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Full Length Research Paper

Effects of pre- and post harvest treatments on changes in sugar content of tomato

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The present investigation was aimed at evaluating the combined effect of pre- and post harvest disinfection and evaporatively coolled storage on the changes in sugar content of tomato (*Lycopersicon esculentum* Mill). The preharvest treatments used were ComCat®, manure, NP and the combinations of ComCat® with the two forms of fertilizers and a control. The tomatoes were periodically analyzed for reducing sugar and total sugar. Preharvest ComCat® and ComCat® + manure treatments improved the quality of tomato in terms of maintaining higher ($P < 0.05$) leveles of sugar during storage. Storage at ambient conditions resulted in rapid change in sugar that resulted in quality deterioration of tomatoes. Disinfection seemed to have very limited effect on the changes in sugar content of tomatoes during storage. Two-way interactions between preharvest and storage conditions on changes in total sugar were significant at $P < 0.05$ level during the first week of storage and at $P < 0.001$, thereafter. In general, maintenance of higher reducing sugar and total sugar in tomatoes was found to be the benefits of the combined effect of preharvest treatments and evaporatively cooled storage.

Key words: ComCat®, tomato, disinfection, evaporative cooling, reducing sugar, total sugar.

INTRODUCTION

Post harvest physiological, microbiological, biological and chemical qualities of tomatoes partly depend up on preharvest factors such as genetic and environmental conditions (Hobson, 1988). Cultural practices such as nutrient and water supply and harvesting methods are also claimed to be factors influencing quality of tomato before and after harvest (Watkins and Pritts, 2001). Recent research findings suggested the possibility of screening natural plants as original untouched wild species, in which the genotypic and biochemical potential was unchanged by humans, for their bio-stimulatory activity (Schenabel et al., 2001). As a result, ComCat® was developed as a natural product with its plant strengthening properties and the ability to improve growth and yield in different agricultural crops including tomato. ComCat® consists of biocatalysts of plant origin and induces resistance via activating plant defence mechanisms against pathogens, and biotical and abiotical stress factors (Schenabel et al., 2001). ComCat® treatment is an alternative to chemical treatments and can fit into future research trends to have a balance between yield and ecologisation. Many post harvest losses are direct results of factors before harvest (Booth, 1978). Fruit and vegetables that are infected with pests and diseases, inappropriately irrigated and fertilized, or generally of poor quality before harvesting can never be improved by post harvest treatments (Harvey, 1978). Very often, the rate of commodity loss is faster if the quality at harvest is below standard. Adoption of post harvest practice can extend the useful post harvest life of fruit and vegetables only to the extent that their quality and condition at harvest permit (Harvey, 1978). Unlike the other preharvest chemical treatments at agricultural input level, the most important advantage of ComCat® is that it is both environmentally and ecologically friendly. However, at present there is no information on the post harvest quality aspects of the high harvest yield ComCat® treated vegetables, and the following questions arise: how do these complex plant growth regulators and natural metabolites affect the quality of tomatoes at harvest? How do ComCat® treated tomatoes perform when subjected to

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different post harvest treatments and during storage? The effect of combined preharvest ComCat® and post harvest treatments on changes in sugar content should therefore be investigated to understand post harvest performance of these ComCat® treated tomatoes.

The microbial load associated with tomatoes during storage plays an important role on quality deterioration (Brackett and Splittstoesser, 1992). Post harvest treatments of chlorine solution and hot water are known to reduce enzymatic activity and post harvest decay problems. Chlorine treatments were found to be effective in reducing the occurrence of post harvest decay by pathogens (Prusky et al., 2001) and hot water washing was also found to be very efficient to control post harvest decay in fruit and vegetables (Fallik et al., 1999). Regarding extended shelf life, literature pointed out low storage temperature and high relative humidity is preferable for best results. A cooling chamber that works on the principle of evapora-tive cooling was developed to alleviate post harvest loss of fruit and vegetables (Seyoum and Woldetsadik, 2004). Generally, quality and duration of shelf life of fruit and vegetables are affected by the combined effect of preharvest and post harvest treatments. Therefore, the increase in yield of tomato due to some of the prehatvest treatments needs to be necessarily accompanied by the use of appropriate techniques that minimize post harvest loss. Considering the above situation, the present experiment was designed to investigate effects of pre- and post harvest treatments on storability and quality of tomatoes.

MATERIALS AND METHODS

Site description

The field experiment was conducted at the farm of Haramaya University in Dire Dawa during the period from September to January, 2004/2005. The Farm is located at an altitude of 1197 m above sea level and lies at 9° 6' N latitude and 41° 8' E longitude in the eastern part of Ethiopia. The station lies in the semi-arid belt of the eastern rift valley escarpment with a long-term average rainfall of 612 mm. The mean annual rainfall is 520 mm and means maximum and minimum temperatures range from 28.1 to 34.6°C and 14.5 to 21.6°C, respectively (Belay, 2002). The soil is classified as Eutric Regosol with a gentle slop (3 - 8%). The texture and structure of the topsoil (0 - 30 cm) are sandy loam and sub angular blocky, respectively. The soil has an average pH (H_2O 1:2.5) of 8.54 and organic matter content of 1.9413% (0 - 15 cm) and 1.84045 (15 - 30 cm).

Sample production

Fresh tomato variety, Marglobe, was raised in glass house at Haramaya University campus for about two weeks from July 30 to August 16, 2004 and were pricked for another two weeks in the field from August 17 to September 2, 2004. The plots prepared consisted of six rows 0.75 m apart, with 90 plants per plot and spaced 0.5 m apart in the row. The spacing between plots in each replication and adjacent replications was 2 m and 1.5 m, respectively. The net area of the experimental field was 875.75 m^2.

The experiment was conducted in a randomized complete block design with three replications per treatment. The inorganic fertilizer, diammonium phosphate (DAP) and urea were applied to each plot at the rate of 200 and 150 kg ha^{-1} respectively. The rate of organic fertilizer (manure) was 20 tons per hectare. Organic fertilizer (manure), DAP and half of the nitrogen fertilizer were incorporated to the experimental plots before planting while the rest of the nitrogen was applied two weeks after the establishment of seedlings. ComCat® was applied at 100 g ha^{-1} in 350 L and sprayed twice during the growth period. First spray was just prior to transplanting of seedlings while the second was carried out before flowering as recommended by Huster (2001). Other agronomic practices were applied as needed during the growth season uniformly to all plots. Plots were irrigated every other day for the first two weeks and then at weekly interval.

Sample preparation

Mature green tomato fruit was obtained from each plot that was subjected to different preharvest treatments. Harvesting was carried out manually with care to minimize mechanical injury. Uniform unblemished fruit having similar size and color were selected and hand washed with tap water. To determine quality of fresh market tomato at harvest, six mature green tomatoes were randomly selected from each plot and were analyzed for reducing and total sugar concentrations after disinfection treatments. For analysis of sugar concentration during storage, washed fruit were subdivided into three groups of 288 kg each, in preparation for dipping treatments. Plastic containers were washed and rinsed with distilled water prior to use for the dipping treatments. The disinfection treatments consisted of chlorinated water, hot water at 52°C and tap water (23°C) dipping as control.

For the chlorinated water dipping treatment, tap water was adjusted to 100 $\mu g\ ml^{-1}$ chlorine with standard grade sodium hypochlorite (5% NaOCl) in which mango was dipped for 20 min (Nunes and Emond, 1999; Seyoum et al., 2003). The chlorine was determined using a test kit from Hach (Model CN-66; USA). The temperature was maintained at 4°C during the measurements of chlorine. A 20 min dipping time in 100 $\mu g\ ml^{-1}$ chlorine supplemented water solutions was selected, as this was reported to be the optimum effective concentration and dipping time without significant effect on the overall quality of fruit and vegetables (Nunes and Emond, 1999). The hot water dipping treatment included dipping mangoes in hot water at 52°C for 5 min. Dipping fruits in tap water (24.2°C) for 20 min was used as control treatment. After the disinfecting treatment, the disinfected fruit was again subdivided and stored in evaporatively cooled storage (432 kg) and at ambient conditions (432 kg) in three replications in a 1 kg unit. A total amount of 864 kg tomatoes was used in the study.

Experimental design and analysis

A factorial combination of six preharvest, three disinfecting and two storage treatments with 3 replications were used in the study. The treatments were arranged in a randomized complete block design (RCBD). On each sampling date, a sample of tomatoes was randomly taken from each treatment for sugar analysis. On each sampling date, a sample of 5 tomato fruit from evaporatively cooled and ambient storage in each treatment was randomly taken for assessment. Data were recorded on 0, 4, 8, 12, 16, 20, 24 and 28 days after storage.

Evaporative cooling system

The evaporative cooling system developed by Seyoum and Woldetsadik (2004) was used as storage chamber in this study. The evaporative cooling chamber maintained lower temperature (14.3 -

19.3°C) and higher relative humidity (70.2 - 82.4%). The ambient temperature and relative humidity ranging from 25.2 - 32.1°C and 32.2 - 50.6%, respectively, were recorded during the storage.

Sugar analysis

Reducing and total sugars were estimated by using the calorimetric methods of Somogyi et al. (1945), as presented by Seyoum (2002). Clear juice (10 ml) was added to 15 ml of 80% ethanol, mixed and heated in a boiling water bath for 30 min. After extraction, 1 ml of saturated lead acetate ($Pb(CH_3COO)_2.3H_2O$) and 1.5 ml of saturated sodium phosphate ($NaHPO_4$) were added and the contents were mixed by gentle shaking. After filtration, the extract was made up to 50 ml with distilled water. An aliquot of 1 ml extract was diluted to 25 ml with 1 ml copper reagent in a test tube and heated for 20 min in a boiling water bath. After heating, the contents were cooled under running tap water without shaking. Arsenomolybdate color reagent (1 ml) was added, mixed, made up to 10 ml with distilled water and left for about 10 min to allow color development, after which the absorbance was determined by a spectrophotometer at 540 nm in a Jenway model 6100 spectrophotometer. For total sugar determination, sugar was first hydrolyzed with 1 N HCl by heating at 70°C for 30 min. After hydrolysis, total sugar was determined following the same procedure employed for the reducing sugar. A blank was prepared using distilled water.

Statistical analysis

Significance tests were made by analysis of variance (ANOVA) for RCBD with factorial arrangement according to Gomez and Gomez (1984). ANOVA was carried out with an MSTAT-C soft ware package (MSTAT, Michigan Univ. East Lansing). Comparisons of the treatment means were done using Duncan's Multiple Range Test at $P < 0.05$ level of significance (Duncan 1955).

RESULTS AND DISCUSSION

Reducing sugar

The general trend observed during storage for reducing sugar (RS) content of tomato was an initial increase followed by a decrease during the later stage of storage (Table 1) which agrees with the previous findings with Lambeth et al. (1964). A particularly pronounced rise occurring with the appearance of yellow pigmentation by Davies and Hobson (1971). A post harvest decline in the sugar content of ripe fruit during storage at ambient temperature has been observed (Davies and Hobson, 1971). The increase in RS could be due to the break down of polysaccharides into water soluble sugar. However, as storage time advances, RS content declines. Similar changes were also observed by Salunkhe et al. (1971). Other findings also indicated that starch is completely hydrolysed into soluble sugar such as glucose, fructose and sucrose as ripening progresses (Matto et al., 1975).

The preharvest factors had significant ($P < 0.01$) effect on the RS content of tomatoes during ripening in storage for 28 days. At harvest and in the early stage of ripeness, the RS content was lower ($p < 0.05$) in ComCat®, ComCat® + NP and ComCat® + manure treated tomatoes. The RS content in manure treated tomatoes seemed to be more when compared to the RS content in tomatoes treated with NP fertilizer from 8 days onwards. Increase in sugar content due to manure application was also observed earlier (Raupp 1996; Cacek and Lagner, 1986). The preharvest ComCat® treated tomatoes had shown significantly ($p < 0.01$) higher RS content after day 8. RS decreases faster if there is high respiration rate, since respiration in plants involves the oxidation metabolism of sugar and organic acids to end products, CO_2 and H_2O with the simultaneous production of energy (Varoquaux and Wiley, 1994). Thus, the accumulation of RS during the later stage of storage in ComCat®, ComCat® + manure and ComCat® + NP treated tomatoes would suggest that the lower RS at the early stage may not be related to the respiration process, but could be in part attributed to the effect of the ComCat® that it delayed the ripening of the fruit. Such correlations were reported by Salunkhe et al. (1975) and Bartholomew et al. (1983). The faster decline in RS content of manure, NP and control tomatoes could be due to higher respiration rate. At the end of the storage period, RS is higher by 51.58, 41.4%, 21.5, 21 and 10.8% in ComCat®, ComCat® + manure, manure, ComCat® + NP and NP treatments, respectively, when compared to the control tomatoes. Disinfection treatments showed nonsignificant ($P > 0.05$) effect on the changes in reducing sugar content of tomatoes during the storage period.

Storage temperature had highly significant ($P < 0.001$) effect on the sugar content (Table 1). A considerable decrease in RS content was found in tomatoes stored at ambient conditions. The sugar content was better maintained in tomatoes stored in the evaporative cooler. This study also clearly confirmed the results presented by Koksal (1989) and Seyoum (2002), who reported that reduced temperature in evaporatively cooled storage reduces fruit metabolism, particularly respiratory activity, delaying the ripening process and increasing fruit shelf life. The two-way interaction between preharvest and storage temperature had significant ($P < 0.01$) influence on the change in reducing sugar content of tomatoes during 20 days of storage. The preharvest factors influenced the effectiveness of post harvest treatments in keeping the nutritional qualities of tomatoes during storage, which was demonstrated by the interactive effect of preharvest treatment with the storage conditions. The preharvest ComCat® and its combination with fertilizer treatments had significantly ($p < 0.05$) increased the reducing sugar contents of tomatoes during storage in the evaporative cooler, while the reducing sugar decreased faster in the control, manure and NP treatments.

Total sugar

The total sugar (TS) varied between 3.44 and 0.537 g 100 g^{-1} of fresh weight (Table 1). Tomato fruit exhibited

Table 1. Interaction effects of pre- and post harvest treatments on changes in the reducing sugar content of tomato fruit over a storage period of 28 days.

Treatment	Reducing Sugar, g $100g^{-1}$							
	0	4 days	8 days	12 days	16 days	20 days	24 days	28 days
Preharvest (A)								
CC	0.69^{bc}	1.90^{b}	2.00^{d}	1.89^{a}	1.47^{a}	1.34^{a}	1.09^{a}	0.88^{a}
M	0.71^{b}	1.88^{b}	2.15^{c}	1.54^{d}	1.17^{c}	0.75^{d}	0.58^{d}	0.48^{cd}
NP	0.77^{ab}	1.95^{ab}	2.45^{b}	1.56^{d}	1.24^{b}	0.85^{c}	0.73^{c}	0.54^{c}
CC+ M	0.62^{cd}	1.84^{b}	2.14^{c}	1.78^{b}	1.48^{a}	1.24^{b}	1.01^{b}	0.72^{b}
CC+NP	0.55^{d}	1.86^{b}	2.09^{cd}	1.66^{c}	1.48^{a}	1.25^{b}	0.76^{c}	0.54^{c}
Control	0.80^{a}	2.04^{a}	2.74^{a}	1.53^{d}	1.03^{d}	0.64^{e}	0.50^{e}	0.42^{d}
LSD	**	*	**	**	**	**	NS	NS
SE	0.02	0.04	0.03	0.02	0.01	0.01	0.02	0.02
Disinfection (B)								
HOCL	0.66^{b}	1.91^{a}	2.27^{a}	1.67^{a}	1.31^{a}	1.01^{a}	0.66^{b}	0.51^{c}
H_2O, 52°C	0.69^{b}	1.92^{a}	2.26^{a}	1.66^{a}	1.31^{a}	1.01^{a}	0.69^{b}	0.69^{a}
H_2O, 24.2°C	0.73^{a}	1.91^{a}	2.26^{a}	1.66^{a}	1.32^{a}	1.01^{a}	0.73^{a}	0.59^{b}
LSD	*	ns	ns	ns	ns	ns	-	-
SE	0.02	0.0250	0.02	0.02	0.01	0.01	-	-
Storage (C)								
EC	-	2.31^{a}	2.28^{a}	1.15^{a}	0.89^{a}	0.67^{a}	-	-
AM	-	1.69^{b}	0.93^{b}	0.41^{b}	0.44^{b}	0.28^{b}	-	-
LSD		**	**	**	**	**	-	-
SE	-	0.02	0.02	0.01	0.01	0.004	-	-
Significance								
AXB	ns	ns	ns	ns	ns	ns	ns	ns
	-	**	***	***	***	***	-	-
BXC	-	ns	ns	ns	ns	ns		
AXBXC	-	ns	ns	ns	ns	ns		

Reducing sugars (g 100 g^{-1}) from day 20 onwards are mean valves for the EC only.
Means within the same column followed by a common letter are not significantly different at P < 0.01 by DMRT where ns, *, **, *** indicate nonsignificant or significantly different at p < 0.05, 0.01 or 0.001, respectively.
A, Preharvest; B, disinfection; C, storage.
CC = ComCat®; M = manure; NP = nitrogen and phosphorus; C = control; C+ M = ComCat® + manure; CC + NP = ComCat® + nitrogen and phosphorus; AM = ambient storage; EC = evaporative cooling.

increasing level of TS up to 8 days of storage and decreased afterwards. Similar trend of increase in TS content of tomatoes during ripening and followed by no further changes or a slight decrease during ripening wasobserved by Baldwin et al. (1991). Preharvest treatments, storage temperature and their interactions affected the total sugar content of tomato fruit throughout the storage period.

At harvest the preharvest ComCat® + NP and ComCat® + manure treated tomato fruit had significantly ($p < 0.001$) lower TS. Preharvest NP treatment showed significantly ($p < 0.01$) lower TS content followed by ComCat® and manure treatments. However, the control tomato fruit showed significantly ($p < 0.01$) higher TS content. The lower TS content associated with ComCat® treated tomato could also be an indication of lower respiration and metabolism rates.

The preharvest ComCat® + manure and ComCat® + NP treatments continued to show lower TS for the first 12 days of storage. Manure and NP treatments had significant ($p < 0.01$) effect on changes in TS content. At the end of the storage period the TS was increased by 28.7, 20, 19.78, 4.5 and 2.59% in ComCat®, ComCat® + manure, manure, ComCat® + NP and NP treatments, respectively, compared with the control treatment.

Disinfection treatments had significant ($p < 0.01$) effect on changes in total sugar contents of tomatoes on day 4 and 16 where tomato fruit dipped in chlorinated water had the least total sugars contents than hot water and tap water treatment. The pervious findings indicated that the hot water treatment did not have a substantial adverse effect on the quality parameters of the fruit (Keryl et al., 2001). On the other hand hot water dipping treatments are known to reduce enzyme activities and respiration

Table 2. Interaction effects of pre- and post harvest treatments on changes in the total sugar content of tomato fruit over a storage period of 28 days.

Treatment	Total sugar, g 100 g^{-1}							
	0	**4 days**	**8 days**	**12 days**	**16 days**	**20 days**	**24 days**	**28 days**
Preharvest (A)								
CC	1.84^{c}	2.35^{c}	4.19^{a}	2.56^{a}	1.96^{a}	0.99^{a}	0.89^{a}	0.63^{a}
M	2.03^{b}	2.83^{b}	3.44^{b}	2.06^{b}	1.33^{b}	0.74^{d}	0.77^{b}	0.56^{ab}
NP	1.63^{d}	2.78^{b}	3.41^{b}	2.01^{b}	1.02^{c}	0.74^{d}	0.63^{d}	0.46^{bc}
CC+ M	1.13^{e}	2.31^{c}	3.17^{c}	1.77^{c}	1.28^{b}	0.95^{b}	0.68^{c}	0.56^{ab}
CC+NP	1.16^{e}	2.348^{c}	2.06^{e}	0.97^{e}	1.33^{b}	0.79^{c}	0.73^{b}	0.47^{bc}
Control	2.62^{a}	3.16^{a}	2.89^{d}	1.60^{d}	0.92^{d}	0.68^{e}	0.66^{cd}	0.45^{c}
LSD	**	**	**	**	**	**	**	**
SE	0.01	0.02	0.03	0.04	0.02	0.01	0.01	0.03
Disinfection (B)								
HOCL	1.08^{a}	1.72^{b}	2.62^{a}	1.81^{a}	1.29^{b}	0.86^{a}	0.73^{a}	0.52^{a}
H_2O, 52℃	1.08^{a}	1.76^{a}	2.64^{a}	1.83^{a}	1.35^{a}	0.83^{a}	0.72^{a}	0.52^{a}
H_2O, 24.2℃	1.08^{a}	1.73^{ab}	2.63^{a}	1.83^{a}	1.28^{b}	0.76^{a}	0.73^{a}	0.53^{a}
LSD	ns	*	ns	Ns	*	ns	ns	ns
SE	0.01	0.01	0.02	0.03	0.01	0.01	0.01	0.02
Storage (C)								
EC	-	1.95^{a}	3.03^{a}	2.23^{a}	1.72^{a}	0.99^{a}	-	-
AM	-	1.52^{b}	2.23^{b}	1.42^{b}	0.89^{b}	0.64^{b}	-	-
LSD	-	**	**	**	**	**	-	-
SE		0.01	0.01	0.01	0.01	0.02	-	-
Significance								
AXB	ns	ns	ns	ns	***	***	**	ns
	-	***	***	***	***	***	-	-
BXC	-	ns	ns	ns	***	***	-	-
AXBXC	-	***	ns	ns	***	*	-	-

Total sugars (g 100 g^{-1}) from day 20 onwards are mean valves for the EC only.
Means within the same column followed by a common letter are not significantly different at P < 0.01 by DMRT where ns, *, **, *** indicate nonsignificant or significantly different at p< 0.05, 0.01 or 0.001, respectively.
A, Preharvest; B, disinfection; C, storage.
CC = ComCat®; M = manure; NP = nitrogen and phosphorus; C = control; C+M = ComCat® + manure; CC + NP = ComCat® + nitrogen and phosphorus; AM = ambient storage; EC = evaporative cooling.

rate of fruit and vegetables (Jordan 1993). However, in this study hot water treatments had a positive effect on total sugar content of tomatoes.

Storage environment significantly (P < 0.05) affected the TS content of tomatoes (Table 2). TS content of tomatoes was higher in tomatoes stored in evaporatively storage. This could be associated with the higher rates of hydrolysis of higher molecule sugar under ambient temperature which is in agreement with the results of Koksal (1989). This indicates that lowering the storage temperature reduces respiration and senescence while high temperature storage hastens the senescence of tomato fruit. Wang (1989) suggested that low temperature storage is the most effective method for preserving the chemical composition of most perishable horticultural commodities because it retards respiration, delays ripening besides imposing other undesirable metabolic changes.The two-way interaction between preharvest and disinfection treatments, and between disinfection and storage treatments had significant (p < 0.01) effect on the TS from day 16 onwards. The three-way interaction between preharvest, disinfections and storage treatments on the TS content of tomato fruit was significant from day 16 onwards (Table 2). These result revealed that in general TS content of tomato fruit was maintained better in tomatoes that were subjected to the preharvest ComCat®, ComCat® + manure and ComCat® + NP treatments and stored using evaporatively cooled storage.

Conclusion

Quality management starts in the field and continues until produce reaches the end user. The response of fruit and vegetables during storage to postharvest factors in part depends on preharvest practices. Understanding and managing the various roles that preharvest factors play in post harvest quality is very important in order to achieve maximum harvest and post harvest quality. The preharvest treatments had influenced ($P < 0.01$) the reducing and total sugars of tomatoes at harvest. The preharvest treatments had also influenced ($P < 0.01$) the changes in total sugar content during storage. Foliar application of ComCat® displayed better maintenance of total sugar and reducing sugar. ComCat® treatment when combined with manure and NP fertilizers had shown lower reducing sugar and total sugar. Manure treated tomato fruit had higher total sugar and reducing sugar. Evaporative cooling positively affected the changes in reducing and total sugars in tomato fruit. This study reveald that integerated agro-technology, combining proper pre- and post harvest treatments, assist in improving the shelf life through maintaining the chemical quality in terms of sugar concentrations of tomatoes.

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