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Evaluation of Tomato (*Lycopersicon esculentum* Mill.) Genotypes for Fruit Quality and Shelf Life

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ABSTRACT

Soft fruit such as tomato has a very short post harvest shelf life. Accordingly, information and knowledge gaps on post-harvest handling, fruit quality and storability of tomato (*Lycopersicon esculentum* Mill.) aggravate the situation. Therefore, an experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine to evaluate the fruit quality and shelf life of nine tomato varieties. Major fruit physicochemical properties, including fruit weight, volume, juice, weight loss, total soluble solids content (TSS), acidity (TTA and pH), TSS/TTA ratio and sensory attributes, which were assessed at 7-day intervals during a 28-day storage period, were collected. There was an increasing trend in physiological weight loss observed during the study period, during which physiological weight loss was highest in 'Eshet', 'Marglobe' and 'Jimma local'. Changes in TTA during storage were relatively small. The TTA content showed a decreasing pattern throughout the storage period. A general decreasing trend in fruits firmness and an increase in fruit color were observed among the varieties as the storage period progressed. Considering fruit quality and shelf life, variety 'H-1350' was better than all other varieties while 'Eshet', 'Marglobe' and 'Jimma local' were the poorest performers in almost all parameters.

Keywords: physicochemical characters, sensory evaluation
Abbreviations: TSS, total soluble solid; **TTA**, titrable acidity

INTRODUCTION

Tomato belongs to the family *Solanaceae*, which (*Lycopersicum esculentum* Mill.) is native to the Andes region of South America. The crop was introduced to Europe in the 1500s, although until the 1700s they were believed to be poisonous if eaten, because the foliage and some other green tissues of tomato plants contain tomatine, a toxic chemical. Tomatine is also present in unripe tomato fruit, but the levels are low enough to be non-toxic (Moraru *et al.* 2004). Tomato fruits respire after harvesting and alive so that their quality and appearance change during post-harvest handling (Chapagain and Wiesman 2004). Tomato fruit quality can be affected by many factors including genetic, pre and post-harvest factors. Accordingly, Stevens *et al.* (1977) reported that tomato fruit quality is largely a function of the cultivar's genetic background where other authors (Hobson *et al.* 1983; Ahumada and Cantwell 1996; Garcia and Barrett 2006) also indicated the presence of big variations in ripening physiology among different tomato varieties. This also indicates the possibility of produce quality maintenance rather than improvement which is only possible through usage of an appropriate variety and associated postharvest technology (Baldwin *et al.* 2000).

The highly perishable nature of tomato fruit requires careful attention during harvest and post-harvest operation in order to reduce losses. However, very little emphasis has been given to post harvest handling of perishable produce and an associated shelf life in Ethiopia (Lemma 2001). The strategies for improving this could be the use of genotypes that have longer post-harvest life beside good agricultural practice (Keidar and Geisenberg 1989).

In Ethiopia, several tomato varieties have been released nationality and recommended by Melkasa Agriculture Research Center (MARC) for commercial production. In contrary, Tomato production has been restricted to certain regions of the country because of appropriate varieties and lack of recommended production system package and post-harvest handling technologies that deserve attention.

Though many new tomato varieties are being developed in order to improve yield, most of them are not yet assessed for their post-harvest quality and storability. The information on tomatoes grown in Ethiopia was limited to studies targeting mostly yielding potential and disease aspects and to a very small extent in fruit quality. Therefore, this study has been initiated partly to fill the information gap through evaluating nine tomato varieties for fruit yield and physicochemical characteristics. The objectives of the study are: 1) To compare tomato varieties cultivated under Jimma condition for their fruit physicochemical characters and sensory qualities. 2) To assess the shelf life and changes in fruit quality of tomato varieties during storage under ambient condition.

MATERIALS AND METHODS

The study site, Jimma University College of Agriculture and Veterinary Medicine (JUCAVM), is located in Oromia Regional State in mid-altitude sub humid Zone in the Southwestern part of Ethiopia, 346 km Southwest of Addis Ababa at 7° 42′ N latitude and 36° 50′ E longitude with an altitude of 1710 m above sea level. Besides, the area receives an average annual rainfall of 1530 mm. The area has average maximum and minimum temperatures of 26.2°C and 11.3°C, respectively and average maximum and minimum relative humidity of 91.40 and 37.92%, respectively (BPEDORS 2000).

Nine tomato varieties four determinate and four indeterminate types ('Bishola', 'Fetan', 'H-1350', and 'Miya' are the determinate types whereas 'Metadel', 'Marglobe', 'Eshet' and 'Moneymaker' are the indeterminate types) including one 'Jimma local' were used for the experiment. The study was conducted in 2010. Tomato varieties in this study were evaluated for shelf life at the post-

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harvest laboratory of Jimma University College of Agriculture and Veterinary Medicine (JUCAVM). Uniform fruits of the different tomato varieties having similar size and colour were obtained. A factorial combination of nine tomato varieties and five storage periods with three replications arranged in Complete Randomized Design (CRD). For each variety per replication a sample size of three kilogram fruits and half kg on each storage period was randomly taken for quality analysis. Both physicochemical and sensory quality analyses were conducted at 7 days interval during 28 days of storage period (Žnidarcic and Pozrl 2006).

Laboratory data were collected in this experiment the data included tomato fruit physicochemical and sensory quality parameters, as described next.

Fruit weight (g): A sample of five fruits of each variety per replicate was randomly taken and the average fruit weight (g) was recorded.

Fruit volume (ml): A sample of five fruits of each variety per replicate were randomly taken and placed in water filled in a jar and the amount of displaced water was measured using a graduated cylinder and the values were recorded. Average fruit volume was taken by subtracting the initial water level in the jar from the final and by the number of fruit immersed and expressed in milliliter (ml).

Fruit juice content (ml/kg): The juice content of randomly taken sample fruits from each replication was extracted using a juice extractor (Slemens-Electrogerate GmbH, E-nr.mk 51000/01). The extracted juice was measured using a graduated glass cylinder. The intact tomato fruit weight was recorded prior to juice extraction. The juice content was expressed in milliliter of juice per kilogram of fruit weight (ml/kg).

Physiological weight loss (PWL) (%): The physiological weight loss during the storage of fruits was calculated for each sampling interval using the formula given below as per (Saeed 2006) and the cumulative weight loss was expressed as the percentage for the respective treatments:

$$WL(\%) = \frac{WI - WF}{WI} * 100$$

where; WL = weight loss, WI = initial weight, and WF = final weight

Total soluble solids (TSS) (°Brix): The TSS of the sample fruits was determined following the procedures described by (Acedo and Thanh 2006). Aliquot of juice was extracted using a juice extractor and the extracted juices were filtered using cheesecloth. The TSS was determined by refractrometer (Bellingham + Stanley 45-02 BS eclipse) with a range of 0 to 32 °Brix and a resolution of 0.2 °Brix by placing 1 to 2 drops of clean juice on the prism. Between samples the prism of the refractrometer was washed with distilled water and dried before use. The refactrometer was standardized against distilled water (0% TSS).

pH values: An extract of aliquot of juice was prepared according to (Acedo and Thanh 2006). Aliquot of juice is first filtered with cheesecloth and the pH value of the juice was measured with a pH meter (CRISON pH meter 507).

TSS to acid ratio: The TSS to acid ratio was calculated by dividing total soluble solid to titratable acidity of the given sample as outlined by (Acedo and Thanh 2006).

Titratable acidity (TTA) (%): The TTA of the sample tomato fruits was measured by the methods described by (Acedo and Thanh 2006). Aliquot of tomato juice was extracted with a juice extractor (Slemens-Electrogerate GmbH, E-nr.mk 51000/01) and the extracted juice was filtered through cheesecloth. The descanted clear juice was used for the analysis. TTA expressed as percentage of citric acid, was obtained by titrating 10ml of tomato juice with 0.1N NaOH. The titratable acidity expressed as percent of citric acid was obtained from the following formula:

$$TTA(\%) = \frac{TITRE * 0.1NaOH * 0.64}{1000} * 100$$

Sensory evaluation tests were performed using a 12 group member panelists including female and men workers at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM). The overall quality was calculated as a means of score as describe by (Acedo and Thanh 2006). The panelists were asked to evaluate the color and firmness of the fruit at 7 days interval during the storage period of 28 days.

Fruit colour: Fruit colour was determined with the aid of colour charts for matching and describing colour of tomato. A rating scale with 1 = green mature, 2 = breaker, 3 = turning, 4 = pink, 5 = light red, and 6 = red (Acedo and Thanh 2006).

Fruit firmness: The degree of softness was measured subjectively with the help of finger pressure to measure change in firmness during the storage period. A rating scale with 5 = very firm, 4 = firm, 3 = moderately firm, 2 = soft and 1 = very soft (Acedo and Thanh 2006) was used to assess firmness.

The data were analyzed as per Montgomery (2005) using the SAS statistical software package and the mean values were compared using the procedure of Ryan-Einot-Gabriel-Welsch Multiple Range Test (REGWQ) (SAS 2003) at 5% level of significance. Pearson's correlation within physicochemical and sensory parameters was also evaluated.

RESULTS AND DISCUSSION

Physicochemical characters of fruits

1. Average fruit weight

Tomato varieties in this study significantly ($P \leq 0.001$) differed in terms of the average fruit weight during the storage period (**Table 1**). At zero day of storage period, the minimum weights were obtained in 'Eshet', 'Marglobe' and 'Jimma local' in contrary to other varieties (**Table 3**).

During 28 days of storage period, a trend of decline in average fruit weights were observed in all tomato varieties tested. Such reduction in fruit weight as the storage period advances could be associated with the difference in the pericarp thickness among the varieties, as thickness decreased resulted in increased loss of moisture and also a contribution may comes from the rate of respiration. This result agrees with the finding of (Žnidarcic and Pozrl 2006) that indicated post-harvest weight change in vegetables is usually due to loss of water through transpiration and evaporation from the fruit surface. This loss of water can lead to wilting and shriveling, which was aggravated by varieties having narrow pericarp thickness.

2. Average fruit volume

Average fruit volume of tomato varieties stored under ambient condition was found to be significantly ($P \leq 0.001$) different throughout the storage period (**Table 1**). At zero day of storage period, variety 'Marglobe' had the lowest in fruit volume where as 'Moneymaker' had the highest value in fruit volume. Average fruit volume of all varieties decreases progressively during ripening of tomatoes from mature green to red ripe stages as the storage period progressed (**Table 4**). This indicates that during ripening of fruits there is a loss of moisture resulting in shriveling of fruits so that fruits displace less water and hence they have less volume. It can be easily observed from the study that fruit volume and fruit weight had a positive correlation ($r = 0.66$) since lower average fruit weight showed lower average fruit volume (**Table 13**). This could be due to increased rate of respiration and activities of cell wall degrading enzymes as ripeness advanced that resulted in loss of moisture and weight as well as shrinkage of the fruits. This finding agrees with that of (Young *et al.* 1993) who reported a decrease in the percent dry matter of tomato genotypes throughout maturation of the fruits.

3. Physiological weight loss

A significantly ($P \leq 0.001$) different variations were observed in the physiological weight loss of tomato varieties during 28 days of storage at ambient condition (**Table 1**). Weight loss ranged from 3.010 to 18.94% during storage indicated in **Table 5** that 'Eshet', 'Marglobe' and 'Jimma local' exhibited the highest percent weight loss while 'Moneymaker' had the lowest records at 28 days of storage

Table 1 ANOVA summary for physicochemical parameters of tomato varieties stored for 28 days at ambient condition.

Source of variations	Df	Mean squares				
		Fruit volume	Fruit colour	Fruit firmness	Fruit weight	Weight loss
Variety	8	8167.7066***	45.9219***	29.7817***	712.3536***	491.9329***
Storage period	4	235.8167	1.143	0.7248	12.6816	12.5232
Variety * Storage period	32	872.8224***	0.3858***	0.2173***	301.4815***	9.8311***
Error	90	319.2018	0.0114	0.0062	97.5486	2.067
CV (%)		20.86	2.70	2.71	15.37	18.67

Df = degree of freedom, CV = coefficient of variation *, **, ***, are significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively and ns = not significant at $P > 0.05$

Table 2 ANOVA summary for physicochemical parameters of tomato varieties stored for 28 days at ambient condition.

Source of variations	Df	Mean squares				
		TSS	TTA	TSS/TTA	p^H	Fruit juice
Variety	8	1.6898***	0.166***	0.01***	0.7258***	64893.3532***
Storage period	4	0.216	0.0009	0.01	0.0228	3309.709
Variety * Storage period	32	0.178	0.059***	30.12***	0.0228**	1822.285
Error	90	0.117	0.009	8.27	0.0107	3049.546
CV (%)		9.19	15.02	25.83	2.36	6.32

Df = degree of freedom, CV = coefficient of variation *, **, ***, are significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively and ns = not significant at $P > 0.05$

Table 3 Changes in fruits weight of tomato varieties stored for 28 days under ambient condition at Jimma.

Varieties	Storage periods (days)				
	0	7	14	21	28
Fetan	84.14 ab	79.13 ab	74.93 ab	70.72 ab	66.51 bc
Bishola	84.67 a	79.06 ab	74.83 ab	70.59 ab	66.36 bc
Eshet	59.09 bc	54.03 ab	51.08 c	48.12 c	45.16 c
H-1350	75.57 ab	71.06 ab	67.28 b	63.51 bc	59.73 bc
Metadel	77.43 ab	72.29 ab	68.42 b	64.55 bc	60.68 bc
Marglobe	59.15 bc	54.09 bc	51.14 c	48.18 c	45.22 c
Moneymaker	78.46 ab	73.76 ab	69.83 ab	65.91 bc	61.99 bc
Miya	74.20 ab	69.27 ab	65.56 bc	61.85 bc	58.14 bc
Jimma Local	60.99 bc	55.79 bc	52.73 bc	49.69 c	46.64 c
SE(±)	5.70	5.70	5.70	5.70	5.70
CV (%)	15.37	15.37	15.37	15.37	15.37

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$ (REGWQ)

Table 4 Changes in fruit volume of tomato varieties stored for 28 days under ambient condition at Jimma.

Varieties	Storage periods (days)				
	0	7	14	21	28
Fetan	125.67 ab	113.89 bc	86.67 cd	70.00 cd	59.33 d
Bishola	125.67 ab	116.67 bc	88.89 c	70.33 cd	64.33 cd
Eshet	94.67 bc	83.00 cd	70.56 cd	61.67 cd	54.33 d
H-1350	142.33 ab	114.33 bc	94.33 bc	80.00 cd	72.33 cd
Metadel	121.00 ab	107.67 bc	74.44 cd	56.67 d	49.00 d
Marglobe	88.00 cd	68.33 cd	59.44 d	53.67 d	46.33 d
Moneymaker	148.33 a	115.67 bc	89.00 c	76.00 cd	71.11 cd
Miya	118.33 b	105.11 bc	100.00 bc	87.00 cd	77.67 cd
Jimma Local	111.67 bc	79.33 cd	66.67 cd	52.00d	41.67 d
SE(±)	10.32	10.32	10.32	10.32	10.32
CV (%)	20.86	20.86	20.86	20.86	20.86

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$ (REGWQ)

period. This difference in the physiological weight loss could be due to variation in the pericarp thickness, thin pericarps aggravating weight loss and rate of respiration among the varieties, as higher rate of respiration is related to higher loss of stored food and dry matter of the fruits. On the other hand, thick pericarps reduce weight loss thought reducing the degree of moisture loss and shriveling. **Table 13** indicates that a negative correlation exists between the physiological weight loss and fruit firmness (r = -0.96), fruit juice content (r = -0.71), fruit volume (r = -0.73) and fruit weight (r = -0.47). That means, as the physiological weight loss increases the firmness, juice content, volume and weight of fruits decreased.

This finding corresponds with those of (Ali and Thompson 1998) who reported that weight loss was increased throughout the storage period and it could be due to senescence or more desiccation and a contribution may have come from the respiration rate of the fruit. The authors indicated weight losses difference among tomato varieties is also due to difference in genetic makeup and loss of water through transpiration. This finding is also in harmony with that of (Shehla and Tariq 2007) who illustrated that weight loss increased as ripening proceeded due to the uncontrolled ripening, as tomatoes are climacteric fruit which showed a sudden increase in ethylene production and respiration rate.

4. Average fruit juice content

Tomato varieties were significantly ($P \leq 0.001$) different in their fruit juice content (**Table 2**). Tomato varieties ‘Fetan’, ‘Bishola’ and ‘Eshet’ had the highest juice content while ‘Miya’ and ‘Jimma local’ were recorded the lowest juice content (**Table 7**). The present study indicated that storage periods have no effect on the juice content of all of the tomato varieties (**Table 6**).

During the study period, differences were observed in juice content in all tomato varieties tested. This difference could be due to genotypic variation that had great contribution for the variability in fruit juice content which is in agreement with the findings of (Adedeji *et al.* 2006) who suggested that juice content is specific to the variety or the genotype. Young *et al* (1993) also reported that differences

Table 5 Changes in fruit physiological weight loss (%) of tomato varieties stored for 28 days under ambient condition at Jimma.

Varieties	Storage periods (days)			
	7	14	21	28
Fetan	3.14 f	6.61 ef	9.75 de	12.89 bc
Bishola	3.32 f	7.20 e	10.52 cd	13.84 bc
Eshet	4.22 f	10.01 d	14.23 bc	18.45 a
H-1350	3.38 f	7.11 e	10.49 cd	13.87 bc
Metadel	3.52 f	7.66 e	11.18 cd	14.71 b
Marglobe	4.34 f	10.27 cd	14.61 bc	18.95 a
Moneymaker	3.01 f	6.32 ef	9.33 de	12.34 c
Miya	3.54 f	7.66 e	11.20 cd	14.75 b
Jimma Local	3.98 f	9.42 de	13.40 bc	17.38 a
SE (±)	0.83	0.83	0.83	0.83
CV (%)	18.67	18.67	18.67	18.67

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$ (REGWQ).

Table 6 Changes in fruit total soluble solid (Brix) and Juice contents of tomato varieties stored for 28 days under ambient condition at Jimma.

Storage periods	Physicochemical parameters of tomato varieties	
	Means square	
	Juice content	TSS
0	878.15 a[a]	3.83 a
7	889.04 a[a]	3.61 a
14	877.41 a	3.62 a
21	863.56 a	3.75 a
28	862.76 a	3.76 a

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$ (REGWQ).

Table 7 Changes in fruit TSS and Juice contents of tomato varieties stored for 28 days under ambient condition at Jimma.

Variety	Physicochemical parameters of tomato varieties	
	Means square	
	Juice content	TSS
Fetan	962.64 a	3.21 e
Bishola	946.05 a	3.43 de
Eshet	941.71 a	3.69 bcd
H-1350	885.56 b	3.92 abc
Metadel	873.50 b	4.25 a
Marglobe	838.19 bc	4.05 ab
Moneymaker	833.80 bc	3.88 bc
Miya	813.82 cd	3.56 cde
Jimma Local	772.39 d	3.45 de
S.E (±)	31.88	0.20
CV (%)	6.32	9.19

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$ (REGWQ).

in the percent dry matter of tomato genotypes throughout the maturation of the fruits.

5. Total soluble solids

A significantly ($P \leq 0.001$) different variations were observed in TSS content of the tomato varieties (**Table 2**). The TSS content of the tomato varieties were in between 3.213 to 4.253. During the study period, the highest TSS contents were recorded in 'Marglobe', 'Metadel' and 'H-1350' whereas 'Fetan' was the lowest in the group (**Table 7**). This finding was in agreement with others (Garcia and Barrett 2005; Turhan and Seniz 2009; Eshteshabul *et al.* 2010; Fabiano *et al.* 2010; Turhan *et al.* 2011; Falak *et al.* 2011) who attained tomato plant a TSS with a range of 3.40-6.02. The present study reveled that the storage periods have no effect on the TSS of the tomato varieties (**Table 6**). The result presented in (**Table 7**), showed varietal differences in TSS of the fruits of tomato varieties. The present finding is in agreement with others' findings (Leonardi *et al.* 2000; Shehla and Tariq 2007).

According to (Žnidarcic and Pozrl 2006) the differences in the soluble solids are caused by the biosynthesis processes or degradation of polysaccharides. Eskin (2000) reported that starch is accumulated in green tomatoes that start to fall with the onset of ripening which is accompanied by rising soluble solids. Salunkhe *et al.* (1974) reported that TSS differs with color and maturity. Difference in TSS of tomato fruits could be due to excessive moisture loss which increases concentration as well as the hydrolysis of carbohydrates to soluble sugars (Wasker *et al.* 1999).

6. Titratable acidity

A significant ($P \leq 0.001$) variations were observed in the TTA of tomato varieties during the storage period (**Table 2**). The TTA varied from 0.981 at harvest to as low as 0.309 at the end of the storage (**Table 8**). In general, the acidity of the fruits decreased throughout the storage periods.

During the storage period, a decline in TTA of all tomato varieties were observed in the study (**Table 8**). The loss of TTA during storage time could be related to higher respiration rate as ripening advances where organic acids are used as substrate in respiration process (Lurie and Klein 1990). The present study agreed with (Žnidarcic and Pozrl 2006) they showed that amount of organic acid usually decreases during maturity, because they are substrate of respiration. The present finding is also in conformity with that of (Lambeth *et al.* 1966; George *et al.* 2004). This finding was in agreement with others (Garcia and Barrett 2005; Turhan and Seniz 2009; Eshteshabul *et al.* 2010; Fabiano *et al.* 2010; Turhan *et al.* 2011; Falak *et al.* 2011) who attained tomato plant a TTA with a range of 0.22-0.501. According to Shehla and Tariq (2007), acidity is often used as an indication of maturity, an acid decreases on ripening of fruit, which is in agreement with the present finding. It has also been reported that during the ripening of tomatoes, malic acid disappears first followed by citric acid, which result in reduction of amount of TTA.

7. TSS to acid ratio

Total soluble solid to acid ratio were significantly ($P \leq 0.001$) different among the varieties during the storage period (**Table 2**). A trend of increase in total soluble solid to acid ratios were observed in each variety throughout the storage periods.

Total soluble solid to acid ratio values were varied from 3.20 at harvest to as high as 11.48 at the end of the storage (**Table 9**). Varieties 'Marglobe', 'Moneymaker' and 'Jimma local' had the highest value while the lowest sugar to acid ratios were recorded in 'Metadel' and 'Bishola' at the end of the storage periods. It can easily be accessed from the table that TSS to acid ratio increased with ripening. At the last stage of ripening fruits showed the highest TSS to acid ratio. This is most likely due to the highest TSS and low acid contents of the fruits, which might be due to the low accumulation of acids in the fruit tissues. The present investigation is in agreement with (Matthews and Phillips 1980; Shehla and Tariq 2007). Moreover, Stevens *et al.* (1977) reported that total soluble solid to acid ratio content is in large part a function of the cultivar's genetic background.

8. pH value

The pH values of tomato fruits were significantly ($P \leq 0.001$) different among tomato varieties during the storage period (**Table 2**). The result showed that the minimum and maximum pH value of the varieties were between 3.777 and 4.69 throughout the storage periods (**Table 10**). The minimum pH value was recorded (3.777) in 'Bishola' others attained the maximum values at zero days of storage period (**Table 10**). This finding was in agreement with others (Garcia and Barrett 2005; Kacjanmarsic *et al.* 2005; Turhan and Seniz 2009; Eshteshabul *et al.* 2010; Fabiano *et al.* 2010; Turhan *et al.* 2011) who attained tomato plant a pH with a range of 3.67-5.25.

A trend of increase in the pH values of tomato varieties

Table 8 Changes in fruit titratable acidity (% citric acid) of tomato varieties stored for 28 days under ambient condition at Jimma.

Varieties	Storage periods (days)				
	0	7	14	21	28
Fetan	0.70 bc	0.63 c	0.61 cd	0.57 cd	0.47 d
Bishola	0.90 ab	0.84 ab	0.80 b	0.77 bc	0.70 bc
Eshet	0.67 bc	0.60 cd	0.55 cd	0.51 cd	0.47 d
H-1350	0.79 bc	0.72 bc	0.66 bc	0.61 cd	0.60 cd
Metadel	0.98 a	0.90 ab	0.83 ab	0.78 bc	0.66 bc
Marglobe	0.68 bc	0.64 c	0.55 cd	0.49 cd	0.34 de
Moneymaker	0.69 bc	0.61 cd	0.53 cd	0.47 d	0.39 de
Miya	0.87 ab	0.81 b	0.75 bc	0.68 bc	0.62 cd
Jimma Local	0.63 c	0.51 cd	0.45 de	0.38 de	0.31 e
SE(±)	0.05	0.05	0.05	0.05	0.05
CV (%)	15.02	15.02	15.02	15.02	15.02

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$ (REGWQ)

Table 9 Changes in fruit TSS to acid ratio of tomato varieties stored for 28 days under ambient condition at Jimma.

Varieties	Storage periods (days)				
	0	7	14	21	28
Fetan	4.56 cd	6.34 bc	7.34 bc	7.42 bc	8.21 bc
Bishola	3.44 cd	4.27 cd	4.76 cd	4.78 cd	4.77 cd
Eshet	5.02 cd	5.82 cd	7.77 bc	7.91 bc	8.15 bc
H-1350	4.27 cd	5.78 cd	7.18 bc	6.95 bc	6.13 bc
Metadel	3.20 d	4.12 cd	4.84 cd	4.90 cd	5.56 cd
Marglobe	5.36 cd	5.94 c	7.49 bc	7.38 bc	9.35 ab
Moneymaker	4.65 cd	7.02 bc	8.67 b	8.90 ab	10.10 ab
Miya	3.62 cd	4.67 cd	6.03 bc	6.07 bc	6.10 bc
Jimma Local	5.22 cd	7.06 bc	9.18 ab	9.85 ab	11.49 a
SE(±)	0.95	0.95	0.95	0.95	0.95
CV (%)	25.83	25.83	25.83	25.83	25.83

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$ (REGWQ).

Table 10 Changes in fruit pH value of tomato varieties stored for 28 days under ambient condition at Jimma.

Varieties	Storage periods(Days)				
	0	7	14	21	28
Fetan	4.07 d	4.17 cd	4.40 bc	4.48 b	4.62 ab
Bishola	3.78 e	4.11 d	4.48 b	4.63 ab	4.69 a
Eshet	4.17 cd	4.30 c	4.46 bc	4.49 b	4.60 ab
H-1350	4.06 d	4.26 cd	4.44 bc	4.52 b	4.61 ab
Metadel	3.99 d	4.21 cd	4.42 bc	4.54 ab	4.68 ab
Marglobe	4.20 cd	4.36 bc	4.47 b	4.51 b	4.64 ab
Moneymaker	4.10 d	4.22 cd	4.46 bc	4.52 b	4.57 ab
Miya	4.01 d	4.21 cd	4.48 b	4.51 b	4.64 ab
Jimma Local	4.10 d	4.12 d	4.47 bc	4.53 ab	4.62 ab
SE(±)	0.06	0.06	0.06	0.06	0.06
CV (%)	2.35	2.35	2.35	2.35	2.35

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$ (REGWQ).

Table 11 Changes in fruit color of tomato varieties stored for 28 days under ambient condition at Jimma.

Varieties	Storage periods(Days)				
	0	7	14	21	28
Fetan	1.15 g	3.15 f	4.10 e	5.04 c	6.00 a
Bishola	1.11 g	3.13 f	4.19 e	5.18 c	6.00 a
Eshet	1.22 g	3.19 f	4.32 de	5.33 bc	6.00 a
H-1350	1.18 g	3.16 f	4.12 e	5.06 c	6.00 a
Metadel	1.13 g	3.12 f	4.21 de	5.20 bc	6.00 a
Marglobe	1.21 g	3.20 f	4.34 de	5.35 b	6.00 a
Moneymaker	1.15 g	3.16 f	4.14 e	5.09 c	6.00 a
Miya	1.14 g	3.14 f	4.23 de	5.22 bc	6.00 a
Jimma Local	1.23 g	3.24 f	4.36 d	5.37 b	6.00 a
S.E (±)	0.06	0.06	0.061	0.06	0.06
CV (%)	2.70	2.70	2.70	2.70	2.70

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$ (REGWQ).

were observed as the storage period advanced to 28 days. (**Table 13**) indicated that a negative correlation exists between pH value and TTA of the fruits (r = -0.54), as the pH increased the TTA decreased. The tendency of increasing in the pH values and reduced acidities were observed as the storage time progressed in line with the report of (Acedo and Thanh 2006) who indicated that TTA and pH have negative relationship and are commonly used acidity indicators of tomatoes. The higher metabolic rate of tomato varieties could be a cause for the faster rate of reduction of TTA and increased pH, differences in pH value are due to genotypic variability. The present finding seemed to confirm the literature information available on the pH values of tomato fruit (Stevens 1972; Matthews and Phillips 1980) that reported that although the pH value of tomatoes may exceed 4.6 and tomato products are generally classified as acids food (pH < 4.60).

Table 12 Changes in fruit firmness of tomato varieties stored for 28 days under ambient condition at Jimma.

Varieties	Storage periods(Days)				
	0	7	14	21	28
Fetan	5.00 a	3.82 bc	2.90 d	1.87 f	1.33 h
Bishola	5.00 a	3.83 b	2.82 d	1.84 f	1.32 h
Eshet	4.90 a	3.70 c	2.59 e	1.64 g	1.10 i
H-1350	5.00 a	3.80 bc	2.87 d	1.84 f	1.30 h
Metadel	5.00 a	3.81 bc	2.79 d	1.82 f	1.30 h
Marglobe	4.91 a	3.67 c	2.57 e	1.62 g	1.08 i
Moneymaker	5.00 a	3.78 bc	2.85 d	1.82 f	1.28 h
Miya	5.00 a	3.79 bc	2.77 d	1.79 f	1.27 h
Jimma Local	4.93 a	3.65 c	2.55 e	1.60 g	1.06 i
S.E (±)	0.04	0.04	0.04	0.04	0.04
CV (%)	2.71	2.71	2.71	2.71	2.71

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$ (REGWQ).

Table 13 Pearson's correlation (r) of physicochemical and sensory quality analysis of tomato varieties.

	TSS	TTA	TSS/ TTA	P^H	FJ	FV	FC	FF	FW	WL
TSS	-									
TTA	-0.17	-								
TSS/TTA	0.41***	-0.90***	-							
P^H	0.27**	-0.54	0.51***	-						
FJ	-0.17*	0.43***	-0.41***	-0.60***	-					
FV	-0.16	0.51	-0.47***	-0.67***	0.65***	-				
FC	0.28**	-0.52***	0.52***	0.87***	-0.75***	-0.74***	-			
FF	-0.24**	0.54	-0.53***	-0.88***	0.75***	0.75***	-0.99***	-		
FW	0.04	0.45***	-0.33***	-0.41***	0.46***	0.66***	-0.44***	0.44***	-	
WL	0.17	-0.55***	0.53***	0.83***	-0.71***	-0.73***	0.93***	-0.96***	-0.47***	-

TSS = total soluble solids, TTA = titratable acidity, FJ = fruit juice content, FV = fruit volume, FC = fruit colour, FF = fruit firmness, FW = fruit weight, WL = weight loss, *, **, ***, correlation is significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively and ns = not significant at $P > 0.05$.

Sensory evaluation of tomato fruits

1. Changes in fruit color

Sensory results on color indicated that the presence of significant ($P \leq 0.001$) variation in fruit color among the varieties during 28 days of storage period (**Table 1**). A comparison of fruit color showed loss of greenness were relatively highest in 'Eshet', 'Marglobe' and 'Jimma local' while loss of greenness were lowest in 'Bishola' and 'Metadel' at zero days of storage. All tomato varieties attained their full red ripe stage at 28 days of storage period (**Table 11**). During the storage period, there was a general change of tomato fruit skin color from mature green to red ripe stage, these increase in color change during storage might be due to the conversion of chlorophyll, the green color of fruits into carotenoids pigments by biochemical reactions. A negative correlation exists between fruit firmness and fruit color of tomato varieties (r = -0.99) (**Table 13**). That is, as the color of fruit increase the firmness of the fruit decrease. Campbell *et al.* (1990) indicated that during normal ripening of tomato fruit, tissue color change from green through orange to red, which coincides with ethylene biosynthesis and a climacteric rise in respiration rate, a similar observation was reported in this study. Davies and Hobson (1971) also reported that color changes were subjected to genetic control in view of the variation in color development across cultivars.

The present finding is in accordance with the findings of (Ali and Thompson 1998) indicated that all tomato fruit color changed progressively during storage, as lycopene constitutes the main red pigments of tomatoes and their concentrations increase steadily through ripening. The same authors also indicated that ethylene is triggering the ripening of tomatoes and it is known closely associated with a sudden change in the physiology of tomato fruits at the onset of ripening.

According to Žnidarcic and Pozrl (2006), color change in fruit corresponds to a fall in chlorophyll and an increase in carotenoids synthesis, reflecting the transformation of chloroplasts to chromoplasts. The color development rate of tomatoes increased with increase in maturity. The authors also point out carotenes and xanthophylls contained in tomato, especially lycopene oxidize during the storage, gradually changed the color of fruits.

2. Change in firmness of fruit

Tomato varieties significantly ($P \leq 0.001$) different in firmness of their fruits during storage period (**Table 1**). As the storage period progress sensory result showed that there was a loss in firmness of fruits from very firm to almost very soft. A comparison in fruit firmness among the varieties indicated that except 'Eshet', 'Marglobe' and 'Jimma local' other attended the maximum in fruit firmness through out the storage period (**Table 12**).

Accordingly, higher percentage of weight loss is an indicator of lower maintenance of firmness as observed in this study. A negative correlation exists between the physiological weight loss and fruit firmness (r = -0.96) as indicated in (**Table 13**). That means, as the physiological weight loss increased firmness of the fruits decreased among the varieties**.** This finding is in harmony with that of (Wu and Abbott 2002) indicated that the firmness of tomatoes decreased during storage, this could be attributed to higher rate of metabolic activities and activity of cell wall degrading enzymes that loosens the fruit skin which result in higher permeability of the cell for higher rate of moisture loss, this moisture loss resulted to wilting, shrinkage and loss of firmness. Ali and Thompson (1998) indicated that all tomato fruit softened progressively during storage. They also point out polygalacturanase (PG) and pectinastarese (PE) are the important enzymes involved in fruit softening by solubilizing the polygalacturonic acid in the pectin fraction of the cell walls during ripening.

CONCLUSIONS

The study indicated that a trend of decrease in average fruit weight and an increase in physiological weight loss was observed as the storage period progressed among the varieties. The TTA was sowing a decreasing value like that of fruit firmness across storage period. The pH was showing an increasing pattern like physiological weight loss and negatively to that of TTA, as pH increased TTA was decreased as the storage period progressed. Sensory evaluation also showed that a trend of decrease in fruit firmness and an increase in colour of the fruit was observed as the storage period progressed among the varieties. Generally the study showed that variety "H-1350" was found to be better than the rest of the varieties in fruit quality and shelf life while 'Eshet', 'Marglobe' and 'Jimma local' are the least.

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