J. Environ. Sci. & Natural Resources, **11(1&2):183-189, 2018** ISSN 1999-7361

Yield and Quality of Tomato Juice as Affected by Ripening Agents

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Abstract

The effects of ethephon on acceleration of ripening as well as differentiation of quality and juice yield of tomato fruit were evaluated. Three groups of ethophon namely Ripen-15 (50% ethephon), Lpen-25 (48% ethephon) and Fast-25 (40% ethephon) along with control solution were applied on mature and uniform shaped tomato at three concentrations (10 ppm, 100 ppm, 1000 ppm). Physical and chemical attributes such as color, firmness, total weight loss, total soluble solids (TSS), vitamin C content, pulp smoothness and juice yield were studied from 3rd to 13th day of application of ethephon. The fastest yield of tomato juice was obtained from 100 ppm as compared to the slowest at 1000 ppm. The highest and lowest juice yield were found by application of Lpen-25 and Fast-25 respectively at 1000 ppm Thus, we concluded that ethephon application on tomato at an appropriate level may accelerate the ripening of tomato fruit and increase the yield of tomato juice.

Key words: Chemical property, Physical property, Ripening agents, Tomato

Introduction

Tomato is one of the most important food crops throughout the world (Muir *et al*. 2001) The use of tomato in the modern diet is very extensive and it is nearly impossible to separate tomato from the menus of fast foods and pizza parlors. The consumption of fresh and processed tomato surpassed 20 kg/yr per capita (Jones *et al*. 1991). With a high amount of lycopene (antioxidant), the fruit is also a very good source of potassium, vitamin C, folic acid and carotenoids. It also contains vitamin E, vitamin K and flavonoids. It has a low calorie content of around 20 kcal/100 g of fruit. Sugars (fructose, glucose, sucrose) and organic acids (malic and citric) are the main reason of its flavor. As the fruit ripens, fructose and glucose content increase and acids content decrease (Jones *et al*. 1991).

In Bangladesh, tomato is very popular both as fruit and vegetable. Due to its overall acceptability and a wide range of usage, the production of tomato in Bangladesh is increasing day by day. Besides people of Bangladesh are becoming more conscious about nutritious food and because of tomatoôs wide range of vitamins and minerals content, people are encouraged to increase tomato production day by day.

Tomato fruit is characterized to follow a ripening-climacteric pattern, which is controlled by the plant hormone ethylene, involving a wide range of physical, chemical, biochemical and physiological changes that start in the plant and follow after detachment from it (Abeles *et al*., 1992). Post harvest ripening of tomato is important in Bangladesh as tomato is harvested in winter (January to April). Due to the cold condition of this weather ethylene production in tomato is inhibited resulting inhomogeneous ripening, which causes unwanted loss to the producers. Therefore, avoiding such unwanted situation demands application of post-harvest ripening technique.

Different groups of ripening agents such as ethylene, ethephon, and calcium carbide are some very common names which are used for ripening tomato as well as other climacteric fruits artificially. Among these group of fruit ripening agent Calcium Carbide is Banned in many countries all over the world for its carcinogenic affect to human body. Other groups of ripening agent are not so poisonous for human body but excessive use of these groups of ripening agents may have bad effect on human health. Therefore, knowing the proper dose of the ripening agents is very necessary. Besides dose of ripening agents affect post-harvest quality and yield of fruit juice (Dhal and Singh, 2013, Wang, 1990, Abeles *et al.* 1992). However, which ripening agent at what concentration has optimal effect on the yield and quality of tomato juice has not yet been studied. Therefore, solving the issue raised, one ripening agent ethephon was applied in various concentrations on matured and uniform shaped tomato for finding out the appropriate dose of Ethephon for ripening tomato in post-harvest condition.

Materials and Method

Materials used

Freshly harvested tomatoes were used for the studies which were collected from the local grower of Sharifpur union, Jamalpur district. Mature and uniform shaped and colored tomatoes were used for conducting the experiments.

Experimental design

Three groups of Ethephon at three different concentrations were used as the ripening agents in the study. Ripen-15 (50%), Lpen-25 (48%), Fast-25 (40%) were used at 10 ppm, 100 ppm and 1000 ppm concentration on tomato for the study. Physical (color, firmness, weight loss) and Chemical (TSS, Ascorbic Acid, Juice Content, Pulp smoothness) parameters were studied for the experiment. All the experiments were carried out in triplicates.

Methods of studying parameter

Weight loss

Weight losses of tomatoes were calculated by the following formula Percentage of weight loss [illegible] = $\frac{\text{[illegible]}}{\text{[illegible]}}$ X 100

Where, WL= Percentage total weight loss, IW= Initial weight of fruit, FW= Final weight of fruit.

Color

The changes in color of tomato were determined using a numerical rating scale of 1-7, where, 1= Green, 2= Breaker, 3= Turning, 4= Pink, 5= Light red 6= Red and 7= Ripe red (Wills *et al.,* 2004).

Firmness

Firmness of tomato was determined by hand estimation using a numerical rating scale of 1-6, where, 1= hard, 2= sprung, 3= between sprung and eating ripe, 4= eating ripe, 5= over ripe, and 6= rotten.

Total soluble solids (TSS)

Total soluble solids (TSS) content of tomato pulp was measured by using Abbe's refractometer and TSS was recorded as % Brix from direct reading of the instrument.

Vitamin C content

Vitamin C (Ascorbic acid) content was determined following by the method of Plummer (1971). The ascorbic acid content was determined by following formula

Vitamin C content (mg/100 g) = $\frac{\text{[illegible]}}{\text{[illegible]}}$

Where, T= Titration, D= Dye factor, V_1= Volume made up. V_2= Volume of extract,
W= Weight of sample.

Statistical analysis

The data on various parameters were analyzed using MSTAT Statistical Package. The mean for all the treatments were calculated and analyzed of variances (ANOVA) for all the parameters was performed by F-test. The significance of difference between the pair of means was compared by least significant difference (LSD) test at the 1% and 5% levels of probability (Gomez and Gomez, 1984).

Results and Discussion

Color

The peel color scores of tomato as influenced by ripener types and level of their concentration applied are shown in Table 1. Table 1 reveals that as the duration of storage progressed at ambient temperature the colour of tomato changed from green to red. However, the kinetics of this change was highly influenced with the types of ripening agents used compared to their levels of concentration. The fastest rate of peel color changes was observed in the control tomatoes, whereas Fast-25 (40%) at 10ppm greatly inhibited the peel color changes from green to red ripe. Concerning to the level of concentration of the ripening agents, the peel colour scores changed slightly during storage up to 7 days and then the colour differences were found insignificant for all the ripeners. This result could be attributed to the reduction of physiological processes like production of ethylene, inhibition of respiration etc. The ripening agent treatment resulted in uniform development of red color after 9 days of ripening with less than 10 percent rotting. The fruits treated with control also resulted in a deep red color after ripening period of 11 days but by that time the rotting was more than 14% which made the fruits unmarketable. Similar results were also observed in banana and guava as reported by Mahajan *et al.* (2010).

Table 1. Effect of ripening agents on color of tomato

Treatments	Color [x] at different days after storage					
	3	5	7	9	11	13
T_0C_0	2.00	3.17	4.00	5.00	5.84	7.00
T_1C_1	1.34	2.06	3.00	3.83	4.50	5.42
T_1C_2	1.27	2.09	2.83	3.33	4.08	5.38
T_1C_3	1.31	2.12	2.34	3.17	4.12	5.25
T_2C_1	1.27	2.23	2.42	3.34	4.08	5.22
T_2C_2	1.18	2.29	2.35	3.35	4.06	5.12
T_2C_3	1.21	2.15	2.54	3.27	4.36	5.29
T_3C_1	1.02	1.84	1.87	3.23	4.35	5.39
T_3C_2	1.01	1.56	1.96	3.24	4.24	5.08
T_3C_3	1.00	1.24	1.76	3.13	4.86	4.98
$LSD_{0.05}$	0.209	0.153	0.333	0.259	0.216	0.385
$LSD_{0.01}$	0.285	0.208	0.454	0.353	0.294	0.526
Level of significance	**	**	**	**	**	**

*** =Significant at 1% level of probability. NS= Not significant. [x] represents color score (1 = Green, 2= Breaker, 3 = Turning, 4 = pink, 5= Light red, 6 = Red, 7 = Red ripe). T_0C_0= Control T_1C_1= Tomato applied with Ripen-15 (50%) at 10ppm. T_1C_2= Tomato applied with Ripen-15 (50%) at 100ppm. T_1C_3= Tomato applied with Ripen-15 (50%) at 1000ppm. T_2C_1= Tomato applied with Lpen-25 (48%) at 10ppm. T_2C_2= Tomato applied with Lpen-25 (48%) at 100ppm. T_2C_3= Tomato applied with Lpen-25 (48%) at 1000ppm. T_3C_1= Tomato applied with Fast-25 (40%) at 10ppm. T_3C_2= Tomato applied with Fast-25 (40%) at 100ppm. T_3C_3= Tomato applied with Fast-25 (40%) at 1000ppm.*

Firmness

The changes of firmness of tomato pulp from hard to eating ripe are obvious. As shown in Fig. 1, the fastest rate of firmness changes was observed in the control tomatoes, whereas the slowest rate of firmness changes was observed in tomato applied with Fast-15 at 1000ppm. The untreated (control) fruits maintained the highest mean firmness (score=1.23) followed by the application of Fast-25 (40%) at 10 ppm (score=1.38). The fruits treated with Ripen-15 (50%) at 1000ppm registered the lowest mean firmness (score=4.72). It was also observed that the firmness of fruits decreased with increase in the concentration of the ripening agents used during the ripening period. 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. The loss of pectin substances in the middle lamella of the cell wall was perhaps the key steps in the ripening process that leads to the loss of cell wall integrity thus cause loss of firmness and softening. The similar explanation was made by Dhall and Singh (2013) for ripening of tomato with ethylene gas generated from a ethylene generator. According to Nurul *et al.* (2012), the action of various enzymes as in the conversion of polysaccharides present in fruit declined to soluble sugar, which decreased the firmness and increased TSS in control fruits. The firmness scores of tomato increased with the advancement of storage duration but at varying rates. However, the rate of change of firmness during storage followed a similar pattern for treated samples but they were different from control.

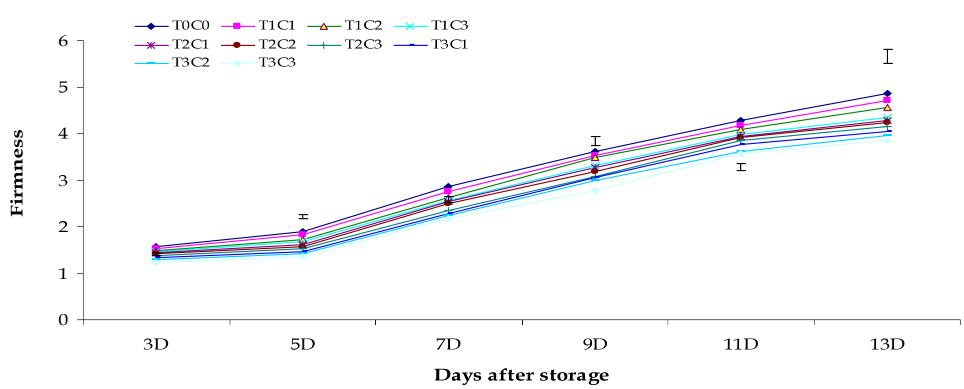

Fig. 1. Effect of ripening agents on firmness of tomato

Total weight loss

The weight loss of tomatoes was increased with the advancement of storage duration but at varying rate as shown in Fig. 2.Significant effects on the total weight loss of treated tomatoes were also observed with the types and levels of concentration of different ripening agents. 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. Among the treatments with ripening agents, application of Fast-25 (40%) (Fig. 3) on tomato was the best in terms of controlling weight loss. At the 13th day of storage, the maximum (5.56%) and at the 3rd day the minimum (3.58%) total weight loss were observed, respectively in tomato with untreated and by the application of Fast-25 (40%) at 10ppm. The increase in physiological loss in weight during ripening of tomato fruits with ripening agent application may be due to upsurge in respiration rate of the fruits. An increase in weight loss in banana fruits during ripening process was caused by ethephon or its analogues reported by Khedkar *et al.* (1981). Lessen the loss of moisture due to different post-harvest treatment were reported by Baldwin (1994) for lemon.

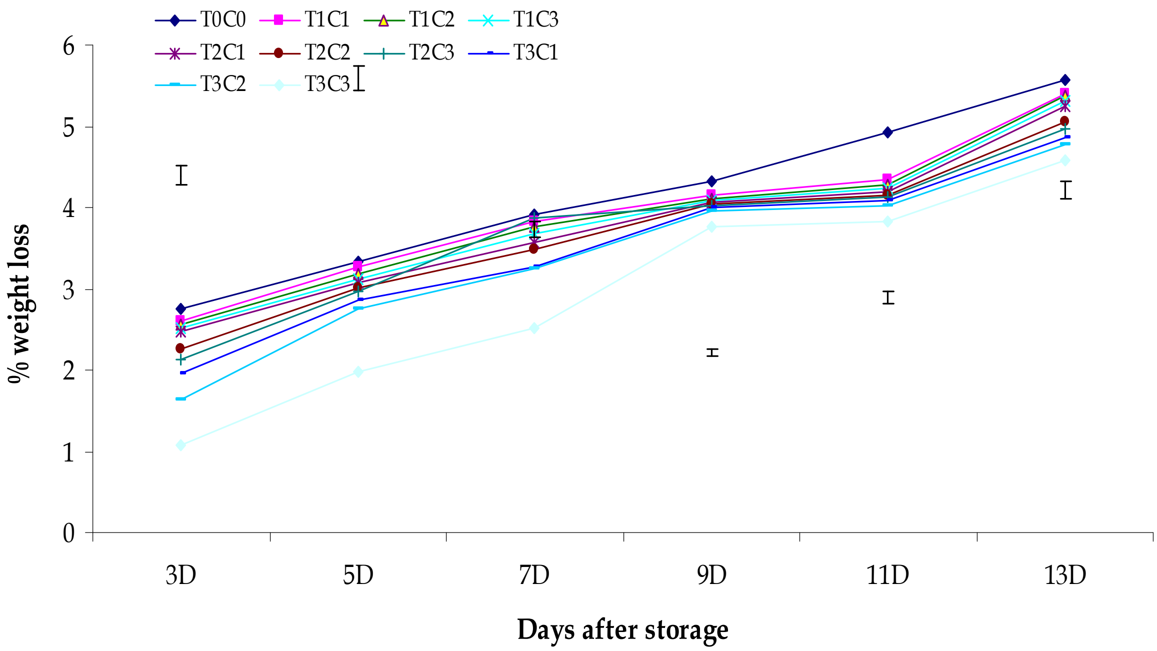

Fig. 2. Graph showing the main effect of treatments on weight loss of tomato

Total soluble solids (TSS)

Application of different concentrations of ethephon group had significant effect on total soluble solids and the results are presented in Table 2. Percentage value of total soluble solid (TSS) were increasing day by day with the application of different types and levels ethephon solution. The mean TSS was minimum (5.12% Brix) with the application of Lpen-25 (48%) and maximum (5.31% Brix) with the application of Ripen-15 (50%) as shown in Table 2. A early stages of treatment, the effect of the concentration of the ripening agents on TSS was found significant. However, the interaction between treatments and ripening period was found to be non-significant at 11th and 13th day respectively with the application of all ripening agents. The similar results were observed in guava (Sing *et al*., 1979). Percentage value of total soluble solid depends on the internal factors and external factors. Among the external factors such as room temperature, humidity, ethylene action etc. The increase in TSS during ripening may result from an increase in concentration of organic solutes as a consequence of water loss. The increase may also be due to the numerous anabolic and catabolic processes taking place in fruits, preparing it for senescence. 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.

Table 2. Effect of ripening agents on total soluble solid

Treatment combination	Total soluble solid (TSS) at different days after storage					
	3	5	7	9	11	13
T_0C_0	3.71	4.53	4.87	5.23	5.30	5.28
T_1C_1	3.58	4.61	4.94	5.28	5.32	5.31
T_1C_2	3.52	4.36	4.72	5.02	5.26	5.23
T_1C_3	3.81	4.52	4.86	5.21	5.25	5.22
T_2C_1	3.62	4.68	4.93	5.33	5.34	5.30
T_2C_2	3.59	4.42	4.67	5.13	5.24	5.12
T_2C_3	3.68	4.63	4.89	5.23	5.28	5.27
T_3C_1	3.62	4.67	4.98	5.21	5.23	5.22
T_3C_2	3.56	4.36	4.72	5.04	5.27	5.26
T_3C_3	3.82	4.12	4.62	4.93	5.18	5.17
$LSD_{0.05}$	0.153	0.179	0.143	0.179	0.222	0.222
$LSD_{0.01}$	0.208	0.244	0.195	0.244	0.303	0.303
Level of significance	**	**	**	**	NS	NS

*** =Significant at 1% level of probability. NS= Not significant.^{x} represents color score (1 = Green, 2= Breaker, 3 = Turning, 4 = pink, 5= Light red, 6 = Red, 7 = Red ripe). T_0C_0= Control T_1C_1= Tomato applied with Ripen-15 (50%) at 10ppm. T_1C_2= Tomato applied with Ripen-15 (50%) at 100ppm. T_1C_3= Tomato applied with Ripen-15 (50%) at 1000ppm. T_2C_1= Tomato applied with Lpen-25 (48%) at 10ppm. T_2C_2= Tomato applied with Lpen-25 (48%) at 100ppm. T_2C_3= Tomato applied with Lpen-25 (48%) at 1000ppm. T_3C_1= Tomato applied with Fast-25 (40%) at 10ppm. T_3C_2= Tomato applied with Fast-25 (40%) at 100ppm. T_3C_3= Tomato applied with Fast-25 (40%) at 1000ppm.*

Vitamin C content

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. The ascorbic acid content of fruit pulp varied significantly among the fruits by the application of different types of ripening agents and their levels of concentration during storage. The finding is presented in Table 3. As shown in Table 3, the significantly highest mean ascorbic acid (27.86 mg/100 g fruit weight) was observed with the application of Lpen-25 (48%) at 1000ppm whereas minimum mean ascorbic acid (11.66 mg/100 g fruit weight) in the untreated (control) fruits. The interaction between treatment and ripening period was found to be significant. However, the effect of the concentration levels on the vitamin C content exhibited inconsistence change. Slight variations in ascorbic acid were observed at initial stages of treatment due to variation in concentration of ripening agents. Similar results were also reported in apple by Gonzalez *et al.* (1998).

Table 3. Effect of ripening agents on amount of ascorbic acid of tomato

Treatment combination	Amount of ascorbic acid (mg/100g of fruit) at different days after storage					
	3	5	7	9	11	13
T_0C_0	11.66	12.58	13.81	15.42	16.92	18.84
T_1C_1	12.21	14.24	16.61	18.41	22.16	24.36
T_1C_2	12.56	14.88	17.76	20.12	23.18	25.68
T_1C_3	12.86	14.28	15.86	17.78	20.64	23.89
T_2C_1	12.06	14.12	16.08	17.91	21.61	22.92
T_2C_2	12.53	14.86	17.74	20.08	23.16	25.66
T_2C_3	12.84	14.26	15.83	17.75	20.62	27.86
T_3C_1	11.90	13.86	15.06	17.12	21.58	11.93
T_3C_2	12.52	14.83	17.72	20.04	23.14	11.92
T_3C_3	12.81	14.22	15.82	17.73	20.63	11.91
$LSD_{0.05}$	0.670	0.641	0.710	1.321	1.042	1.532
$LSD_{0.01}$	0.913	0.874	0.968	1.801	1.421	2.089
Level of significance	*	**	**	**	**	**

*** =Significant at 1% level of probability. NS= Not significant.^{x} represents color score (1 = Green, 2= Breaker, 3 = Turning, 4 = pink, 5= Light red, 6 = Red, 7 = Red ripe). T_0C_0= Control T_1C_1= Tomato applied with Ripen-15 (50%) at 10ppm. T_1C_2= Tomato applied with*

Ripen-15 (50%) at 100ppm. T_1C_3= Tomato applied with Ripen-15 (50%) at 1000ppm. T_2C_1= Tomato applied with Lpen-25 (48%) at 10ppm. T_2C_2= Tomato applied with Lpen-25 (48%) at 100ppm. T_2C_3= Tomato applied with Lpen-25 (48%) at 1000ppm. T_3C_1= Tomato applied with Fast-25 (40%) at 10ppm. T_3C_2= Tomato applied with Fast-25 (40%) at 100ppm. T_3C_3= Tomato applied with Fast-25 (40%) at 1000ppm.

Pulp smoothness

Pulp smoothness of the tomato relies on the character of fine and coarseness attributes of tomato pulp particles. The pulp smoothness of tomato as affected by postharvest treatments given in the study is presented in Fig. 3. Results presented in figure revealed that the lowest mean percentage of pulp smoothness (1.34%) in terms of ripening was recorded with the application of Fast-25 (40%) at 1000ppm and the highest mean percentage of pulp smoothness (5.46%) in terms of ripening was recorded with untreated fruits. The interaction between treatment and ripening period was found significant. The pulp smoothness percentage increased with increasing duration of storage for which the fruits were kept for ripening. Pulp smoothness of tomato is gradually decreased in the advancement tomato ripening, which is contradictory of the results reported by Knys and Largskis (1970). They referred that pulp become finer with the process of ripening.

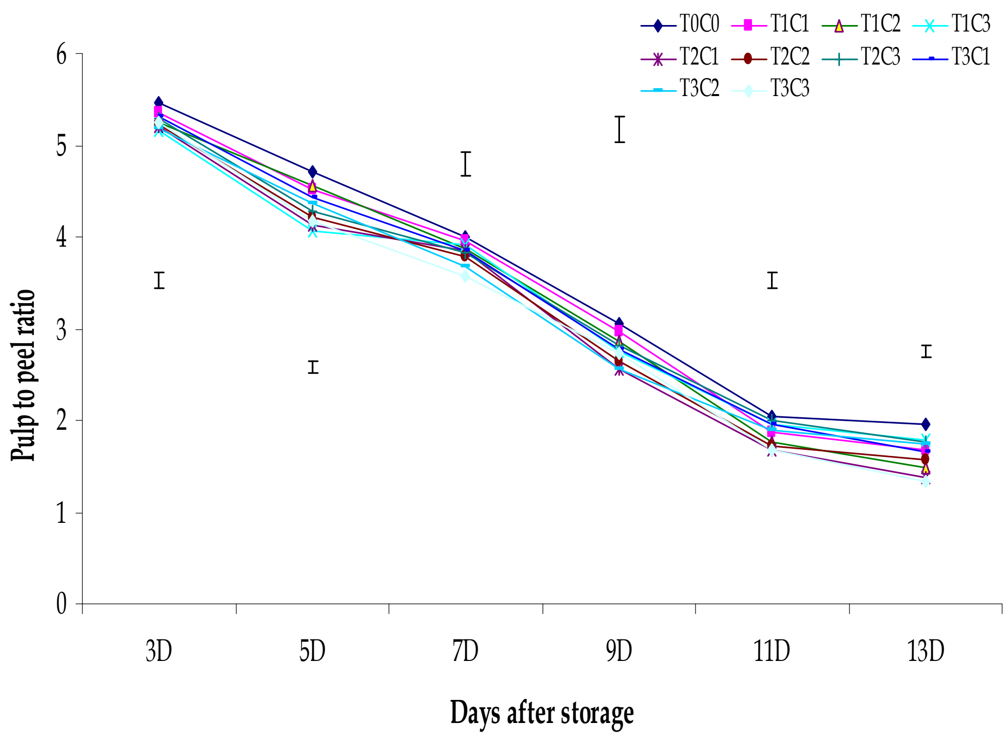

Fig. 3. Graph showing the main effect of treatments on smoothness of pulp of tomato

Tomato juice yield

The yield of tomato juice was influenced by the effect of ethephon treatment (Table 4). Juice yield of tomato showed a liner increasing trend during ripening and was found to be maximum (34.90%) with the application of Lpen-25 (48%) at 100ppm at 9th day which was closely followed by (30.81%) with the application of Ripen-15 (50%) at 10ppm at 9th day of ripening of tomato. Percentage amount of juice yield of tomato was merely increased at untreated condition but highly increased with the application of Lpen-25 (48%) at 100ppm. There is no significant different with the application of Fast-25 (40%) at 10ppm, 100ppm and 1000ppm. The treated tomatoes with the application of Fast-25 (40%) at 1000ppm at 13th day showed the minimum amount (11.91%) of juice yield. The increase of juice yield due to advanced ripening stage which resulted in the substantial utilization of sugars and hence the increased juice amount was observed. Similar results were reported by Lin and Chen (2003) in case of determining the various carotenoids in tomato juice.

Table 4. Effect of ripening agents on juice yield of tomato

Treatment combination	Percent amount of juice at different days after storage					
	3	5	7	9	11	13
T_0C_0	15.53	17.23	18.11	18.86	18.61	17.96
T_1C_1	28.30	29.16	30.71	30.81	30.04	29.46
T_1C_2	21.62	22.20	23.12	23.04	22.64	22.08
T_1C_3	19.25	20.64	21.56	22.02	21.71	18.96
T_2C_1	19.19	20.16	21.15	21.86	21.36	19.86
T_2C_2	30.01	33.20	34.56	34.90	34.24	31.96
T_2C_3	26.35	28.86	29.13	29.79	29.55	27.86
T_3C_1	19.19	21.16	22.36	23.01	22.96	11.92
T_3C_2	22.35	23.06	24.26	24.96	23.82	11.94
T_3C_3	12.59	15.16	16.20	17.23	15.21	11.91
$LSD_{0.05}$	0.863	1.156	1.425	1.512	1.427	1.232
$LSD_{0.01}$	1.177	1.577	1.943	2.062	1.946	1.680
Level of significance	**	**	**	**	**	**

*** =Significant at 1% level of probability. NS= Not significant.^{x} represents color score (1 = Green, 2= Breaker, 3 = Turning, 4 = pink, 5= Light red, 6 = Red, 7 = Red ripe). T_0C_0= Control T_1C_1= Tomato applied with Ripen-15 (50%) at 10ppm. T_1C_2= Tomato applied with Ripen-15 (50%) at 100ppm. T_1C_3= Tomato applied with Ripen-15 (50%) at 1000ppm. T_2C_1= Tomato applied with Lpen-25 (48%) at 10ppm. T_2C_2= Tomato applied with Lpen-25 (48%) at 100ppm. T_2C_3= Tomato applied with Lpen-25 (48%) at 1000ppm. T_3C_1= Tomato applied with Fast-25 (40%) at 10ppm. T_3C_2= Tomato applied with Fast-25 (40%) at 100ppm. T_3C_3= Tomato applied with Fast-25 (40%) at 1000ppm.*

Conclusions

Maintenance the juice quality of tomato is one of the major problems owing to serious nutritional and quality losses occurred during post-harvest handlings. The study suggested that Lpen-25 (48%) has the overall significant result in all cases among all the parameters. Along with application of ripening agent, use of improved technology such as edible coating, modified atmosphere packaging (MAP) can improve the tomato juice yield and quality, which requires further studies.

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