Effect of Storage Conditions and Packing Materials on Shelf life of Tomato

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Abstract
Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated and extensively consumed horticultural crops and ranks second in production after potato (*Solanum tuberosum*) worldwide. It is one of the very perishable fruit and it changes continuously after harvesting. There are many postharvest technologies that extend the marketable life of fruits and vegetables. The research was conducted with the overall objective to evaluate the effect of storage condition and packing materials on shelf life and quality of tomato. Three types of packing material were taken i.e. modified-atmosphere packaging (MAP), high density polyethylene (HDPE) and low density polyethylene (LDPE) brought to Post harvest laboratory of JUCAVM. Two types of storage refrigerator and ambient were used. The highest weight loss was recorded for tomato stored in ambient atmosphere without packaging (control) (11.68%) while the least loss was recorded in refrigerator in packaging HDPE (1.67%) after 24 days. The amount of organic acid usually decreases during maturity, because it is substrate of respiration. Significant difference in firmness values was observed for stored tomato fruit due to effect storage condition. Even though decrease in firmness was observed in storage days the trend was not linear over storage days. In general, decreasing the storage temperature (refrigerator) slows the metabolic activity of the stored product including firmness.
Keywords: high density polyethylene, low density polyethylene, modified atmosphere packaging and packing material

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated and extensively consumed horticultural crops globally (Chapagain and Wiesman, 2004; Grandillo *et al*., 1999) and ranks second in production after potato (*Solanum tuberosum*) worldwide ((Mohan *et al*., 2016). In terms of per capita consumption, tomato is the leading processed vegetable (Ullah, 2009). Average yearly consumption is around 17 kg per capita but in Italy and Greece it exceeds 55–60 kg (Brandt *et al*., 2006). The world's total tomato production is 113.3 million tons; China is the largest producer followed by the USA, Turkey, Italy, Egypt and India (Alam and Goyal, 2007). Tomatoes are used either as fresh fruits or in the form of various processed products such as paste, whole peeled tomatoes, diced products, and various forms of juices and soups (Grandillo *et al*., 1999). Tomato contains essential as well as beneficial components like carbohydrates, fiber, minerals, protein, fat, glycoalkaloids, phytosterols etc. (Davies *et al*., 1981). Several essential vitamins like vitamin A, vitamin C, vitamin E, folic acid and several water-soluble vitamins are also present in tomato (Beecher, 1998). According to Brandt *et al*. (2006) in many recent studies, it has been reported that the consumption of tomatoes and tomato-based foods reduces the risk of atherosclerosis, carcinogenesis and cardiovascular disease and pays a great part in the prevention of many types of cancer.

The post harvest (post production) and marketing system is a chain of interconnected activities from the time of harvest to the delivery of the food to the consumer, often referred to as "farm to fork" (Zorya *et al*., 2011). Post-harvest losses refer to the measurable quantitative and qualitative food loss in the postharvest system (Aramyan and van Gogh, 2014; FAO, 2013). Losses in fresh horticultural produce are directly related to quality degradation. Quality loss is the result of improper handling and transportation in marketable of produce (Kumar *et al*., 2015). Postharvest losses which average between 24 and 40% in developing countries, and between 2 and 20% in developed countries are a major source of waste. High levels of waste result in higher prices for fresh produce, and the farmer increasingly facing poverty (Rosa, 2006). Thus, the reduction of post-harvest losses of perishables is of major importance when striving for improved food security in developing countries (Kader, 2005).

Tomato is one of the very perishable fruit and it changes continuously after harvesting. Depending on the humidity and temperature it ripens very soon, ultimately resulted in poor quality as the fruit become soft and unacceptable (Ullah, 2009). Hence, it must be harvested at the right time because overripe tomato is more susceptible to physical injury than ripe and pink ones (Ullah, 2009). After harvest, ripening continues and tomatoes can became overripe very rapidly. This can result in loss of quality and restricted shelf life (Geeson *et al*., 1985).

Storage under low temperature has been considered the most efficient method to maintain quality of most fruits and vegetables due to its effects on reducing respiration rate, transpiration, ethylene production, ripening, senescence and rot development (Hardenburg *et al*., 1986). Extending the shelf life of tomatoes is very important for domestic and export marketing. Generally shelf life of tomatoes is extended by refrigerated storage (Risse *et al*., 1985). De Castro *et al*. (2005) also reported that tomato can be stored at ambient temperature for a period of time (days).

Tomato fruit kept within sealed packages resulted in an atmosphere with high CO_2 and low O_2 content. These conditions retained flesh firmness, low acidity and soluble solids concentration and delayed fruit lycopene (Saeed *et al*., 2010). Among the various techniques developed to extend fruit postharvest life, the use of plastic film is growing in importance because it is convenient in the many different conditions throughout the chain of handling from producer to consumer. Sealed citrus fruit kept at 20°C lost less weight and was firmer than non-sealed fruit at optimal (lower) temperatures (Ben-Yehoshua *et al*., 1983). Rosa (2006) also stated in their work that LDPE film is generally used for the packaging of fresh fruits and vegetables, owing to its high permeability and softness when compared to HDPE film. Polyethylene can be easily sealed, has good O_2 and CO_2 permeabilities, low temperature durability, and good tear resistance and is of a good appearance.

Premature harvesting, poor storage facilities, lack of infrastructure, lack of processing facilities, and inadequate market facilities cause high food losses in developing countries along the entire Food Supply Chain (FSC) (Aulakh *et al*., 2013). So far, information about effect of storage condition and packaging material on shelf life of tomato fruit is limited in our country case. Therefore, taking this fact into consideration the research was conducted with the overall objective to evaluate the effect of storage condition and packing materials on shelf life and quality of tomato.

MATERIALS AND METHODS

Description of the Study Area

The research was conducted in Postharvest Physiology and Quality Analysis Laboratory of Jimma University College of Agricultural Veterinary Medicine (JUCAVM) in Southwest Ethiopia. JUCAVM is geographically located at 346km southwest of Addis Ababa, **lies at an elevation of** 1710 **meters above sea level and** 7^0, 33' N latitude **and** 36^0, 57' E **longitude. The mean annual rainfall of the area ranges from 1200 to 2000** mm. Within a year, the maximum temperature ranges from 25^0C to 30^0C from January to April while the minimum ranges from 7^0C to 12^0C, from October to December (BPEDORS, 2000).

Experimental Materials

Matured light red/pink colored local tomato fruits were bought from Jimma town local market. The tomato fruits had medium size and it tried to have similar size and color to control biasness during sampling. The tomato fruits were free from defects such as sun scorch and pest or disease damage. Initially, tomatoes were cleaned, washed, dried before preparing each sample/plot. Then tomatoes were divided into 24 samples. Three types of packing material were taken i.e. MAP, HDPE and LDPE used. Two types of storage refrigerator and ambient were used.

Treatments and Experimental Design

Eight treatments (two different storage conditions, i.e. refrigerator and ambient condition each combine with three packaging materials (MAP, HDPE and LDPE), and for comparison without packaging (control) were used for the experiment. The experiment was laid out in a 2 x 4 factorial arrangement in Completely Randomized Design with three replications and a total of 24 experimental units.

Procedure

The grouped tomato fruits were placed into MAP, HDPE and LDPE and fitted. Each experimental unit had 500gm weight of tomato fruit. The packed and control samples were put into refrigerator and in ambient on open table in laboratory. The weight loss data was taken consecutively with 3 days interval starting from the day the sample was purchased to it deteriorates. TSS, TA and firmness were measured accordingly. Randomly single tomato fruit from each plot was taken and firmness was recorded using Texture analyzers (TA-XT plus) instrument. The randomly selected tomato fruit that used for measuring firmness was used for recording TSS as TA. Tomato juice was prepared by chopping the fruit to obtain at least 20ml of clear juice following the methods: cut tomato fruit into a blender, homogenize, centrifuge slurry, and pour off clear liquid for analysis.

$$\text{Weight loss} = \frac{(W_I - W_F)}{W_I} \times 100$$

Where, W_I= Initial weight, W_F= final weight

Total soluble solid (TSS in °Brix) of the tomato juice was measured using hand refractometer. From the prepared tomato juice single drop was added on the adjusted refractometer and record was taken. Titratable acidity (TA) was measured following the method developed. As a color changing indicator, three drops of Phenolphthalein was added into 5 ml of tomato juice solution and steered slowly until the color changed to pink. NaOH solution was added from the burette in controlled manner until a pink color was observed and the amount of NaOH used to change color was recorded from the graduated burette. The acid content of the tomato fruit sample was calculated based on the volume of 0.1 N NaOH used for neutralizing the acid content in the sample and multiplying by a correction factor of 0.0064 to estimate titratable acidity as percentage of citric acid. The titratable acidity was calculated using the following equation:

$$\%TA = \frac{[\text{mls NaOH used}] \times [0.1\ N\ NaOH] \times [\text{milliequivalent factor}] \times [100]}{\text{ml of sample}}$$

Data Collected

To determine the effect of packaging material and storage condition on the quality characteristics of tomato fruit physical parameters and chemical compositions were recorded. Physical parameters such as weight loss and firmness, whereas, chemical compositions such as Total Soluble Solids (TSS) (°Brix) and Titratable Acidity (TA) were determined. The data were recorded in three day interval. Data was recorded up to 21 days starting from the first day of storage. Then after the final day recodes the result was used for statistical analysis.

Statistical Analysis

Analysis of variance was computed for each parameter in order to identify the variability among the packaging materials and storage condition based on the procedures described by Analysis of Variance (ANOVA) and computed using SAS version 9.2. (SAS, 2008). For significant parameters, multiple comparisons of means were conducted to separate the means of significant effects including control by using LSD (Least Significance Difference) test at P < 5 % probability levels.

RESULTS AND DISCUSSION

The total storage life of tomato both storage conditions were determined for 24 days. The interaction effect of storage condition and packaging material for weight loss of tomato was highly significant (P< 0.0008). The highest weight loss was recorded for tomato stored in ambient atmosphere without packaging (control) (11.68%) while the least loss was recorded in refrigerator in packaging HDPE (1.67%) after 24 days (Table 1). This evidence shows that lower temperature can also prevent weight loss. Weight loss was depending on the storage condition and packaging materials. Both factors storage condition and packaging material for weight loss of tomato was highly significant (P<0.0001). As a result an average of 7.06 % weight loss was recorded at ambient storage. Regarding to packaging material the minimum loss (2.70%) was recorded when tomato fruit packed using HDPE (Table 2).

The trend of weight loss of tomato was not linear at both the storage condition and packaging materials. As expected, tomato fruits stored at ambient weight loss were faster than those stored in refrigerator. The weight loss during the first observation days had not difference between the different storage conditions and packaging materials. In cases ambient storage condition the weight loss increased more rapidly whereas the tomato fruit stored in refrigerator weight loss was gradual (Fig 1). The appearance (color) the tomato fruit stored at ambient storage condition changed faster than the refrigerator storage. The tomato fruit was turning to brown from light red/pink colored.

Table 1: interaction effect of storage condition and packaging materials tomato weight loss

Storage condition	Type of packaging material	Percentage of weight loss
Ambient	Control	11.63[a]
	MAP	7.70[b]
	LDPE	5.17[c]
	HDPE	3.73[d]
Refrigerator	Control	5.73[c]
	MAP	4.07[d]
	LDPE	2.47[e]
	HDPE	1.67[e]
LSD 5%		1.16
CV (%)		12.66

Table 2: Effect of storage condition and packaging materials tomato weight loss

Storage condition	**Weight loss Percentage**
Ambient	7.06[a]
Refrigerator	3.48[b]
LSD 5%	0.58
Type of packaging material	
Control	8.68[a]
MAP	5.88[b]
LDPE	3.82[c]
HDPE	2.79[d]
LSD 5%	0.82
CV(%)	12.66

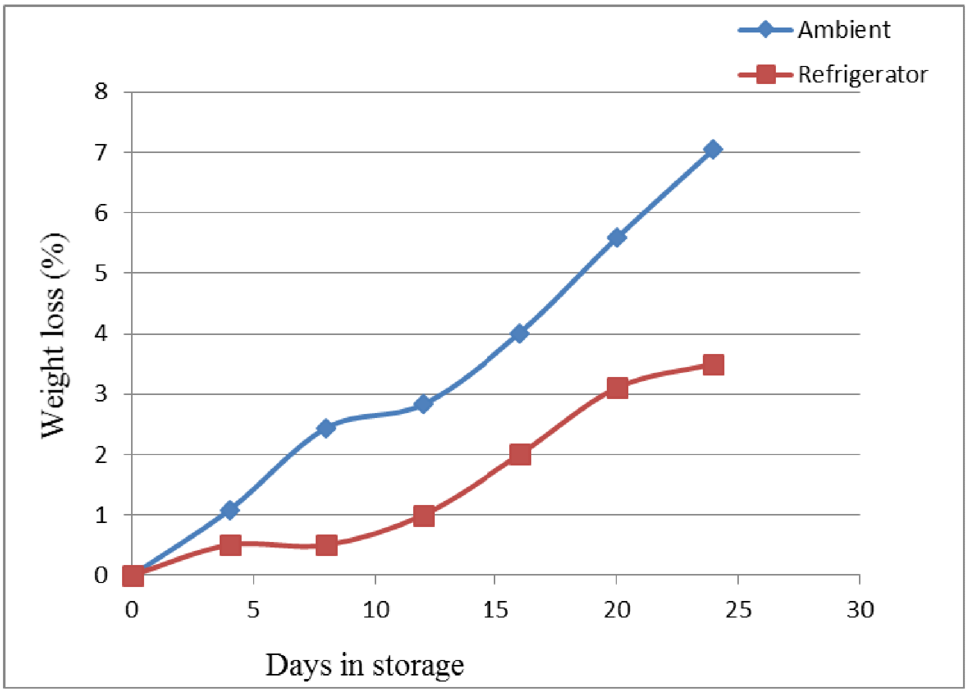

Fig 1: Changes in weight loss (%) of tomato stored in different storage conditions

The total soluble solid content of tomato fruit's was highly and significantly (0.0047) affected by the interaction effect of storage condition and packaging materials. The higher value was achieved when tomato fruit stored in ambient without packaging material (6%) at the end of 24 storage days. Lower value recorded was 4.33 for tomato fruit stored in refrigerator storage condition packed modified plastic bag. During the starting day of storage the TSS was 4% the increment of TSS was 4.00 to 6.00 recorded (Table 3). The increment of soluble solids is caused by the biosynthesis processes or degradation of polysaccharides during maturity (Salunkhe *et al.*, 1974). In addition the single factor storage condition and packaging materials was highly significant. Hence TSS exempted out of the packaging material the control (without packaging was) showed high value (5.33) whereas the other three packaging were not significantly differ. An average of 5.17 % and 4.67% TSS were recorded at ambient and refrigerator storage respectively (Table 4).

Table 3: Interaction effect of storage condition and packaging materials total soluble solids

Storage condition	Type of packaging material	TSS
Ambient	Control	6.00[a]
	MAP	4.83[bc]
	LDPE	4.83[bc]
	HDPE	5.00[b]
Refrigerator	Control	4.67[bc]
	MAP	4.50[c]
	LDPE	4.83[bc]
	HDPE	4.67[bc]
LSD 5%	0.49	
CV (%)	5.87	

Table 4: Effect of storage condition and packaging materials tomato total soluble solids

Storage condition	**TSS**
Ambient	5.17[a]
Refrigerator	4.67[b]
LSD 5%	0.25
Type of packaging material	
Control	5.33[a]
MAP	4.67[b]
LDPE	4.83[b]
HDPE	4.83[b]
LSD 5%	0.35
CV(%)	5.87

The interaction of storage condition and packaging material was highly significant (P<0.0001) for titratable acidity during storage. There was also highly significant individual effect of storage condition and packaging material on titratable acidity content of tomato fruits. The lower (0.68%) titratable acidity achieved when tomato fruit stored in ambient storage condition without packaging material at the end storage day (Table 5). Whereas the higher value (1.58) of titratable acidity was for tomato fruit stored in refrigerator storage condition packed using HDPE. In case of packaging material the lower (1.07) % titratable acidity was recorded tomato fruit stored without any packaging materials (Table 6). Starting from the first day of storage to the end storage day there was no linear trend of titratable acidity.

The average value titratable acidity in refrigerator storage condition was increased to 1.50 % whereas the ambient storage condition decreased to 1.02% from the starting titratable acidity value (1.20%) fig 2. The decrease of titratable acidity was not linear in all cases storage even if significant deference was recorded. In general the titratable acidity was decreased due to storage time. Wills *et al.* (1981) showed that amount of organic acid usually decrease during maturity, because they are substrate of respiration. De Castro *et al*. (2005) reporting that acidity decrease with maturity evolution.

Table 5: Interaction effect of storage condition and packaging materials TA of tomato

Storage condition	Type of packaging material	TA
Ambient	Control	0.68^{g}
	MAP	0.98^{f}
	LDPE	1.12^{e}
	HDPE	1.28^{d}
Refrigerator	Control	1.45^{bc}
	MAP	1.53^{ab}
	LDPE	1.43^{c}
	HDPE	1.58^{a}
LSD 5%	0.09	
CV (%)	4.07	

Table 6: Effect of storage condition and packaging materials tomato titratable acidity

Storage condition	TA
Ambient	1.02^{a}
Refrigerator	1.50^{b}
LSD 5%	0.04
Type of packaging material	
Control	1.07^{d}
MAP	1.26^{c}
LDPE	1.28^{b}
HDPE	1.43^{a}
LSD 5%	0.06
CV (%)	4.07

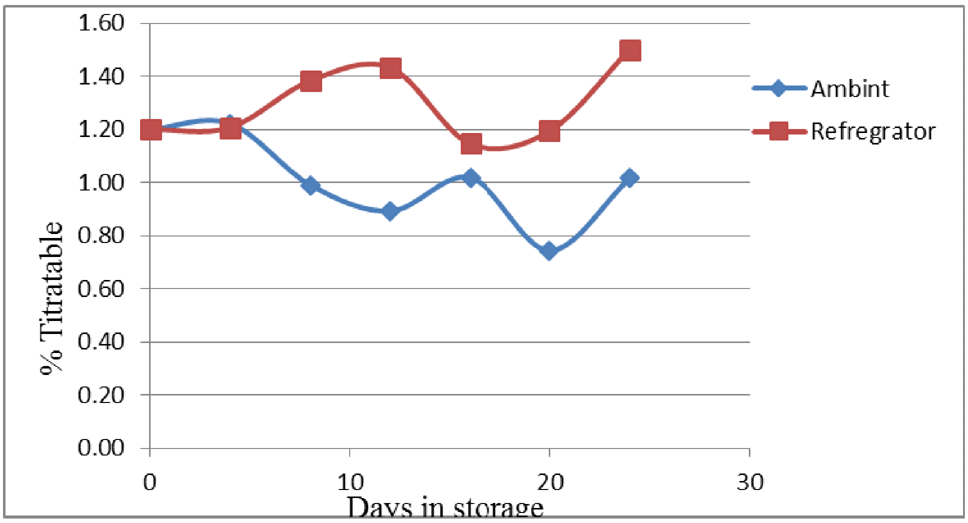

Fig 2: Trend of titratable acidity (%) of tomato stored in different storage conditions

The interaction of storage condition and packaging material was not significant for tomato fruit at the end of storage days on the firmness. The single factor packaging material was also not significant for stored tomato fruits firmness. Significant difference in firmness values was observed for stored tomato fruit due to effect storage condition. As a result higher (13.33) value of firmness was achieved when tomato fruit stored in refrigerator storage condition (Table 8). Even though decrease in firmness was observed in storage days the trend was not linear over storage days (fig 3). In general, decreasing the storage temperature slows the metabolic activity of the stored product down including firmness. It was concluded that softening of tomato tissue during storage is mainly caused by the enzymatic breakdown of pectin (Van Dijk *et al*., 2006). Tomato stored under ambient storage condition may be come mature than under refrigerator the reason for decrease of firmness. Maturation caused a slight softening in tomato when compared with less mature tomato fruits (Ali, 2004).

Table 7: Interaction effect of storage condition and packaging materials firmness of tomato

Storage condition	Type of packaging material	FN
Ambient	Control	10.41
	MAP	11.27
	LDPE	13.15
	HDPE	12.11
Refrigerator	Control	14.01
	MAP	13.67
	LDPE	12.38
	HDPE	13.25
LSD 5%	NS	
CV (%)	11.32	

Table 8: Effect of storage condition and packaging materials firmness of tomato

Storage condition	FN
Ambient	11.74[b]
Refrigerator	13.33[a]
LSD 5%	1.23
Type of packaging material	
Control	12.21
MAP	12.47
LDPE	12.77
HDPE	12.68
LSD 5%	NS
CV(%)	11.32

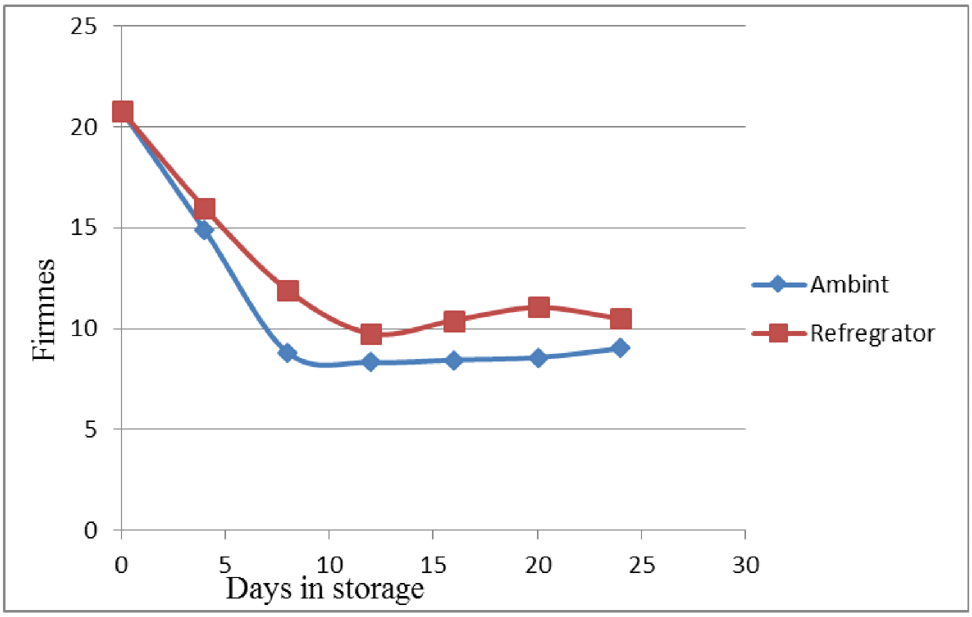

Fig 3: Trend of Firmness of tomato stored in different storage conditions

CONCLUSION

Total storage life of tomato storage conditions was determined for 24 days. Storage condition and packaging material were for weight loss, titratable acidities, total soluble solids and also firmness of tomato. The tomato fruits stored under ambient and refrigerator with different packaging materials were evaluated for their quality. The final results generally coincided with our expected results. Based on the research result the following conclusions were drawn. Weight loss of tomato fruit is closely related with storage condition and packaging materials. Except tomato fruit stored at ambient atmospheric condition without packaging material (control) have an acceptable weight loss. Tomato fruit stored at lower temperature had more stability and greater storage life than fruit stored at ambient atmosphere. The content of soluble solids progressively increased with storage time increased and the titratable acidities decreased at storage time increased. The increment of soluble solids is caused by the biosynthesis processes or degradation of polysaccharides during maturity. The amount of organic acid usually decreases during maturity, because it is substrate of respiration. Significant difference in firmness values was observed for stored tomato fruit due to effect storage condition. Even though decrease in firmness was observed in storage days the trend was not linear over storage days. In general, decreasing the storage temperature (refrigerator) slows the metabolic activity of the stored product including firmness.

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