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ORIGINAL ARTICLE

Effects of variety on the quality of tomato stored under ambient conditions

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Abstract Three processing and six fresh market tomato varieties harvested at "mature green" stage were evaluated for changes in quality. The total soluble solid, titratable acidity, sugar-acid ratio, pH, ascorbic acid content, colour and firmness were assessed. The storage room air temperature and relative humidity varied from 15.4°C to 16.2°C and 34.8% to 52.4%, respectively. At harvest, *Marglobe Improved* had better chemical quality characteristics compared with the other five fresh market varieties while towards the end of the storage period, chemical quality characteristics were maintained better in *Fetane*. The highest pH and sugar/acid ratio were obtained in *Metadel* compared with all other varieties throughout the storage period. Among the processing tomato variety, Roma VF had better chemical quality than other two processing varieties. *Melkashola* had the highest total soluble solid content in the group. Although the processing varieties ripened earlier than fresh market ones, they were notably firmer with better quality. The processing types were better in their chemical quality than fresh market genotypes. The fresh table tomato varieties had higher sugar-acid ratio and vitamin C. *Marglobe Improved* and *Metadel* could be selected in favor of higher nutritional quality whereas Fetane could be considered for maintenance of better overall quality characteristics.

Keywords Tomato · Chemical · Variety · Colour · Firmness · Quality

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Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most widely consumed vegetable crops in the world, not only because of its volume, but the main supplier of several phytonutrients and providing an important nutritional value to human diet and its important role in human health (Willcox et al. 2003). Tomatoes rank first in the "relative contribution to human nutrition" when compared to 39 major fruits and vegetables (Bourne 1977). One medium sized tomato provides 40% of the Recommended Daily Allowance (RDA) of vitamin C (ascorbic acid), 20% of the RDA of vitamin A, substantial amounts of potassium, dietary fiber, calcium, and lesser amounts of iron, magnesium, thiamine, riboflavin, and niacin, yet contains only about 35 calories (FAO 1979).

Giovannucci (1999) reviewed a number of epidemiological studies and concluded that the intake of tomato products was associated with a lower risk of a variety of cancers. The main antioxidants in tomatoes are carotenoids, ascorbic acid and phenolic compounds (Giovanelli et al. 1999). The types of antioxidants present in tomato are also used to differentiate tomato cultivars (Langlois et al. 1996). The overall antioxidant activity of tomatoes varies considerably according to the genetic variety, ripening stage and growing conditions (Davies and Hobson 1971 and 1981; Leonardi et al. 2000). There is large variation in Vitamin C levels among tomato cultivars. There appears to be a relationship between high vitamin C levels and relatively poor yield (Taylor 1986).

Soluble sugars and organic acids are the major components of the soluble solids. These components and their interaction are important for tomato quality and for processed concentrate as they affect sweetness, sourness and flavor intensity (Stevens 1972). It has usually been reported that total solids content increased with colour and maturity (Salunkhe et al. 1974; Kundan et al. 2011). Young et al. (1993) found that both total solids and total soluble solid decreased as colour increased in a typical cultivar. Young et al. (1993) reported that the soluble solids content of some tomato lines increased as fruits ripen.

Postharvest product quality develops during growing of the product and that could be maintained, but not improved by postharvest technologies. This could be achieved through selection of genotypes with better keeping quality when harvested at optimum maturity Ramakrishnan et al. 2010; Vijay et al. 2010a, b). Moreover, Tan (2006) indicated that available genetic material allows discrimination of external and internal quality attributes that must satisfy consumer requirements and indulgences. Therefore, this study was initiated to partly fill the information gap through evaluating chemical characteristics and sensory quality characteristics of nationally released six fresh markets (non-processing) and three processing tomato varieties.

Materials and methods

Treatments and experiments design Fruits of the three processing and six fresh market tomato varieties grown at Haramaya university fruit and vegetable research farm were obtained from the central four rows per plot. Sample fruits harvested at mature green stage were analyzed for five chemical and two sensory quality parameters. Uniform unblemished fruits having similar size and colour were taken and hand washed with tap water to remove field heat, soil and to reduce microbial populations on the surface and then stored under ambient conditions using Randomized Complete Block Design with three replications at Haramaya University. Each variety had a sample size of 90 fruits per replication, which were assessed for shelf life over the storage period. On each sampling date, seven fruits per experimental unit were randomly taken from each replication for quality analysis. The samples were taken to the Horticulture Laboratory of the Department of Plant Science at Haramaya University for physicochemical and sensory quality analysis at 4 days interval during 32 days of storage period.

Chemical analysis The total soluble solid (TSS) was determined following the procedures described by Seyoum et al. (2009). An aliquot of juice was extracted using a juice extractor (6001x Model No. 31JE35 6x.00777) and 50 ml of the slurry was filtered using cheesecloth. The TSS was determined by refractrometer (Model Misco®) with a range of 0 to 32 °Brix and a resolution of 0.2 °Brix by placing 1 to 2 drops of clear juice on the prism. Between samples the prism of the refractrometer was washed with distilled water and dried before use. The refractrometer was standardized against distilled water (0 °Brix TSS). The pH value of tomato juice was measured with a pH meter. Sugar-acid ratio was calculated by dividing total soluble solid to titratable acidity of the given sample under analysis as described by Mohammed et al. (1999). The titratable acidity (TTA) of tomato was measured by the methods described by Seyoum et al. (2009). An aliquot of tomato juice was extracted from three tomatoes with a Kenwood juice extractor (6001x model No. 31JE35 6x.00777). The fruit slurry was filtered through cheesecloth and 100 ml was centrifuged for 15 min. The decanted clear juice was used for the analysis. The titratable acidity expressed as percentage citric acid, was obtained by titrating 10 ml of tomato juice to pH 8.2 with .01 N NaOH manually. Ascorbic acid (AA) was determined by the 2, 6-dichlorophenolindophenol method (AOAC 1990). An aliquot of 10 ml tomato juice extract was diluted to 50 ml with 3% met phosphoric acid in a 50 ml volumetric flask. An aliquot was centrifuged at 10000 × g for 15 min and titrated with the standard dye to a pink end-point (persisting for 15 s). The ascorbic acid content (%) was calculated from the titration value, dye factor, dilution and volume of the sample.

Subjective quality analysis Sensory evaluation tests were performed on nine tomato varieties using a 10-member. The panelists were trained 1 h to evaluate the sensory characteristics of tomato samples so that most of them acquire experience on how to execute sensory evaluation tests. A questionnaire examining consumer attitudes was developed. The panelists were asked to evaluate and score separately products using a panel score sheet. The scoring was based on a scale of one to six. The overall quality was calculated as a mean of the scores as described by Moraru et al. (2004). Individual panelists were presented with samples of five to six tomatoes from each cultivar with three replications in random order. Whole tomato fruits and halves were presented and the panelists were asked to evaluate the colour and firmness. Assessments were continued until fruit condition was considered unacceptable in terms of colour, firmness and general appearance in 4 days interval over the storage period of 32 days under ambient conditions. The colour of tomato fruits was determined with the aid of colour charts for matching and describing colour of in tomatoes by the panelists. A rating scale with: 1 “Green mature”, 2 “Breaker”, 3 “Turning”, 4 “Pink”, 5 “Light red”, 6 “Red”, was used to evaluate colour change during storage period. Firmness was measured subjectively with the help of fingers pressure to measures change in firmness during the storage period. In this case, a rating scale with: 1 “very soft”, 2 “soft”, 3 “slightly soft”, 4 “moderately firm”, 5 “firm” and 6 “very firm” was employed to evaluate firmness.

Statistical analysis Significance tests were made by analysis of variance (ANOVA) for RCBD with SAS (SAS Corporation, Cary, NC, USA version 6.12 TS020) software. Comparisons of the treatment means were done using Duncan's Multiple Range Test.

Results and discussion

Temperature and relative humidity The storage room air temperature and relative humidity varied from 15.4°C to 16.2°C and 34.8% to 52.4%, respectively. The temperature of the storage room was in the range that was previously reported by Tefera et al. (2007) for evaporatively cooled chamber under semi-arid conditions that maintained temperature between 14.3°C and 19.2 °C for storage of mango. Hence, the ambient storage conditions did not have extremes of temperature and relative humidity that could affect the stored tomato.

A comparison of the ambient temperature shows that Dire Dawa is about 59% hotter than that of Haramaya (Tefera et al. 2007). This indicates that Haramaya had a temperature range that could be comparable with the evaporative cooler chamber that Improved shelf life of tomatoes (Getinet et al. 2008). Thus, this could have a better implication for knowing the shelf life and quality maintenance of tomatoes stored under cooler areas of the country because most of warm season fruits like tomato are produced in warmer area of the country and sold in cooler areas like Addis Ababa. Moreover, Hardenburg et al. (1986) mentioned that storage under relatively low temperature is the most efficient method to maintain quality of most fruit and vegetables due to its effects on reducing respiration rate, transpiration, ethylene production, ripening, senescence, and rot development. It is generally agreed that mature green tomato can be stored for relatively longer period at a temperature of 10–15°C and 85–95% relative humidity (Castro et al. 2005). In this background, it is interesting to note here that the temperature of the storage room also offered similar conditions except that the relative humidity was low.

Total soluble solids Significant ($P \leq 0.001$) difference was observed in TSS content of the tomato varieties during 32 days storage at ambient conditions (Table 1). At harvest, the TSS content of Marglobe Improved was the highest while that of Melkasalsa was the least. The TSS values the fresh market varieties ranged from 4.23 °Brix in Fetane to 5.22 °Brix in Marglobe Improved. The values are below the TSS content reported by Giordano et al. (1994). Similarly, the processing varieties had TSS values at harvest that was 4.11 °Brix in Melkasalsa to 4.18 °Brix in Melkashola. Rodriguez et al. (1994) observed TSS contents for processing tomatoes between 4.08 °Brix and 8.68 °Brix. Emery and Munger (1970) reported the range of 4.43–5.67 °Brix for three varieties of tomato that had determinate and indeterminate growth habit, which is in agreement with the present finding.

In general, the values commonly obtained for soluble solids of different varieties of tomato fruit range from 4 to 6 ºBrix (Cramer et al. 2001). Fresh market tomato varieties attained their peak TSS contents earlier on day 16 while processing tomato varieties acquired on day 20 of the storage period. Afterwards, diminishing pattern in TSS content was observed in all the varieties. This could be due to slower rate of hydrolysis of carbohydrates in the later group, which has implication for better quality maintenance of processing tomatoes over the fresh market tomatoes. The general trend observed during storage was an initial increase in total soluble solids followed by a decrease. Eskin (2000) reported that starch is accumulated in green tomatoes that start to fall with the onset of ripening this decrease is accompanied by rising soluble solids. It has been also reported that total soluble solids increase with colour and maturity (Salunkhe et al. 1974) which is in agreement with the present result. Increase 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 (Waskar et al. 1999; Nath et al. 2011). Hence, it indicates the durability and longer shelf life of processing tomatoes over the non-processing tomatoes.

The result presented in Table 1, shows varietals differences in the TSS of the fruits which agrees with the finding of Moraru et al. (2004). Moraru et al. (2004) indicated that TSS content are variety dependent and frequently correlates with greater tomato yield, but in general varieties with high °Brix values tend to be agronomically less productive. It agrees with the present study that determinate tomato varieties produced a better yield but lower in their TSS content as compared to the indeterminate types like Marglobe Improved, which were less productive and have higher TSS. A similar study by Mohammed et al. (1999) also reported that non-processing cultivars had higher TSS content than processing cultivars.

Titratable acidity Table 2 shows significance variations in the titratable acidity (TA) of processing and fresh market tomato varieties during 32 days of storage period. The TTA was significantly ($P \leq 0.001$) different among the tomato varieties tested and varied from 0.891% at harvest to as low as 0.25% at the end of the storage which agrees with previous values reported by Davies and Hobson (1981) and Salunkhe et al. (1991).

In a study of 250 fresh tomato accessions Lambeth et al. (1966) observed percentage citric acid range from 0.4% to

Table 1 Total soluble solid (°Brix) content of tomato varieties stored under ambient conditions

Tomato varieties	Storage period (days)								
	0	4	8	12	16	20	24	28	32
Processing									
Roma VF	4.2^{h}	4.2^{h}	4.3^{g}	4.8^{h}	5.2^{f}	5.2^{d}	4.6^{h}	4.1^{g}	4.0^{e}
Melkasalsa	4.1^{i}	4.1^{i}	4.2^{h}	4.4^{i}	4.6^{g}	4.9^{e}	4.4^{i}	4.0^{g}	3.8^{f}
Melkashola	4.2^{g}	4.2^{g}	4.4^{f}	5.0^{g}	5.4^{e}	5.4^{cd}	4.7^{g}	4.2^{f}	4.1^{d}
Fresh market									
Metadel	4.8^{c}	5.0^{c}	5.1^{c}	5.5^{c}	5.8^{b}	5.7^{bc}	5.2^{c}	4.7^{c}	4.6^{b}
Eshete	4.3^{e}	4.7^{e}	4.9^{d}	5.3^{e}	5.6^{c}	5.5^{bcd}	5.0^{e}	4.5^{e}	4.2^{d}
Marglobe Improved.	5.2^{a}	5.4^{a}	5.7^{a}	5.8^{a}	6.2^{a}	5.9^{a}	5.5^{a}	5.2^{a}	4.9^{a}
Fetane	4.2^{f}	4.3^{f}	4.7^{e}	5.1^{f}	5.5^{d}	5.4^{cd}	4.8^{f}	4.2^{f}	4.2^{d}
Hienz 1350	4.5^{d}	4.8^{d}	5.0^{cd}	5.4^{d}	5.8^{b}	5.6^{bc}	5.1^{d}	4.6^{d}	4.5^{c}
Bishola	5.0^{b}	5.2^{b}	5.3^{b}	5.7^{b}	5.8^{b}	5.8^{b}	5.3^{b}	4.8^{b}	4.6^{b}
Significance	***	***	***	***	***	***	***	***	***
SE±	0.031	0.012	0.040	0.014	0.011	0.009	0.094	0.014	0.040
CV (%)	0.40	0.44	1.42	0.48	0.33	3.11	0.34	0.43	1.47

(n=3)

Means within the same column followed by a common letter are not significantly different at $P\leq$ 0.05. *** indicate significant difference at $P\leq$0.001.

0.91% which is in agreement with the present study In a comparative study, George et al. (2004) also evaluated titratable acidity in fruit of 12 tomatoes genotypes and reported fruit acidity that varied from 0.256 to 0.704 g 100 g^{-1}. At harvest, the fresh market tomato variety Marglobe Improved had 12% and 19% more TTA when compared with the fresh market tomato variety Fetane and the processing type *Melkasalsa* that had the lowest record in their group, respectively. This variation could be due to variability in fruit weight. Tittonell et al. (2001) showed that large sized tomato fruit had higher acidity, which is in agreement with the findings in the present study.

After 24 days of storage under ambient conditions, the processing tomato varieties maintained better titratable acidity over fresh market tomatoes. This could be due to slower rate of hydrolysis of organic acid in processing tomato varieties when compared with fresh market tomatoes. Getinet et al. (2008) also shown that total sugars (primarily reducing sugars) were positively correlated to pH and titratable acidity. The authors illustrated that positive correlation between sugars and pH and between sugars and titratable acidity means that plants with high sugars have more free organic acids and less hydrogen ion concentration than plants with low sugars. Castro et al. (2005) reported similar relationship in the changes of titratable acidity of tomatoes during ripening and storage where overall acidity slightly increased soon after harvest and then tended to decrease throughout the storage period. The

Table 2 Titratable acidity (% citric acid) of tomato varieties stored under ambient conditions

Tomato varieties	Storage period (days)								
	0	4	8	12	16	20	24	28	32
Processing									
Roma VF	0.753^{h}	0.755^{h}	0.695^{g}	0.579^{h}	0.574^{g}	0.524^{b}	0.455^{d}	0.391^{d}	0.351^{cd}
Melkasalsa	0.748^{i}	0.751^{i}	0.692^{h}	0.545^{i}	0.526^{h}	0.532^{b}	0.462^{c}	0.398^{c}	0.372^{a}
Melkashola	0.756^{g}	0.759^{g}	0.718^{f}	0.616^{g}	0.593^{e}	0.542^{b}	0.467^{b}	0.412^{a}	0.363^{b}
Fresh market									
Metadel	0.845^{c}	0.877^{c}	0.865^{b}	0.692^{c}	0.622^{c}	0.381^{e}	0.340^{h}	0.294^{g}	0.250^{h}
Eshete	0.791^{f}	0.818^{e}	0.757^{d}	0.648^{e}	0.590^{e}	0.482^{c}	0.430^{g}	0.334^{f}	0.289^{g}
Marglobe Improved	0.889^{a}	0.911^{a}	0.891^{a}	0.774^{a}	0.656^{a}	0.570^{a}	0.466^{b}	0.406^{b}	0.344 d
Fetane	0.788^{e}	0.764^{f}	0.738^{e}	0.636^{f}	0.580^{f}	0.541^{a}	0.472^{a}	0.411^{a}	0.346^{cd}
Hienz 1350	0.834^{d}	0.835^{d}	0.815^{c}	0.668^{d}	0.600^{d}	0.517^{b}	0.458^{d}	0.405^{b}	0.324^{e}
Bishola	0.864^{b}	0.890^{a}	0.886^{b}	0.717^{b}	0.634^{b}	0.490^{bc}	0.435^{f}	0.365^{e}	0.308^{f}
Significance	***	***	***	***	***	***	***	***	***
SE±	0.0010	0.0010	0.0037	0.0014	0.0015	0.0096	0.0010	0.0011	0.0034
CV (%)	0.286	0.254	0.834	0.359	0.433	3.417	0.397	0.485	1.768

(n=3)

Means within the same column followed by a common letter are not significantly different at $P\leq$ 0.05. ***indicate significant difference at $P\leq$0.001.

higher loss of titratable acidity during the 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). On day 32 of storage period, Fetane had 38% more titratable acidity when compared with *Metadel* that had the lowest value in the group. Similarly, *Melkasalsa* had 7% more titratable acidity as compared with the lowest record of Roma VF. On the same date comparison of tomato varieties showed that, processing tomatoes had 47% more titratable acidity than the fresh market tomatoes. This explanation has merit since the higher TTA of processing cultivars could explain their lower incidence of fungal infection compared with the non-processing cultivars (Mohammed et al. 1999).

Sugar-acid ratio Sugar-acid ratio of processing and fresh market tomato varieties is presented in Table 3. The ratio significantly ($P \leq 0.001$) varied among the tomato varieties during the 32 days of storage period under ambient conditions. There was a general increase in sugar/acid ratio in each group as storage time advanced which is in agreement with the reports of Mohammed et al. (1999). The report also indicated that the ratio was generally higher for fresh market than processing tomato cultivar, which is in agreement with the present findings.

At harvest, the fresh market tomato variety Marglobe Improved had 9% more sugar/acid ratio than Fetane while at the end of the storage period; *Metadel* had about 53% more sugar/acid ratio than Fetane. Similarly, Roma VF and *Melkashola* had 12% more sugar/acid ratio than *Melkasalsa* at the end of the storage period. At zero date, Marglobe Improved had 7% more sugar/acid ratio when compared with the processing tomato variety *Melkasalsa*. After 32 days of storage period, the fresh market variety *Metadel* had about 81% more sugar/acid ratio when compared with processing tomato varieties. The processing tomato variety *Melkasalsa* had 62% more sugar/acid ratio than Roma VF and *Melkashola*. This could have a better implication that fresh market tomatoes contains better flavor than processing tomato varieties. Garcia and Barrett (2006) reported that flavor characteristics of processed tomato products are influenced by the balance of sugar and acid contents. Thus, it is obvious from the result that the higher sugar/acid ratio of fresh market cultivars compared with processing cultivars was adequate evidence to confirm the superior flavor of fresh market than processing tomatoes. Moreover, Stevens (1972) reported that sugar/acid content is in large part a function of the cultivar genetic background, which may account for difference in metabolic propensity for the accumulation of volatile and nonvolatile flavor compounds. Nonvolatile compounds such as sugar, TTA and soluble solids plays a great in determining flavour of the fruits beside the nonvolatile ones (Pairin and Edgar 2008).

pH values Table 4 displays the pH values of processing and fresh market tomato varieties stored under ambient conditions of Haramaya University for 32 days. The pH values of tomato fruits were significantly ($P \leq 0.001$) different among the varieties both at harvest and during storage period. The result showed pH values ranging from 3.37 in *Melkasalsa* at harvest to 4.92 for *Metadel* after 32 days of storage. This result seemed to confirm the literature information available on the pH values of tomato fruit (Mohammed et al. 1999). Stevens (1972) reported that although the pH of ripe tomatoes may exceed 4.6, tomato products are generally classified as acidic foods (pH<4.6).

Table 3 Sugar-acid ratio of tomato varieties stored under ambient conditions

Tomato varieties	Storage period (days)								
	0	4	8	12	16	20	24	28	32
Processing									
Roma VF	5.5^{d}	5.5^{f}	6.2^{d}	8.3^{a}	9.0^{f}	10.0^{c}	10.1^{f}	10.5^{f}	11.4^{g}
Melkasalsa	5.5^{e}	5.5^{f}	6.1^{f}	8.1^{c}	8.8^{h}	9.2^{d}	9.5^{g}	10.1^{i}	10.2^{h}
Melkashola	5.5^{d}	5.6^{f}	6.2^{e}	8.1^{c}	9.1^{e}	10.0^{c}	10.1^{f}	10.2^{h}	11.4^{g}
Fresh market									
Metadel	5.7^{c}	5.7^{d}	5.9^{g}	8.0^{d}	9.3^{c}	15.0^{a}	15.3^{a}	16.0^{a}	18.5^{a}
Eshete	5.5^{e}	5.8^{c}	6.5^{a}	8.2^{b}	9.5^{b}	11.4^{b}	11.7^{d}	13.5^{b}	14.6^{c}
Marglobe Improved	5.9^{a}	6.0^{a}	6.4^{b}	7.5^{e}	8.9^{g}	10.3^{d}	11.9^{c}	12.9^{d}	14.2^{d}
Fetane	5.4^{f}	5.6^{e}	6.4^{c}	8.1^{c}	9.5^{b}	10.0^{c}	10.2^{f}	10.3^{g}	12.1^{f}
Hienz 1350	5.4^{e}	5.8^{c}	6.2^{e}	8.1^{c}	9.7^{a}	10.9^{c}	11.2^{e}	11.4^{e}	13.7^{e}
Bishola	5.8^{b}	5.9^{b}	6.0^{g}	8.0^{d}	9.2^{d}	11.9^{b}	12.2^{b}	13.2^{c}	15.0^{b}
Significance	***	***	***	***	***	***	***	***	***
SE±	0.01	0.01	0.02	0.02	0.02	0.16	0.03	0.04	0.06
CV (%)	0.43	0.39	0.60	0.40	0.40	2.48	0.47	0.56	0.75

(n=3)

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$. ***indicate significant difference at $P \leq 0.001$.

Table 4 pH Values of tomato varieties during the 32 days of storage under ambient conditions

Tomato varieties	Storage period (days)								
	0	4	8	12	16	20	24	28	32
Processing									
Roma VF	3.96^{g}	4.32^{g}	4.36^{g}	4.46^{g}	4.48^{e}	4.49^{e}	4.51^{f}	4.63^{g}	4.72f
Melkasalsa	3.37^{i}	4.16^{i}	4.21^{i}	4.40^{i}	4.42^{h}	4.43^{f}	4.45^{h}	4.60^{i}	4.65^{h}
Melkashola	3.92^{h}	4.31^{h}	4.34^{h}	4.44^{h}	4.45^{g}	4.47^{e}	4.48^{g}	4.62^{h}	4.70^{g}
Fresh market									
Metadel	4.44^{a}	4.48^{a}	4.49^{a}	4.67^{a}	4.71^{a}	4.79^{a}	4.81^{a}	4.90^{a}	4.92^{a}
Eshete	4.41^{b}	4.46^{b}	4.47^{b}	4.61^{b}	4.64^{b}	4.66^{b}	4.67^{b}	4.73^{b}	4.85^{b}
Marglobe Improved	4.14^{e}	4.40^{e}	4.43^{e}	4.49^{e}	4.55^{e}	4.56^{d}	4.60^{e}	4.67^{e}	4.73^{e}
Fetane	4.08^{f}	4.34^{f}	4.40^{f}	4.44^{f}	4.52^{f}	4.59^{c}	4.62^{d}	4.64^{f}	4.71^{e}
Hienz 1350	4.25^{d}	4.43^{d}	4.45^{d}	4.55^{d}	4.57^{d}	4.60^{c}	4.62^{d}	4.68^{d}	4.80^{d}
Bishola	4.36^{c}	4.42^{c}	4.44^{c}	4.57^{c}	4.59^{c}	4.64^{b}	4.66^{c}	4.69^{c}	4.81^{c}
Significance	***	***	***	***	***	***	***	***	***
SE±	0.0013	0.0014	0.0038	0.0015	0.0016	0.0097	0.0013	0.0013	0.0035
CV (%)	0.054	0.052	0.148	0.059	0.062	0.366	0.048	0.049	0.013

(n=3)

Means within the same column followed by a common letter are not significantly different at $P\leq$ 0.05. ***indicate significant difference at $P\leq$0.001.

pH below 4.5 is a desirable trait, because it halts proliferation of microorganisms.

At harvest, *Metadel* had 9% more pH values than the lowest record by Fetane. Moreover, *Metadel* had the highest pH while Fetane had the lowest pH values through out the storage period among the fresh market tomato varieties. Similarly, Roma VF had 18% more pH than the lowest record of *Melkasalsa*. Comparison of means showed that the fresh market tomatoes had 14% more pH than the processing tomatoes at the time of harvest. The pH values of *Melkasalsa* were found to be the lowest compared to the pH values of all other tomato varieties during the storage time. This could be due to genotypic variability. Similar results were reported by Mohammed et al. (1999).

There was a general trend of increase in pH values of tomato varieties tested as the storage period advanced which is in agreement with the findings of Mohammed et al. (1999) that both processing and non-processing tomato cultivars follow similar trend. The tendency of increasing pH value and reduced acidity observed with longer storage time is in line with reports of Paulson and Stevens (1974) that high correlation of pH with titratable acidity, citric acid and malic acid. The increases in pH for fresh market cultivars occurred earlier than processing cultivars as the storage period advances.

The present study clearly indicates that lower pH values were positively correlated with slower rate of respiration and better quality maintenance. The higher metabolic rate of fresh market tomato varieties could be a cause for the faster rate of reduction of TTA and increased pH values over processing tomato varieties as the storage period advanced. However, the increase in pH value as storage time progressed was found to be inconsistent which is in agreement with the findings of Stevens (1972). The author also indicated that titratable acidity and pH have inverse relationship and are commonly used acidity indicators of tomato.

Ascorbic acid Ascorbic acid is one of the most important nutritional value parameter in fruits and vegetables. Hence, changes in ascorbic acid in fruits during storage should be monitored in order to investigate level of effects of genetic factors or postharvest treatment. Table 5 shows the ascorbic acid (AA) content of processing and fresh market tomato varieties that had significant ($P\leq$0.001) variation during the 32 days of storage under ambient conditions. The range of ascorbic acid content in this study at harvest was 9.29–15.08 mg. 100 g^{-1} which is in agreement with the concentration of ascorbic acid between 14.6 and 21.7 mg. 100 g^{-1} for fresh ripe tomato fruit reported by Toor and Savage (2006).

At harvest, comparison of the tomato varieties showed 49% more ascorbic acid form fresh market tomatoes while at the end of the storage period, ascorbic acid content of processing tomatoes were found to be higher by 61% over the fresh market tomatoes. There appears to be a relationship between high vitamin C levels and relatively poor yield (Taylor 1986). Accordingly, *Marglobe Improved* that gave relatively lower yield (27.53 tons ha^{-1}) than *Fetane* (45.23 tons ha$^{-1)}$ and *Melkasalsa* (44.9 tons ha^{-1}). After 20 days of storage period, processing tomatoes had higher ascorbic acid content when compared with fresh market tomatoes. On day 32, the processing tomato variety *Melkasalsa* had about 61% more AA content as compared to the fresh market tomato variety *Metadel* that had the lowest value in the group.

Table 5 Ascorbic acid (mg 100 g−1) content of tomato varieties stored under ambient conditions (n=3)

Tomato varieties	Storage period (days)								
	0	4	8	12	16	20	24	28	32
Processing									
Roma VF	11.6^{e}	13.2^{f}	14.8^{e}	18.0^{e}	19.5^{f}	20.4^{f}	15.8^{c}	14.3^{c}	13.4^{c}
Melkasalsa	10.1^{h}	12.0^{h}	13.2^{g}	14.8^{h}	16.6^{h}	17.9^{h}	16.7^{a}	15.8^{a}	14.7^{a}
Melkashola	11.0^{g}	12.2^{g}	14.1^{f}	17.1^{f}	17.3^{g}	18.6^{g}	16.1^{b}	14.9^{b}	14.2^{b}
Fresh market									
Metadel	14.1^{c}	15.1^{c}	16.2^{c}	18.6^{c}	21.5^{c}	23.2^{c}	12.9^{i}	11.1^{i}	9.2^{i}
Eshete	11.2^{f}	14.0^{e}	15.2^{d}	18.2^{d}	19.9^{e}	22.1^{e}	13.5^{h}	11.3^{h}	9.4^{h}
Marglobe Improved	15.1^{a}	16.5^{a}	17.8^{a}	21.1^{a}	22.4^{a}	25.0^{a}	14.4^{e}	12.2^{e}	11.2^{e}
Fetane	9.21^{i}	9.8^{i}	12.0^{h}	14.2^{i}	16.2^{i}	17.2^{i}	15.3^{d}	13.8^{d}	11.3^{d}
Hienz 1350	13.9^{d}	14.7^{d}	16.2^{c}	16.5^{g}	20.2^{d}	22.6^{d}	14.2^{f}	12.1^{f}	10.5^{f}
Bishola	14.3^{b}	15.2^{b}	16.5^{b}	19.3^{b}	22.3^{b}	23.8^{b}	14.0^{g}	11.8^{g}	10.3^{g}
Significance	***	***	***	***	***	***	***	***	***
SE±	0.01	0.01	0.037	0.013	0.014	0.09	0.01	0.01	0.03
CV (%)	0.15	0.14	0.43	0.13	0.12	0.79	0.12	0.15	0.52

(n=3)

Means within the same column followed by a common letter are not significantly different at $P\leq$ 0.05, ***indicate significant difference at $P\leq$0.001.

The higher AA content of processing tomatoes near the end of the storage period could be due to slower rate of metabolic activities. This could have better implication to wards maintenance of higher AA content in processing tomato varieties. Mohammed et al. (1999) also indicated that Vitamin C content was generally higher initially for non-processing than processing cultivars while near the end of the storage period processing tomatoes maintained higher AA content. In the present study there was a general trend of increase in AA content, followed by a fall during the full ripening stage. This trend was in agreement with the previous data that AA content increased with ripeness (Toor and Savage 2006). Several investigators reported an increase in ascorbic acid content with ripening with either a continuing rise or a slight fall during the final stages of ripening (Dalal et al. 1965). For example Brecht et al. (1976) found increased vitamin C content with ripeness while *Watada* et al. (1976) reported that there were no change in vitamin C content with ripeness. The intercultivar difference in vitamin C content both in the processing and fresh market tomatoes varied in this study is similar to those reported by Mohammed et al. (1999).

Colour Colour changes are one of the indications of physicochemical developmental stages in tomato fruits (Table 6). Sensory results on colour indicated the presence of significant ($P\leq$0.001) differences in fruit colour among the tomato varieties from 4 to 28 day while no significance ($P\geq$0.05) difference observed at harvest and after 32 days of storage at ambient conditions (Table 6). During the storage period, there was a general change of tomato fruit skin colour from mature green to red ripe form were observed. Campbell et al. (1990) that during normal ripening of tomato fruit, tissue colour changes from green through orange to red, which coincides with ethylene biosynthesis and a climacteric rise in respiration reported similar observations. On day 4, a comparison of fruit from the fresh market tomato variety showed that loss of greenness was highest in *Metadel* while it was lowest in Fetane, in which all fruits were nearly green. The processing tomato variety Roma VF showed faster rate of loss of greenness while it was slower for *Melkasalsa*

All processing tomato varieties attained full red ripe stage after 24 days of storage period while the fresh market tomato varieties attained the full red ripe stage after 28 days of storage period. This could be due to inherent genetic variation of the varieties that result in slower rate of attractive red colour development in fresh market tomatoes compared with the processing tomatoes. Davies and Hobson (1981) also reported that colour changes were subjected to genetic control in view of the variation in colour development across cultivars. Processing cultivars changed colour more rapidly while they maintained higher firmness ratings (Table 7) than non-processing cultivars, suggesting slower degradation of protopectin by the two enzymes pectinesterase and polygalacturonase than chlorophyll breakdown and pigment synthesis which is also in agreement with the findings of Mohammed et al. (1999) and Moraru et al. (2004).

Moreover, Sahlin et al. (2004) also reported that lycopene, which is responsible for the development of red colour of tomatoes, varies considerably between cultivars. It was interesting to observe that under the same growing conditions, lycopene content in all processing tomato cultivars was higher than in the for fresh market tomato cultivar in addition to their retention of ascorbic acid after

Table 6 Changes in colour (rating scale) of tomato varieties stored under ambient condition

Tomato varieties	Storage period (days)								
	0	4	8	12	16	20	24	28	32
Processing									
Roma VF	1.0	2.5^{d}	3.2^{cd}	5.0^{cd}	5.2^{b}	5.6^{abc}	6.0	6.0	6.0
Melkasalsa	1.0	2.2^{f}	3.1^{d}	4.8^{e}	5.1^{b}	5.7^{abc}	6.0	6.0	6.0
Melkashola	1.0	2.3^{e}	3.1^{d}	4.9^{ed}	5.1^{b}	5.7^{abc}	6.0	6.0	6.0
Fresh market									
Metadel	1.0	2.3^{a}	3.1^{a}	4.1^{a}	5.7^{a}	5.8^{a}	5.8^{ab}	6.0^{a}	6.0
Eshete	1.0	2.2^{b}	3.0^{ab}	4.0^{a}	5.5^{b}	5.7^{a}	5.8^{abc}	5.9^{ab}	6.0
Marglobe Improved	1.0	1.7^{d}	2.9^{c}	3.8^{b}	5.1^{c}	5.4^{b}	5.5^{dc}	5.9^{ab}	6.0
Fetane	1.0	1.5^{e}	2.5^{d}	3.4^{c}	5.1^{c}	5.3^{b}	5.6^{bcd}	5.8^{b}	6.0
Hienz 1350	1.0	1.7^{d}	2.9^{bc}	3.8^{b}	5.1^{c}	5.4^{b}	5.4^{d}	5.9^{ab}	6.0
Bishola	1.0	2.0^{c}	3.1^{a}	4.1^{a}	5.5^{b}	5.7^{a}	5.9^{ab}	6.0^{a}	6.0
Significance	NS	***	***	***	***	***	**	*	Ns
SE±	0.01	0.02	0.04	0.05	0.043	0.08	0.10	0.04	0.01
CV (%)	2.96	2.20	2.43	2.32	1.440	2.58	3.04	1.19	0.50

(n=3)

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$. *, **, *** indicate significant difference at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$, respectively. Rating scale: 1, Green mature; 2, Breaker; 3, Turning; 4, Pink; 5, Light red; 6, Red.

long period of storage. Moraru et al. (2004) also reported processing tomato cultivars, high lycopene content was found together with high ascorbic acid content. Thus, a positive result in the present study facilitates the choice of processing cultivar, especially since they have better shelf life. Extensive reviews have been reported on the impact of various factors including genetic variability on sensory evaluation of colour using colour charts (Moraru et al. 2004).

Firmness Tomato varieties significantly ($P \leq 0.001$) differed in firmness of their fruits during storage period of 8–28 days (Table 7). As the storage period progress sensory results showed that there was a loss in firmness of fruits from very firm to very soft. Lana et al. (2005) indicated that the firmness of tomatoes decreased during storage, which is in agreement with the present findings. The result of the study showed that processing tomatoes maintained better firmness level than the fresh market types through out the storage period. 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 in fresh market tomatoes than in processing types. Moisture loss also induces wilting, shrinkage, and loss of firmness (Mohammed et al. 1999).

Accordingly, higher percentage of moisture loss is an indicator of lower maintenance of firmness as observed in

Table 7 Firmness (rating scale) of tomato varieties stored under ambient conditions

Tomato varieties	Storage period (days)								
	0	4	8	12	16	20	24	28	32
Processing									
Roma VF	6.0	5.9	5.8^{abc}	5.6^{a}	5.5^{b}	4.0^{a}	3.0^{b}	2.0^{c}	1.0
Melkasalsa	6.0	6.0	5.9^{a}	5.8^{a}	5.7^{a}	4.1^{a}	3.1^{a}	2.3^{a}	1.0
Melkashola	6.0	6.0	5.8^{ab}	5.7^{a}	5.5^{b}	4.1^{a}	3.0^{b}	2.1^{b}	1.0
Fresh market									
Metadel	6.0	5.8	5.4^{d}	5.1^{c}	4.8^{f}	3.1^{d}	2.2^{h}	1.1^{g}	1.0
Eshete	6.0	5.8	5.4^{d}	5.2^{c}	4.9^{e}	3.1^{d}	2.4^{g}	1.2^{f}	1.0
Marglobe Improved	6.0	5.9	5.7^{abcd}	5.4^{b}	5.1^{c}	3.8^{b}	2.9^{d}	1.7^{d}	1.0
Fetane	6.0	5.9	5.7^{abcd}	5.4^{b}	5.1^{c}	3.8^{b}	2.9^{c}	1.7^{d}	1.0
Hienz 1350	6.0	5.9	5.5^{bcd}	5.3^{bc}	5.1^{cd}	3.2^{d}	2.6^{e}	1.5^{e}	1.0
Bishola	6.0	5.9	5.5^{cd}	5.2^{bc}	5.0^{ed}	3.4^{c}	2.4^{f}	1.2^{f}	1.0
Significance	Ns	Ns	***	***	***	***	***	***	Ns
SE ±	0.02	0.08	0.09	0.06	0.038	0.048	0.02	0.02	0.01
CV (%)	0.51	2.38	2.83	1.91	1.257	2.315	1.07	1.59	2.14

(n=3)

Means within the same column followed by a common letter are not significantly different at $P \leq 0.05$. ns, indicate non significant difference. ***indicate significance difference at $P \leq 0.001$. Rating scale: 1, very soft; 2, soft; 3, slightly soft, 4, moderately firm; 5, firm; 6, very firm.

this study. Taylor (1986) also reported that flesh firmness varies greatly among varieties and that it is brought by changes in cell wall content among which pectic substances play a major role. Firmness is an important criterion for determining the marketability of tomatoes, because it is associated with good culinary quality and long shelf life. Mohammed et al. (1999) indicated that fruits of the processing cultivars ripened earlier but remained firmer and were less prone to physical injuries. The present study also clearly indicates that firmness and keeping quality were better maintained in processing tomatoes where they retained attractive red colour that could the main reason for their acceptability by producers and by consumers in our country over tomatoes of the fresh market types.

Conclusions

Available genetic material allows discrimination of external and internal quality attributes that must satisfy consumer requirements. Chemical properties including total soluble solid, titratable acidity, sugar/acid ratio, pH, and ascorbic acid content were carried out during the storage period. Furthermore, subjective quality analysis was done on percentage marketability and sensory quality evaluation of colour and firmness. Significant ($P \leq 0.001$) differences in chemical and sensory quality properties among the tomato varieties were observed. At harvest, Marglobe Improved had higher total soluble solid, titratable acidity, sugar/acid ratio and ascorbic acid as compared to *Fetane* while to wards the end of the storage *Fetane* maintained titratable acidity and ascorbic acid than the other five fresh market tomato varieties. On the other hand, *Metadel* showed pH, and sugar/acid ratio than all other tomato varieties. Similarly, Roma VF had higher total soluble solids, titratable acidity, sugar/acid ratio, pH and ascorbic acid when compared with the other two processing tomato varieties. *Melkashola* had the highest total soluble solid content while sugar/acid ratio was at par with Roma VF. To wards the end of the storage period, *Melkasalsa* maintained titratable acidity and ascorbic acid than all other tomato varieties. Furthermore, fruits of the processing varieties ripened earlier, remained firmer and were less prone to physical injuries than fruits of fresh market tomato varieties.

Although fruits from the processing varieties showed earlier ripening and were notably firmer with better keeping quality than the fresh market tomato varieties, the latter genotypes were more suitable as a fresh or table fruit than the former genotypes. Accordingly, the fresh table tomato cultivars were identified to have superior chemical quality characteristics e.g. higher sugar/acid ratio and lower TTA and higher vitamin C. Consequently, the fresh market tomato variety *Marglobe Improved* and *Metadel* could be selected in favor of higher nutritional quality whereas Fetane from the point of view maintaining better overall quality characteristics than the other five fresh market tomatoes. Excellent processing quality attributes were obtained for all processing varieties tested; however, *Melkasalsa* was found to maintain better overall quality characteristics.

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