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Effect of different precooling techniques on the storage behavior of tomato fruits at low and ambient temperatures

Bhaumik B Patel*, Roy F Sutar, Sonali C Khanbarad and VB Darji[1]

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Abstract

A comparative study was carried out to determine the efficacy of different precooling treatments at three different cooling media temperatures on the shelf life of tomato fruit (cv. Narendra-2) when stored under low (13°C) and ambient temperature. The precooling with chilled water dipping took least time (<0.33 h) compared to hydrocooling (<0.41 h) and forced air cooling (<1.45 h) to remove field heat of tomato fruit. The maximum increase in shelf life up to 18 days was observed for treated fruit as compared to control under low temperature storage. For samples treated at 4°C, forced air cooling had a maximum shelf life of 27 days under ambient storage compared to control (18 days). The stored samples were periodically analyzed for various physico-chemical parameters. After 12 days storage maximum physiological loss in weight 7.68%, spoilage 31.08%, firmness 468.64 N, total soluble solids 4.4%, titratable acidity 0.37% and lycopene content 4.20 mg/100g was observed.

Key words: Precooling, Lycopene content, Shelf life, Storage

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most widely grown vegetable in the world and ranks third in priority after potato and onion in India (Luthria *et al.* 2006). Tomato fruits are consumed fresh in salads or cooked in sauces, soup and meat or fish dishes. Tomato fruits are processed into purees, juices and ketchup. Canned and dried tomatoes are economically important processed products.

Tomatoes contribute to a healthy, well-balanced diet. They are rich in minerals, vitamins, essential amino acids, sugars and dietary fibers. Tomato contains much vitamin B and C, iron and phosphorus. Lycopene is considered the predominant carotenoid of tomato fruit (80-90%), followed by â-carotene (5-10%) (Lenucci *et al.* 2006). Most importantly, tomato consumption has been shown to reduce the risks of cardiovascular disease and certain types of cancer, such as cancers of prostate, lung, and stomach (Canene-Adams *et al.* 2005). The high water content of tomatoes makes them vulnerable to post-harvest losses. Harvesting on time and proper post-harvest treatment of the fruit is very important. Good temperature management is the most effective way to reduce post-harvest losses and preserve the quality of fruits and vegetables. Products harvested from hot fields often carry field heat and have high rates of respiration. Rapid removal of field heat by precooling is effective in quality preservation and widely used for highly perishable fruits and vegetables. Currently used precooling methods include room cooling, forced-air cooling, water cooling, vacuum cooling and package icing.

Tomato being a climacteric fruit, the start of ripening is accompanied by a rapid rise in respiration rate called 'respiratory climacteric' during which oxidative breakdown of complex substrates occur, ageing follows, leading to product deterioration. Also, tomatoes being fleshy fruits, continue to lose water after harvest. This results in a wilted, dull appearance that reduces the consumer appeal and freshness and eventually becomes unmarketable. According to Kumar *et al.* (2004) postharvest losses of tomato is about 20-35% of total production. Storage of fruit for extended availability and minimization of market glut is very much important in tomato. Pre-cooling of freshly harvested fruits reduces respiration rate, microbial activity, water loss and decay and thereby it helps in maintaining the quality and prolongs shelf life of the fruits. Thus, a study was carried out to study the effects of various precooling techniques and

College of Food Processing Technology and Bio-energy, Anand Agricultural University, Anand-388110, Gujarat

[1]Department of Agricultural Science, College of Agricultural Information Technology, Anand Agricultural University, Anand-388110, Gujarat

*Corresponding author, E-mail: patel13_13@live.com

various storage conditions on shelf life of tomato fruit based on the physico-chemical changes in the tomato fruits during storage.

Materials and Methods

For the present study matured, breaker stage tomatoes (cv. Narendra-2), freshly harvested from the local fields of village Malataj, Gujarat was selected on the basis of size, color, and absence of external injuries. The fruits were washed with plain water to remove adhered soil and latex. Fruits were then subjected to three different precooling treatments viz. hydrocooling, forced air cooling and chilled water dipping at three different cooling temperatures (4, 6 and 8°C). Tomato fruits were precooled till the desired final product temperature 10°C was achieved. Fruits without precooling served as control. The total time required to precool tomato fruits using different precooling methods was recorded. Also for the determination of the precooling rate, temperature ratio, cooling coefficient and half cooling time were calculated as per method given in detail by Brosnan and Sun (2001). Two sets of 5 kg tomato for each treatment were subjected to various precooling treatments and then stored under two different storage conditions, i.e. ambient temperature and low temperature storage (13 °C). Various precooling treatment combinations obtained were T1, T2 and T3 viz. Hydrocooled at 4, 6 and 8°C respectively, T4, T5 and T6 viz. Forced air cooled at 4, 6 and 8°C respectively, and T7, T8 and T9 viz. Chilled water dipped at 4, 6 and 8°C respectively. The 4, 6 and 8°C were cooling media temperatures and T10 was Control without precooling treatment. Treated and control samples were immediately transferred to storage chamber.

Precooling systems: Three different precooling systems viz. Hydrocooling, Forced air precooling and Chilled water dipping as described in detail by Patel *et al.* (2015) were used in the present study. The temperature at the center of the fruit was monitored and recorded using RTD type PT 100 temperature sensors connected to a digital datalogger (Datataker Make, DT-600). The temperature was recorded at an interval of 5s till the temperature of the fruit at the center reaches to 10°C. RTD based thermostatic control system was used to maintain the temperature of cooling media. Periodical evaluation of stored samples was carried out for Physiological loss in weight (PLW) (Karki 2005), Spoilage (Behboudian and Tod 1995), Firmness (Arazuri *et al.* 2007), Total soluble solids (TSS) (Jha *et al.* 2005), Titratable acidity (AOAC 1975), Lycopene content (Thimmaiah 1999). All the quality measurements were made at every three day interval for both storage conditions throughout the shelf life.

Statistical analysis: The mean values generated from the analysis of each of the quality attribute obtained from three replications during the experimentation were subjected to statistical analysis using completely randomized design (CRD). ANOVA tables were prepared and the significance of the influence of each parameter on the specific characteristic was tested at 5% significance level.

Results and Discussion

Cooling rate of tomato fruits: Precooling characteristic is a representation of the total cooling time, i.e. time required to precool the tomato fruits from field temperature to desired cooling temperature. The total time taken for precooling by different methods, temperature ratio, cooling coefficient and half cooling time are shown in Table 1. It was observed that the precooling methods and precooling temperature has significant effect on the total precooling time. Chilled water dipping took least time to precool tomato fruits at desire temperature among all other precooling method followed by hydrocooling and forced air cooling. Also, the results indicate that in case of chilled water dipping, the value of cooling coefficient was higher and half cooling time was less while the temperature ratio and half cooling time was higher and the cooling coefficient was lower in forced air cooling. This is due to the higher heat transfer coefficient of water than that of air. In systems with chilled water, coefficient of convective heat transfer can be up to six times higher compared to the cooling system with forced air (Barbara *et al.* 2003). In case of hydrocooling system the water was sprayed on stationary fruits and there was no complete contact between the fruits and the cooling media. However, as

Table 1: Precooling characteristics of tomato fruits

Treatments	Total precooling time (hr)	Temperature ratio	Cooling coefficient	Half cooling time (hr)
T1	0.33	0.26	-4.08	0.17
T2	0.36	0.18	-4.76	0.14
T3	0.41	0.09	-5.87	0.12
T4	0.9	0.26	-1.5	0.46
T5	1.41	0.20	-1.14	0.61
T6	1.45	0.11	-1.52	0.46
T7	0.14	0.27	-9.35	0.07
T8	0.27	0.19	-6.15	0.11
T9	0.33	0.10	-6.98	0.1

All above values are mean of three replications the water was flowing over the fruits, the heat transfer between cooling water and fruits was faster than the forced air cooling. Also, it was noted that for all three precooling methods, the rate of cooling was higher at 4°C cooling media temperature compared to 6 and 8°C. This is due to the difference between the temperature of cooling media and temperature of the fruit.

Physiological loss in weight (PLW) of tomato: For all the treatments under both storage conditions, PLW of tomato fruits increased throughout shelf life and it was maximum at the end of shelf life. Table 2 shows the results of precooling treatments and different storage conditions on physiological loss in weight of tomato at the end of 12 days storage. Weight loss of fresh tomatoes is primarily due to transpiration and respiration (Jha and Matsuoka 2002). PLW was lower under low temperature storage than the ambient storage at the end of shelf life. Treatment T4 had minimum PLW (1.35%) on the 12th day of storage under low temperature storage and all treatments were significantly different. PLW was varied from 1.35% to 7.68% among the various treatments on the 12th day of storage.

Table. 2: PLW in treated fruits under different storage conditions after 12 days storage

Storage condition ?	PLW (%)	
Treatment ?	Low temperature storage	Ambient storage
T1	2.10	7.52
T2	2.10	7.22
T3	1.75	6.00
T4	1.35	5.11
T5	1.80	5.17
T6	1.39	4.71
T7	2.22	7.68
T8	1.77	7.52
T9	2.30	7.50
T10	2.45	5.47
S.Em	T*ST = 0.040	
CD (p=0.05)	T*ST = 0.114	
CV% = 1.65		

All above values are mean of three replications

Fruits stored under low temperature had a low weight loss, as temperature effects vapour pressure difference between fruit and surrounding air and increases water retention in the fruit (Tasdelen and Bayindirli, 1998). Similar results were reported by Bussel and Kenigsberger (1975) in green bell pepper and by Efiuvwevwere and Oyelade (1991) in oranges. Salunkhe *et al.* (1991) indicating that higher temperature increases the difference in vapour pressure between the fruit and the surrounding. This difference is one of the driving factors that induce a faster moisture transfer from the tomato fruit to the surrounding air (Seyoum and Woldetsadik, 2004) leading to higher weight loss under ambient temperature storage. This result is in confirmation with the study of Castro *et al.* (2006).

Spoilage of tomato fruits: The results of spoilage on the 12th day as influenced by precooling treatments and storage temperature is depicted in Table 3. It was observed that the spoilage in fruits gradually increased in all storage conditions with the advancement of storage period. The spoilage was maximum for treatment T10 (31.08%) and it was at par with treatments T9 (25%) and T2 (26.67%) under ambient storage at the end of 12 days. Treatment T1 had minimum (5%) spoilage under low temperature storage at the end of 12 days and was at par with treatments T2, T3, T4, T5, T6, T7, T8 and T9 under low temperature storage and with treatments T3, T4, T5 and T6 under ambient storage at 5% significance level. The spoilage was slower under low temperature storage than ambient storage. This result is in agreement with the study of Castro *et al.* (2006) which signifies that the temperature plays an important role in the spoilage of the fruits. The effectiveness of precooling treatment and low temperature storage in extending the shelf life of the breaker mature tomato may be attributed to the low temperature, which has a delaying effect on the onset of respiratory climacterics (Wills *et al.* 1998).

Table 3: Spoilage in treated fruits under different storage conditions after 12 days storage

Storage condition ?	Spoilage (%)	
Treatment ?	Low temperature storage	Ambient storage
T1	5.00	21.25
T2	8.89	26.67
T3	6.76	6.25
T4	5.88	7.35
T5	10.00	8.57
T6	7.50	7.14
T7	7.50	21.25
T8	8.33	18.75
T9	7.29	25.00
T10	14.06	31.08
S.Em	T*ST = 2.280	
CD (p=0.05)	T*ST = 6.516	
CV% = 29.14		

All above values are mean of three replications

Firmness of tomato: The results of firmness indicates that after 12 days storage, treatment T8 stored under low temperature storage retained maximum firmness of 468.64 N where as T10 stored under ambient storage had minimum firmness of 208.28 N. Fig. 1 represents

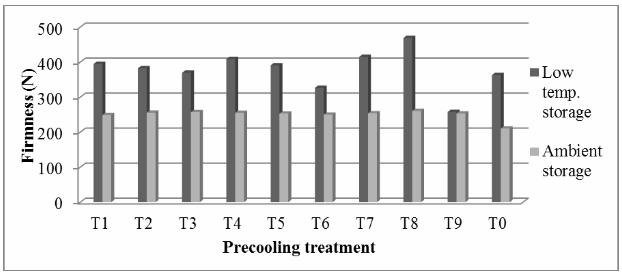

Fig. 1: Firmness of treated tomato fruits after 12 days storage

the effect of precooling treatments and different storage conditions on the spoilage of tomato at the end of 12 days storage. It was observed that as storage period increased firmness decreased for both storage conditions. Under ambient storage firmness of tomato fruit decreased rapidly as compared to low temperature storage and all treatments were significantly different at the 5% significance level. These data are in agreement with Vanegas (1987), who demonstrated that tomato reaches the maturity sooner and then loses its firmness faster at ambient temperature than at lower temperatures. Desmet *et al.* (2003) found that tomatoes at harvest were less susceptible to puncture injury than after storage for several days. The softening of the fruit and the loss of the skin strength during storage are factors which can explain the increase of susceptibility to lose firmness during storage.

Total soluble solids of tomato: With an increase in storage period TSS of tomato was increased under both storage conditions. TSS was minimum for treatment T7 (3.25°bx) which was at par with T2 (3.35°bx) and it was maximum for T10 (4.40°bx) under ambient storage at the end of 12 days storage. Increase in TSS during storage might be associated with the transformation of the pectic substances, starch, hemicellulose or other polysaccharides in soluble sugar and also with dehydration of fruits (Hoda *et al.* 2000). It was found that TSS increased at a slower rate under low temperature storage than at ambient storage. This result is in confirmation with the result of Getinet *et al.* (2008). In relation to this, Xie *et al.* (2006) indicated that low temperature storage is the most popular storage condition for maintaining postharvest quality of tomato fruit.

Titratable acidity of tomato: The data on titratable acidity (TA) as influenced by precooling treatments and storage conditions is depicted in Fig. 2. It was observed that acidity decreased with advancement of ripening and storage period. After the storage of 12 days, it was observed that acidity was minimum in T1 (0.17%) under low temperature storage where as it was maximum in

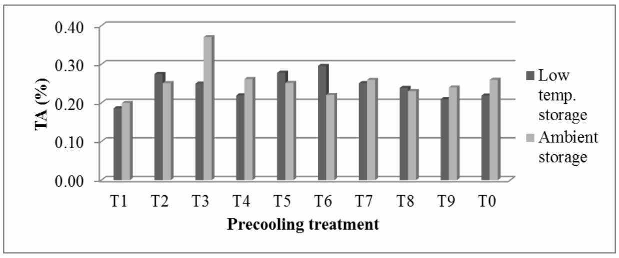

Fig. 2: TA of treated tomato fruits after 12 days storage

T3 (0.37%) under ambient storage and all treatments were significantly different at the 5% significance level. The reduction in acidity during storage might be due to the conversion of organic acid into sugar and their derivatives or their utilization in respiration (Bhullar *et al.* 1981). According to Toor and Savage (2006), high acidity is responsible for the stability of ascorbic acid in fruits.

Lycopene content of tomato: The effect of precooling treatments and different storage conditions on the lycopene content of tomato at the end of 12 days storage presented in Fig. 3. For both storage conditions, it was observed that the lycopene content increased with the increase in the storage period and was maximum at the end of the shelf life. Maximum lycopene content was found in treatment T9 (4.20 mg/100g) which was at par with treatments T4 and T5 under ambient storage at 5% significance level. Minimum lycopene content was found in treatment T4 (1.87 mg/100g) under low temperature storage. The increased levels of lycopene in tomato during storage might be due to ripening advancements of tomato fruits and conversion of chloroplasts to chromoplasts. Uniform dark red color development was observed in treated fruits stored under low temperature storage, whereas under ambient storage

Table 4: Shelf life of treated fruits under different storage conditions

Storage condition ? / Treatment ?	Shelf life (No. of days)		
	Low temperature storage	Ambient storage	Mean
T1	30	12	21
T2	30	15	22.5
T3	39	18	28.5
T4	33	27	30
T5	30	24	27
T6	30	18	24
T7	27	15	21
T8	33	15	24
T9	30	12	21
T10	21	15	18
Mean	30.3	17.1	

All above values are mean of three replications

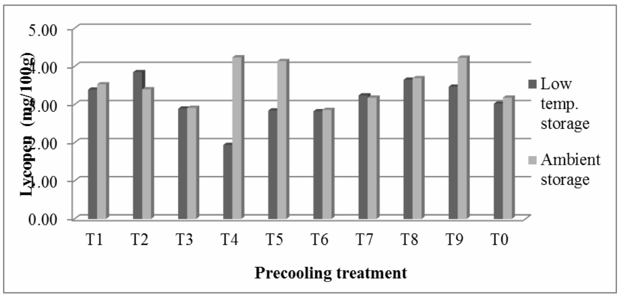

Fig. 3: Lycopene content of treated tomato fruits after 12 days storage

the color development was yellowish red to red. The increasing in redness of tomatoes during ripening is due to lycopene accumulation, in association with the internal membrane system (Grierson and Kader, 1986). This effect has been reported earlier by Ajlouni *et al*. (2001). The peel color changes from green to yellow could be correlated with maturity (Jha *et al.* 2007).

Shelf life of tomato: The results of shelf life of tomato for precooling treatments and different storage conditions are shown in Table 4. Under ambient storage, treatment T4 had a maximum shelf life of 27 days while lowest shelf life of 12 days was recorded in the treatment T1 and T9. The maximum shelf life of 39 days was observed in the treatment T3 and the lowest shelf life was recorded in the T10 i.e. 21 days under low temperature storage. Thus, treatment T4 was found beneficial giving 12 days advantage over the control under ambient storage, whereas under low temperature storage, treatment T3 was found beneficial giving 18 days advantage over the control. Paull (1999) revealed that low temperature has been used to extend the shelf life of temperate fruits and vegetables since antiquity, while the negative effect of low temperature (<10°C) on the shelf life of tropical fruits.

* The above values are mean of three replications

From the present study, it can be concluded that hydrocooling of tomato fruits (cv. Narendra-2) at 8°C followed by low temperature storage is the best treatment for the precooling of tomato as it gave maximum shelf life and the best storage in terms of high marketability and low physiological loss in weight. Thus significant effect of precooling treatment followed by low temperature storage on extension of shelf life of tomato fruits was observed, which is advantageous for safe transient and on farm storage of the commodity. For ambient storage condition, 4°C, forced air cooling is the best precooling treatment as it gave maximum shelf life of 27 days having 12 days advantage over control, proving significant effect of the treatment. Along with aid in extension of shelf life, precooling treatment and low temperature storage has the advantage of better retention of nutritive as well as the market value of tomato fruit.

सारांश

टमाटर की किस्म नरेन्द्र–2 के फलों का विभिन्न पूर्वशीतन शोधन का तीन विभिन्न ठंडा माध्यम तापमान का स्वजीवन ज्ञात करने के लिए भण्डारण निम्न तापक्रम (13 डिग्री सेन्टीग्रेड) तथा परिवेशी तापमान पर रखकर तुलनात्मक अध्ययन किया गया। पूर्वशीतन के साथ अति ठंडा पानी में डुबोने हाइड्रोकुलिंग (<0.41 घण्टे) की तुलना में कम समय (<0.33 घण्टे) लगे तथा बलपूर्वक हवा शीतन (<01.45 घण्टे) टमाटर के फलों के प्रक्षेत्र गर्मी को दूर करने में लगा। नियन्त्रित कम तापमान भण्डारण की तुलना में अधिकतम स्वजीवन समता 18 दिनों तक शोधित करने पर पाया गया। चार डिग्री सेन्टीग्रेड तापमान पर बलपूर्वक हवाशीतन से स्वजीवन क्षमता 27 दिनों तक पायी गयी जबकि परिवेशी भण्डारण नियंत्रक में मात्र 18 दिन रहा। भण्डारित प्रतिदर्शों को भौतिक–रासायनिक गुणों के लिए समय–समय पर विश्लेषण किया गया। भण्डारण के 12 दिनों उपरान्त अधिकतम दैहिकीय नुकसान भार (7.68 प्रतिशत), रद्दी (31.08 प्रतिशत), कसावट (468.64 एफ), कुल विलेप ठोस (4.4 प्रतिशत), गणनीय अम्लता (0.37 प्रतिशत) तथा लाइकोपिन की मात्रा 4.20 मि.ग्रा/100 ग्राम पाया गया।

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