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Studies on the effect of exogenous application of salicylic acid on post-harvest quality and shelf life of tomato fruit Cv. *Abhinav*

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Abstract

An investigative research experiment was undertaken to study the effect of exogenous application of salicylic acid on tomato fruit of Cv. *Abhinav* during its storage period at 24°C. The fresh tomato fruits (*Lycopersicon esculentum* Mill.) of Cv. *Abhinav* were harvested at the proper stage of physiological maturity. The fruits were washed thoroughly with clean water followed by fungicidal treatment of 500 ppm benomyl before salicylic acid treatment. Thereafter, the fungicide treated tomato fruits were subdivided into four different lots and then immersed in salicylic acid (SA) solutions at 50, 100, 150 and 200 ppm concentrations for 30 mins respectively and kept for storage studies along with control fruits. During the storage period, the observations were recorded at frequent intervals for various physico-chemical parameters in which tomatoes treated at 200ppm salicylic acid concentration found significant with respect to the lower physiological loss in weight (10.3%), a gradual increase in TSS and colour (h) from 1.4 to 3.3°Brix and -3.63 to 2.59 respectively. Moreover, the considerable decrease was observed in titrable acidity from 1.34 to 0.14%, Ascorbic Acid (SA) content from 73.14 to 22.10 mg/100 g and texture in terms of firmness decreased from 354 to 96 gf. The total phenolic content of 200 ppm salicylic acid treated tomatoes showed a gradual decrease from 3.79 to 3.14 mg GAE/g and lycopene content increased slowly from 7.01 to 12.31 mg/100 g therefore, found significant as compared to rest of the treatments and control fruits.

1. Introduction

Tomato is a major contributor of carotenoids (especially lycopene), phenolics, vitamin C and small amounts of vitamin E in daily diets (Khachik *et al*., 2002). The two main carotenoids in tomato fruits are lycopene which imparts the red colour to the tomato and carotene which accounts for approximately 7% of tomato carotenoid content. Tomato fruits are also rich in phenolic compounds, which are considered as potentially health-promoting substances due to their anti-oxidative, anti-cancer, anti-diabetic and cardiovascular protective effects. Tomatoes contain quercetin, naringenin, rutin and chlorogenic acid as the main phenolic compounds, which along with ascorbic acid is determinant of the hydrophilic antioxidant activity. Due to carotenoids, lycopene and β-carotene, tomatoes have high nutritional value (Rao *et al*., 2000).

Ethylene plays a key role in the ripening of climacteric fruits such as tomato by triggering several ripening related physiological changes and its ripening is highly dependent on ethylene action (Lelievre *et al.,* 1997). But the production of excess ethylene leads to over-ripening and facilitates microbial growth thereby reducing the shelf life. Therefore, control over ethylene action is required. Global estimates of losses for fruits and vegetables after harvest ranges as high as 30 to 40 %, with much of these losses occurring in regions of tropical fruit production. The rapid ripening of fruit after harvest limits storability and is a concern during transportation and marketing. Therefore, delaying the ripening, one approach involves inhibition of ethylene action. Ethylene synthesis and action in fruits can be affected by low temperature storage, controlled or modified atmosphere and application of ethylene antagonists such as salicylic acid (Fung *et al*., 2004).

Many compounds have shown the ability to block the ethylene binding site, causing either the suppression or the inhibition of ethylene effects (Sisler and Serek, 1997). However, none of these compounds is commercially acceptable due to toxicity and

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manufacturing concerns (Fan *et al.*, 1999) but salicylic acid unlike other compounds has no proven potential toxicity so far and therefore may be undertaken for its application on different fruits in order to make it more commercially viable and reliable ethylene antagonist compound.

Thus, salicylic acid (SA), a plant hormone plays an important role in the induction of plant defense against a variety of biotic and abiotic stresses through morphological, physiological and biochemical mechanisms. The function of exogenous salicylic acid at non-toxic concentrations has been exposed for delaying the ripening and softening of banana (Srivastava and Dwivedi, 2000) and it has also been used for different crops to prolong their shelf life. Many physiological, biochemical and structural changes occur during fruit repining which induces starch degradation or other polysaccharides to produce sugars. Therefore, the aim of this study was to utilize the metabolic roles of salicylic acid to delay the ripening of tomato to extend the shelf life and hence the present investigation was undertaken to provide a better understanding of the role of SA in the control of tomato fruit specifically of cv. *Abhinav* variety ripening and its effect on various physicochemical parameters during storage.

2. Materials and methods

The present study was carried out in the Food Technology Laboratory, Department of Chemical Technology, Dr Babasaheb Ambedkar Marathwada University, Aurangabad.

2.1 Materials

Tomato fruit harvested at breaker stage of maturity of Cv. *Abhinav*. The good quality analytical grade chemicals including benomyl fungicide, BHT, hexanal, ethanol, Folin–Ciocalteu reagent, methanol and acetone were obtained from the reputed manufacturers. Salicylic acid powder procured from Himedia Laboratory Chemicals Limited. The sophisticated analytical instruments available in the Food technology laboratories were effectively and efficiently used in the present research work. The instruments like Cool Chamber (Nanolab India), Minolta Colorimeter (Model-CR-10, Konica, Japan), Handheld Digital Refractometer (PAL-3, Atago, Japan), Analytical Weighing Balance, etc. were used for carrying out analytical processes.

2.2 Selection of tomato fruits

The fresh tomato fruits (*Lycopersicon esculentum* Mill.) of Cv. *Abhinav* were harvested at breaker stage from well-managed commercial farms of village Devgaon Rangari from Aurangabad district of Maharashtra, India. The fruits were washed thoroughly with clean water and then prepared for the treatments.

2.3 Treatment of salicylic acid

Tomatoes harvested at breaker stage of maturity were selected, washed and graded on the basis of their specific gravity and given the benomyl fungicidal application of 500 ppm for 20 mins followed by salicylic acid treatment at various concentrations as per Table 1 viz. 50, 100, 150 and 200 ppm by immersing in salicylic acid solutions for 30 mins respectively and stored along with absolute control sample at 24°C.

Table 1. Treatment details of salicylic acid concentration, storage period and storage

Treatment	Treatment details
T_0	Control Fruit (Tomato) + 24 °C Storage temperature
T_1	Salicylic acid - 50ppm + 24 °C Storage temperature
T_2	Salicylic acid - 100ppm + 24 °C Storage temperature
T_3	Salicylic acid - 150ppm + 24 °C Storage temperature
T_4	Salicylic acid - 200ppm + 24 °C Storage temperature

2.4 Physicochemical analysis of tomato fruits

Various physicochemical analyses of the control and treated fruits were carried out in order to determine the effect of treatments of salicylic acid on quality and shelf life extension of tomato fruit. The observations were recorded at frequent intervals of 4 days during the storage period for various parameters.

2.4.1 Percent physiological loss in weight of fruit

Physiological loss in weight of tomato fruit was calculated by using analytical weighing balance to determine the degree of maturity during the storage of salicylic acid treated and control fruit samples by the method suggested by Nunes (2008).

2.4.2 Surface colour

Color value L, a and b was determined using a colorimeter (Konica Minolta CR-10) with a standard CIE illuminant and by calculating the hue angle by using formula given by Bai *et al*. (2004).

$$\text{Hue angle (h)} = \text{Tan}^{-1}.(B/A)$$

2.4.3 Fruit firmness

The textural characteristic of tomatoes in terms of firmness was determined by using a texture analyzer (TMS-Pro, FTC, USA). The fruit was placed below probe and the 5 mm diameter probe with 1mm/s test speed and 0.5 N trigger force was inserted into the surface of fruits at 10 mm distance. The maximum force generated during probe's travel was measured in gram force (gf) and the results in terms of firmness were expressed in gram force (gf) as described by Xie *et al*. (2009).

2.4.4 Total soluble solids

The total soluble solid (°Brix) in the fruits was recorded by Atago digital Pocket Refractometer PAL-3 (AOAC, 2016). For precision and accuracy of the values, the prism of refractometer was washed with distilled water and wiped dry before every reading.

2.4.5 Titrable acidity

Total titrable acidity of salicylic acid treated tomato fruits was determined by titrating the extracted juice against 0.1 N NaOH (sodium hydroxide) using phenolphthalein as an indicator and expressed as oxalic acid content in percentage as suggested by Ranganna (2002).

2.4.6 Ascorbic acid content

The ascorbic acid content of tomatoes was estimated by using 2, 6 dichlorophenol indophenols dye titration method (Ranganna, 2002; AOAC, 2016) and expressed as mg 100 g^{-1}.

2.4.7 Total phenolic content

The total phenolic contents of the tomatoes extracted by methanol determined by reading absorbance on UV-VIS Spectrophotometer (LABINDIA-3000+plus, India) at 765 nm using Folin–Ciocalteu reagent as with slight modification in the analytical method given by Singleton (1974). The results were expressed as gallic acid as a standard in mg gallic acid equivalents per gram (mg GAE/g) of tomato fruits.

2.4.8 Lycopene content

The lycopene content of the tomato fruits during storage period was estimated as per the method specified by Fish *et al*. (2002) and modified by Ranveer *et al*. (2013). Extraction was carried out by using solvents such as BHT, acetone and ethanol with the help deionized water and thus allowing the mixture for phase separation followed by dilution of the uppermost solvent layer with the addition of hexanal in 1:10 proportion. Later on, the absorbance of the same was measured at 503 nm by using UV-Vis Spectrophotometer (Model Make, 3000+ LabIndia)

$$\text{Lycopene } (\mu g/g) = \frac{\text{Absorbance} \times 31.2 \times \text{Dilution}}{\text{gram of sample}}$$

3. Results and discussion

3.1 Effect of salicylic acid on physiological loss (%) in weight (PLW) of tomato fruit

The percentage of physiological loss in weight PLW (%) and colour of tomatoes are important physical quality parameters determining wholesomeness and shelf life of any fruits. The phase transformation from maturity to senescence which results in spoilage of fruit is identified by these quality parameters. Results in Table 2 showed that PLW of control sample increased from 2.9 to 12.3% within 12 days of storage. The tomatoes which were treated at 200 ppm salicylic acid concentration showed a very gradual increase in PLW from 2.8 to 10.3% on 32 days of their shelf life with better retention of quality parameters than any other treatments. The increases in the percentage of PLW of tomato might be due to the transpiration of tomato in the 24^0C storage condition and results were found in close proximity with Park *et al*. (2016).

3.2 Effect of salicylic acid treatment on surface colour of tomato fruits

As shown in Table 3, the decrease in L values in the last days of storage lead changes in hue angle. Control samples showed rapid increase the lightness value from -3.28 to 4.97 within 12 days of storage period whereas T_4 samples which were treated with 200 ppm salicylic acid showed slow changes in color values up to their maximum shelf life of 32 days. The surface color of tomatoes in T_4 treatment observed turning red from faint yellow color in gradual manner as shown in Figure 1

Table 2. Effect of salicylic acid on physiological loss in weight (PLW) of tomato fruits (%)

Treatments	Storage Period (Days)								
	0	4	8	12	16	20	24	28	32
T_0	0	4.9	8.7	12.9	*	*	*	*	*
T_1	0	2.7	4.3	8.5	11.8	*	*	*	*
T_2	0	3.1	4.9	6.7	8.9	11.7	*	*	*
T_3	0	3	4.7	6.3	8.4	9.5	10.8	*	*
T_4	0	2.8	3.5	5.3	7.2	8.8	9.1	9.8	10.3
Mean±SD	0±0	3.3±0.8	5.2±1.8	7.9±2.7	7.2±3.9	6.0±5.0	4.0±4.9	2.0±3.9	2.1±4.1

T_0: Control, T_1:50 ppm, T_2: 100 ppm, T_3: 150 ppm, T_4: 200 ppm .*Discarded due to spoilage

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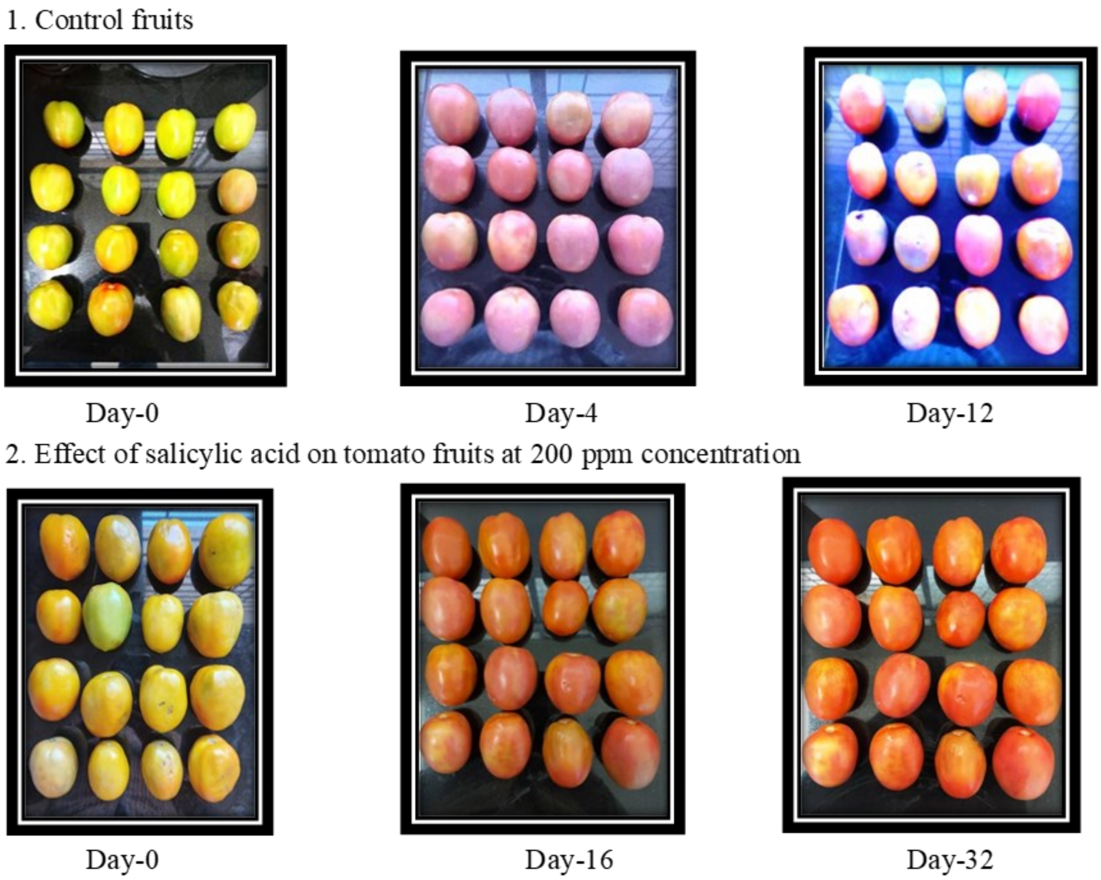

Figure 1. Effect of salicylic acid on tomato fruits cv. *Abhinav* during storage

appeared quite significant and acceptable as compared with other treatments. Asghari and Aghdam (2010).

3.3 Effect of salicylic acid treatments on firmness of tomato fruits

Texture or firmness of tomato fruits expressed in gram force gives an idea about the overall quality of the fruits during storage. Higher values indicate the firm or hard texture of tomatoes which is a good indicator of the maturity stage of a particular fruit and hence useful in determining quality at a particular storage period. Significant retention of firmness was observed in tomatoes treated with salicylic acid as compared with untreated control fruits. As shown in Figure 2, the most significant results were shown by fruits treated with 200 ppm salicylic acid in which, at the end of the 32 days storage life the firmness was 96 gf which was far better than the control fruits which lasted only for 12 days with 69 gf firmness due to loss of rigidity of tissues during ripening (Bhowmik and Pan, 1992).

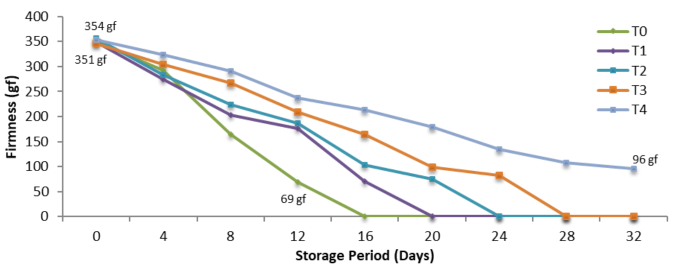

Figure 2. Effect of salicylic acid on firmness (gf) of tomato fruits

3.4 Effect of salicylic acid treatment on TSS of tomato fruits

Total soluble solids content (TSS) is one of the most important quality parameters of the fruits and indicates the degree of ripening. The effect of salicylic acid concentrations, exposure time and storage temperatures on the TSS content of fruits were studied and the results obtained are presented in Table 4.

All the fruits which were given salicylic acid treatment shown a very gradual change in TSS except the control fruits which showed rapid change in TSS from 1.3 to 2.7^{o}Brix within very less shelf life of only 12 days as compared with salicylic acid treated fruits at 200 ppm which was having shelf life of 32 days. The TSS of tomatoes having given the T_4 treatment was 3.3^{o}Brix even on the 32nd day of its storage period which was superior to any other treatments which found similar with the investigations reported by Gharezi *et al*. (2012).

3.5 Effect of salicylic acid treatment on titrable acidity (%) of tomato fruits

Titrable acidity is one among the two major parameters which determine the wholesomeness of any fruits other being TSS as far as the keeping quality fruits is concerned. Table 5 shows the effect of salicylic acid treatment on the percent titrable acidity of the tomatoes. The tomatoes treated with salicylic acid at 200 ppm and stored at 24^{o}C temperature recorded highest shelf life of

Table 3. Effect of salicylic acid on surface color (hue angle) of tomato fruits

Treatments	Storage Period (Days)								
	0	4	8	12	16	20	24	28	32
T_0	-3.28	1.74	2.46	4.97	*	*	*	*	*
T_1	-3.32	1.34	1.69	2.16	4.68	*	*	*	*
T_2	-3.21	1.49	2.07	2.93	3.87	4.42	*	*	*
T_3	-3.28	2.53	2.73	3.09	3.44	3.47	4.11	*	*
T_4	-3.19	1.23	1.53	1.85	2.39	2.97	3.26	3.48	4.01
Mean±SD	3.3±0.0	1.7±0.5	2.1±0.5	3.0±1.1	2.9±1.6	2.2±1.8	1.5±1.8	0.7±1.4	0.8±1.6

T_0: Control, T_1:50 ppm, T_2: 100 ppm, T_3: 150 ppm, T_4: 200 ppm .*Discarded due to spoilage

Table 4. Effect of salicylic acid treatment on TSS (°Brix) of tomato fruits

Treatments	Storage Period (Days)								
	0	4	8	12	16	20	24	28	32
T_0	1.3	1.5	1.9	2.7	*	*	*	*	*
T_1	1.5	1.8	2.1	2.3	2.6	*	*	*	*
T_2	1.4	1.7	1.9	2.1	2.7	2.9	*	*	*
T_3	1.2	1.4	1.4	1.5	1.9	2.3	3.1	*	*
T_4	1.4	1.5	1.9	2.1	2.3	2.7	2.9	3.1	3.3
Mean±SD	1.4±0.1	1.6±0.1	1.8±0.2	2.1±0.4	1.9±1.0	1.6±1.3	1.2±1.5	0.6±1.2	0.7±1.3

T_0: Control, T_1:50 ppm, T_2: 100 ppm, T_3: 150 ppm, T_4: 200 ppm .*Discarded due to spoilage

Table 5. Effect of salicylic acid treatment on titrable acidity (%) of tomato fruits

Treatments	Storage Period (Days)								
	0	4	8	12	16	20	24	28	32
T_0	0.39	0.31	0.23	0.11	*	*	*	*	*
T_1	0.37	0.30	0.26	0.18	0.13	*	*	*	*
T_2	0.35	0.30	0.27	0.21	0.19	0.13	*	*	*
T_3	0.41	0.38	0.33	0.29	0.24	0.17	0.11	*	*
T_4	0.38	0.35	0.32	0.29	0.27	0.23	0.19	0.15	0.11
Mean±SD	0.4±0.0	0.3±0.0	0.3±0.0	0.2±0.1	0.2±0.1	0.1±0.1	0.1±0.1	0.0±0.1	0.0±0.0

T_0: Control, T_1:50 ppm, T_2: 100 ppm, T_3: 150 ppm, T_4: 200 ppm .*Discarded due to spoilage

Table 6. Effect of salicylic acid treatment on ascorbic acid content (mg/100 g) of tomato fruits

Treatments	Storage Period (Days)								
	0	4	8	12	16	20	24	28	32
T_0	73.51	61.97	41.23	23.47	*	*	*	*	*
T_1	72.32	64.51	48.59	41.81	23.20	*	*	*	*
T_2	74.58	68.93	51.98	45.2	37.29	23.2	*	*	*
T_3	72.19	68.93	55.37	47.46	42.94	36.16	22.90	*	*
T_4	73.14	66.67	49.72	44.07	40.68	37.29	35.03	31.64	22.10
Mean±SD	73.1±0.9	66.2±2.7	49.4±4.7	40.4±8.7	28.8±16	19.3±16.5	11.6±14.7	6.3±12.7	4.4±8.8

T_0: Control, T_1:50 ppm, T_2: 100 ppm, T_3: 150 ppm, T_4: 200 ppm .*Discarded due to spoilage

Table 7. Effect of salicylic acid treatment on total phenolic content (mg GAE/g) of tomato fruits

Treatments	Storage Period (Days)								
	0	4	8	12	16	20	24	28	32
T_0	3.73	3.39	3.01	2.87	*	*	*	*	*
T_1	3.68	3.63	3.42	3.21	2.91	*	*	*	*
T_2	3.85	3.78	3.67	3.53	3.29	3.11	*	*	*
T_3	3.97	3.74	3.63	3.56	3.38	3.27	3.18	*	*
T_4	3.79	3.73	3.66	3.59	3.51	3.43	3.34	3.22	3.14
Mean±SD	3.8±0.1	3.7±0.1	3.5±0.3	3.4±0.3	2.6±1.3	2.0±1.6	1.3±1.6	0.6±1.3	0.6±1.3

T_0: Control, T_1:50 ppm, T_2: 100 ppm, T_3: 150 ppm, T_4: 200 ppm .*Discarded due to spoilage

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Table 8. Effect of salicylic acid treatment on lycopene content (mg/100 g) of tomato fruits

Treatments	Storage Period (Days)								
	0	4	8	12	16	20	24	28	32
T_0	6.98	8.25	10.63	12.19	*	*	*	*	*
T_1	7.02	8.01	9.89	11.63	12.22	*	*	*	*
T_2	6.89	7.87	9.13	10.69	11.13	12.20	*	*	*
T_3	6.94	7.73	8.97	9.98	10.87	11.46	12.23	*	*
T_4	7.01	7.59	8.48	9.73	10.59	11.31	11.97	12.08	12.31
Mean±SD	7.0±0.0	7.9±0.2	9.4±0.8	10.8±0.9	6.5±5.3	7.0±5.7	4.8±5.9	2.4±4.8	2.5±4.9

T_0: Control, T_1:50 ppm, T_2: 100 ppm, T_3: 150 ppm, T_4: 200 ppm .*Discarded due to spoilage

32 days with a significant decrease in the titrable acidity from 0.38 to 0.11. This change in the percent titrable acidity was gradual and acceptable as compared to other treatments. In control fruits which kept good only for 12 days, the acidity changed drastically from 0.39 to 0.11%. Similar findings were reported by Mandal *et al.* (2016).

3.6 Effect of salicylic acid treatment on ascorbic acid content (mg/100 g) of tomato fruits

Generally ascorbic acid content of any fruits decreases during the length of its storage period, therefore the estimation of its content at regular time intervals during storage indicates keeping quality characteristics of the stored fruits at a particular time period. Table 6 shows the ascorbic content of all the treatments during storage study of the fruits.

There was a significant difference in ascorbic acid content among salicylic acid treated and untreated fruits. Ascorbic acid content in fruits treated with highest salicylic acid concentration was found to be reduced gradually from 73.14 to 22.10 mg/100 g up to the 32^{nd} day of its storage life. However ascorbic content in untreated control fruits reduced drastically from 73.51 to 23.47 mg/100 g within only 12 days of their shelf life. This is attributed to long term storage reduces ascorbic acid content reported by Dokhanieh *et al.* (2016).

3.7 Effect of salicylic acid treatment on total phenolic content of tomato fruits

During storage of the salicylic acid treated tomato fruits, the total phenolic contents of the fruits didn't show any drastic change. However, the decrease in total phenolic content of the untreated fruits was slightly rapid as compared with treated fruits as shown in Table 7. Moreover, the fruit treated with 200 ppm salicylic acid concentration had shown significant retention of total phenolic content and decrease in the total phenolic was very gradual i.e. from 3.79 to 3.14 mg GAE/g at the end of its shelf life of 32 days which found closely related with the research findings published by Mandal *et al*. (2016).

3.8 Effect of salicylic acid treatment on lycopene content of tomato fruits

From the lycopene values mentioned in Table 8, it clearly depicts that the untreated tomato fruits showed a sudden increase in lycopene content due to rapid ripening. Whereas the fruits treated with salicylic acid showed a gradual increase in lycopene content specifically in case of 200 ppm treated fruits the lycopene content was increased gradually from 7.01 to 12.31 mg/100 g which shows the enhanced length of tomato ripening which increased its shelf life up to 32 days and found best as compared with control and other treatments. Similar findings were reported by Khairi *et al*. (2018) in tomatoes stored in different conditions.

4. Conclusion

The findings of present investigations conclude that when the salicylic acid concentration increased from 50 ppm to 200 ppm, the shelf life also increased. It was observed that the shelf life was recorded higher (32 days) in the tomatoes treated with 200 ppm salicylic acid concentration. The effect of storage temperatures of treated fruits on shelf life was also investigated and recorded the highest shelf life (32 days) at 24°C storage temperature as compared to the control sample storage (12 days). SA has the potential to maintain the physico-chemical properties by delaying the ripening process and retarding the internal gaseous changes which occur during storage. It concluded from the current experiments that salicylic acid is valuable for postharvest treatment for enhancing the shelf life of tomato fruit. Furthermore, it could be suggested for usage in international as well as local markets for extending the shelf life of horticultural produces. SA treatment can be easy and safe used for delaying/shifting ripening processes of tomato with improving fruit quality during shelf-life.

Conflict of Interest

The authors declare no conflict of interest.

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