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Postharvest ripening and quality of tomato (*Solanum lycopersicum* L.) during cold storage

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Abstract

The present studies were conducted to obtain information about the effect of ethephon and ethylene gas on ripening and quality of winter tomato (*Solanum lycopersicum* L.) using hybrid Avinash-3. The first experiment comprised of treatment of mature green tomatoes with different concentrations of aqueous solution of ethephon (500, 1000 and 1500 ppm) for 5 minutes. The fruits were packed in plastic crates and kept in storage room at 20±1°C and 90-95% RH. The second experiment comprised of exposing the mature green tomatoes to ethylene gas (100 ppm) inside the ripening chamber for 24 hours (20±1°C and 90-95% RH) and thereafter kept in the ripening chamber maintained at 20±1°C and 90-95% RH. The one lot of fruits was not treated and kept as control. The physico-chemical parameters of fruits from mature green to senescent stage of maturation were analyzed. The ethylene gas (100 ppm) treatment registered the highest ripening percentage. The ripening and rotting percentage increased with increase in the concentration of ethephon (500-1500 ppm) and with the duration of days for which the fruits were kept for ripening. The titratable acidity of tomato fruits experienced a linear decline but ascorbic acid and lycopene content registered an increase with the advancement of ripening period irrespective of any treatment. The tomato fruits harvested at green mature stage get successfully ripened in 9 days with application of ethephon (500, 1000, 1500 ppm) but the rotting was more than 14 per cent till 9th day in Hybrid-1001 which makes fruits unmarketable. Therefore, the application of ethephon for ripening is not a good option. Treatment with ethylene gas (100 ppm) resulted in adequate ripening of fruits after 9 days with uniform red colour, desirable firmness, minimum rotting and acceptable quality and therefore this treatment is better over ethephon. In control fruits similar results of ripening, firmness, rotting and quality were observed as in case of ethylene gas (100 ppm) treatment but the fruits get longer time (11 days) to uniformly ripen.

Keywords: Ethephon, ethylene gas, ripening, tomato, quality

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Introduction

Tomato (*Solanum lycopersicum* L.) is a important vegetable crop of the world including tropical, sub-tropical and temperate regions. Worldwide tomato ranks third in area and production after potato and sweet potato but ranks first among processed vegetables. Tomato is a rich source of vitamin A and C and is referred as "poor man's orange'. Among fruits and vegetables, tomato ranks 16th as a source of vitamin A and 13th as a source of vitamin C. Lycopene that imparts red colour to ripe tomatoes is reported to possess anti-cancerous properties. It also serves as an anti-oxidant as the â-carotene functions to help prevent and neutralize free radical chain reactions and ascorbic acid is an effective scavenger of superoxide, hydrogen peroxide, singlet oxygen and other free radicals.

The colour and quality of ripe tomatoes are important considerations to the consumer and hence to the commercial grower. During the growth and development period, there are many chemical and physical changes occurred in tomato that have an impact on fruit quality and ripening behaviour after harvest. Tomato ripening is characterized by loss of chlorophyll and rapid accumulation of carotenoids, particularly lycopene, as chloroplasts are converted to chromoplasts (Khudairi 1972). However, ripening is a problem in tomato during winter months (December- Mid February) due to foggy weather and low temperature which does not allow tomatoes to mature themselves on the plant (Gonzalez 1999). The low temperature also slows down the degradation of chlorophyll and synthesis of lycopene (Koskitalo and Omroh 1972). Such conditions interfere with colour, texture and flavour development of the fruits. As a result, tomato fruit fail to ripen and develop full colour and flavour, irregular (blotchy) colour development, premature softening, surface pitting, browning of seeds and increased decay, especially black mold caused by *Alternaria* sp. Ripening agent like calcium carbide is often utilized in India to speed up the ripening process during winter months. As the use of calcium carbide is prohibited in India due to health reasons (PFA 2003), an alternative of this chemical is required. In this direction, ethylene gas and ethephon chemical have been found to accelerate the ripening of mature green tomato fruits and has already been used commercially in other countries for uniform and early ripening of tomatoes (Kasmire 1981; Cantwell 1994; Gonzalez 1999; Sargent 2005). But in Indian context, there is need to standardize the method of ripening of winter tomatoes by use of ethylene gas and by use of safe chemicals like ethephon so that uniform ripened tomato can fetch remunerative price in the domestic and export markets. Considering these points in mind, the present studies were undertaken.

Materials and Methods

Fruit materials: The tomato fruits of cv. Avinash-3 (Syngenta India Pvt. Ltd.) were harvested at mature green stage in the first week of February from the field of progressive farmer of district Ludhiana (Punjab) and were pre-cooled by using forced air cooling system. After pre-cooling, the bruised and diseased fruits were sorted out and healthy, uniform sized fruits were selected for the present study. Ten tomato fruits were randomly taken from the lot of experimental fruits and their physico-chemical properties were assessed before giving the ripening treatments.

Tomato fruits of each hybrid were divided into five lots. The first lot was exposed to ethylene gas (100 ppm) inside the ripening chamber for 24 hrs (20 ± 1^{0}C and 90-95% RH) using portable ethylene generator (Model 9002, Ventech Agrionics, South Africa). The 2nd, 3rd and 4th lot was treated by immersion in a solution of Ethephon {(2-chloroethyl) phosphonic acid} at 3 different concentrations of 500 ppm, 1000 ppm and 1500 ppm for 5 minutes. The 5th lot was not treated and kept as control. The surface of fruit was air dried and kept in plastic crates and stored at 20 ± 1^{0}C and 90-95% RH in walk-in ripening room. The data on various physico-chemical attributes were recorded from 3rd day after treatment at one day interval for the period of 13 days.

Fruit quality analysis: Total soluble solids (TSS) concentration of fruit flesh was determined by an Erna Hand refractometer (Tokyo, Japan) and results are reported as °Brix at 20°C. Titratable acidity (TA) in pulp was assayed based on the method of Bassetto *et al.* (2005). Briefly, 10 g of fresh fruit sample was diluted with 90 mL of water, titrated with 0.1 N sodium hydroxide to pH 8.1 and expressed as a percentage of citric acid. For ascorbic acid analysis, 10 g of fresh fruit sample was homogenized with 25 ml metaphosphoric acid acetic acid (MPA) solution and filtered after making the volume of 100 ml with MPA (AOAC 1990). Took 10 ml of the filtrate and titrated it against standard indophenol solution. The end point was indicated by the appearance of light pink colour, which persisted for about 15 seconds. The reading of the standard indophenol solution used for 10 g of the sample was noted and expressed as milligram ascorbic acid per 100 gm of fresh weight. Ascorbic acid was calculated by following formula: V x S x D, Where V = Volume of standard indophenol solution used for this sample, S = Standardization value (mg ascorbic acid/ ml of indophenol solution) and D = Dilution factor. Dilution factor was calculated by following formula: A / (B x C) x 100, where A= Volume made, B= Volume of aliquot taken and C= weight of sample taken.

For lycopene content analysis, 20 g of fresh fruit sample was extracted with 40-50 ml acetone in 4-5 lots. Thereafter filter it and evaporate acetone to dryness. Add petroleum ether to the residue and make volume to 25 ml and read optical density (OD) at 505 nm at the absorption low colorimeter (AOAC 1990). Lycopene content was calculated by following formula: A / B x OD at 505 nm, where A is the final volume made (25 ml) and B is the quantity of sample taken in gram (20g). The results were expressed as mg per 100g fresh weight.

Fruit firmness, physiological loss in weight, colour, ripening and rotting percentage: The fruit firmness of randomly selected fruits (three from each replication) was measured with the help of Texture Analyzer (Model TA-Hdi, Make Stable Microsystem, UK) using stainless probe of 2 mm diameter and results were expressed in g force. The per cent loss in weight after each storage interval was calculated by subtracting final weight from the initial weight of the fruits and appraisals were made for physiological loss in weight. The physiological loss in weight was calculated on fresh weight basis by following formula: (A - B) /A x 100 where A is the fruit weight just before storage and B is the fruit weight after special storage period. For colour determination of each sample, the reflectance spectra were measured at 2 different points on the fruit surface and then the mean reflectance spectrum was obtained. These measurements were taken with colour difference meter (model: Mini Scan XE Plus, Hunter Lab, USA) and expressed as L, a, b Hunter colour values (Hunter 1975). The ripening percentage of the fruits was estimated by counting the total number of ripened fruits on the basis of their appearance and desirable colour with the help of tomato colour chart and results were expressed in per cent. Ripening percentage is calculated by the following formula: A / B x 100, where A is the number of fully ripened fruits and B is the total number of fruits. The rotting percentage of the fruits was estimated by counting the total number of rotten fruits on the basis of their appearance and results were expressed in per cent. Ripening percentage is calculated by the following formula: A / B x 100, where A is the number of rotten fruits and B is the total number of fruits.

Statistical Analysis: The results obtained from the present investigation were subjected to statistical analysis as suggested by Singh *et al.* (1991). The mean of the treatments was compared for statistical differences at 5%.

Results and Discussion

Physiological loss in weight (PLW): There were significant differences among the various ripening treatments with regard to Physiological loss in weight (Table 1), which, in general increased during ripening period. The PLW of the tomato fruit was also found to increase with the increase in the concentration of ethephon during the ripening period. The lowest mean PLW (3.09%) was observed in the untreated (control) fruits which was followed by the ethylene gas treatment (4.55%) and these were found to be statistically significant as compared to other treatments. On the other hand, the highest mean PLW (5.90%) was observed in fruits treated with 1500 ppm ethephon. During different ripening period, untreated fruits recorded the lowest weight loss ranged between 0.87 to 5.10 per cent from 3 to 13 days ripening period, respectively as compared to ethephon 1500 ppm treatment where PLW ranged from 2.33 to 8.23 per cent during same interval. The ethylene gas treatment (100 ppm) also recorded the low mean PLW (4.55%) and was found to be statistically significant as compared to other treatments. As the ethephon concentration increased, the ripening percentage increased due to the rise in the respiratory climacteric, thus the loss of moisture from the fruits increased owing to more weight loss of fruits as compared to control. The increase in PLW during ripening of tomato fruits with ethephon and ethylene gas application may be due to upsurge in respiration rate of the fruits (Kretchman and Short 1972, 1978). Khedkar *et al.* (1981) and Mahajan *et al.* (2010) also

Table 1. Effect of ethephon treatments and ethylene gas on chemical properties of tomato during storage (20±1°C and 90-95% RH)

Treatment	3D	5D	7D	9D	11D	13D	Mean	LSD (p = 0.05)
Physiological loss in weight (%)								
Ethephon (500 ppm)	1.57	3.00	5.27	5.90	6.93	7.23	4.98	Treatment (T)= 0.12
Ethephon (1000 ppm)	2.13	4.37	5.43	6.33	7.23	7.57	5.51	Storage periods (S)=0.14
Ethephon (1500 ppm)	2.33	4.57	5.87	6.57	7.80	8.23	5.90	T x S = 0.31
Ethylene gas (100 ppm)	1.40	2.97	4.50	5.50	6.02	6.90	4.55	
Control	0.87	1.93	2.63	3.73	4.30	5.10	3.09	
Mean	1.66	3.37	4.74	5.61	6.46	7.01		
Fruit firmness (g force)								
Ethephon (500 ppm)	924.72	903.85	859.22	808.38	750.85	719.97	827.83	Treatment (T)= 15.89
Ethephon (1000 ppm)	910.42	897.22	835.35	779.01	724.88	701.22	808.02	Storage periods (S)=18.80
Ethephon (1500 ppm)	900.91	875.73	803.67	746.60	670.60	650.03	774.59	
Ethylene gas (100 ppm)	963.62	935.26	906.96	851.62	813.02	782.67	875.53	T x S = NS
Control	1039.51	990.42	975.64	940.66	881.24	842.08	944.93	Initial value at harvest = 1055.22 g force
Mean	947.84	920.50	876.17	825.25	768.12	739.19		
Ripening (%)								
Ethephon (500 ppm)	22.28	40.60	60.94	77.08	84.81	88.22	62.32	Treatment (T)= 1.24
Ethephon (1000 ppm)	25.40	42.12	67.39	79.25	86.06	90.99	65.20	Storage periods (S) = 1.47
Ethephon (1500 ppm)	27.66	45.12	73.81	86.55	90.07	94.31	69.59	T x S = 3.28
Ethylene gas (100 ppm)	25.33	43.15	77.81	87.12	96.33	98.02	71.29	
Control	18.24	35.40	58.91	74.21	84.21	89.42	60.07	
Mean	23.78	41.28	67.77	80.84	88.30	92.19		
Rotting (%)								
Ethephon (500 ppm)	5.21	7.51	11.24	15.32	19.39	28.81	14.58	Treatment (T) = 0.14
Ethephon (1000 ppm)	7.81	9.32	14.01	18.90	22.91	30.56	17.25	Storage periods (S)= 0.16
Ethephon (1500 ppm)	8.00	9.98	18.21	23.83	29.34	37.89	21.21	
Ethylene gas (100 ppm)	3.12	5.12	7.80	8.45	9.98	13.24	7.95	T x S= 0.36
Control	3.28	4.52	6.65	7.95	9.72	12.73	7.48	
Mean	5.48	7.29	11.58	14.89	18.27	24.65		

reported an increase in weight loss in banana fruits during ripening process caused by ethephon or its analogues. The interaction between treatment and ripening period were found to be significant.

Fruit firmness: The data on fruit firmness revealed that the firmness of tomato fruits during ripening period was significantly affected by the different treatments. It is evident from the data that the fruit firmness, in general, followed a declining trend commensurate with advancement in ripening period (Table 1). A perusal of data shows that during ripening period of 13 days the fruit firmness values had decreased from the initial value of 1050.22 g force to 827.83, 808.02, 774.59 and 857.53 g force in the fruits treated with 500 ppm ethephon, 1000 ppm ethephon, 1500 ppm ethephon and 100 ppm ethylene gas respectively, whereas the corresponding value in case of control fruits was recorded to be 944.93 g force. It was also observed that the firmness of fruits decreased with increase in the concentration of ethephon (500-1500 ppm) during the ripening period. The fruits treated with ethylene gas (100 ppm) and untreated fruits maintained higher firmness as compared to different concentrations of ethephon (500, 1000 and 1500 ppm) during complete ripening period. The untreated fruits maintained highest fruit firmness throughout the stipulated ripening period of 13 days. On the other hand the fruits treated with 1500 ppm ethephon experienced the faster loss of firmness during ripening period, thereby leading to excess softening and shriveling of fruits. This reveals that untreated (control) fruits and ethylene gas (100 ppm) treatment delays the softening process in tomato fruits. The interaction between treatment and ripening period was found to be significant. The decrease in firmness during ripening may be due to breakdown of insoluble protopectin into soluble pectin or by cellular disintegration leading to membrane permeability (Brinston *et al.* 1988). The loss of pectin substances in the middle lamella of the cell wall is perhaps the key steps in the ripening process that leads to the loss of cell wall integrity thus cause loss of firmness and softening (Solomos and Laties 1973). Similar results were also observed in tomato (Gonzalez 1998; Hicks *et al.* 1984).

Ripening: The ripening percentage showed significant differences among the various treatments during the ripening period (Table 1). It was observed that ripening of tomato fruits increased during the ripening period in all the treatment. The ethylene gas (100 ppm) treatment registered the highest ripening percentage (98.02%) while the lowest was recorded in control (89.42%) during 13th day of ripening period. There is increase in the ripening percentage of fruits as the concentration of the ethephon increased from 500 to 1500 ppm during ripening period (13 days) but at that time it also resulted more than 28 per cent rotting which makes the fruits unmarketable. Enhanced ripening with the post-harvest application of ethephon is due to binding of ethylene to receptor which forms an activated complex leading to a wide variety of physiological responses including ripening (Yang, 1980). The ethylene gas (100 ppm) treatment resulted quicker and uniform ripening of 87.12 per cent in 9 days with minimum rotting (8.45%). The similar type of ripening (84.21%) was observed in the control fruits with 9.72 per cent rotting during the 11th day of ripening. Enhanced ripening with the post-harvest application of ethylene or its analogues has been reported in tomato (Fidler and Nashwortham 1950; Heinze and Craft 1953; Sims 1969; Tremblay and Perron 1991; Gonzalez 1998), mango (Mann and Singh 1985; Novelo 1998; Kulkarni *et al.* 2004), guava (Mahajan *et al.* 2008), and kiwi fruit (Park *et al.* 2006; Bal and Kok 2007). The interaction between the treatments and ripening period was found to be significant.

Rotting: The data on rotting of tomato fruits revealed that rotting of fruits during ripening period was significantly affected by the different treatments (Table 1). It was observed that rotting percentage increased with increase in ripening period. The lowest mean cumulative spoilage (7.48%) in terms of rotting was recorded in control fruits, which was followed by ethylene gas (100 ppm) treated fruits (7.95%). The 1500 ppm ethephon treatment showed the highest mean spoilage of 21.21% and ranged from 8.00% to 37.89% from 3 to 13 days of ripening period. However, the rotting percentage was lowest in control (3.28% to 12.73%) and ethylene gas treated fruits (3.12% to 13.24%) from 3 to 13 days of ripening period. The interaction between treatment and ripening period was found significant. The rotting percentage increased with duration of days for which the fruits were kept for ripening. As the concentration of ethephon increased (500-1500 ppm), the rotting and ripening percentage also increased simultaneously. The rotting percentage is more than tolerable limits in all the ethephon treatments which make the fruits unmarketable after 7 days of ripening period. The highest rotting in ethephon dip treatments may be due to direct contact of fruits with water because some unnoticeable injuries and bruises on fruit surface may absorb the water during dipping which later on became the entry point for the fungal infection. The rotting with higher dose of ethephon is obvious due to faster respiration rate leading to over softening and spoilage of fruit (Bondad and Pantastico 1972). The untreated (control) and ethylene gas (100 ppm) ripened fruits recorded minimum rotting

(< 10%) during ripening period of 11 days. Moreover, at that time maximum and uniform ripening has been achieved. Similar types of results were corroborated in Avocados (Jeong *et al.* 2002).

Total Soluble Solids (TSS): The TSS of tomato fruits were influenced by various treatments (Table 2). The ethylene gas treated fruits recorded maximum average TSS content (4.89%) followed by 1500 ppm ethephon treatment (4.85%) and both are significantly different from each other. The control fruits recorded the lowest average TSS content (4.60%). It was further observed that TSS content increased slowly and steadily in all the treatments during the ripening period. The increase in TSS during ripening may result from an increase in concentration of organic solutes as a consequence of water loss (Ryall and Pentzer 1982). The increase may also be due to the numerous anabolic and catabolic processes taking place in fruits, preparing it for senescence (Smith *et al.*, 1979). The reason for the increase in TSS could be attributed to the water loss and hydrolysis of starch and other polysaccharides to soluble form of sugar. Mostly, all the treatments showed a non-significant difference among themselves with regard to TSS. The significant differences were observed among the ripening days upto the 11th days of ripening. In all the ethephon treatments, there was decrease in the TSS content on 13th day which may be due to advanced ripening stage which resulted in the substantial utilization of sugars and hence the reduced TSS was observed. The interaction between treatments and ripening period was non-significant. The similar results were observed in tomato (Paynter and Jen 1976; Hicks *et al.* 1984; Gonzalez 1998), pear (Mann and Singh 1990; Kulbushan 2010), guava (Singh *et al.* 1979; Mahajan *et al.* 2008), peach (Ochel *et al.* 1993).

Titratable acidity: Titratable acidity of tomato showed a liner declining trend during ripening and was found to be maximum (0.51%) in 1500 ppm and 1000 ppm ethephon treatment which was closely followed by 500 ethephon treatment (0.50%) (Table 2). The overall mean acidity was showed as 0.77, 0.69, 0.56, 0.43, 0.31 and 0.26 per cent at 3, 5, 7, 9, 11 and 13 days of ripening, respectively. The mean acidity content of 1000 and 1500 ppm ethephon treatment were at par with each other and significantly differs from the ethylene gas (100 ppm) treatment. The minimum mean acidity was noted in the control fruits i.e. 0.48 per cent. A significant difference in the acid content of the fruits was observed among the different ripening days.

The amount of acidity in tomato fruit decreases gradually during the entire period of ripening which may be attributed to utilization of organic acid in pyruvate decarboxylation reaction occurring during the ripening process of fruits (Rhodes *et al.* 1968; Pool *et al.* 1972; Ulrich 1974). The increased membrane permeability allows the acids, stored in cell vacuoles to be respired at faster rate. These observations are in agreement with the findings of Knys and Largskij 1970; Hicks *et al.* 1984; Gonzalez 1999 in tomato. The interaction between treatment and ripening period was found to be significant. Similar results were also observed in guava (Venkatesha and Reddy 1994; Mahajan *et al.* 2008), mango (CenturianYan *et al.* 1998; Novelo 1998; Kulkarni *et al.* 2004)

Ascorbic acid: The various treatments showed a significant difference among themselves with regard to ascorbic acid (Table 2). The ascorbic acid content registered increase with the advancement of ripening period. The significantly highest mean ascorbic acid was observed in ethylene gas (100 ppm) treatment (18.28 mg/100 g fruit weight) whereas minimum mean ascorbic acid (14.15 mg/100 g fruit weight) in the untreated (control) fruits. The interaction between treatment and ripening period was found to be significant. The fruits treated with ethylene gas on 13th day of ripening had the highest ascorbic acid content (23.50 mg/100 g fruit weight) while the lowest value was recorded in the ethephon (500 ppm) fruits (11.70 mg/100 g fruit weight) on the 3rd day of ripening. The increase in the ascorbic acid content may be attributed to the higher synthesis of some metabolic intermediary substances which promoted the greater synthesis of the precursor of ascorbic acid (Juhasz and Kaszta 1966). Gonzalez (1998) and Novelo (1998) also found an increase in the ascorbic acid content of tomato with application of ethephon. Similar results were also reported in guava (Singh *et al.* 1979; Mahajan *et al.* 2008).

Lycopene content: A perusal of data revealed that the lycopene content increased with increase in ripening period (Table 2). All the treatments (except 500 ppm ethephon with 1000 ppm ethephon) showed a significant difference among themselves with respect to lycopene content. The significantly highest mean lycopene content (10.40 mg/100g fruit weight) was observed in ethylene gas (100 ppm) treatment whereas minimum mean lycopene content (8.89 mg/100 g fruit weight) in control fruits. A perusal of data shows that during ripening period of 13 days, the mean lycopene content were 9.09, 9.51 and 10.06 in the fruits treated with 500 ppm ethephon, 1000 ppm ethephon and 1500 ppm ethephon, respectively. The interaction between treatment and ripening period was found to be significant. The lycopene content increased with duration of days for which the fruits were kept for ripening. Similar results were also

Table 2. Effect of ethephon treatments and ethylene gas on chemical properties of tomato during storage (20±1°C and 90-95% RH)

Treatment	3D	5D	7D	9D	11D	13D	Mean	LSD (p = 0.05)
			Total soluble solids (%)					
Ethephon (500 ppm)	3.70	4.40	4.73	5.07	5.21	5.27	4.73	Treatment (T)= 0.11
Ethephon (1000 ppm)	4.10	4.50	4.63	4.98	5.25	5.21	4.78	Storage periods (S)=0.13
Ethephon (1500 ppm)	3.94	4.47	4.77	5.33	5.37	5.23	4.85	T x S = NS
Ethylene gas (100 ppm)	3.80	4.63	5.03	5.25	5.30	5.32	4.89	Initial value at harvest = 3.40%
Control	3.50	4.07	4.67	4.97	5.13	5.27	4.60	
Mean	3.81	4.41	4.77	5.12	5.25	5.26		
			Titratable acidity (%)					
Ethephon (500 ppm)	0.77	0.66	0.55	0.42	0.32	0.29	0.50	Treatment (T)= 0.01
Ethephon (1000 ppm)	0.76	0.67	0.57	0.44	0.33	0.28	0.51	Storage periods (S)=0.02
Ethephon (1500 ppm)	0.76	0.71	0.56	0.43	0.33	0.28	0.51	
Ethylene gas (100 ppm)	0.79	0.73	0.58	0.43	0.31	0.24	0.51	T x S = 0.03
Control	0.76	0.67	0.54	0.41	0.27	0.21	0.48	Initial value at harvest = 0.73%
Mean	0.77	0.69	0.56	0.43	0.31	0.26		
			Ascorbic acid (mg/100g)					
Ethephon (500 ppm)	11.70	12.09	13.20	14.80	16.90	18.70	14.57	Treatment (T)= 0.01
Ethephon (1000 ppm)	12.40	13.80	16.70	18.20	19.50	21.80	17.07	Storage periods (S) =0.02
Ethephon (1500 ppm)	12.80	13.50	15.80	16.90	18.80	20.10	16.32	T x S = 0.03
Ethylene gas (100 ppm)	12.50	15.09	17.89	19.50	21.20	23.50	18.28	Initial value at harvest = 11.50 mg/100 g
Control	11.90	12.80	13.30	14.10	15.50	17.30	14.15	
Mean	12.26	13.46	15.38	16.70	18.38	20.28		
			Lycopene content (mg/100g)					
Ethephon (500 ppm)	5.97	7.30	8.74	9.49	10.79	12.22	9.09	Treatment (T) = 0.11
Ethephon (1000 ppm)	6.70	7.79	8.41	9.81	11.50	12.86	9.51	Storage periods (S)= 0.13
Ethephon (1500 ppm)	6.97	7.70	9.10	10.89	12.09	13.63	10.06	
Ethylene gas (100 ppm)	6.66	7.49	9.42	10.89	13.19	14.72	10.40	T x S= 0.28
Control	6.49	7.19	7.91	9.12	10.49	12.11	8.89	
Mean	6.56	7.49	8.72	10.04	11.61	13.11		

Table 3. Effect of ethephon and ethylene gas on colour (L, a ,b) of tomato during storage (20±1°C and 90-95% RH)

Ripening periods (days)	Treatments														
	Ethephon (500 ppm)			Ethephon (1000 ppm)			Ethephon (1500 ppm)			Ethylene gas (100 ppm)			Control		
	L	a	b	L	a	b	L	a	b	L	a	b	L	a	b
3	52.80	-2.74	23.09	51.92	-3.20	24.01	54.41	-3.10	24.87	52.38	-1.07	22.38	51.10	-5.48	24.22
5	50.10	6.37	19.90	49.59	7.92	20.20	50.72	8.27	20.40	47.82	8.00	19.00	49.26	-1.93	22.18
7	45.31	13.39	19.13	44.09	13.89	18.11	46.69	14.10	18.80	43.22	13.71	18.69	46.75	8.59	19.89
9	40.71	18.35	15.12	39.81	19.99	17.71	44.21	20.74	16.97	39.11	19.05	15.11	43.68	12.59	17.42
11	35.83	22.38	12.90	37.98	22.99	15.29	40.20	23.40	14.76	38.59	22.92	12.73	41.44	18.62	15.65
13	33.61	25.41	10.21	35.82	25.88	9.23	35.83	25.62	11.46	34.23	25.48	10.25	40.02	24.87	12.49

corroborated by Juhasz and Kaszta (1966) and Mandal *et al.* (2008) in tomato.

Fruit colour: Regarding fruit colour, there was consistent increase in redness value (a) and decrease in yellowness value (b) of fruit pericarp with the advancement in the ripening period for all the treatments (Table 3). The fruits treated with ethylene gas (100 ppm) developed uniform red colour after ripening period of 9 days whereas in control fruits the similar results were obtained after ripening period of 11 days. No doubt, all the ethephon treatments resulted in significant improvement in tomato colour during the ripening period of 9 days but the rotting was also more than 15 per cent during the 9th day which makes these ethephon treatments unsuitable for ripening.

Ethylene gas and ethephon treatments are known to accelerate the chlorophyll degradation or synthesis of carotenoids by stimulating the synthesis of chlorophyllase enzyme in calamondin tissue which is responsible for chlorophyll degradation and expression of â-carotene pigments (Reyes and Paull 1995; Mahajan *et al.* 2008). The ethylene gas (100 ppm) treatment resulted uniform development of red colour after 9 days of ripening with less than 10 percent rotting. The control fruits also results uniform development of red colour but after 11 days of ripening at 20±1^{o}C and having less than 10 per cent rotting. Similar results were also observed in tomato (Rabinowitch and Rudich 1972; Sims and Kasmire 1972), banana (Mahajan *et al.* 2010) and guava (Mahajan *et al.* 2008).

सारांश

टमाटर की शंकर प्रजाति अभिनाश–3 का जाड़े के मौसम में फलों के पकाव पर इथीफान एवं इथायलीन गैस के प्रभाव सम्बन्धित सूचना ज्ञात करने के लिए अध्ययन किया गया। प्रथम प्रयोग में टमाटर के पके हरे फलों पर इथीफान घोल की जलीप सान्द्रता (50,1000,व 1500 पी पी एम) से शोधित किया गया। पके फलों को प्लास्टिक के बक्से में भरा गया तथा उन्हें 20±1 डिग्री सेन्टीग्रेड तापमान व 90–95 प्रतिशत सापेक्ष आर्द्रता वाले भण्डारण कक्ष में रखा गया। द्वितीय प्रयोग में पके हरे टमाटर को इथापसीन गैस (100 पी पी एम) आधारित पकने वाले कक्ष में 24 घण्टे (20±1 डिग्री सेन्टीग्रेड व 90–95 सापेक्ष आर्द्रता) तथा तत्पश्चात् उन्हें पकाव कक्ष में (20±1 डिग्री सेन्टीग्रेड व 90–95 सापेक्ष आर्द्रता) स्थान्तिरत किया गया। नियंत्रक के तौर पर एक ढेर का शोधन नहीं किया गया। पके हरे फलों से अन्तिम पके फल अवस्था का भौतिक–रासायनिक विश्लेषण किया गया। इथायलीन गैस (100 पी पी एम) से अधिकतम पकाव प्रतिशत दर्ज किया गया। पकाव तथा सड़न प्रतिशत में बढ़ाव इथीफान की सान्द्रता (500–1500 पी पी एम) वृद्धि एवं पकने लिये रखे दिन–अवधि के साथ दर्ज की गयी। टमाटर फलों की गणनीय अम्लता में रौखिक गिरावट देखी गयी लेकिन एस्कार्विक एसीड व लाइकोपीन की मात्रा बढ़ते पकाव अवधि में किसी भी निरपेक्ष शोधन में पाया गया। टमाटर के तोड़े गये हरे पके फलों की अवस्था में इथीफान (500,1000,1500 पी पी एम) के प्रयोग से सफलतापूर्वक 9 दिनों फल पक गये। लेकिन 90वें दिन प्रजाति हाइबिड–1001 में सड़न 14 प्रतिशत से अधिक हुआ जिसे बाजार योग्य नहीं पाया गया। इसलिए इथीफान का प्रयोग पकाने का उत्तम विकल्प नहीं है। इथायलीन (100पी पी एम) गैस से शोधन करने पर 9वें दिन एक समय लाल रंग पर्याप्त फल पाये गये। तथा इनमें वांछित कसावट, कम सड़न तथा स्वीकार्य गुणवत्ता पायी गयी अतः इथीफान की तुलना में यह ज्यादा प्रभावी है। नियंत्रक शोधन में एक समान फलों का पकाव, कसावट, सड़न व गुणवत्ता वैसा ही रहा जैसा इथायलीन (100 पी पी एम) गैस शोधक में था लेकिन फलों के एक समान पकाव में ज्यादा दिन (111 दिन) लगे।

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