ISSN 0258-7122
Bangladesh J. Agril. Res. 40(4): 567-580, December 2015

INFLUENCE OF ETHEPHON ON RIPENING AND QUALITY OF WINTER TOMATO FRUIT HARVESTED AT DIFFERENT MATURITY STAGES

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Abstract

An experiment taking tomato fruits (cv. BARI Tomato-14) of three maturity stages (mature green stage, breaker stage and half ripen stage) and four ethephon levels [control (distilled water spray), 500, 750 and 1000 ppm] was carried out at the laboratory of plant physiology section of Horticulture research centre, Bangladesh Agricultural Research Institute) during February 14, 2013 to February 27, 2012 to find out the suitable stage of fruit maturity for post harvest application of ethephon (ethrel) for tomato ripening. The source of ethrel was Spectrum (ethephon 39%) manufactured in the United States of America. Treatment with 500 - 1000 ppm ethephon hastened ripening of tomato by 4 days in mature green stage but by 2 and 4 days in breaker stage tomatoes when compared with control fruits. The highest value of rotting was shown by half ripen tomatoes. The 1000 ppm ethrel gave the maximum rotting irrespective of maturity stages. However, the maximum weight loss and shelf life were found in green mature tomatoes. The shelf life of tomato fruits of green mature and breaker stage tomatoes treated with 500 and 750 ppm was also high. The percentage of rotting and weight loss was increased with gradual advancement of time. The highest value of weight loss and shelf life was recorded in green mature tomatoes without ethephon and with 500 and 750 ppm ethephon treatment. The highest value of vitamin-C, TSS and titrable acidity were shown by half ripen and pH by green mature tomatoes at different days of storage. The ethephon concentration of 750 ppm the gave maximum vitamin-C at 6 and 9 days of storage but 1000 ppm gave the maximum TSS% followed by 750 ppm ethephon. The ethephon @ 750 ppm produced the maximum TSS at 9 day of storage in mature green tomatoes but in breaker and half ripen stage tomatoes 750 ppm ethephon gave TSS identical to 1000 ppm at different days of storage. The residue level of ethrel in tomato fruits treated with all ethephon concentrations at 3 and 5 days of storage was below 2 mg/kg which is safe for human health. Therefore, treated tomatoes should be consumed after 3 days of ethephon application.

Keywords: Maturity stage, ethephon (ethrel), ripening, quality, postharvest, tomato.

Introduction

Tomato (*Solanum lycopersicon* L.) is one of the most important and popular vegetables in Bangladesh with a considerable total production of 190.2 thousand

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tons produced in an area of 23,828 hectares (BBS, 2011). Tomato is an important horticultural commodity worldwide and plays a key role in the human diet. Tomatoes are rich in flavonoids and other phytochemicals that have anticarcinogenic properties. They are also an excellent source of lutein, zeaxanthin, vitamin C, which is most concentrated in the jelly-like substance that surrounds the seeds, as well as vitamins A, E and B-complex, potassium, manganese and phosphorus.

Proper harvesting at suitable stage determines the nutrient contents as well as storage durability of any fruit. Tomatoes are harvested at different maturity stages, such as green mature stage, breaker stage, half ripen stage and red ripen stage all over the world. Fruits are often harvested at the mature green stage to minimize the damage during post harvest handling. The fruits may later ripen spontaneously or after treatment with ethylene releasing compound (ethephon) before shipment to retailers (Wills and Ku., 2002). Losses often occurred from excessive deterioration during holding and marketing of tomatoes. This problem is especially acute with tomato when harvested at the breaker or more advanced stages of ripeness. Although ripening makes fruit edible and flavourful, it also initiates the gradual deterioration of fruit quality especially in climacteric fruits such as tomato, in which the onset of ripening is considered to be initiated by endogenous ethylene (Abeles *et al*., 1992). Shelf life is the most important aspect in loss reduction biotechnology of fruits and vegetables. There is a natural tendency for the perishable fruits and vegetables to degrade to the simpler compounds (CO_2, H_2O and NH_3) through spontaneous biochemical reaction. This type of reaction reduces the shelf life as well as other qualities of fruits and vegetables. Anju-Kumari *et al*. (1993) reported that the shelf life for all tomato cultivars were longest with harvesting at the mature green stage (10.9-13.5 days). The acid content is lower in immature fruit and is the highest at the stage when colour starts to appear, with a rapid decrease when the fruit ripens (Cantwell, 1994). During maturation and ripening of fruit there are changes in total soluble solid (TSS). TSS increases from mature green stage to red ripen stages (Helyes *et al.*, 2006). The palatability of fruits depends on TSS which increases throughout the development of fruit.

Ethephon or ethrel (2-chloroethylphosphonic acid), an ethylene releasing compound, is known as a plant growth regulator which stimulates ripe evenly fruit, decreasing preservation time and minimizing post-harvest losses (Quoc, *et al.*, 2012). Recently, there have been many mixed opinions on the toxicity of ethephon that confused the customers in Bangladesh. Ethephon has been registered with EPA (US Environmental Protection Agency) since 1973 as a plant growth regulator used to promote fruit ripening and flower induction. Ethephon is irritant to the skin or the eyes but is not a skin sensitizer, it was not a carcinogen and is classified by IARC (International Agency for Research on Cancer) as group D (not carcinogenic to humans) and FAO pointed out a maximum allowable daily intake for ethephon at 0.05 mg/kg body weight/day

(Bui, 2007). The recommended residue level of ethephon is 2 mg/kg of tomato fruit (Anon., 2001). The tomato fruits which are harvested at mature green or breaker stage are treated with different ethephon containing compounds for the colour development and ripening. At present ethephon present in different commercial products viz. Tomtom, Profit and Ripen-15 is being utilized for ripening of immature tomato fruit indiscriminately in high doses (100 ml/5-7 litre of water for 600-800 kg tomatoes) (BARC, 2012) in Bangladesh. Suitable stages of fruit maturity and optimum doses of ethephon for quality and storage of tomato has not yet been developed for developing countries like Bangladesh. Keeping all above facts in mind, this experiment was conducted to find out the suitable stage of tomato fruit for post harvest application of ethephon and to determine the optimum ethephon dose (s) for tomato ripening without affecting its nutrients.

Materials and Method

Site: The experimental site was in the physiology laboratory, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. The experiment was conducted during February 14, 2013 to February 27, 2012 at ambient condition. Tomato fruits of different maturity stages were dipped in various concentrations of ethephon (etherl) for five minutes.

Plant material: Freshly harvested tomato fruits of the variety BARI Tomato-14 were collected as per requirement of the study from the vegetable field of HRC, where tomato plants have been grown for this purpose. Tomato fruits were harvested at two maturity stages according to the description by Mitcham *et al.* (1989): mature green (fully expanded but unripe fruit with mature seed) and breaker (first visible sign of carotenoid accumulation on bottom). Another set of fruits were harvested at half ripen stages (50% of the fruit surface are pink coloured) (Moneruzzaman *et al.* 2008a). After drying in air, each group of fruits was further divided into two parts. One as for the inoculation experiment; the other was directly placed into plastic boxes with approx. 90% relative humidity (RH), stored at 20 ^{o}C, and sampled from fruit pericarp at various time of intervals

Treatment setting: The experiment consisted of three maturity stages (M_1 = Mature green stage, M_2 = breaker stage and M_3 = Half- ripen stage) and four levels of ethephon concentrations (T_1 = control , T_2 = 500 ppm, T_3 = 750 ppm and T_4 = 1000 ppm). Fruits were selected based on the uniform size and no physical injuries or infections. Prior to use, fruits were surface-disinfected with 2% (v/v) sodium hypochlorite for 2min, rinsed with tap water, and air-dried. Then, fruits at each stage were immersed in different solutions for 5 min. Ten tomato fruits weighing 1000 g were placed for each treatment. The experiment was laid out in CRD with three replications. The source of ethephon was Spectrum (Ethephon 39%) manufactured in the United States of America. The temperature and relative humidity was 23.5 ^{0}c ± 1.5^{o}C and 65-70%, respectively in the laboratory.

Parameter studied: The parameters studied were days required for ripening, shelf life, weight loss (%), rotting (%), vitamin-C in tomato pulp, pH of tomato juice, total titrable acidity content, TSS content of tomato pulp. Each data was recorded at 3 days interval upto 9 days but rotting (%) and shelf life was observed up to 11 and 14 days.

Days required for ripening: In order to determine days required for ripening, tomatoes were daily observed for their colour and the time (days) required to reach light red stage, between 60 and 90% fully red ripe stage (that is red colour of tomato surface between 60 and 90%) was measured.

Shelf life: The shelf life was calculated by counting the days required to attain the last stage of ripening but up to the stage when fruit remained still acceptable for marketing.

Weight loss: The weight loss of tomato fruit sample was calculated by using the following formula:

$$\textit{Total weight loss of fruit (\%)} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

Rotting (%): Rotting was determined by visual observation. Unmarketable tomatoes including fruits with various spots developed on the peel, rotten, decayed and shriveled fruits were considered as rotten.

Vitamin-C content of tomato pulp: Vitamin-C in tomato pulp was estimated by 2,6-Dichlorophenol-indophenol visual titration method as described by Rangana (1986). The reagents used for the estimation of vitamin-C were as follows: 1) Metaphosphoric acid (6%), 2) standard ascorbic acid solution, 3) 2-6 dichlorophenol-indophenol dye. For estimation of vitamin-C, the following steps were followed: Standardization of dye solution, preparation of solution and titration.

$$\textit{Vitamin-C content (mg per 100 g of fruit pulp)} = \frac{T \times D \times V1 \times 100}{V2 \times W}$$

Where, T = Titre, D = Dye factor, V_1 = Volume made up, V_2 = Volume of extract taken for estimation and w = weight of sample taken for estimation

Total titrable acidity content of tomato pulp: Total titrable acidity was determined using the following steps (Rangana, 1986): At first sample blended, filtered, transferred to volumetric flax and volume made up to the mark. Ttitrated with 0.1 0.1N NaOH. Percentage of titrable acidity was calculated using the following formula:

$$\textit{Total titrable acidity (\%)} = \frac{T \times N \times E \times V1 \times 100}{V2 \times W}$$

Where, T = Titre, N = normality of NaOH, V_1 = Volume made up,E = Equivalent weight of acid V_2 = Volume of extract taken for estimation and w = weight of sample taken for estimation.

pH of tomato juice: The sample for pH determination was prepared by the method described by Rangana (1986). One gram of sample was homogenized in 1 ml of boiled distilled water and 1 ml of de-ionized water of pH 7.0 and the pH of tomato juice was recorded by an electronic pH meter. The pH meter was standardized with the help of buffer solution.

TSS content of tomato pulp: Total Soluble Solid (TSS) content of tomato fruit pulp was determined by using Digital Hand Refractometer by placing a drop of pulp solution on its prism. The percentage of TSS was obtained from the direct reading of the refractometer.

Residue level of ethephon: Residue level of ethephon in ethrel (0-1000 ppm) treated tomatoes of green mature stage was measured by Gas Chromatography flame-ionized detector in Toxicology laboratory, Entomology Division, Bangladesh Agricultural Research Institute *(*Rahman *et al*., 2012*)*. Extra treatment (tomatoes treated with 2000 ppm ethrel) was also analyzed for clear understanding although this treatment was not included in this experiment.

The data collected were subjected to an analysis of variance using MSTAT-C. Mean separation was performed by DMRT at 5% level of probability.

Results and Discussion

Days required for ripening

The mature green tomatoes took about 6 days to reach the full ripening stage whereas breaker stage tomatoes took 5 days and half ripen tomatoes 4 days (Table 1). The ethephon hastened ripening of tomatoes compared to control (Table 1). The 500, 750 and 1000 ppm ethephon hastened tomato ripening by 2, 3 and 4 days compared to control. In mature green tomatoes, 500 ppm ethephon accelerated ripening by 4 days while 750 and 1000 ppm ethephon accelerated ripening by 6 days (Table 2). But in breaker stage tomatoes 500 and 700 ppm ethephon accelerated ripening by 2 days and 1000 ppm by 3 days. In case of half ripen tomatoes 500 ppm ethephon hastened ripening by 2 days while 750 and 1000 ppm by 3 days. Moura *et al.* (1997) found 1000 ppm ethephon solution was more efficient in hastening tomato ripening. It was found by Olympio and Norman (2000) that concentrations of 500 and 1000 ppm ethephon reduced the ripening time. The mango cultivars treated with 0.8% (8000 ppm) ethephon accelerated ripening (Thanh Hai, *et al*., 2009).

Shelf life of tomato

Mature green tomato had a higher storability than the breaker stage followed by half ripen tomatoes (Table 1). Maximum shelf life was 11.3 days in mature green tomatoes followed by breaker stage (8.6 days) and minimum was 7.6 days for half ripen tomatoes. It was found by Moneruzzaman *et al*. (2008a) that mature green tomatoes of cv. Roma VF had the highest shelf life (13 days) followed by

half ripen tomato (12 days). Ethephon levels had also significant effect on shelf life of tomatoes (Table 1). Control was recorded to give the longest shelf life (10.22 days), followed by 500 ppm (9.33 days) and 750 ppm (9.00 days). The lowest shelf life was recorded by 1000 ppm ethephon (8.00 days). After penetration into cell ethephon might cause damage to some tissues that helps in rotting of fruits and thus reduced the shelf life (Anon., 2010).

Table 1. Main effect of maturity stage and ethephon on days required for ripening and shelf life of treated tomato (var. BARI Tomato-14).

Treatment	Days required for ripening	Shelf life (days)
Maturity stages		
Mature green stage (M_1)	5.9 a	11.3 a
Breaker stage (M_2)	5.0 b	8.6 b
Half ripen stage (M_3)	4.0 c	7.6 c
Ethephon concentration		
Control (distilled water) (T_1)	7.4 a	10.22 a
500 ppm (T_2)	5.1 b	9.33 b
750 ppm (T_3	4.1 c	9.00 b
1000 ppm (T_4)	3.2 d	8.00 c
CV (%)	8.87	6.32

Means within a column having different letters are significantly different at 5% level by DMRT.

Table 2. Combined effect of maturity stages and ethephon on days required for ripening and shelf life of tomato (var. BARI Tomato-14).

Treatment		Days required for ripening	Shelf life (days)
Maturity stage	Ethephon conc.		
M_1	T_1	9.7 a	12.3 a
	T_2	6.0 c	11.3 a
	T_3	4.3 ef	11.3 a
	T_4	3.7 fgh	10.0 b
M_2	T_1	7.0 b	9.3 bc
	T_2	5.3 cd	8.3 cd
	T_3	4.7 de	9.00 bcd
	T_4	3.0 h	7.7 de
M_3	T_1	5.7 c	9.0 bcd
	T_2	4.0 efg	8.3 cd
	T_3	3.3 gh	6.7 ef
	T_4	3.0 h	6.3 f
CV (%)		8.87	6.32

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green stage, M_2 = Breaker stage, M_3 = Half ripen stage, T_1 = Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm.

The maximum shelf life (12.3 days) was recorded in case of mature green tomatoes without ethephon application (Table 2). The lowest shelf life was found from 1000 ppm ethephon applied in half ripen tomatoes (6.3 days) closely followed by 750 ppm ethephon (6.7 days) applied in the same stage tomatoes. The ethephon level of 500 and 750 ppm coupled with mature green tomatoes gave shelf life identical to green mature tomatoes treated with distilled water (control). Similar results were given by 500 and 750 ppm ethephon in breaker stage tomatoes. The ethephon level of 500 ppm coupled with half ripen tomatoes gave shelf life identical to same stage tomatoes treated with distilled water (control).

Table 3. Main effect of maturity stages and ethephon on weight loss and rotting of tomato at different days of storage.

Treatment	Duration of storage								
	Weight loss (%)				Rotting (%)				
	0D	3 D	6 D	9 D	0D	3 D	6 D	9 D	11D
Stage of maturity									
M_1	0.00	3.52a	5.25a	7.64a	0.00	0.00	0.00c	6.67c	8.33c
M_2	0.00	2.93b	4.35b	6.04b	0.00	0.00	2.23b	23.17b	35.83b
M_3	0.00	2.65c	4.02b	5.90b	0.00	0.00	5.83a	30.83a	50.83a
Ethephon Conc.									
T_1	0.00	2.31c	3.82b	5.16c	0.00	0.00	0.00c	2.22c	2.22d
T_2	0.00	2.78b	3.49b	5.12c	0.00	0.00	0.00c	15.56b	22.22c
T_3	0.00	3.48a	5.26a	7.77b	0.00	0.00	5.56b	32.22a	45.56b
T_4	0.00	3.56a	5.60a	8.54a	0.00	0.00	11.11a	30.22a	56.67a
CV (%)		7.23	7.68	7.09			11.58	13.56	13.39

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green stage, M_2 = Breaker stage, M_3 = Half ripen stage, T_1 = Control Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm, D = Day.

Weight loss (%)

Maturity stages, ethephon levels and their combination were found to have significant effect on total loss in weight of fruit (Tables 3 and 4). Total weight loss in mature green tomatoes was always higher during the entire period of storage. At the third day of storage, it was 3.52% that rose to 7.64% at 9th day. In half ripen tomatoes, weight loss was the lowest, being 2.65% at 3rd day and 5.90% at 9th day of storage. Weight loss in mature green tomatoes was higher because of higher rate of dehydration that generally happened in tender tissue. This is in line with the result of Moneruzzaman *et al.* (2008a). Ethephon solution also had significant effect on weight loss of tomato (Table 3). The ethephon solution of 750 and 1000 ppm gave higher weight loss than other treatments at 3 and 6 day of storage. Ethephon 1000 ppm gave the highest weight loss at 9 day

of storage. The ethephon level of 500 ppm produced higher weight loss than control at 3 day of storage but this level gave weight loss identical to control at 6 and 9 day of storage. The interaction effect was significant at 3, 6 and 9 day of storage with regard to total weight loss in fruit (Table 4). Here the weight loss gradually increased with the advancement of storage period. Ethephon at 750 and 1000 ppm at the 3rd and 6th day of storage and 1000 ppm at 9 day of storage gave maximum weight loss in green mature tomatoes. The half ripen tomatoes coupled with control gave minimum weight loss at all days of storage. It was also found by Quoc *et al*. (2012) that during post harvest ripening, weight loss rate in acerolas fruit treated with ethephon increased over the preservation time.

Rotting (%)

Stages of maturity, ethephon levels, and their combinations were found to have significant effect on rotting (%) of tomatoes (Tables 3 & 4). Rotting in half ripen tomatoes was found always higher during the entire period of storage. There were no rotten tomatoes found at 3rd day in all maturity stages. The green mature tomatoes also did not get rotten at 6 day of storage. At the 6th day of storage total rotting percent was 5.83% that rose to 50.83% on 9 day of storage in half ripen tomatoes (Table 3). On the other hand rotting percent in mature green tomatoes being 6.67% at 9th day and was 8.33% at 11 day of storage. In breaker stage the rotting percent was 2.23% at 6 day, 23.17% at 9 day that rose to 35.83% at 11 day of storage. The rotting percent was higher in half ripen tomatoes because of higher rate of transpiration, more skin permeability for water loss and high susceptibility to decay organism of this climacteric type of fruit. This corroborates the report of Moneruzzaman *et al*. (2008a). The highest rotting of 11.11% was recorded in 1000 ppm ethephon at 6 day of storage. But at 9 day of storage the maximum rotting % was noticed in 750 ppm and 1000 ppm ethephon. Again at 11 day of storage rotting % was found highest in 1000 ppm ethephon. The ethephon level of 1000 ppm gave the highest rotting percent irrespective of maturity at 6 day of storage (Table 5). The ethephon 500 and 750 ppm did not show any rotting at 6 day of storage. The ethephon solution of 750 ppm gave no rotting at 6 days storage. At 9 day of storage there was no significant difference between 750 and 1000 ppm ethephon irrespective of maturity stages. The highest rotting percent was recorded from 1000 ppm ethephon in half ripen tomatoes closely followed by same ethephon solution in breaker stage tomatoes and 750 ppm ethrel in half ripen tomatoes at 11 day of storage. This is perfect agreement with the results of Dhall and singh (2013) who reported that rotting percentage of green mature tomatoes 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 green mature and breaker stage tomatoes gave no rotting when no ethephon was applied.

Table 4. Combined effect of maturity stages and ethephon on weight loss of tomato (cv.BARI Tomato-14) fruit during storage.

Days after storage					
Treatment		0D	3D	6D	9D
Maturity stages	Ethephon conc.				
M_1	T_1	0.00	2.68cd	4.40de	5.93e
	T_2	0.00	3.21bc	3.92ef	5.71e
	T_3	0.00	4.01a	6.18a	9.02b
	T_4	0.00	4.17a	6.51a	9.90a
M_2	T_1	0.00	2.25de	4.74fg	5.04f
	T_2	0.00	2.72cd	3.4gh	5.00f
	T_3	0.00	4.40b	5.03bc	7.54c
	T_4	0.00	3.37b	5.25b	8.03c
M_3	T_1	0.00	2.00e	3.34gh	4.50f
	T_2	0.00	2.42de	3.17h	4.65f
	T_3	0.00	3.02bc	4.56cd	6.75d
	T_4	0.00	3.15bc	5.03bc	7.70c
CV(%)			7.23	7.68	7.09

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green stage, M_2 = Breaker stage, M_3 = Half ripen stage, T_1 = Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm; D = Day.

Table 5. Combined effect of and maturity stages and ethephon on rotting of tomato (cv.BARI Tomato-14) fruits during storage.

Days after storage						
Treatment		0D	3D	6D	9D	11D
Maturity stages	Ethephon conc.					
M_1	T_1	0.00	0.00	0.00d	0.00e	0.00d
	T_2	0.00	0.00	0.00d	10.00d	10.00c
	T_3	0.00	0.00	0.00d	10.00d	10.00c
	T_4	0.00	0.00	6.68c	6.68d	6.68cd
M_2	T_1	0.00	0.00	0.00d	0.00e	0.00d
	T_2	0.00	0.00	0.00d	13.34d	13.33bcd
	T_3	0.00	0.00	6.68c	36.67ab	53.33ab
	T_4	0.00	0.00	13.33a	36.67ab	76.67a
M_3	T_1	0.00	0.00	0.00d	6.68d	6.68d
	T_2	0.00	0.00	0.00d	23.34bc	36.67bcd
	T_3	0.00	0.00	10.00b	50.00a	73.33a
	T_4	0.00	0.00	13.33a	47.33a	86.67a
CV (%)				11.58	13.56	13.39

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green stage, M_2 = Breaker stage, M_3 = Half ripen stage,T_1 = Control Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm; D = day.

Vitamin-C content of tomato pulp

Vitamin-C content of tomato pulp varied significantly in fruits of different maturity (Table 6). Results showed that vitamin-C content was decreased with the advancement of time. Half ripen tomato contained the highest quantity of vitamin-C (18.10mg/100g) while the mature green tomato contained the lowest quantity of vitamin-C (11.43mg/100g) at harvest. This is perfect agreement with Moneruzzaman *et al.* (2008b). At 6 and 9 day of storage ethephon treatment with all concentrations maintained a lead over control in respect of vitamin-C content. This in agreement with Thanh Hai, *et al*. (2009) who got the maximum Vitamin-C content in mango compared to control using 0.8% (8000 ppm) ethephon. The 1000 ppm ethephon gave the highest vitamin-C at 6 day of storage whereas 750 ppm ethephon gave the maximum at 9 day of storage. Maturity stages, ethephon and their combinations were found to have significant effect (Table 7). The maximum vitamin-C content at 6^{th} and 9^{th} day of storage was recorded in half ripen tomato coupled with 1000ppm ethephon which was statistically similar to 1000 ppm ethephon coupled with the same maturity. In mature green and breaker stage tomatoes 1000 ppm ethephon produced the maximum vit.-C.

Table 6. Main effect of maturity stages and ethephon on vitamin -C and pH content of tomato (cv. BARI Tomato-14) at different days of storage.

Treatment	Duration of storage							
	Vitamin-C (mg/100g)				pH			
	0D	3 D	6 D	9 D	0D	3 D	6 D	9 D
Maturity stages								
M_1	11.43c	10.34c	10.25c	7.51c	4.12a	4.14	4.18a	4.22a
M_2	14.26b	12.93b	13.20b	11.75b	4.09b	4.10	4.13ab	4.18b
M_3	18.10a	16.45a	16.93a	14.54a	4.04c	4.06	4.09b	4.14c
Ethephon conc.								
T_1	14.56	14.38a	12.87d	11.02c	4.08	4.09	4.14	4.18
T_2	14.60	13.00b	13.43c	10.81c	4.09	4.12	4.13	4.17
T_3	14.60	13.82b	13.67b	11.88a	4.08	4.10	4.13	4.18
T_4	14.62	12.76b	13.87a	11.36b	4.09	4.10	4.13	4.19
CV (%)	3.74	4.73	3.52	3.87	4.06	3.17	4.05	2.74

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green, M_2 = Breaker stage, M_3 = Half ripen stage,T_1 = Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm; D = Day.

pH of tomato juice

The pH content of tomato juice varied significantly in fruits of different maturity (Table 6). It was found that pH increased with the advancement of ripening of fruit. Matsumoto *et al.* (1983) declared that organic acids are metabolized by the fruit during ripening and storage. During entire period of storage the highest pH value was observed in mature green tomatoes followed by breaker stage and half ripen fruit, respectively. This result corroborates the results of Moneruzzaman *et al.* (2008b). The effects of ethephon on pH of tomato were not found significant during storage. The interaction effect on pH was also insignificant.

Table 7. Combined effect of maturity stages and ethephon on vitamin-C content of tomato (cv. BARI Tomato-14) fruits during storage.

Duration of storage					
Treatment		0D	3D	6D	9D
Maturity stages	Ethrel conc.				
M_1	T_1	11.41	11.38	10.04g	7.45g
	T_2	11.47	10.15	10.14f	7.82g
	T_3	11.41	9.45	10.35f	7.87g
	T_4	11.43	9.88	10.47f	6.91h
M_2	T_1	14.20	14.15	12.54d	11.16f
	T_2	14.25	12.68	12.52d	11.79e
	T_3	14.29	12.40	12.40e	12.32d
	T_4	14.29	12.50	12.48e	11.73e
M_3	T_1	18.06	17.61	16.04b	14.44b
	T_2	18.08	16.18	13.12c	12.82c
	T_3	18.10	16.12	16.09b	15.45a
	T_4	18.15	16.89	16.46a	15.45a
CV (%)		3.74	4.73	3.52	3.87

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green stage, M_2 = Breaker stage, M_3 = Half ripen stage,T_1 = Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm; D = Day.

Table 8. Main effect of maturity stages and ethrel and on TSS and titrable acidity content of tomato (cv. BARI Tomato-14) at different days of storage.

Duration of storage								
Treatment	TSS				Titrable acidity			
	0D	3 D	6 D	9 D	0D	3 D	6 D	9 D
Maturity stages								
M_1	3.83c	4.20c	4.21c	4.45b	0.35c	0.37c	0.42c	0.43
M_2	4.06b	4.28b	4.38b	4.57a	0.38b	0.41b	0.44b	0.44
M_3	4.27a	4.39a	4.50a	4.61a	0.42a	0.45a	0.46a	0.44
Ethephon conc.								
T_1	4.06	4.111c	4.24d	4.36c	0.38	0.39	0.41c	0.43
T_2	4.06	4.32b	4.32c	4.58b	0.37	0.41	0.43b	0.44
T_3	4.08	4.36ab	4.42b	4.58b	0.39	0.42	0.46a	0.45
T_4	4.02	4.37a	4.46a	4.65a	0.39	0.43	0.46a	0.46
CV (%)	3.55	2.69	3.84	4.06	2.78	2.52	3.45	4.13

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green stage, M_2 = Breaker stage, M_3 = Half ripen stage,T_1 = Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm; D = Day.

TSS content of tomato pulp

TSS content of tomato pulp varied significantly in fruits of different maturity (Table 8). Half ripen tomato contained the highest quantity of TSS (4.27%) while it was the lowest (3.83%) in mature green tomatoes at harvest. For all maturity stages, TSS increased gradually with the advancement of ripening process. This is in consonance with the results of Moneruzzaman *et al*. (2008b) and Helyes *et al.* (2006). Ethephon levels were also found to have significant effects on changes in TSS content of tomato juice at 3, 6, and 9 days of storage. The

ethephon level of 1000 ppm gave the maximum TSS content at 3, 6 and 9 day of storage, followed by 750 ppm ethephon in all days of storage. This corroborates the results of Bal and Kok (2007) who found the highest value of TSS at 1000 ppm ethephon compared to 500 ppm ethephon. At 3 day of storage there was no significant difference between 750 and 1000 ppm with regard to TSS content.

Table 9. Combined effect maturity stages and ethephon on TSS content of tomato (cv. BARI Tomato-14) fruits during storage.

Duration of storage					
Treatment		0D	3D	6D	9D
Maturity stage	Ethephon conc.				
M_1	T_1	3.82	3.92g	4.11g	4.26f
	T_2	3.85	4.25e	4.18f	4.46de
	T_3	3.85	4.31de	4.25e	4.49d
	T_4	3.80	4.32de	4.28e	4.59c
M_2	T_1	4.07	4.12f	4.23e	4.42e
	T_2	4.05	4.31de	4.35d	4.61bc
	T_3	4.09	4.35bcd	4.44c	4.61bc
	T_4	4.03	4.34cd	4.51b	4.65bc
M_3	T_1	4.28	4.30de	4.38d	4.40e
	T_2	4.05	4.40abc	4.43c	4.68ab
	T_3	4.28	4.42ab	4.57a	4.65abc
	T_4	4.22	4.46a	4.61a	4.72a
CV (%)		3.55	2.69	3.84	4.06

Means within a column having different letters are significantly different at 5% level by DMRT, M_1 = Mature green, M_2 = Breaker stage, M_3 = Half ripen stage, T_1 = Control (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_6 = 1000 ppm; D = Day.

The TSS content was also found to be significantly influenced by the combined effect of maturity stages and ethephon levels at 3, 6 and 9 days of storage (Table 9). At 3, 6 and 9 days of storage 500, 750 and 1000 ppm ethephon gave the highest total soluble solid (TSS) compared to control. In green mature tomatoes there was no significant difference between 750 and 1000 ppm ethephon with regard to TSS%. In breaker stage 500, 750 and 1000 ppm ethephon maintained a lead over control but they give identical results in respect of TSS content at 3 and 6 days of storage. Again in full ripen stage 750 and 1000 and 2000 ppm ethephon produced statistically similar TSS % at all days of storage.

Titrable acidity content of tomato pulp

The total titrable acidity in tomato pulp varied significantly in fruits of different maturity (Table 8). The half ripen tomato pulp gave the maximum titrable acidity at harvest and also during entire period of storage except 9 day of storage and contained the highest quantity of titrable acidity (0.46%) at 6 day of storage followed by breaker stage tomatoes. The mature green tomatoes produced lower titrable acidity in fresh and 3 and 6 day of storage. This is in consonance with the

results of Moneruzzaman *et al*. (2008b). However, there was no significant difference among green mature stage, breaker stage and half ripen stage in respect of titrable acidity at 9 day of storage. The ethephon effect on titrable acidity was significant at 6 day of storage. The ethephon level of 750 and 1000 ppm gave the highest titrable acidity (0.46%) at 6 day of storage but no significant effect was found at 3 and 9 day of storage. The interaction effect was insignificant.

Table 10. Estimated residue level of ethrel (ethephon) (ppm) in treated tomato (var. BARI Tomato-14).

Ethephon level	Days after application	
	3 day	5 day
T_1	0.00	0.00
T_2	0.520	0.471
T_3	0.658	0.569
T_4	0.881	0.802
T_5*	1.468	1.234

T_1 = Contro (distilled water), T_2 = 500 ppm, T_3 = 750 ppm, T_4 = 1000 ppm, *T_5 = 2000 ppm (extra treament), Existing CXL (codex residue level)-2 mg/kg (2 ppm) ethephone (Anon., 2001).

Residue Level of ethephon

Table 10 revealed that the tomato fruits treated with 2000 ppm ethrel solution showed the maximum residue value at 3 and 5 day of storage. The residue level in treated tomatoes decreased at 5 days compared to 3 days. It might be the reason that ethephon was a volatile compound. This was in perfect agreement with Beitz *et al.* (1977). The resdue level of ethrel in tomato fruits treated with 500-2000 ppm ethephon was less than the recommended residue level of ethephon (2 mg/kg) (Anon., 2001).

Based on the results and discussion it might be concluded that tomato fruits should be harvested at mature green stage and breaker stage for distant marketing for ethephon application @ 750 ppm for tomato ripening. The ethephon treated fruits should be consumed after 3 or 4 days of ethephon application.

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