to moisture content increment and removal of the decayed tomato from the storage to prevent cross contamination [17].

In third day of observation there was significant difference among all storage types and harvesting stages of tomato except for three harvesting stages of tomato stored in zero energy cool chambers and both half and fully ripe tomato stored in wooden box (control). This result also matches with the findings of Bhaumik et al. [18]. The highest weight loss (24%) of stored tomato was measured from mature green in wooden box and the lowest value (8%) was from fully ripe tomato stored in aerobically underground storage. This finding coincides with the results of Bui and Hoang [19]. At the end of storage period the highest weight loss (71.7%) was recorded from fully ripe tomato stored in wooden box and the lowest (28.7%) was from zero energy cool chambers respectively. This result is in line with findings from Gharezi et al. [20] who observed in general, that the physiological loss in weight of tomato was lower under cold storage compared to ambient storage.

Decay and shelf life of tomato

Percentage decay: In 4th day of storage Significant ($p \leq 0.05$) difference was observed for the decay of tomato in all treatments except for mature green and half ripen tomato stored in zero energy cool chamber and half ripen and full ripen in zero energy cool chamber and full ripen tomato stored in all storages (Table 3). The highest values (4%) for decay was recorded from half ripen tomato stored in wooden box while mature green in the same storage was the least (1.3%). When storage period increased from 4th to 8th day there was no significant difference attained at($p \leq 0.05$) in intra storage in all three storage conditions except for mature green stored in wooden box storage. Decay was increased from 4th day to 8th day in all treatments and harvesting stages due to tomato moisture loss. This result is in harmony with findings from Naik et al. [21] spoilage/decay of tomato fruits was increased in all the treatments over storage period. In 12th day of storage period there was significant difference among mature green tomato stored in aerobically underground storage followed by half ripen and full ripen. Wooden box storage has also significant difference in three harvesting stages and zero energy cool chambers was non-significant for decay in three harvesting stages and types of storage. This finding confirms with similar result from Diaz-perez et al.[22].

Table 3: Percentage decay and shelf life of tomato in different types of storage and harvesting stage.

Treatments combination	Decay %					Shelf life(days)
	Day 4	Day 8	Day 12	Day 16	Day 20	
M1S1	2.12	4.5	12.6	50.7	60	21
M2S1	1.38	4.5	12.9	51.2	60.8	19
M3S1	1.59	6.9	12.6	50.4	63.9	17
M1S2	3.3	12.3	10.97	45.6	76	15.3
M2S2	1.36	12.6	9.8	47	73.7	14
M3S2	1.47	14.7	8.4	51	69.3	11.3
M1S3	1.3	12.3	14.2	56.3	86.7	7.3
M2S3	4.02	22.4	13	51.9	87.1	6
M3S3	1.54	23.6	12.9	48.9	88.9	4.3
LSD(0.05)	0.43	6.4	1	6.6	19.8	1.74
CV(%)	11.7	29	5	7.7	15.6	7.94

In 16th day of storage, there was significant difference in mature green tomato stored in wooden box. The highest decay percentage (56.3) was recorded from wooden box with mature green tomato and the lowest decay percentage was recorded from tomato harvested at half ripening stage stored in aerobically underground storage. As storage day increased from 12th to 16 day, the decay of tomato also increased. Moneruzzaman et al. reported that as storage day of the tomato fruit increased the decaying also increased. In 20th day of storage, percentage decay showed significance difference in zero energy cool chamber and wooden box storage in three harvesting stages but there was no significance difference in intra storages of all three harvesting stages and types of storage. The highest decay value (88.9%) was from the storage of tomato in wooden box and the lowest (60%) was from mature green tomato stored in zero energy cool chamber storage. similar result from Zakari et al. also confirms this finding. Starting from 4th day to 20th day decay percentage of tomato increased as the storage day increased. This finding is similar with results from Naik et al.

Shelf life of tomato

The major quality parameter of tomato is the shelf life it stays in three types of storages without changing its physical color to have acceptance at consumer and market level without deterioration. The significant ($p \leq 0.05$) difference was observed in harvesting stages and types of storage of tomato except for mature green and half ripen in aerobically underground storage and half ripen and full ripen in wooden box storage. The longest (21st) day in shelf life was recorded from zero energy cool chamber storage and tomato harvested at mature green stage. This finding is in conformation with the report from Moneruzzaman et al. (2009) mature green fruits have shown maximum shelf life (13 days), followed by half ripen (12 days) and full ripen (10.33 days) In contrary to this, the shortest (4th) day in shelf life was observed from tomato harvested at fully ripen stage and stored in common wooden box storage. This finding is in harmony with the report from Kumar et al. (2018), it was observed that the shelf life of tomatoes could be increased for 18- 21 days when it is kept inside the cool chamber as compared to ordinary room condition Results of this study indicated that as the storage period in the day increased, tomato started to loss moisture which enhances its loss in weight and decay. Storing tomato in zero energy cool chamber in three harvesting stage reduced the decay and deterioration. This finding is in accordance with the work done by Moneruzzaman et al. who reported that storage of tomato at low temperature and high relative humidity decrease the early deterioration percentage. Bachmann and Earles [23] also reported that, when fruit storage at extremely low temperature preserves quality better at increased storage period. The similar report from Isaac et al. (2016) indicated that tomatoes handlers in tropical countries can store tomatoes for short to intermediate time by using evaporative cooling. Moreover, Getinet et al. [24] also mentioned that evaporative cooler chamber that improved shelf life of tomatoes (Table 4).

Table 4: Mean percentage weight loss of tomato with different storage types and harvesting stages.

Treatments combination	Firmness(N)			Total soluble solids(obrix)		
	Day 1	Day 4	Day 8	Day 1	Day 4	Day 8
M1S1	6.2	3.5	2.78	3.06	4.7	3.82
M2S1	5.27	3.18	2.3	3.48	3.7	4.03
M3S1	2.48	2.5	2.13	3.93	4.32	4.48
M1S2	6.14	4.02	2.35	3.23	4.25	4.58
M2S2	5.17	3.02	2.28	3.40	3.68	4.83
M3S2	2.7	2.47	1.79	3.90	4.85	5.2
M1S3	6.22	2.5	2.4	2.94	4.13	3.77
M2S3	5.23	2.13	1.9	3.40	3.66	3.65
M3S3	2.5	2.03	1.93	3.99	4.2	4.14
LSD(0.05)	0.2	0.17	0.13	0.19	0.33	0.2
CV(%)	2.56	3.6	3.46	3.2	4.6	2.7

Fruit firmness

Significant ($p \leq 0.05$) difference for firmness of stored tomato was attained in 1st day from all three intra harvesting stages and types of storage (Table 3). Non significance difference was observed between mature green and half ripen tomato stored in three storage conditions. In the beginning day of storage, the highest (6.22N) firmness was recorded from mature green tomato stored in wooden box storage and the lowest (2.48N) record was from zero energy cool chamber storage with fully ripen tomato. Esa et al. (2015) reported similar results for tomatoes stored in zero energy cool chamber attained the least (3.585N) record after 10 day of storage when compared to other storage methods. Rab et al. [25] also reported that the mean fruit firmness was the highest (7.90 kg/cm^2) at breaker/mature green stage, which declined 6.95 and 6.3 kg/cm^2 in fruit harvested at yellow stage and pink mature stages.

When the storage period extends to 4^{th} day, there was significance different among the treatments and tomato harvesting stages at ($p \leq 0.05$) in mature green in all three storages and half ripen stored in zero energy cool chamber and wooden box followed by half ripen in aerobically underground storage and wooden box. The recording of firmness in 4^{th} day has the highest value (4.02obrix) from mature green in aerobically underground storage and fully ripe tomato stored in wooden box was the least (2.03obrix). in each types of storage and harvesting stages, as the storage period increased from 1st day to 4^{th} day and from 4^{th} day to 8th day the firmness value was decreased accordingly. Lana et al. (2005) also reported that the firmness of tomatoes decreased during storage. This probably, because stored tomato loss high amount of moisture to environment in ambient temperature with increased respiration and transpiration and cell wall break down which is in agreement with reports from Pinheiro et al. and Paul et al.[26,27] pointed out that the change in fruit firmness can occur due to the loss of moisture through transpiration phenomenon. Mohammed et al. and Wakabayashi [28,29] also reported that moisture loss also induces wilting, shrinkage, and loss of firmness since maturation to red ripe stage involve cell wall breakdown. Among all the treatments, zero energy cool chambers have acceptable range of firmness which is common quality parameters at market and consumer level to choice the tomato. Zakari et al. [30] also reported that tomatoes stored in the evaporative cooler still retained its firmness but those stored in the ambient have started losing their firmness after the third day and after the sixth day most of the tomatoes have started rotting. Babotola et al. [31] also indicated similar report that firmness decreased with time of storage except under deep freezer condition.

Total Soluble Solids (TSS)

Significant ($p \leq 0.05$) difference was attained for total soluble solids(TSS) in starting day in all harvesting stages and types of storage of tomato except for mature green and half ripen tomato stored in aerobically underground storage. Hamid et al. (2011) pointed out that with respect to TSS; the most significant changes were observed in cold storage, which increased significantly from 5.07 to 5.47. The TSS value was highest (3.99) in fully ripe tomato stored in wooden box and the lowest (3.06) record was from mature green tomato stored in zero energy cool chambers. As the day of storage increased from 1st to 4^{th} day, the value of TSS was also increased in all harvesting stages and types of storage. This result is in harmony with the findings from Eskin who indicated that starch is accumulated in green tomatoes that start to fall with the onset of ripening this decrease is accompanied by rising soluble solids.

In 4^{th} day of storage, significant difference for total soluble solids was existed in all three harvesting stages (mature green, half ripen and full ripen) and types of storages(zero energy cool chamber, aerobically underground and wooden box) except for mature green in zero energy cool chamber and fully ripen in aerobically underground storage followed by both half and full ripen in zero energy cool chamber and all three harvesting stages in aerobically underground and wooden box storage respectively. The value for TSS was highest (4.85obrix) in fully ripe tomato stored aerobically underground storage and the lowest (3.66) value was recorded from common wooden box storage in fourth day of observation. The value for total soluble solids (TSS) of tomato increased across all treatments and harvesting stages from the first day of observation to fourth day. This result correspond the finding of Karki and Abrar et al. [32,33]the total soluble solids generally increased with advancement in maturity and during storage.

The third observation (8th) day of tomato for combined effect of harvesting stages and types of storages on total soluble solids was showed in Table 5. The significant (p≤0.05) difference was observed in each intra storages with all harvesting stages except mature green and half ripen tomato stored in wooden box storage. The result for TSS was highest in fully ripen tomato stored in aerobically underground storage (5.2 obrix) and the lowest record was from half ripen tomato in wooden box storage (3.65 obrix) in 8th observation day. In all harvesting stage and storage condition as storage period increased the TSS value also increased. This was due to the degradation of the starch in tomato as its ripening stage changes from mature green to half ripen and full ripen in color. Crouch [34] also indicated that the increase in TSS could be attributed to the breakdown of starch into sugars or the hydrolysis of cell wall polysaccharides.

Vitamin C content of tomato

Vitamin C content of tomato attained significant difference at (p<0.05) for three intra storage types and harvesting stages except for half ripen and full ripen tomato stored in wooden box and aerobically underground storage (Table 4). The highest amount of vitamin C content(18.6mg/100g) was recorded from fully ripe tomato stored in zero energy cool chamber while the lowest result was recorded from mature green tomato stored in wooden box(17.13mg/100ml) at first day of observation. This result agrees with reports from Toor and Savage (2006) who indicated that ascorbic acid ranged between 14.6 and 21.7 mg/100 g for fresh ripe tomato fruit.

The first day record of vitamin C was control which has simply harvested at fresh and in each harvesting stage(mature green, half ripen and full ripen) and just evaluated without storing which agrees with similar result from Tigist et al. indicated that the range of ascorbic acid content at harvest was 9.29– 15.08 mg/ 100 g

Vitamin C content in 4th day of storage attained significant difference at (p ≤ 0.05) in almost all types of storage and harvesting stages except mature green stored in zero energy cool chamber and full ripen tomato stored in aerobically underground storage and half ripen tomato stored in zero energy cool chamber. In fourth day of storage the highest(18.51mg/100g) vitamin C content was recorded from zero energy cool chamber storage with full ripen tomato while the smallest(16.03mg/100g) record was from wooden box storage with full ripen tomato. When compared to vitamin C content at fresh harvest in first day of observation to fourth day of storage, the amount of vitamin C content has decreased in small amount except for mature and half ripen tomato stored in zero energy cool chamber and aerobically underground storage with mature green tomato. Dalal et al. [35] also reported an increase in ascorbic acid content with ripening with either a continuing rise or a slight fall during the final stages of ripening.

In the final day of observation for vitamin C content, there was significant difference (p<0.05) existed in almost all combinations of harvesting stages and storage conditions in exception to mature green and half ripen, half ripen and full ripen stored in zero energy cool chamber, wooden box for the former again and aerobically underground storages. The result showed the maximum(18.67mg/100g) value for vitamin C content on fourth day of storage was from fully ripe tomato in the zero energy cool chamber while the minimum(15.53mg/100g) value was recorded from half ripen tomato stored in wooden box storage. This coincides with similar findings from Rab et al. who indicated that mean ascorbic acid was the lowest (5.07 mg/100 g) in fruits harvested at breaker stage as compared to Pink and yellow stages 6.35 and 8.06 mg/100 g, respectively. Vitamin C content was increased from first day of storage to eighth day at mature green and half ripen tomato in zero energy cool chamber storage while full ripen tomato in the same storage was decreased from first day of observation to the fourth day. Brecht et al. [36] indicated increased vitamin C content with ripeness of tomato fruit. in the rest of combination of harvesting stage and types of storage , the amount of vitamin C content was decreased from first day to the last day of observation slightly. This result is in accordance with the report from María et al. [37] who indicated that during the storage it was observed a significantly increase (p < 0.05) of the vitamin C in tomatoes stored at 7 and 37°C, while in tomatoes stored at 22°C the vitamin C decreased significantly (p<0.05) at day 5 of storage

Vitamin C content was ranged from 15.53-18.67mg/100g from tomatoes harvested at mature green to full ripen and stored in three types of storage. In this study as the harvesting stage progressed from mature green to full ripen and stored in zero energy cool chamber, the amount of vitamin C was increased generally. This finding was in agreement with report from Tigist et al. who described that there was a general trend of increase in Ascorbic Acid content, followed by a fall during the full ripening stage.

Harvesting stage of tomato plays important role in its vitamin C content as it increased from (16-18mg/g).this range is also similar with report from Sánchez-Moreno et al.[38] indicated that, the ascorbic acid content of ripe tomato ranges from 15 mg to 23 mg/100 g fruit. As tomato harvesting stage step up from one stage to another (mature green- half ripen- fully ripen), vitamin C content was also increased until its senescence period. This result is in accordance with similar findings of Erip-Roberts et al. [39] who observed an increase in ascorbic acid content in fruit is thought to be an indication that the fruit is still in the ripening stage, while a decrease indicates a senescent fruit.

Moisture content of tomato

Moisture content of tomato fruit is important component of their quality parameters which prevents premature shriveling and enhance ripening until the senescence stage. In this study significance difference at (p ≤ 0.05) was attained for moisture content in first day of observation was in most of harvesting stages and types of storages except for mature in both zero energy cool chamber and aerobically underground storage followed by half and full ripen in all three storages. The maximum (86.83%) recorded value of moisture content and the minimum (83.52%) was from full and half ripen tomato stored in zero energy cool chamber respectively on first day of observation.

When storage period extended from first day to fourth day the moisture content was decreased across all types of storage and harvesting stages except tomato stored in zero energy cool chamber with three harvesting stages. Bargel and Neinhuis informed that the resistance of the fruit to moisture loss decreases as it advances in maturity to the pink and red stages. There was significant difference (p<0.05) in all harvesting stages and storage types except tomato stored in wooden box with three harvesting stages. The highest mean value for moisture content(91.9%) was observed from fully ripe tomato stored in aerobically underground storage while the lowest record(82.07%) was from wooden box storage with half ripen harvesting stage. The result showed that zero energy cool chamber storage was the best for tomato in three harvesting stages to retain its weight and reduce post-harvest weight loss and decay. Ratnesh. et al. [40,41] indicated that evaporative cooler reduces the storage temperature and also increases the relative humidity within the optimum level of the storage thereby helps in keeping them fresh. Znidaricic and Pozrl, [42,43] also pointed out that post-harvest changes in vegetables is usually due to loss of water through transpiration and evaporation from the fruit surface.

The last observation day for moisture content in combination of harvesting stage and types of storage was also indicated in Table 5. Tomato harvested at mature green and full ripen stored in wooden box and mature green in aerobically underground storage followed by half ripen and full ripen stored in zero energy cool chamber are statistically similar. In third day of observation the maximum value for moisture content was recorded from full ripen tomato stored in aerobically underground storage (91.4%). In other hand, the minimum (84.74%) record was obtained from tomato harvested at half ripen stage and stored in wooden box [44-46]. Moisture content of tomato increased as the storage period increased from first day of observation to the expiration date of storage, especially in zero energy cool chambers at three harvesting stages. This is in conformation with the findings of work done on effect of storage period on some nutritional properties of orange and tomato in which the moisture content of tomato increased from 74.77% to 95.34% after 14th day of storage [47].

Table 5: Effect of harvesting stage and types of storage on vitamin C and moisture content of tomato.

Treatments combination	Vitamin C(mg/100 g)			Moisture content(g/100 g)		
	Day 1	Day 4	Day 8	Day 1	Day 4	Day 8
M1S1	17.33	18.04	18.33	84.30	85.83	86.30
M2S1	18.06	18.2	18.35	83.52	86.20	87.09
M3S1	18.6	18.51	18.67	86.83	86.75	87.18
M1S2	17.24	17.62	16.81	84.45	90.71	87.50
M2S2	18.11	17.95	17.51	83.53	90.07	89.02
M3S2	18.43	2.47	1.79	3.90	4.85	5.2
M1S3	17.13	16.77	15.57	84.44	82.16	85.30
M2S3	17.99	17.02	15.53	83.54	82.07	84.74
M3S3	18.32	16.03	16.90	86.76	82.17	85.54
LSD(0.05)	0.36	0.14	0.26	0.3	0.22	0.53
CV(%)	1.18	0.47	0.89	0.2	0.15	0.35

CONCLUSION

As the result of this study indicated that storing tomato in locally eco-friendly low cost storages such as zero energy cool chambers improved the shelf life and other quality parameters of tomato fruit. When the storage period increased weight loss, decay, moisture content, and total soluble solids were generally increased irrespective of storage conditions, while fruit firmness was decreased as tomato gets soft due to moisture loss and vitamin C contents was decreased in other storages except in zero energy cool chamber. From this research finding we conclude that simple and economical storage for tomato that maintain the fruit quality and extended longest shelf life was zero energy cool chambers which could be applicable for farmers and small scale producers.

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DECLARATION OF COMPETING INTEREST

We declare that there is no competing of interest of others on this research work that would bias the collection, analysis, reporting or publishing of this paper.

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