

Effect of Post Harvest Treatment on Stored Cherry Tomatoes

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Abstract

Cherry tomatoes are grown for its edible fruits, which can be consumed either fresh as a salad or after cooking as snacks. Cherry tomato is a store house of antioxidants such as Lycopene, ascorbic acid and phenolics. The study was conducted to undertake the effect of storage conditions on the post harvest quality of Cherry tomato cv. Marilee red (*Lycopersicon esculentum* Mill) harvested at pink stages. The experiment consisted of three post harvest treatments comprising fruits dipped in cold water for five minutes (control), fruits dipped in CaCl_2 @ 2% and fruits dipped in acetic acid @ 5%. Fruits imposed with post harvest treatments were stored at ambient (temperature $25^\circ\text{C} \pm 2$ and relative humidity approx. $75 \pm 5\%$) and cold storage conditions ($10^\circ\text{C} \pm 2$). Physico-chemical changes recorded on 0, 2, 4, 6, 8, 10, 12, 14 days of storage. Lycopene, ascorbic acid and total sugar changes recorded on 0, 4, 9, 14 days of storage. The data on physical characteristics (firmness, taste, juiciness, decay, colour, gloss, uniformity, shrivel) were recorded. CaCl_2 was the best treatment followed by control and acetic acid treatment. Significant differences observed among the chemical parameters due to various post harvest treatments and storage conditions. CaCl_2 had highest ascorbic acid, lycopene content and had lowest PLW, moisture content. Acetic acid had highest PLW, titratable acidity, moisture content and lowest TSS, lycopene, total sugar content. Control had highest TSS, total sugar content, lowest titratable acidity and ascorbic acid content at ambient and cold temperatures. TSS and acidity contents increased rapidly initially, but started decreasing gradually afterwards in all storage treatment. CaCl_2 was found highly effective in controlling storage loss as well as in maintaining the quality of the produce during storage. Although the ascorbic acid registered a decrease during storage, it could still contribute significantly towards the dietary intakes.

Keywords: Cherry tomato; Post harvest; Physico-chemical; Acetic acid; CaCl_2

Introduction

The tomato (*Lycopersicon esculentum*) is one of the most widely consumed fresh vegetable in the industrialized world [1]. Botanically, tomatoes are fruits (berry), but they are commonly referred to as vegetable. Fresh-market tomatoes are a popular and versatile fruit vegetable, making significant contributions to human nutrition throughout the world for their content of sugars, acids, vitamins, minerals, lycopene and other carotenoids, among other constituents [2,3]. Being a climacteric and perishable vegetable, tomatoes have a very short life span, usually 2-3 weeks. The small size snacking tomatoes (cherry, grape types) contain high concentrations of sugars and acids, major contributors to tomato flavor, and now comprise about 24% of retail sales of tomatoes in the U.S. [4]. Tomatoes are consumed widely throughout the world and their consumption has recently been demonstrated to possess health benefits because of its rich content of phytonutrients [5,6]. Postharvest recommendations indicate that tomatoes, including cherry tomatoes, should be stored at 10°C or higher to avoid chilling injury [7,8] and even 10°C may be detrimental to tomato flavor quality [9]. Cherry and grape tomatoes are sometimes held at lower than recommended temperatures. Also cherry and grape tomatoes are routinely used as components on fresh cut vegetable trays under modified atmospheres, with expected shelf-life of 14-18 days at $5-10^\circ\text{C}$. A few studies have characterized changes in small tomatoes stored at below recommended temperatures alone or in combination with modified atmosphere packaging [10,11]. Different studies explained that calcium chloride reduced post harvest decay, controlled development of physiological disorders, improved quality and delayed aging or ripening [12]. It improves the skin strength [13] making the cell wall and tissues more resistant and less accessible to the enzymes that are produced by fungi and bacteria, limiting infection while controlling ripening, softening, storage breakdown, rotting and decay at the same time [14-16]. According to different studies, it improved

the Ca^{2+} contents, lycopene contents, ascorbic acid contents, firmness index [17,18] and reduced the disease index [19]. Bioregulators affect fundamental processes of plant growth and development.

Acetic acid (AA) is plant bioregulator belonging to the auxin group. Plant bioregulators are organic compounds, either natural or synthetic that modifies or control one or more specific physiological processes within a plant. They can accelerate or retard the growth or maturation rate or otherwise alter the behaviour of plants or their products [20,21]. Bioregulators are used to advance or delay fruit harvest by influencing fruit maturation and ripening [22]. An increase in the storage life and improvement of tomato fruit quality is really desirable and the initial step required for ensuring successful marketing is to harvest the crop at the optimum stage of maturity. Full red, vine-ripened tomatoes may be ideal to meet the needs of a roadside stand, but totally wrong if the fruits are destined for long distance shipment [23]. Extending the shelf life of tomatoes is very important for domestic and export markets. Storage at 13°C was more favorable as compared to 24°C for prolonged shelf life and increasing vitamin C content of fruits [24]. Cherry tomatoes are sold at a premium in many of the large retail stores in the country. There is an interest in finding ways to improve the shelf life. Safe and low cost methodologies that can extend the shelf life while at the same time retain the quality under ambient as well as cold conditions need to

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Days of storage	Ambient temperature			Cold temperature		
	CaCl ₂	Acetic Acid	Control	CaCl ₂	Acetic Acid	Control
0	●●● ◇◇◇	●●● ◇◇◇	●●● ◇◇◇	●●● ◇◇◇	●●● ◇◇◇	●●● ◇◇◇
1						
2	●●●	●●●	●●●	●●●	●●●	●●●
3						
4	●●● ◇◇◇	●●● ◇◇◇	●●● ◇◇◇	●●● ◇◇◇	●●● ◇◇◇	●●● ◇◇◇
5						
6	●●●	●●●	●●●	●●●	●●●	●●●
7						
8	●●●	●●●	●●●	●●●	●●●	●●●
9	◇◇◇	◇◇◇	◇◇◇	◇◇◇	◇◇◇	◇◇◇
10	●●●	●●●	●●●	●●●	●●●	●●●
11						
12	●●●	●●●	●●●	●●●	●●●	●●●
13						
14	●●● ◇◇◇	●●● ◇◇◇	●●● ◇◇◇	●●● ◇◇◇	●●● ◇◇◇	●●● ◇◇◇

●●●- observations taken on alternate days
 physical observation (firmness, taste, juiciness, decay, colour, gloss, uniformity observation)
 moisture
 acidity
 TSS
 ◇◇◇- observations taken on 5 days interval
 Lycopene
 Total sugar
 Ascorbic acid

Table 1: Description of replications in study on storage of pretreated fresh cherry tomatoes (cv. Marilee red).

be evaluated. Hence the present investigation was undertaken to study the effect of pretreatment on shelf life, physico-chemical and sensory characteristics.

Materials and Methods

For the experiments on storage study of fresh cherry tomato, 15 kg of the variety Marilee Red were harvested from orchards at Namdhari Seed Company, Bidadi, Karnataka and transported to laboratory. The fruits were refrigerated (10°C) to cool, brought to the laboratory with least damage and utmost care. Samples were assigned to the different experimental test conditions. These conditions are described in following paragraph.

Storage study of fresh cherry tomato

One hundred grams of tomato sample was filled in foam trays measuring 12.5 x 12.5 cm. For each treatment there were 3 trays for each day of observation and totally there were 36 trays. Thus, in all 108 trays were used for the entire study as there were two treatments and control as indicated in Table 1. Cherry tomatoes were stored at i) ambient conditions prevailing in the laboratory (temperature (25°C ± 2) and relative humidity around (50 ± 10%)) and ii) a refrigerator maintained at cold temperature (10°C ± 2), which had provision for proper aeration and light, arranged side by side (Annexure).

Pre treatments for storage of fresh tomato

CaCl₂ is often used for extending the shelf life of tomatoes [25] and acetic acid is a known surface sanitizer. Therefore for studying the shelf life of cherry tomato (cv. Marilee Red), 2% CaCl₂, 5% acetic acid solution and distilled water (control) were used. Samples were dipped

for 5 min and wiped before storage at two temperatures (10°C and ambient temperature).

Thus, in this study the following pretreatments were used:

T₁ - Fruits dipped in cold water for five minutes (Control)

T₂ - Fruits dipped in CaCl₂ @ 2% for five minutes

T₃ - Fruits dipped in acetic acid @ 5% for five minutes

Packaging system: After those treatments fruits were placed in foam trays measuring 12.5 x 12.5 cm and wrapped with PVC film. (Plate 1 and 2)

Observations: Physico-chemical observations (Firmness, taste, juiciness, decay, colour, gloss, uniformity, shrivel) were recorded on 0, 2, 4, 6, 8, 10, 12, 14 days of storage. For estimating lycopene, ascorbic acid and total sugar content, samples were drawn on 0, 4, 9, 14 days of storage as already explained.

Analytical procedure

Evaluation of quality characters [7]: Fruits were ranked for quality parameters, from higher to lower descending order of acceptability. Colour, flavor, taste, decay, gloss, firmness, uniformity, shrivels and over-all acceptability of the fruit were determined by visual assessment and grouped. Quality characters were determined by a panel of 5 semi trained judges on a 5 point hedonic scale.

Physiological loss in weight [26]: For determining the physiological loss in weight, fruits were weighed before imposing the treatment which served as the initial fruit weight. The loss in weight was recorded at 7 days interval until 14 days which served as the final weight. The physiological loss in weight was determined by the following formula and expressed as percentage.

$$PLW(\%) = \frac{\text{Initial fruit weight} - \text{Fruit weight on the day observation}}{\text{Initial fruit weight}} \times 100$$

Total soluble solids (TSS) [27]: Total soluble solids were determined using hand refractometer 0-32 (°Brix) range A drop of juice was used to record the TSS and values were expressed as °brix.

Titrateable acidity: A known volume of filtered juice was diluted with a known volume of distilled water. An aliquot was taken from this

STORAGE DAYS	TEMPRETURE (°C)		RELATIVE HUMIDITY (%)	
	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
1 st day	20	27	63	80
2 nd day	19	26	65	77
3 rd day	18	26	70	82
4 th day	18	27	68	79
5 th day	19	25	66	81
6 th day	18	25	70	82
7 th day	19	24	71	82
8 th day	19	25	68	79
9 th day	18	26	69	82
10 th day	20	26	70	81
11 th day	20	24	71	80
12 th day	19	24	72	78
13 th day	18	23	68	80
14 th day	17	24	68	79
15 th day	19	25	69	81

Annexure: Temperature and relative humidity recorded during storage of cherry tomato under ambient condition.



Plate 1: Storage of fresh cherry tomatoes subjected to specific pretreatments (1) CaCl_2 2%, (2) Acetic acid 5% and (3) Control.



Plate 2: Packaging material used in study of fresh cherry tomato (cv. Marilee Red).

sample and titrated with 0.1 N NaOH using phenolphthalein indicator. The appearance of light pink colour was marked as the end point. Acidity was computed and expressed as per cent citric acid.

$$\% \text{acid} = \frac{\text{Titre value} \times \text{Normality} \times \text{m.eq. wt. of acid}}{\text{Volume of sample}} \times 100$$

Milli-equivalent weight of citric acid = 0.06404

Ascorbic acid content: Ascorbic acid was estimated by indicator method. This method is based on stoichiometric reduction of the dye 2,6-dichlorophenol indophenol by ascorbic acid into a colourless compound. The filtration was conducted in the presence of acetic acid and metaphosphoric acid.

Lycopene content [28]: Lycopene was estimated by rapid method. Lycopene was extracted in petroleum ether and the absorbance was measured by using spectrophotometer at 503 nm using UV-VIS spectrophotometer-Shimadzu.

Estimation of moisture: Moisture was determined by taking about 10 g of sample in petri dish and dried in an oven at 105°C till the weight of the petri dish with its content was constant. Each time before weighing, the petri dish was cooled in desiccators. Moisture content of the sample was expressed in g/100g of sample.

$$\text{Moisture content}(\%) = \frac{\text{Initial weight (g)} - \text{Final weight (g)}}{\text{Weight of the sample}} \times 100$$

Estimation of total sugar by Phenol Sulphuric acid method [29]: The intensity of colour developed by the reaction of phenol sulphuric acid with total sugar was read at 490 nm in a colorimeter (Elico SL 164, Spectrophotometer).

Statistical analysis: The data pertaining to physiological and biochemical parameters of the fruit were subjected to statistical analysis of FCRD using analysis of variance (ANOVA) as per the procedure given by Fischer (1960). The level of significance used in F test and 't' test was $p \leq 0.05$. Critical difference values were calculated wherever the 'F' test was found significant. The data were subjected to Minitab Statistical Software (Minitab Inc., USA).

Results and Discussion

Pre-packaging plays an important role in quality maintenance by slowing down the biochemical changes and reducing the moisture loss, thus increasing the shelf life of fresh produce [30]. The role of calcium in the physiology of plant tissue is well established. Addition of calcium rigidifies cell wall and obstructs enzymes such as polygalacturonase from reaching active sites [25]. Calcium compounds have shown promising results in the quality retention of fruits and vegetables through maintenance of firmness and reducing the respiration rates [16]. Influence of various post harvest treatments and storage conditions in cherry tomato cv. Marilee Red was studied. The experiment consisted of three post harvest treatments comprising fruits dipped in cold water for five minutes (control), fruits dipped in CaCl_2 @ 2% and fruits dipped in acetic acid @ 5%. Fruits imposed with post harvest treatments were stored at ambient (temperature $25^\circ\text{C} \pm 2$ and relative humidity approx. $75 \pm 5\%$) and cold storage conditions ($10^\circ\text{C} \pm 2$). Observations on various physico-chemical and quality changes during storage were recorded at two or five day's intervals for 14 days. The results obtained from the investigation are presented in the following paragraphs.

Physiological loss in weight (PLW) (%)

Weight loss of fresh tomatoes is primarily due to transpiration and respiration. Transpiration is a mechanism in which water is lost due to differences in vapour pressure of water in the atmosphere and the transpiring surface. Respiration causes a weight reduction because a carbon atom is lost from the fruit each time a carbon-dioxide molecule is produced from an absorbed oxygen molecule and evolved into atmosphere [31]. Physiological loss of weight can influence the economic returns. The data on physiological loss in weight as influenced by post harvest treatments and the storage conditions are presented in Figure 1 which indicated significant differences between both post harvest treatments and storage conditions ($p \leq 0.05$). It was observed in general, that the PLW was lower under cold storage compared to ambient storage in all the treatments. Among post harvest treatments, PLW was lowest in CaCl_2 treated samples (3.49%) which was significantly lower over all other treatments under both cold (1.62%) and ambient (5.37%) conditions at 7 days of storage. The next best treatment in terms of low PLW was control. The PLW progressively increased with an increase in the storage period, irrespective of the storage condition and the

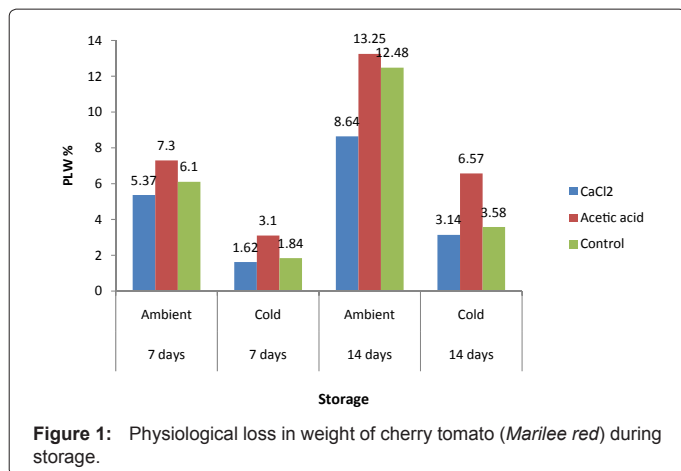


Figure 1: Physiological loss in weight of cherry tomato (*Marilee red*) during storage.

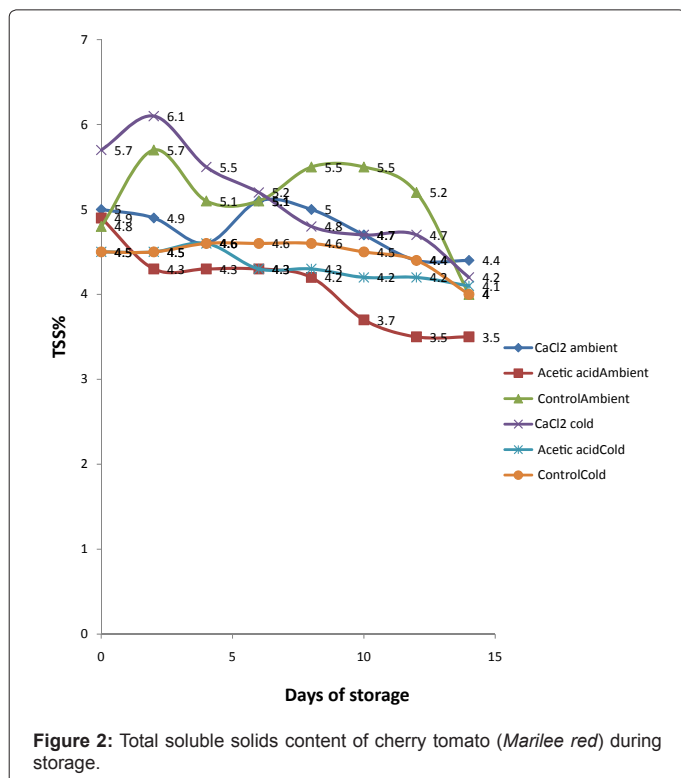


Figure 2: Total soluble solids content of cherry tomato (*Marilee red*) during storage.

treatments. Among the treatments, PLW was maximum in acetic acid treatments under both ambient and cold storage conditions at 7 and 14 days. In the present investigation, weight loss was significantly lower in CaCl₂ pretreatment under ambient and cold storage. This could be attributed to the maintenance of high humidity in the microatmosphere within the packages by the respiring fruits and due to low water vapour transmission rates of packaging material [26]. Cold stored fruits had a low weight loss due to temperature effects on vapour pressure difference and increased water retention [32].

Total soluble solids (°brix)

Results on the effect of storage at ambient temperature on the total soluble solids (TSS) are presented in Figure 2. It was observed that significant differences existed between the post harvest treatments at all stages of observation (0, 2, 4, 6, 8, 10, 12 and 14 days) ($p \leq 0.05$). Among

the post harvest treatments, mean TSS was lowest in acetic acid treated (4.08%) followed by CaCl₂ treated (4.76%) fruits. However, the control (5.11%) fruits recorded highest TSS among all of them in ambient temperature. Among the post harvest treatments, mean TSS was lowest in acetic acid treated (4.33%) and followed by CaCl₂ treated (4.46%) fruit and the highest was in control (5.11%) in cold temperature. The means of the results were subjected to student 't' test. There were no statistically significant differences between ambient temperature and cold temperature. The total soluble solids acts as a rough index of the amount of sugars present in fruits. It is the amount of sugar and soluble minerals present in fruits and vegetables. Sugars constitute 80-85 per cent of soluble solids. The total soluble solids increased during the ripening due to degradation of polysaccharides to simple sugars thereby causing a rise in TSS [30]. However, in the present study, control had highest TSS in post harvest treatment, CaCl₂ and acetic acid treatments were lower than that of control samples treated with distilled water. The reduction in the TSS of calcium treated cherry tomato fruit was probably due to slowing down of respiration and metabolic activity, hence retarding the ripening process. In this regard, the view of [33] is noteworthy that the slower respiration also slows down the synthesis and use of metabolites resulting in lower TSS due to the slower change from carbohydrates to sugars. Dewanto et al. [34] stated that application of calcium increased fruit calcium content and influenced several post harvest treatment senescence changes involving free sugars, organic acid, anthocyanin content and texture of fruits.

Titrateable acidity (%)

The data on titrateable acidity presented in Figure 3 indicated significant differences ($p \leq 0.05$) among the post harvest treatments at all stages of observation (0, 2, 4, 6, 8, 10, 12 and 14 days of storage) and ($p \leq 0.05$). Acetic acid treated fruit recorded significantly higher mean titrateable acidity (0.39%) over all other treatments followed by

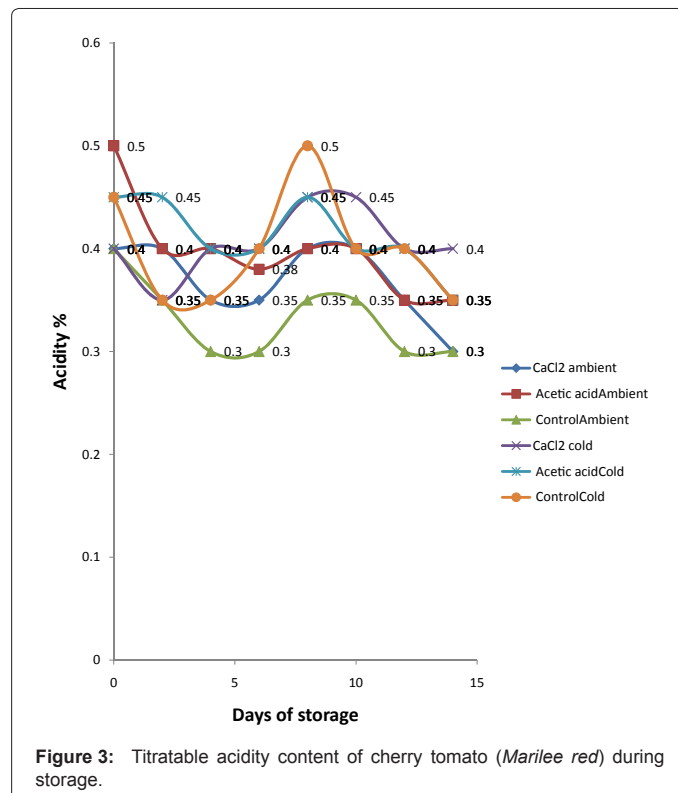


Figure 3: Titrateable acidity content of cherry tomato (*Marilee red*) during storage.

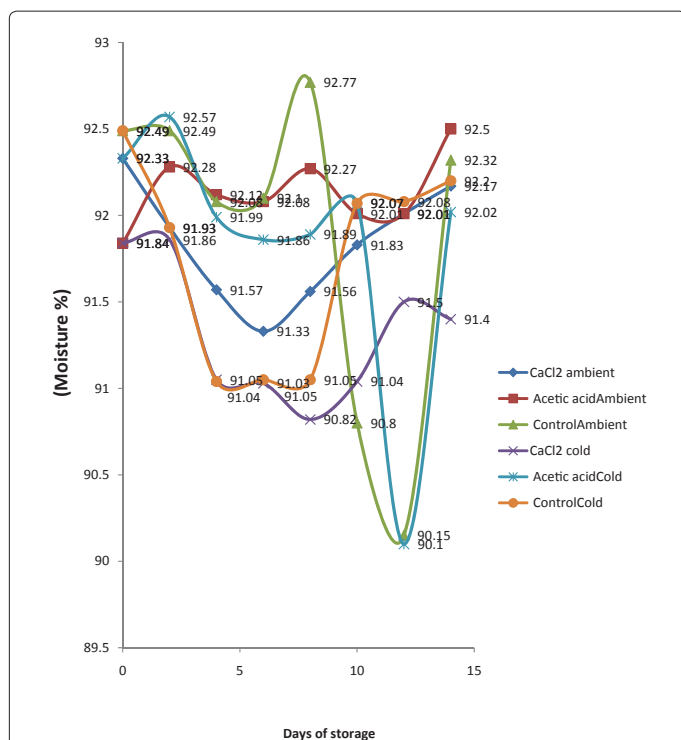


Figure 4: Moisture (%) content of cherry tomato (*Marilee red*) during storage.

CaCl₂ treated (0.36%) fruit, control treatments had lowest titratable acidity (0.33%) at ambient temperature of observation. Among the treatments, significantly higher mean titratable acidity was recorded in acetic acid treated (0.41%) fruit over all other treatments at cold temperature. The next best treatment was CaCl₂ treated (0.40%) fruit. Significantly lower titratable acidity was recorded in control (0.40%) fruits at cold temperature. The means of the values were subjected to student 't' tests to assess the effect of interaction between storage temperature and pretreatment. There were statistically significant differences between ambient temperature and cold temperature and pre treatments. Acidity in fruits is an important factor in determining maturity. Titratable acidity gives the total or potential acidity, rather than indicating the number of free protons in any particular sample. It is a measure of all aggregate acids and sum of all volatile and fixed acids. In the present study, the titratable acidity of the cherry tomato fruits differed significantly over the storage period. A gradual decline in the titratable acidity was noticed by the end of storage period among the cherry tomato fruits. The changes in organic acids during ripening have been attributed to a rise in citrate and fall in malate, indicating a change in metabolism of citrate [35] and reduction in the level of citric acid. As Bhatnagar et al. [36] stated that during storage the fruit itself might utilize the acid so that the acid in the fruits during storage periods decreases. However, predietry fruits treated with acetic acid had higher acidity throughout the period of study.

Moisture content (%)

The data on moisture content presented in Figure 4 indicated non-significant differences in moisture content among the post harvest treatments at all stages of observation (0, 2, 4, 6, 8, 10, 12 and 14 days of storage) at ambient temperature ($p \leq 0.05$). Acetic acid treatment recorded significantly higher mean moisture content (92.1%) over all other treatments followed by control (91.9%), CaCl₂ treatments

had lowest mean moisture content (91.7%) at ambient temperature of observation. Non-significant differences in moisture content were observed among the post harvest treatments at all stages of observation (0, 2, 4, 6, 8, 10, 12 and 14 days of storage) at cold temperature. Acetic acid treated fruit recorded significantly higher mean moisture content (91.9%) over all other treatments followed by control (91.7%), CaCl₂ treatments had lowest moisture content (91.3%) at cold temperature. The means of the results were subjected to student 't' test. There were statistically significant differences between ambient temperature and cold temperature.

Ascorbic acid content (mg/100 g fr.wt)

The data on ascorbic acid content presented in Figure 5 indicated significant differences in ascorbic acid content among the post harvest treatments at all stages of observation (0, 2, 4, 6, 8, 10, 12 and 14 days of storage) at ambient and cold temperatures ($p \leq 0.05$). Treatment with CaCl₂ recorded significantly higher mean ascorbic acid content (21.84 mg/100 g) over all other treatments followed by acetic acid treated (20.24 mg/100 g), control treatments had lowest ascorbic acid content (17.88 mg/100 g) at ambient temperature. Pre-treatment with CaCl₂ recorded significantly higher ascorbic acid content (22.78 mg/100 g) over all other treatments followed by acetic acid treatment (21.13 mg/100 g) and control (20.45 mg/100 g) at cold temperature. The means of the results were subjected to student 't' test among the storage conditions, significantly higher ascorbic acid content were recorded at ambient temperature compared to cold storage. An increase in ascorbic acid content in fruit is thought to be an indication that the fruit is still in the ripening stage, while a decrease indicates a senescent fruit [37]. In addition, Miller and Evans [38] reported that phenolic substances have been found to play a protective effect on the ascorbic acid. The presence

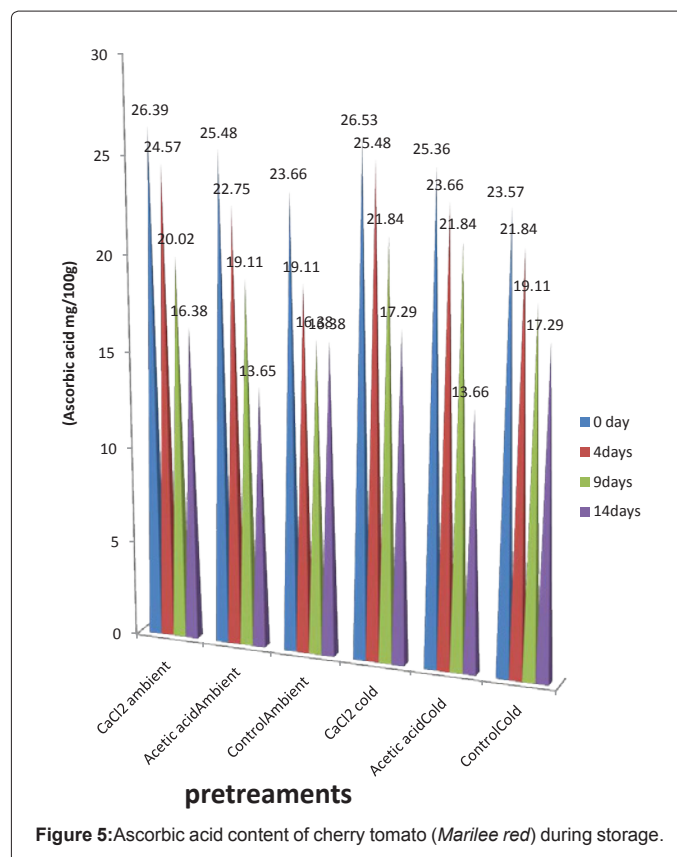


Figure 5: Ascorbic acid content of cherry tomato (*Marilee red*) during storage.

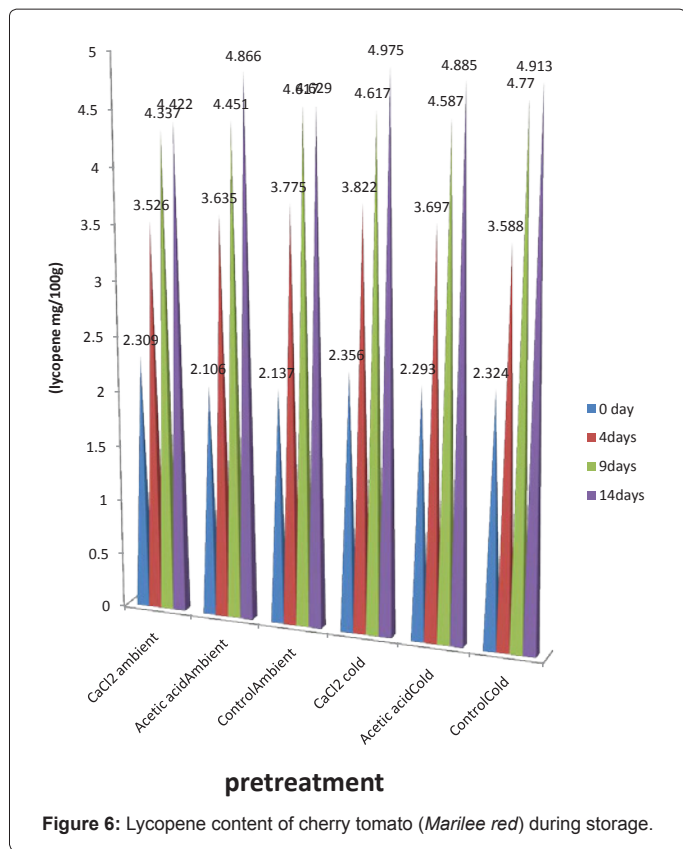


Figure 6: Lycopene content of cherry tomato (*Marilee red*) during storage.

of phenolics in the fruit cells may help to maintain the ascorbic acid content. Tomatoes are rich source of ascorbic acid. The ascorbic acid content of ripe tomato ranges from 15 mg to 23 mg/100 g fruit [35]. Ascorbic acid (vitamin C) content has been found to have a significant role in the assimilation of iron obtained from other sources. It is essential for the formation of normal teeth and bones. Preservation of ascorbic acid content during storage is a difficult task since it undergoes oxidation [39]. An increase in ascorbic acid content in fruit is thought to be an indication that the fruit is still in the ripening stage, while a decrease indicates a senescent fruit [40]. In the present investigation, the ascorbic acid content of fruits was significantly influenced by various post harvest treatments and storage conditions. Ascorbic acid contents significantly decreased during storage. It was also observed that fruits treated with calcium chloride showed the highest ascorbic acid content followed by that of simply packed fruits. Among all treatments, control showed lowest ascorbic acid contents. Subbiah and Perumal [17] also observed higher ascorbic acid values in tomatoes that were treated with CaCl₂ when compared to untreated samples. According to them, CaCl₂ pretreatments in high carbon dioxide atmosphere affect the ripening rate, delaying ascorbic acid production. Loss of ascorbic acid in cold stored tomatoes was significantly slower than air stored tomatoes. Tasdelen and Bayindirli [32] found similar results in ascorbic content during storage of tomatoes.

Lycopene content (mg/100 g. fr. wt)0

Lycopene is the pigment principally responsible for the characteristic deep red colour of ripe tomato fruits. It is the most abundant carotenoid in ripe tomatoes, comprising approximately 80 to 90 per cent of the pigments present [41]. Normally, tomatoes contain about 3 to 5 mg lycopene per 100 g of fruit [42,43]. Lycopene exists

as small globules, in the chromoplasts which are suspended in the tomato pulp throughout the fruit. Lycopene is an efficient antioxidant and quenches highly reactive singlet oxygen radicals and acts as a preventive agent for cancer [44]. Lycopene needs to be protected from excessive heat and extreme pH conditions, exposure to light, oxygen and lipid degrading enzymes in order to prevent its oxidation and isomerization [45]. The data on lycopene content presented in Figure 6 indicates significant differences in lycopene content among the post harvest treatments at all stages of observation (0, 2, 4, 6, 8, 10, 12 and 14 days of storage) at ambient temperature ($p \leq 0.05$). Pretreated tomatoes with CaCl₂ recorded significantly higher lycopene content (3.82 mg/100 g) over all other treatments followed by control (3.79 mg/100 g), acetic acid treatments had lowest mean lycopene content (3.60 mg/100 g) at ambient temperature. Significant differences in lycopene content was observed among the post harvest treatments at all stages of observation (0, 2, 4, 6, 8, 10, 12 and 14 days of storage) at cold temperature ($p \leq 0.05$). CaCl₂ treated fruit recorded significantly higher lycopene content (3.94 mg/100 g) over all other treatments followed by control (3.90 mg/100 g), while those treated with acetic acid had lowest lycopene content (3.87 mg/100 g) at cold temperature. The means of the results were subjected to student 't' test among the storage conditions, cold storage recorded significantly higher lycopene content compared to ambient temperature. In the present investigation, tomato fruits showed a significant increase in lycopene content during the storage period. Chlorophyll degradation and increased lycopene synthesis results in the characteristic colour development during ripening in tomatoes [46]. Cherry tomatoes treated with acetic acid significantly delayed the lycopene biosynthesis. This can be attributed to delay in ripening due to reduced respiration rate. Similar results have been reported by Nguyen [47], and Causse et al. [48] Brandt et al. [49] in tomato.

Total sugar

Significant differences in total sugar content were observed among

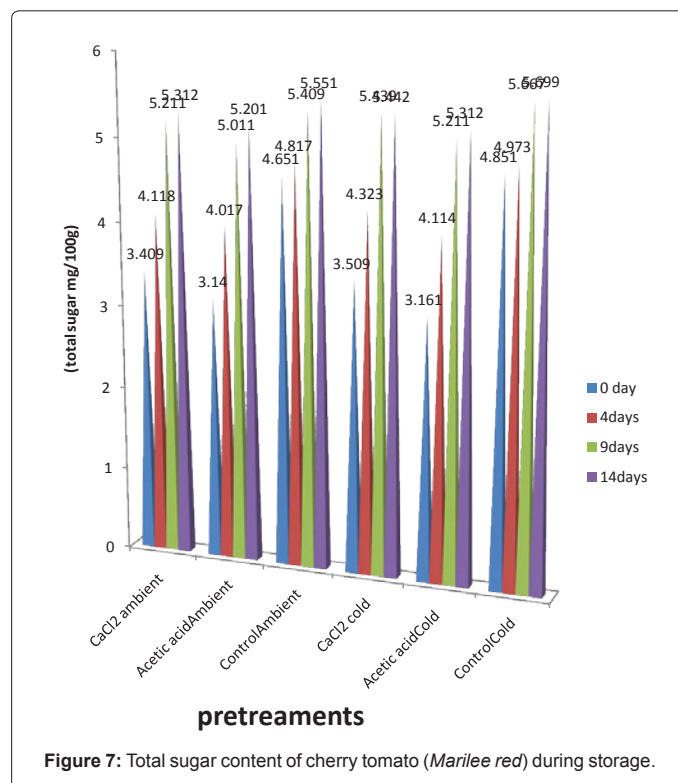


Figure 7: Total sugar content of cherry tomato (*Marilee red*) during storage.

the post harvest treatments at all stages of observation (0, 2, 4, 6, 8, 10, 12 and 14 days of storage) at ambient temperature ($p \leq 0.05$). Control recorded significantly higher mean total sugar content (5.10 mg/100 g) over all other treatments followed by CaCl_2 (4.51 mg/100 g), acetic acid treatments had lowest total sugar content (4.34 mg/100 g) at ambient temperature of observation (Figure 7). Significant differences in total sugar content were observed among the post harvest treatments at 0, 2, 4, 6, 8, 10, 12 and 14 days of storage at cold temperature ($p \leq 0.05$). Control recorded significantly higher total sugar content (5.29 mg/100 g) over all other treatments followed by CaCl_2 (4.67 mg/100 g) and acetic acid treatments (4.44 mg/100 g) at cold temperature. Among the storage conditions, cold storage recorded significantly higher total sugar content compared to ambient temperature.

The means of the results were subjected to student 't' test among the storage conditions, cold storage recorded significantly higher total sugar content compared to ambient temperature. The metabolic breakdown of organic acid into carbon dioxide and polysaccharides into water soluble sugar might be a reason for an increase in the sugar content. The findings of [50] also indicated that starch is completely hydrolyzed into soluble sugar such as glucose, fructose and sucrose as ripening progresses. Their result of sugar content in cherry tomato is in agreement with present findings.

Physical characteristics

The data on physical characteristics (firmness, taste, juiciness, decay, colour, gloss, uniformity, shrivel) are presented in Tables 2, 3 and 4. For these characteristics there were no significant differences between the three pretreatments of cherry tomatoes. The means of the results were subjected to student 't' test. CaCl_2 was best treatment followed by control and acetic acid treatment.

Shrinkage: Shrinkage is one of the indications of deterioration, degrading the quality and reducing the quantity. In the present study shrinkage occurred in all samples both treated as well as un-treated and those stored at different temperatures. The effect of temperature showed clearly that at lower temperature the shrinkage is less while it became more at ambient temperature. However, treated samples showed less shrinkage as compared to un-treated sample. This indicates that with treatment, tomatoes can be stored at a bit higher temperature which is

Characteristics	Days of storage															
	0		2		4		6		8		10		12		14	
	C ₁	A ₂	C	A	C	A	C	A	C	A	C	A	C	A	C	A
Firmness	5	5	5	5	4	4	4	4	4	4	4	4	4	3	3	2
Taste	3	3	3	3	3	3	3	4	4	4	4	4	5	5	5	5
Juiciness	5	5	5	5	5	5	5	5	4	4	4	4	4	4	3	2
Decay	5	5	5	5	5	5	5	5	4	4	4	4	4	4	3	3
Colour	5	5	5	5	5	5	4	4	4	4	4	4	4	4	3	3
Gloss	5	5	5	5	5	5	4	4	4	4	4	3	3	3	3	2
Uniformity	5	5	5	5	5	5	5	4	4	4	4	4	4	3	3	3
Shrivel	5	5	5	5	5	5	5	4	4	4	4	4	4	3	3	2
	CONTROL TEMPERATURE							AMBIENT TEMPERATURE								
F-RATIO	NS							NS								
CD	-							-								
S.Em±	0.26							0.33								

NS-Non significant
1-cold temperature ($10^\circ\text{C}\pm 2$); 2-ambient temperature ($25^\circ\text{C}\pm 2$) and relative humidity ($50\pm 10\%$).

Table 2: Effect of post harvest calcium chloride treatment on keeping quality of cherry tomato (Marilee red).

Characteristics	Days of storage															
	0		2		4		8		10		12		14			
	C ₁	A ₂	C	A	C	A	C	A	C	A	C	A	C	A		
Firmness	5	5	5	5	4	4	4	4	4	3	3	3	3	2	2	2
Taste	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4
Juiciness	5	5	5	5	5	5	4	4	4	3	4	3	3	2	2	1
Decay	5	5	5	5	5	4	4	4	4	4	4	3	4	3	3	2
Colour	5	5	5	5	5	5	5	4	4	4	4	4	4	4	3	3
Gloss	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	2
Uniformity	5	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3
Shrivel	5	5	5	4	5	4	4	4	4	3	4	3	3	2	3	2
	COLD TEMPERATURE							AMBIENT TEMPERATURE								
F-RATIO	NS							NS								
CD	-							-								
S.Em±	0.29							0.36								

NS-Non significant
1-cold temperature ($10^\circ\text{C}\pm 2$); 2-ambient temperature ($25^\circ\text{C}\pm 2$) and relative humidity ($50\pm 10\%$)

Table 3: Effect of post harvest acetic acid treatment on keeping quality of cherry tomato (Marilee red).

Characteristics	Days of storage															
	0		2		4		8		10		12		14			
	C ₁	A ₂	C	A	C	A	C	A	C	A	C	A	C	A		
Firmness	5	5	5	5	5	5	5	5	4	4	4	3	4	3	3	3
Taste	3	3	3	3	3	3	3	3	3	4	4	4	4	5	5	5
Juiciness	5	5	5	5	5	5	4	4	4	4	4	4	3	3	3	2
Decay	5	5	5	5	5	5	5	4	4	4	4	4	4	3	3	3
Colour	5	5	5	5	5	4	5	4	4	3	4	3	4	3	3	2
Gloss	5	5	5	5	5	4	4	4	4	3	4	3	3	3	3	2
Uniformity	5	5	5	5	5	4	5	4	4	4	4	4	4	3	3	3
Shrivel	5	5	5	5	5	4	5	4	4	4	4	4	3	4	3	2
	COLD TEMPERATURE							AMBIENT TEMPERATURE								
F-RATIO	NS							NS								
CD	-							-								
S.Em±	0.27							0.34								

NS-Non significant
1-cold temperature ($10^\circ\text{C}\pm 2$); 2-ambient temperature ($25^\circ\text{C}\pm 2$) and relative humidity ($50\pm 10\%$).

Table 4: Keeping quality cherry tomato (Marilee red) subjected to no pretreatment.

energy saving. Although samples stored at higher temperature showed more shrinkage, but still the treated sample exhibited less shrinkage as compared to un-treated [51].

Firmness: The most important factor next to visual appearance in tomato quality is firmness which is closely associated with ripeness stage. Most consumers prefer firm fruits which do not lose too much juice when sliced and which do not have tough skins. Firmness affects susceptibility of tomatoes to physical damage and consequently their shipping ability [50]. The textural quality of tomatoes is influenced by skin toughness, flesh firmness, and internal fruit structure which vary greatly among cultivars.

All fruit softened progressively during storage, firmness of tomato was influenced by temperature and storage time. Firmness decreased during storage at both temperatures. Treatment with CaCl_2 resulted in higher firmness compared to others. Calcium dips retarded the metabolism as indicated by the slow ripening rate. Calcium chloride improves the firmness of tomato fruits. All the treatments delayed ripening and improved the storage life and quality significantly.

Flavour: Flavour is a combination of taste and aroma sensations. The four tastes, sweet, sour, salty, and bitter are perceived by certain regions of the tongue, while volatiles are perceived by the olfactory nerve endings of the nose [52]. Tomato flavour involves perception of the tastes and aromas of many chemical constituents. Sugars, acids and their interactions are important to sweetness, sourness, and overall flavour intensity in tomatoes [53]. The characteristic tomato flavour, thus, is produced by the complex interaction of the volatile and non-volatile components [54,55]. High sugars and relatively high acids are required for best flavour. High acids and low sugars will produce a tart tomato while high sugars and low acids will result in a bland taste. When both sugars and acids are low, the result is a tasteless, insipid tomato. In the present study highest flavour score was observed in the fruits treated with CaCl_2 followed by control. This may be due differential ripening resulting in better sugar to acid ratio which determines taste [56]. Progressive deterioration in flavour score were observed throughout the period of storage. Differences were seen in the different pretreatments and storage conditions. Prolonged packaging sometimes led to the anaerobic respiration causing the formation of ethanol and aldehydes contributing to undesirable aroma [57]. Aromas have important influence on food preferences [58] and as these scores are the result of decision of panel of judges, the loss of volatiles may have led to the lower flavour scores.

Colour: External colour of tomatoes is the result of both flesh and skin colours. A pink tomato has a colourless skin and red flesh while a red tomato has a yellow skin and red flesh. Fruits of some tomato genotypes have pink, purple, orange, dark yellow, light yellow, yellow with pink end, and other colours. However, most consumers prefer the deep, uniform red-coloured tomatoes. In the present study highest colour score was observed in the fruits treated with CaCl_2 followed by control. Colour is an indicator of tomato ripeness stage. Several subjective rating scales and colour charts have been developed for classifying ripeness, included in the U.S. Standards [59]. Objective methods of tomato colour evaluation include light reflectance measurement [60] and light transmittance techniques [36,61].

Shelf life: Organoleptic evaluation in the present study in terms of colour, aroma and texture differed significantly between the different post harvest treatments and storage conditions over the storage period. Organoleptic scoring was high for fruits stored in CaCl_2 . However, the fruits kept in cold storage suffered chilling injury at the end of storage period, with a reduction in the firmness and aroma. But, the fruits packed and kept in cold storage had a reduced chilling injury. A better avoidance of chilling injury was observed in cold stored CaCl_2 fruits. The fruits maintained a better aroma and texture and delay in colour development was observed. This is in conformity with the studies of Nirupama et al. [62] and Speirs et al. [57] in tomatoes, Smith and Reyes [63] in celery, Escalona et al. [64] in kohlrabi. Extension of shelf life by CaCl_2 has also been observed by many workers viz., Hong and Gross [65] and Tasdelen and Bayindirli [32] in tomato, Lizana et al. [66] in mangoes.

Conclusion

The obtained results indicated that acetic acid, calcium chloride and control play a very effective role in controlling the weight loss, shrinkage, colour, flavor, firmness percentage and other compositional changes such as titratable acidity, total soluble solids, total sugars, total lycopene, ascorbic acid and moisture content of cherry tomatoes stored at both ambient and cold temperature. Calcium chloride treatment had delayed the ripening process more effectively and with a minimum

quality loss, as compared to the control sample which had greater compositional changes with maximum quality loss during storage at ambient temperature. The shelf life of cherry tomato could be extended more than 15 days without excessive deterioration in quality by treating the fruits with calcium chloride. Among all the tested treatments, calcium chloride treatment benefits storage life capacity and maintains quality characteristics as compared to the fruits of control set. Thus it may be concluded that the post harvest chemical treatments selected for the present study have the potential to extend the shelf life of tomato while retaining its nutritional quality.

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