

Total Soluble Solids, Titratable Acidity and Ripening Index of Tomato In Various Storage Conditions

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Abstract: Effects of controlled atmosphere storage (CAS) and modified atmosphere packaging (MAP) in comparison with conventional cold storage on qualitative properties of green-mature harvested tomato were evaluated. Qualitative properties included Total Soluble Solids (TSS) content, Titratable Acidity (TA) and Ripening Index (RI). Under CAS and MAP conditions, gas composition was 5 kPa O₂ and 3 kPa CO₂. Although amongst storage treatments, the maximum value of TSS was observed in cold storage, its decreasing trend in CAS was slower than that in cold storage. Additionally, MAP and especially CAS slowed down the diminishing trend of TA in tomatoes. Results showed that the ability of CAS and MAP to retard the ripening index was more than cold storage and trend of changes were more stable in MAP and CAS.

Keywords: Controlled atmosphere storage; Modified atmosphere packaging; Cold storage; Total soluble solids; Titratable Acidity, Tomato.

INTRODUCTION

In climacteric fruit such as tomato (*Lycopersicon esculentum*), ripening process is affected by the rate of ethylene production (Carrari and Fernie, 2006; Alexander and Grison, 2002). Upon ripening, ethylene production rate increases too that it accelerates to severity of changes and reduction of quality (Giovannoni, 2001). This cause changes in fruit sugar content, organic acid metabolism during the ripening process (Valero *et al.*, 2005). 'Fruitiness' (Bucheli *et al.*, 1999) and 'sweetness' (Kamal *et al.*, 2001) have been identified as two critical contributors to flavor of fresh tomatoes. The major sugar substances that contribute to sweetness are glucose and fructose that play a major role in taste (Stevens *et al.*, 1977). A strong positive correlation is observed between trained panel response to sweetness and reducing sugar or total soluble solids content (Malundo *et al.*, 1995; Tandon *et al.*, 2003). The sour taste in tomato is attributed mainly to citric and malic acids (Petro-Turza, 1987). 'Sourness' closely correlates with titratable acidity (Malundo *et al.*, 1995; Bucheli *et al.*, 1999; Tandon *et al.*, 2003). Decline in the acidity level has been associated with quality loss during tomato postharvest storage and together with soluble solids content, can influence consumer's acceptability (Guillén *et al.*, 2006; Zapata *et al.*, 2008). Qualitative attributes generally changes with time, as part of the normal metabolism of the product (Tijskens and Polderdijk, 1996). Low temperature is the most important factor in maintaining quality and extending the shelf-life of fruits and vegetables after harvest. Gas composition of the ambient air also plays an important role. Controlled atmosphere storage (CAS) or modified atmosphere packaging (MAP), combined with low temperature storage, can reduce respiration and ethylene production rates, then slow down changes related to ripening and senescence (Ahvenainen, 1996; Jacxsens *et al.*, 1999; Saito and Rai, 2005). This technique needs a wide range of research about its quality properties and gas compositions appropriate to extended storage time at various fruits and their variety. The objective of this study was to evaluate and compare the effects of three methods of tomato storage at green-maturity stage under MAP, CAS and cold storage on TSS, TA and ripening index.

Materials and methods:

Plant material and Treatments:

Tomato fruits (var. superjeff) were harvested at mature-green stage from experimental field (Karaj-Iran). Fruit maturation level was precisely selected and the fruit color was compared in the field using biological color chart of USDA (1991). Harvesting was carried out manually in the morning. Disease-free fruits with having uniform shape, size and weight without any injuries or defects were selected and hand washed with tap water. Then the fruit surface was dried using a soft cloth and placed in controlled/modified atmosphere and Cold storage. Six tomatoes, placed in a sealed polyethylene bag (thickness 0.05mm), were used for MAP treatment. For MAP and CAS treatments, an initial gas composition of 5kPa O₂ and 3 kPa CO₂ was used (Saltveit, 2003). Temperature for all storage treatments was 13°C (Grierson and Kader, 1986). Relative humidity in CAS and Cold storage were 85-90% and 60-65% respectively. Tomato samples were taken for quality analysis every 10

days starting from the day of harvest. On each sampling date, three packs (replications) from the MAP treatment and six tomatoes from each replication in the CAS and cold storage treatments were randomly taken. Tomatoes were evaluated for changes in titratable acidity and total soluble solids content.

Total soluble Solids (TSS) Content and Titratable Acidity (TA):

Total soluble solids (TSS) were determined for each sample fruit in two replications using an Atago DR-A1 digital refractometer (Atago Co. Ltd., Japan) at 20°C and expressed as °Brix. Titratable acidity (TA) was obtained by titrating 5 ml of tomato juice with 0.1 N NaOH up to pH 8.1. The result was expressed as grams of citric acid per 100 g of fresh tomato weight. The TSS to TA ratio (ripening index) was also calculated.

Statistical Analysis:

Factors considered in the statistical analysis of the data were storage type, storage time and replication. Data analysis was performed using analysis of variance (ANOVA) with the SAS program package (SAS Institute, Cary, NC, USA 1988). For the statistical study, randomly selected three samples from each of three replications in any treatments. The means were compared using the least significant difference (LSD) test at $P < 0.05$. Sources of variation included storage type and storage time. Dependent variables were titratable acidity (TA), total soluble solids (TSS) content and the ripening index (TSS/TA).

RESULTS AND DISCUSSION

Total Soluble Solids Content:

With respect to TSS, the most significant changes were observed in cold storage, which increased significantly from 5.07 to 5.47 then decreased to 4.9 during 40 days of storage (Fig. 1A). Minimum changes were found in CAS where TSS increased from 5.2 to 5.59 then decreased to 5.18 during 90 days. There was a peak in TSS graph of tomato occurring after 20 days of cold storage, 40 days of MAP and 50 days of CAS. Results indicated a decreasing trend after the peak in TSS value. Significant differences ($P < 0.01$) were found in TSS content in cold storage between different stages of the experiment, but the loss of TSS in MAP and CAS were lower than Cold storage during the storage period. Values of TSS increased during the first stages of storage for all treatments, although the highest value of TSS (5.7) for all treatments and experiment stages was obtained in cold storage after 20 days. On day 40, tomato firmness in cold storage reached its lowest value and due to its unacceptable appearance, further measurements were discontinued. This phenomenon occurred on day 70 in the MAP treatment. Tomatoes in CAS treatment kept an acceptable level of firmness till the 90th day. The most effective treatment in delaying the TSS loss was CAS after 90 days of storage (5.18) since TSS of cold storage was 4.9 on day 40. Generally, tomato fruit in CAS and MAP treatments retained significantly higher total soluble solids than those in cold storage for all the storage periods. This was in harmony with the study by Erkan *et al.*, (2004) who observed that soluble solids of apple were higher in 2% O₂ and 2% CO₂ environment than in normal atmosphere after 9 months of storage. There was no difference in soluble solids content of peach and persimmon fruits among storage treatments over the 7 and 8-day storage periods, respectively (Wright *et al.*, 1997a).

Titratable Acidity:

Measurement of titratable acidity (TA) revealed that TA decreased during all storage treatments (Fig. 1B). However, these changes were more severe in cold storage with a value of 0.376 after 40 days of storage compared to 0.439 for MAP and 0.481 for CAS. There was a significant decline in TA with time for cold storage while its loss was at much lower rates when using CAS and the decrease was not significantly different for MAP and CAS. Results indicated that the effects of both CAS and MAP were obvious on retarding the titratable acidity loss; especially for tomato fruits kept in CAS, while tomatoes in cold storage did not exhibit any large reduction in TA during storage. Analysis shows that tomato samples in CAS had higher TA values after 90 days of storage than the ones in cold storage during the first 40 days. Wright *et al.* (1997b) found that there were significant differences in titratable acidity of strawberries in all storage treatments during a 7-day storage period. Intact fruits in air treatment showed an increase, sliced fruit stored under 2% O₂ showed no changes and sliced fruits in air treatments showed a decreasing trend in TA. Erkan *et al.* (2004) reported that titratable acidity of apples decreased continuously during a 9-month storage period, while statistically significant differences were found between CAS and normal-atmosphere storage of apples, whereas the differences in titratable acid among apples kept at different CAS concentrations were not statistically significant. Girardi *et al.* (2005) showed that decline of titratable acidity during storage is inevitable but CAS treatment can help to better retain titratable acidity. Sabir *et al.* (2011) reported that MAP slightly restrained the decrease in TA values than control treatment after 2nd week of storage.

Repining Index:

Out of the 3 treatments, the highest variations of repining index (TSS/TA) were found in the cold storage treatment (Fig. 1C). Results showed that Repining index in cold storage first reaching the maximum value at 13.35, then there was a decrease followed by an increasing trend. In MAP treatment, TSS/TA values from 10 to 70 days of storage, except in the first and lasted (on day 70) experimental stages, were significantly higher than that of CAS. However, TSS/TA value (13.422) at CAS after 90 days of storage was the highest. This may be due to the fact that the decrease in TA loss in MAP was higher than that of CA, therefore, the ratio of TSS/TA was higher. Results of analysis indicated an increasing trend in TSS/TA in CAS during all the storage periods while TSS/TA in MAP showed a decreasing trend during the first 60 – 70 days of storage. Hodges *et al.* (2006) found that soluble solids to titratable acidity ratio was highest in controlled atmosphere storage of cauliflower than air storage of the late-harvest crop, but there was no difference between controlled atmosphere storage and air storage for the two earlier harvests. Sabir *et al.* (2011) reported that during the storage, the increased trend of TSS/TA was lower in MAP than others treatments, although the effects of treatments were insignificant.

Conclusions:

Results indicated the importance of storage treatment and its effect on slowing the decline in qualitative properties of tomatoes during storage controlled and modified atmosphere storage significantly retarded the ripening process compared to conventional cold storage. Tomato quality, measured by total soluble solids, titratable acidity and ripening index, was preserved in Controlled atmosphere storage for almost 90 days, better than MAP and superior to conventional cold storage.

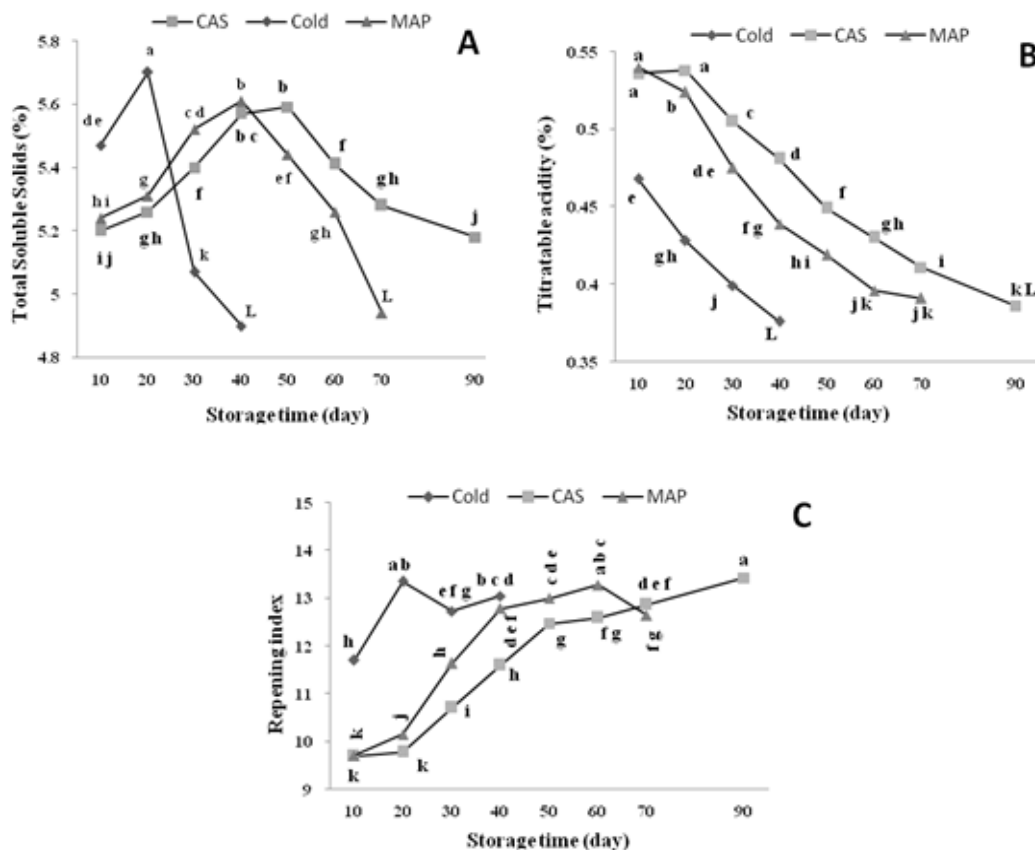


Fig. 1: Changes in quality of tomato during storage under different conditions (n=9), Cold (cold storage), CAS (Controlled atmosphere storage), MAP (Modified atmosphere packaging), Values with different letters on each point differ significantly ($P < 5\%$).

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