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Effect of Ethephon and Ethylene Gas on Ripening and Quality of Tomato (*Solanum Lycopersicum* L.) during Cold Storage

RK Dhall* and Pricedeep Singh

Department of Vegetable Science, Punjab Agricultural University, Ludhiana, Punjab, India

Abstract

The investigation was carried out to obtain information about effect of ethephon and ethylene gas on ripening and quality of winter tomato (cv. Hybrid-1001). The mature green tomatoes were treated with different concentrations of aqueous solution of ethephon (500, 1000 and 1500 ppm) for 5 minutes, thereafter packed in plastic crates and kept in storage room at 20 ± 1°C and 90-95% RH. In another experiment, mature green tomatoes were exposed 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 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 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 fruits harvested at green mature stage get successfully ripened in 9 days with application of ethephon but the rotting was more than 14% till 9th day 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

Introduction

Tomato (*Solanum lycopersicum* L.) is most 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 color to ripe tomatoes is reported to possess anti-cancerous properties. It also serves as an anti-oxidant as the β-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 color 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 behavior after harvest. Tomato ripening is characterized by loss of chlorophyll and rapid accumulation of carotenoids, particularly lycopene, as chloroplasts are converted to chromoplasts [1]. However, ripening is a problem in tomato during winter months due to foggy weather and low temperature which does not allow tomatoes to mature themselves on the plant [2]. The low temperature also slows down the degradation of chlorophyll and synthesis of lycopene [3]. Such conditions interfere with color, texture and flavor development of the fruits. As a result, tomato fruit fail to ripen and develop full color and flavor, irregular (blotchy) color 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 [4], 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 [2,5-7]. But in Indian context, there is need to standardize the method of ripening of winter tomatoes by use of ethylene gas and 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 cvs. Hyrbid-1001 (Nunhems Proagro Seeds Pvt. Ltd.) was 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.

***Corresponding author:** Dhall RK, Department of Vegetable Science, Punjab Agricultural University, Ludhiana-141004, Punjab, India, Tel: 0161-2404460; E-mail: dhallrk2007@rediffmail.com

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Treatment

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°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°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. [8]. 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 [9]. 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 [9]. 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 (20 g). The results were expressed as mg per 100 g fresh weight.

Measurement of fruit firmness, physiological loss in weight, colour, ripening and rotting

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% 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 [10].

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%. 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 percentage. 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 [11]. The mean of the treatments was compared for statistical differences at 5%.

Results

Physiological loss in weight (PLW)

There were significant differences among the various ripening treatments with regard to Physiological loss in weight (PLW) (Figure 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 (2.99%) was noticed in the untreated fruits which was statistically significant as compared to treatments given with ethephon and ethylene gas. On the other hand, the highest mean PLW (5.82%) was observed in fruit treated with 1500 ppm ethephon, which was followed by 1000 ppm ethephon (5.64%) and 500 ppm ethephon (4.91%). These ethephon treatments (500, 1000 and 1500 ppm) resulted in shriveling, softening and over ripening of fruits, thus found unsuitable. The PLW during ripening may be attributed to increased rate of respiration which is correlated with the increase in ethephon concentrations. As the ethephon concentrations increased, the ripening percentage increased. The interaction between treatment and ripening period were found to be significant. It showed that during different ripening periods, untreated (control) fruits recorded the lowest weight loss ranging between 0.80 to 5.00% from 3 to 13 days of ripening period, respectively as compared to ethephon 1500 ppm treatment where PLW ranged from 2.23 to 8.60% during same interval. The ethylene gas (100 ppm) treatment also recorded low mean PLW (4.16%) as compared to all the ethephon treatments and was found to be statistically significant as compared to other treatments.

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 (Figure 1). The untreated (control) fruits maintained the highest mean firmness (930.43 g force) followed by ethylene gas treatment (843.92 g force) and also at all stages of ripening intervals. The fruits treated with 1500 ppm ethephon registered the lowest mean firmness (761.06 g force). The fruits treated with ethylene gas (100 ppm) and untreated fruits maintained higher firmness as compared to

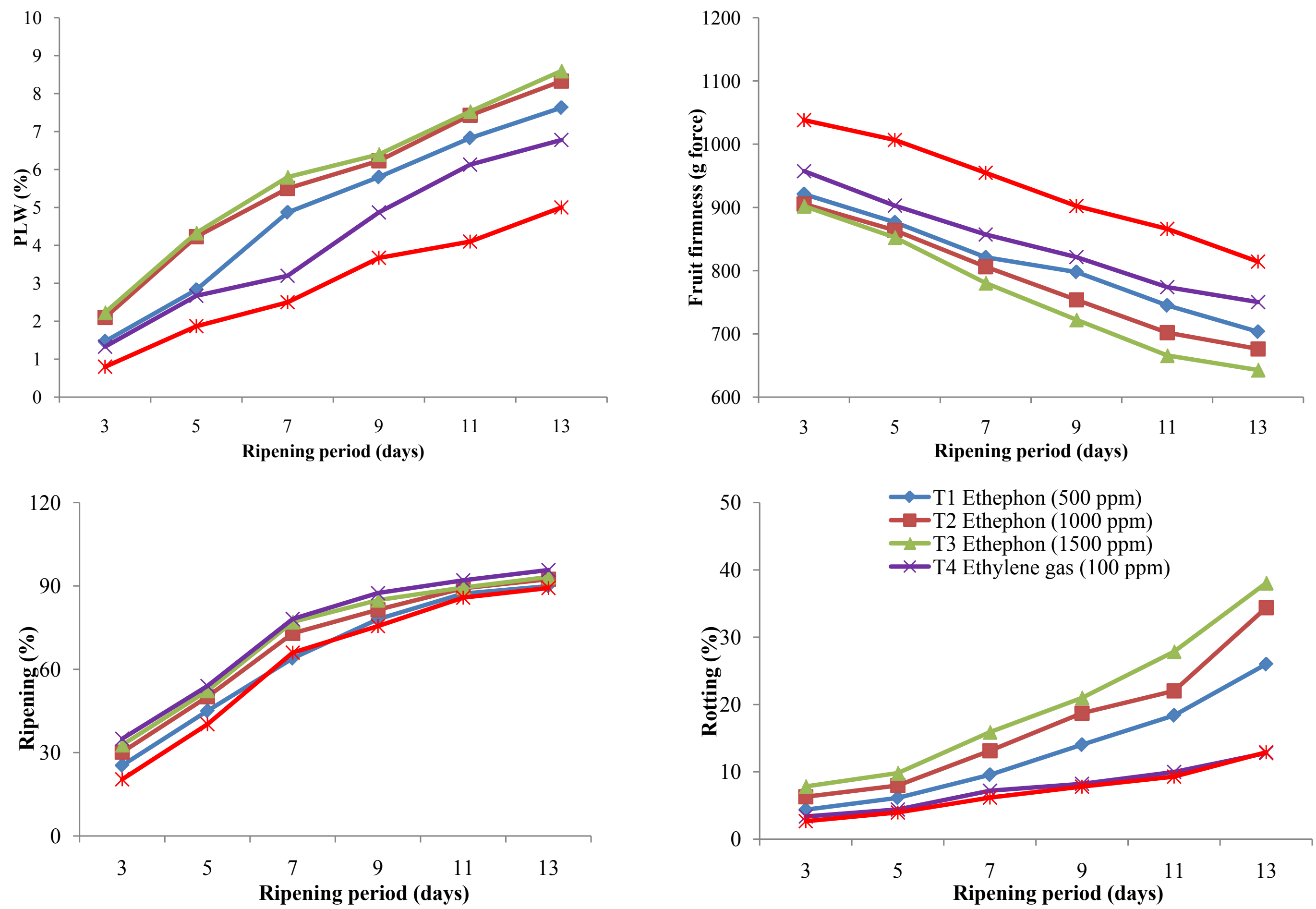

Figure 1: Effect of ethephon and ethylene gas on physiological loss in weight (%) , fruit firmness (g force) , ripening (%), rotting (%) of tomato 20 ± 1oC temperature and 90-95% RH.

different concentrations of ethephon (500, 1000 and 1500 ppm) during complete ripening period. 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 untreated fruits maintained highest fruit firmness throughout the stipulated ripening period of 13 days which ranged between 1038.20 to 814.40 g force as compared to other treatments. On the other hand the fruits treated with 1500 ppm ethephon experienced the faster loss of firmness during ripening period and ranged between 902.17 to 642.87 g force, thereby leading to excess softening and shriveling of fruits. The tomato fruits treated with ethylene gas (100 ppm) also registered slower and steadier loss in firmness (957.39-750.38 g force) during ripening period of 13 days. The interaction between treatment and ripening period was found to be significant.

Ripening

The ripening percentage showed significant differences among the various treatments during the ripening period (Figure 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 (95.71%) while the lowest was recorded in control (89.24%) after 13 days 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 25% rotting which makes the fruits unmarketable. The ethylene gas (100 ppm) treatment resulted quicker and uniform ripening of 87.42% in 9 days with minimum rotting (8.22%). The similar type of ripening (85.79%) was observed in the control fruits with 9.29% rotting during the 11th day of ripening. 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 (Figure 1). It was observed that rotting percentage increased with increase in ripening period. The lowest mean cumulative spoilage (7.13%) in terms of rotting was recorded in control fruits, which was followed by ethylene gas (100 ppm) treated fruits (7.66%). The 1500 ppm ethephon treatment showed the highest mean spoilage of 20.07% and ranged from 7.83% to 38.04% from 3 to 13 days of ripening period. However, the rotting percentage was lowest in control fruits (2.67% to 12.90%) and ethylene gas treated fruits (3.37% to 12.80%) 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

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percentage is more than tolerable limits in ethephon treatment of 1000 and 1500 ppm after 7 days of ripening period i.e. 13.13 and 15.89% which makes the fruits unmarketable.

Total Soluble Solids (TSS)

The TSS of tomato was influenced by various treatments (Table 1). The ethylene gas treated fruits recorded maximum average TSS content (4.84%) followed by 1500 ppm ethephon treatment (4.80%) and both are significantly different from each other. The control fruits recorded the lowest average TSS content (4.63%). It was further observed that TSS content increased slowly and steadily in all the treatments during the ripening period. 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. The increase in mean TSS was observed with the advancement of ripening period i.e. from 3.73 to 5.25% in 3 to 13 days. In all the ethephon treatments, there was decrease in the TSS content during the 13th day of ripening. The decrease in TSS on 13th day 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.

Titratable acidity

Titratable acidity of tomato showed a liner declining trend during ripening and was found to be maximum (0.51%) in 1500 ppm ethephon treatment which was closely followed by 500 and 1000 ppm ethephon treatment (0.49%) (Table 1). The data also showed significant difference between 1500 and 1000 ppm ethephon treatment and between 500 and 1500 ppm ethephon treatment. The mean acidity content of 500 and 1000 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. 0.46%. A significant difference in the acid content of the fruits was observed among the different ripening days. The interaction between treatment and ripening period was found to be significant.

Ascorbic acid

The various treatments showed a significant difference among themselves with regard to ascorbic acid (Table 1). The ascorbic acid content registered increase with the advancement of ripening period. The significantly highest mean ascorbic acid (19.04 mg/100 g fruit weight) was observed in ethylene gas (100 ppm) treatment whereas minimum mean ascorbic acid (14.88 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 (25.69 mg/100 g fruit weight) while the lowest value (11.68 mg/100 g fruit weight) was recorded in the control fruits on the 3rd day of ripening.

Lycopene content

A perusal of data revealed that the lycopene content increased with increase in ripening period (Table 1). 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 (10.99 mg/100g fruit weight) was observed in ethylene gas (100 ppm) treatment whereas

Treatment	3D	5D	7D	9D	11D	13D	Mean	LSD (p = 0.05)
Total Soluble Solids (%)								
Ethephon (500 ppm)	3.83	4.37	4.70	5.07	5.27	5.30	4.76	Treatment (T)= 0.08 Storage periods (S)= 0.12 T x S= NS Initial value of total soluble solids at harvest = 3.45%
Ethephon (1000 ppm)	3.53	4.37	4.73	5.03	5.27	5.22	4.69	
Ethephon (1500 ppm)	3.87	4.43	4.83	5.17	5.30	5.20	4.80	
Ethylene gas (100 ppm)	3.60	4.63	4.97	5.27	5.29	5.30	4.84	
Control	3.80	4.10	4.60	4.90	5.17	5.23	4.63	
Mean	3.73	4.38	4.77	5.09	5.26	5.25		
Titratable Acidity (%)								
Ethephon (500 ppm)	0.76	0.67	0.52	0.40	0.31	0.27	0.49	Treatment (T) = 0.01 Storage periods (S) = 0.02 T x S = 0.03 Initial value of titratable acidity at harvest = 0.72%
Ethephon (1000 ppm)	0.76	0.68	0.51	0.40	0.31	0.27	0.49	
Ethephon (1500 ppm)	0.78	0.70	0.53	0.42	0.34	0.28	0.51	
Ethylene gas (100 ppm)	0.78	0.68	0.53	0.37	0.30	0.24	0.48	
Control	0.74	0.63	0.50	0.40	0.26	0.21	0.46	
Mean	0.76	0.67	0.52	0.40	0.30	0.25		
Ascorbic Acid (mg/100g)								
Ethephon (500 ppm)	12.27	12.90	14.90	16.50	17.89	20.59	15.84	Treatment (T) = 0.01 Storage periods (S) = 0.01 T x S = 0.03 Initial value of ascorbic acid at harvest = 11.50 mg/100 g
Ethephon (1000 ppm)	12.89	14.29	15.89	17.80	20.69	23.90	17.58	
Ethephon (1500 ppm)	12.93	15.39	17.19	18.79	20.49	22.89	17.95	
Ethylene gas (100 ppm)	12.57	14.89	17.79	20.09	23.19	25.69	19.04	
Control	11.68	12.59	13.91	15.39	16.89	18.79	14.88	
Mean	12.47	14.01	15.94	17.71	19.83	22.37		
Lycopene Content (mg/100g)								
Ethephon (500 ppm)	7.13	8.36	10.44	11.26	13.58	12.08	10.48	Treatment (T) = 0.22 Storage periods (S) = 0.26 T x S = 0.58 Initial value of lycopene content at harvest = 6.25 mg/100 g
Ethephon (1000 ppm)	7.30	8.64	9.27	10.51	12.93	13.82	10.41	
Ethephon (1500 ppm)	7.77	8.73	9.80	11.22	12.88	14.01	10.74	
Ethylene gas (100 ppm)	7.90	8.45	9.52	11.78	13.02	15.27	10.99	
Control	6.59	7.33	8.54	9.80	11.67	12.30	9.37	
Mean	7.34	8.30	9.51	10.91	12.82	13.50		

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

minimum mean lycopene content (9.37 mg/100 g fruit weight) in control fruits. 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.

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 2). 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. The fruits treated with ethephon (500, 1000 and 1500 ppm) also resulted a deep red colour after ripening period of 9 days but by that time the rotting is more than 14% which makes the fruits unmarketable.

Discussion

Physiological loss in weight (PLW)

As the ethephon concentrations 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 physiological loss in weight during ripening of tomato fruits with ethephon and ethylene gas application may be due to upsurge in respiration rate of the fruits [12,13]. An increase in weight loss in banana fruits during ripening process was caused by ethephon or its analogues [14,15].

Fruit firmness

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 [16]. 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 [17]. Similar results were also observed in tomato [18,19].

Ripening

A perusal of data shows that ripening percentage increased with increase in the concentration of ethephon. 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 [20]. Enhanced ripening with the post-harvest application of ethylene or its analogues has been reported in tomato [18,21-24], mango [25-27], guava [28,29] and kiwi fruit [30,31].

Rotting

The rotting percentage increased with the increase in the ripening period. Moreover, maximum rotting was observed 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 [32]. The untreated (control) and ethylene gas (100 ppm) ripened fruits recorded minimum rotting of less than 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 [33].

Total soluble solids (TSS)

The increase in TSS during ripening may result from an increase in concentration of organic solutes as a consequence of water loss [34]. The increase may also be due to the numerous anabolic and catabolic processes taking place in fruits, preparing it for senescence [35]. 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. The mean TSS was minimum in untreated fruits and maximum in ethylene gas (100 ppm) treatment. The interaction between treatments and ripening period was found to be non significant. The similar results were observed in tomato [18,19,36], pear [25,37], guava [29,38], peach [39].

Titratable acidity

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 [40-42]. The increased membrane permeability allows the acids, stored in cell vacuoles to be respired at faster rate. The similar observations were reported in tomato [2,19,43,44]. The interaction between treatment and ripening period was found to be significant. Similar results were also observed in guava [28,29,45], mango [26,27,46].

Ascorbic acid

The maximum value of ascorbic acid was recorded in the ethylene gas (100 ppm) treatment after 13 days 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 [46]. 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 [18,26].

Lycopene content

The maximum lycopene content was observed in all the ethylene

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	46.35	-4.63	19.33	47.12	-2.49	20.50	48.96	-4.44	19.79	48.09	-0.89	18.84	50.02	-5.03	20.45
5	49.07	3.80	18.97	48.55	4.11	19.60	45.97	5.85	18.36	45.10	8.47	18.71	48.12	-1.02	20.37
7	47.57	13.70	17.90	40.93	15.69	17.26	41.58	16.64	15.75	39.43	17.01	16.16	45.72	12.26	18.27
9	39.78	19.95	12.96	36.38	20.76	15.98	36.65	21.37	12.31	34.75	21.28	14.15	41.94	18.23	17.07
11	37.95	24.08	11.25	33.55	24.34	10.77	35.15	22.95	11.76	34.09	24.63	12.30	40.02	20.42	14.26
13	36.39	24.32	10.05	33.64	25.40	9.75	33.88	23.78	10.99	33.50	25.06	10.48	38.42	23.18	11.43

Table 2: Effect of ethephon and ethylene gas on colour (L, a,b) of tomato during storage (20 ± 1°C and 90-95% RH).

gas (100 ppm) treatments. The untreated (control) fruits recorded minimum lycopene content during the ripening period. Similar results were also observed in tomato [43,47,48].

Fruit colour

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 β-carotene pigments [29,49]. 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°C and having less than 10% rotting. Similar results were also observed in tomato [50,51], banana [15] and guava [29].

References

1. Khudairi AK (1972) The ripening of tomatoes. J Amer Sci 60: 696-707.
2. Gonzalez J (1999) Use of ethylene (ethephon) in uniform ripening of processing tomato (*Lycopersicon esculentum*) in California. Acta Hort 487: 179-182.
3. Koskitalo DN, Omrod DP (1972) Effects of sub optimal ripening temperatures on the colour quality and pigment composition of tomato fruit. J Food Sci 37: 56-58.
4. PFA (2003) Prevention of Food Adulteration Act 1954 Rules, In: International Law Book Co (19th edn), Delhi, India.
5. Kasmire RF (1981) Continuous flow ethylene gassing of tomatoes. California Tomatorama. Fresh Market Tomato Advisory Board Information Bulletin No. 29.
6. Cantwell M (1994) Optimum procedures for ripening tomatoes. Perishable Handling Newsletter. University of California, Davis 80: 24-26.
7. Sargent SA (2005) Ripening and quality responses of tomato fruit to ethylene. Postharvest Biol Technol 36: 127-134.
8. Bassetto E, Jacomino AP, Pinheiro AL, Kluge RA (2005) Delay of ripening of 'Pedro Sato' guava with 1-methylcyclopropene. Postharvest Biol Technol 35: 303-308.
9. AOAC (1990) Official methods of analysis. (12thEdn) Association of Official Analytical Chemists, Washington DC.
10. Hunter S (1975) The measurement of appearance. John Wiley and Sons. New York, USA.
11. Singh S, Bansal ML, Singh TP, Kumar R (1991) Statistical Methods for Research Workers.Kalyani Publishers, New Delhi, India.
12. Kretchman DW, Short TH (1972) Studies on effect of ethephon on tomato cv. Napoli. Scientia Hort 65: 86-88.
13. Mutton LL (1978) Effect of moisture stress on the ethephon response in tomatoes. ScientiaHort 8: 299-305.
14. Khedkar DM, More RM, Patil VK, Warke DC, Ballal AL (1981) Studies on physico-chemical changes in banana during ripening. In: Symposium on recent advances in fruit development, Ludhiana, India.
15. Mahajan BVC, Kaur T, Gill MIS, Dhaliwal HS, Ghuman BS, et al. (2010) Studies on optimization of ripening techniques for banana. J Food Sci Technol 47: 315-319.
16. Brinston K, Dey PM, John MA, Pridhan JB (1988) Post harvest changes in *Mangiferaindica*L mesocarp walls and cytoplasmic polysaccharides. Phytochem 27: 719-723.
17. Solmos T, Laties GG (1973) Cellular organization and fruit ripening. Nature 245: 390-391.
18. Gonzalez J (1998) Symposium on protected cultivation of solanacea in mild winter climates. Acta Hort 366: 105-107.
19. Hicks JR, Mandez MJ, Master JF (1984) Influence of storage temperature and ethylene on firmness, acids and sugars of chilling sensitive and chilling tolerant tomato. J Amer Soc Hort Sci 109: 273.
20. Yang SF (1980) Regulation of ethylene biosynthesis. Hort Sci 15: 238-243.
21. Fidler JC, Nashwortham JRH (1950) Ripening of tomatoes II further experiment on the effects of ethylene. J Hort Sci 26: 43-46.
22. Heinze PH, Craft CC (1953) Effectiveness of ethylene for ripening tomatoes. Proc Amer Soc Hort Sci 62: 397-404.
23. Sims WL (1969) Effect of ethrel on fruit ripening in tomatoes. Calif Agric 23: 12-14.
24. Tremblay N, Perron Y (1991) Effect of fertilization and ethephon on the tomato cv. Heinz 2653. Canadian J Plant Sci 71: 1203-1209.
25. Mann MS, Singh B (1990) Effect of ethrel on ripening of fruits of Patharnakh pear harvested on different dates. Acta Hort 279: 529-532.
26. Novelo SAG (1998) The effect of ethephon on the colour, composition and quality of mango. (*Mangiferaindica*,cv Kent). J Food SciTechnol 4: 199-205.
27. Kulkarni SG, Kudachi VB, Vasantha MS, Keshava MN, Aravinda B, et al. (2004) Studies on effect of ethrel dip treatment on the ripening behavior of mango (*Mangiferaindica* L.) variety 'Neelum'. J Food Sci Technol 41: 216-220.
28. Singh G (2006) Effect of post-harvest treatments on ripening and storage of winter guava (*Psidiumguajava* L.). M.Sc. Thesis, Punjab Agricultural University, Ludhiana, India.
29. Mahajan BVC, Singh G, Dhatt AS (2008) Studies on ripening behaviour and quality of winter guava with ethylene gas and ethephon treatments. J Food Sci Technol 45: 81-84.
30. Park YS, Jung ST, Gorinstein S (2006) Ethylene treatment of 'Hayward' kiwifruits (*Actinidiadeliciosa*) during ripening and its influence on ethylene biosynthesis and antioxidant activity. Scientia Hort 108: 22-28.
31. Bal E, Kok D (2007) The effects of glycerine added ethephon treatments on fruit characteristics of Actinidiadeliciosa cv. Hayward. Bulg J Agric Sci 13: 291-300.
32. Bondad ND, Pantastico EB (1972) Ethrel- induced ripening of immature and mature green tomato fruits. Econ Bot 26: 238-244.
33. Jeong J, Donald JH, Sargent SA (2002) Postharvest ethylene treatment for uniform ripening of west Indian type avocado fruit. Proc Fla State Hort Soc 115: 68-71.
34. Ryall AL, Pentzer WT (1982) Handling, transportation and storage of fruits and vegetables. Vol 2, AVI Publishing Company, Westport, Connecticut, USA.
35. Smith RB, Lougheed EC, Franklin EW, McMillan I (1979) The starch iodine test for determining stage of maturation in apples. Can J Plant Sci 59: 725-735.
36. Paynter VA, Jen JJ (1976) Comparative effects of light and ethephon on the ripening of detached tomatoes. J Food Sci 41: 1366-1369.
37. Kulbhusan A (2010) Effect of pre harvest ethephon treatment on fruit ripening and ambient storage in pear cv. Patharnakh. M.Sc. Thesis, Punjab Agricultural University, Ludhiana, India.
38. Singh IS, Singh HK and Chauhan KS (1979) A note on the effect of pre harvest application of ethephon on ripening and quality of Phalsa (*Grewiaasiatica*). Haryana J Hort Sci 8: 196-197.
39. Ochel CO, Basionny FM, Woods FM (1993) Calcium mediated post harvest change in storage ability and fruit quality of peaches. Proc Fla State Hort Soc 106: 266-269.
40. Rhodes MJC, Woodtorton LSC, Gallard, Hulme AC (1968) Metabolic changes in excised fruit tissue I. Factor affecting the development of a malate decarboxylation system during the ageing of disc of pre-climacteric apples. Phytochem 7: 1439-1451.
41. Pool KM, Weaver RJ, Kliewer KM (1972) The effect of growth regulators on the changes in fruit of Thompson seedless during cold storage. Amer Soc Hort Sci J 97: 67-70.
42. Ulrich R (1974) Organic acids. In: Biochemistry of fruits and their products. Vol I. Hulme AC (Ed) Academic Press, London, UK.
43. Boe AA, Salunkhe DK (1967) Ripening tomatoes: ethylene, oxygen and light treatments. Economic Botany 21: 312-319.
44. Knys AN, Largskij JN (1970) Changes in the quality of tomatoes rapidly ripened in an ethylene atmosphere. J Agric 7: 73-75.
45. Venkatesha M, Reddy TV (1994) Extension of storage life of guava (*Psidiumguajava*L.) fruits. Indian Food Packer 48: 5-10.

46. CenturianYan AR, GonzalecNovelo SA, Tamayo Cortes JA, Argumedo JJ, Sauri D (1998) The effect of ethephon on the colour, composition and quality of mango (*Mangiferaindica* cv. Kent). Food Sci Tech International 4: 199-205.

47. Juhasz K, Kaszta D (1966) Comparative test on tomatoes ripening by ethylene on the plant and untreated tomatoes. J Agric 6: 208-209.

48. Mandal P, Misra TK, Singh ID, Nayak CR (2008) Chemical phytotoxicity and use of ethrel as ripening agent on productivity and quality of tomato (*Lycopersiconesculentum*). Indian J Agri Sci 78: 581-583.

49. Reyes MU, Paull RF (1995) Effect of storage temperature and ethylene treatment on guava fruit ripening. Postharvest Biol Technol 6: 357-365.

50. Rabinowitch HD, Rudich J (1972) Effects of Ethephon and CPTA on colour development of tomato fruits at high temperatures. J Hort Sci 7: 76-77.

51. Sims WL, Kasmire RF (1972) Ethephon response favourable on fresh market tomatoes pre and post harvest studies show earlier production and more uniform ripening. Calif Agric 26: 3-4.