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Role of oxalic acid on shelf-life and physicochemical characteristics of tomato

Kamal Kant, Ajay Arora*, V.P. Singh and Raj Kumar**
Division of Plant Physiology, Indian Agricultural Research Institute, New Delhi 110012

ABSTRACT

Green mature fruits of tomato were treated with different concentrations of oxalic acid (1, 2, 3 and 4 mM) solutions by dipping and water as control for 15 min at 20°C. Different physico-chemical properties were analyzed at the end of ripening. The fruits were kept for four days additionally, at 20°C to study the rate of disease incidence in treated as well as control. The most effective concentration of oxalic acid was found to be 3 mM for controlling the shelf-life as well as disease incidence as compared with control and other treatments. Hence, it can be concluded that postharvest dipping with oxalic acid at 3 mM has the potential to control disease incidence, prolong the shelf-life and preserve valuable attributes of tomato fruits because it maintained the ascorbic acid content, titrable acidity, soluble solids concentration and fruit firmness by reducing activities of cell wall hydrolyzing enzymes such as polygalacturonase and pectin methyl esterase.

Key words: Oxalic acid, tomato, postharvest, shelf-life, ripening.

INTRODUCTION

Tomato is one of the main vegetables of world. In India, two cultivars, namely, Pusa Gaurav and Pusa Rohini have gained popularity in the domestic and export markets. However, the short shelf life limits the export of the fruits to distant markets. The ripe fruits soften rapidly and are easily infected by diseases and proned to chilling injuries as a result of exposure to low temperature. Therefore, owing to its high perishability there is much wastage. Recent research work established the various roles of oxalic acid (OA) in the physiology of fruit tissues such as delaying the ripening process, reducing decay incidence and controlling the browning in the fruits (Ding *et al*., 2; Zheng *et al*., 12, 13, 14 & 15). Treatment with OA during initiation of ripening improves AsA (ascorbic acid) content, maintains SSC (soluble solids concentration) and retains TA (titrable acidity) during ripening (Zheng *et al*., 15). It also enhanced antioxidant activity, retards ethylene production, improves rigidity of cell wall and obstruct enzymes such as PG (polygalcturonase), PME (pectin methyl esterase) etc. from reaching their active sites (Zheng *et al*., 15, 16; Wu *et al*., 10), thereby retarding tissue softening and delaying ripening. Oxalic acid inhibits the ripening of mango, peach (Zheng *et al*., 13, 14), plum etc. and its application for food preservation has received much attention, as it has been shown not only to be an anti-browning agent for harvested vegetables, banana slices and litchi fruit (Zheng and Tian, 12), but also to be regulator of antioxidant in the ripening fruits (Zheng *et al*., 16; Ding *et al*., 2). Hence, our attention in this study was to determine the effects of different concentrations of OA on tomato fruits such as Pusa Gaurav- slow ripening and Pusa Rohini- fast ripening cultivars in delaying of ripening.

MATERIALS AND METHODS

Tomato fruits (*Solanum lycopersicon* L. cv. Pusa Gaurav and Pusa Rohini) were harvested at the green mature stage from horticultural field, Indian Agricultural Research Institute, New Delhi. Harvested fruits were selected for uniformity in size and appearance. The selected fruits were washed and clean with double distilled water (DDW) and air-dried. They were dipped in DDW as control and 1, 2, 3 and 4 mM oxalic acid solutions separately for 15 min at 20°C as treatment. Three replicates from each cultivar of control and treated fruits were placed separately on bench at 20°C. The different physico-chemical characteristics were measured after end of ripening of control and treated fruits. One kilogram fruits from each cultivar were kept as control and treatment separately for monitoring disease incidence. The shelf-life of tomato fruits was calculated by counting the days from treatment to the last stage of ripening, but up to the stage when they remained still acceptable for marketing. Disease incidence was monitored by determining the number of fruits showing the visible symptoms of rot and lesion on the surface of fruits and recording the percentage. Weight loss

*Corresponding author's E-mail: romiarora@yahoo.com
**Division of Vegetable Science, Indian Agricultural Research Institute, New Delhi 110012

percentage (WLP) of tomato fruits was calculated by considering the differences between initial weight at the day of treatment and final weight at the day of last stage of ripening divided by their initial weight. For estimation of firmness and colour changes visual and manual methods applied which are based on fruit ripening criteria available in literature in relation to oxalic acid. Soluble Sodids Concentration (SSC) was determined with a BS Eclipse refractometer (Bellingham + Stanley, UK; °Brix). The readings were multiplied by dilution factor to obtain the original percent SSC of the tomato pulp. pH (Eutech pH Tutor, Singapore) was determined (Sadler *et al*., 7) by using the remainder of the filtrate from SSC determination. TA was analyzed using the titration method (Sadler *et al*., 7). Pulp tissues were homogenized with distilled water using pestle-mortar and filtered through cotton wool. Ten ml of the filtrate with one to two drops of phenolphthalein (1%) as indicator was titrated using 0.1 N NaOH to an end point pink (pH 8.2). The results were expressed as percentage of citric acid per 100 g fresh weight.

Ascorbic acid content was determined using the Dye method (Albrecht, 1). Fruit pulp were homogenized with 3% metaphosphoric acid (HPO_3) using a pestle-mortar. The mixture was filtered through cotton wool and the aliquot was titrated with a standard dye solution (2,6-dichlorophenol-indophenol) to a pink colour. The ascorbic acid content was expressed as mg per 100 g of fresh fruits. Cell wall hydrolyzing enzymes such as PG and PME were extracted from fruit pulp with sodium acetate buffer (0.2 M; pH 6.0) with pinch of $Na_2S_2O_4$ and polyvinyl polypyrrolidone (PVPP) in a chilled mortar. The homogenate was centrifuged at 15000 × g for 20 min. at 4°C. The supernatant was used for assay of PG (Lazan *et al.,* 5) and PME (Rouse and Atkins, 6) activity. Results of PG expressed as mg of glucose equivalent per gram fresh weight per hour and PME expressed as units eqv. min^{-1} g^{-1} fw.

All treatments were done with three replications. Data represent the mean ± SE and they were analyzed by using Duncan's Multiple Range Test. Significance of difference among means of control and treatment using Duncan's multiple range tests at 5% level. Difference at $p \leq 0.05$ was considered as significant.

RESULTS AND DISCUSSION

Shelf-life was extended significantly to maximum duration of 21 days for Pusa Gaurav and 19 days for Pusa Rohini using OA dip treatments at 3 mM compared to other treatments and control (Table 1). Shelf-life was significantly prolonged using OA treatments at 3 and 2 mM by 21 and 19 days for Pusa Gaurav, respectively and 19 and 17 days for Pusa Rohini, respectively as compared to the untreated fruit (control), but no significant differences between 1 and 4 mM treatments and control were observed (Table 1). Oxalic acid (OA) dip treatments at 3 and 2 mM tended to extend the shelf-life by 4 and 2 days, respectively. Similar results were obtained in mango (Zheng *et al*., 14, 15), peach (Zheng *et al*., 13), plum (Wu *et al*., 10), litchi (Zheng *et al*., 12), apple (Dong *et al*., 7), pomegranate (Sayyari *et al*., 8), muskmelon (Jian jun *et al*., 4) and kiwi fruit (Zhang *et al*., 11) as measured by a delay in accumulation of sugars, decrease in organic acids and prevention of browning and disease development.

Oxalic acid treatment at 3 mM controlled rotting compared to all other treatments and minimum rot 54.46 and 59.05% were observed in 3 mM treated fruits after 23 and 25 days of treatment in Pusa Rohini and Pusa Gaurav, respectively (Table 1). The maximum rot 91.2% (Pusa Gaurav) and 92.05% (Pusa Rohini) were found in control. Previous work suggested that OA keep the apples disease-free and increased shelf-life (Dong *et al*., 7) and protects peach and mango from the physiological disorders, but also helps in reducing decay, by strengthening the cell wall and regulating the metabolic activity of the fruit (Zheng *et al*., 15, 16). Control of these metabolic activities, increased fruit quality and extended post-harvest life of fruits.

In present study, WLP was lower in 3 mM treated fruits as compared with control and other treatments (Table 2). Oxalic acid treatments at concentrations 1, 2 and 4 mM increased the weight loss progressively

Table 1. Effect of oxalic acid on shelf life and disease incidence in two different cultivars of tomato. (Pusa Gaurav and Pusa Rohini).

Trait	Cultivar	Control	T_1	T_2	T_3	T_4
Shelf-life (days)	Pusa Gaurav	17.33 ± 0.47	17.66 ± 0.47	19.33 ± 0.47	21.33 ± 0.47	16.66 ± 0.47
	Pusa Rohini	15 .33 ± 0.47	16.33 ± 0.47	17.33 ± 0.47	19.66 ± 0.81	15.33 ± 0.47
Disease incidence (%)	Pusa Gaurav	91.20 ± 0.04	87.32 ± 0.02	71.65 ± 0.04	54.46 ± 0.02	88.67 ± 0.04
	Pusa Rohini	92.05 ± 0.03	85.65 ± 0.04	70.29 ± 0.03	59.05 ± 0.04	85.49 ± 0.03

T_1-1 mM; T_2-2 mM; T_3-3 mM and T_4-4 mM oxalic acid.

Table 2. Effect of oxalic acid on different physicochemical traits in two different tomato cultivars (Pusa Gaurav and Pusa Rohini).

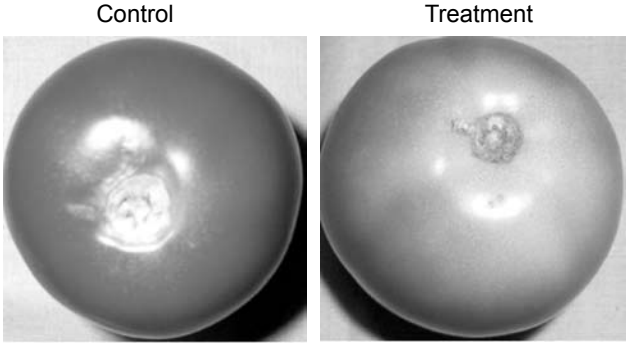
Cultivar trait		Pusa Rohini		Pusa Gaurav	
	Treatment	15 day	19 day	17 day	21 day
Weight loss percentage	Control	12.84 ± 0.05	32.68 ± 0.02	11.92 ± 0.06	33.21 ± 0.12
	T1	11.65 ± 0.04	31.25 ± 0.03	12.65 ± 0.04	31.38 ± 0.10
	T2	12.21 ± 0.06	29.87 ± 0.02	10.32 ± 0.05	32.23 ± 0.13
	T3	8.96 ± 0.03	11.32 ± 0.03	9.21 ± 0.03	12.31 ± 0.09
	T4	13.62 ± 0.04	28.97 ± 0.04	11.25 ± 0.04	13.64 ± 0.08
Soluble solids (%)	Control	4.87 ± 0.04	4.95 ± 0.03	4.64 ± 0.06	4.69 ± 0.03
	T1	4.83 ± 0.04	4.56 ± 0.02	4.62 ± 0.05	4.72 ± 0.02
	T2	4.75 ± 0.02	4.81 ± 0.03	4.47 ± 0.02	4.76 ± 0.03
	T3	4.12 ± 0.04	4.02 ± 0.01	3.89 ± 0.01	4.05 ± 0.02
	T4	4.71 ± 0.01	4.23 ± 0.02	4.54 ± 0.03	4.62 ± 0.04
pH	Control	4.56 ± 0.02	4.62 ± 0.03	4.59 ± 0.01	4.61 ± 0.03
	T1	4.52 ± 0.01	4.61 ± 0.01	4.57 ± 0.02	4.59 ± 0.02
	T2	4.53 ± 0.02	4.58 ± 0.03	4.54 ± 0.03	4.56 ± 0.01
	T3	4.49 ± 0.03	4.53 ± 0.02	4.51 ± 0.02	4.53 ± 0.02
	T4	4.52 ± 0.01	4.54 ± 0.03	4.52 ± 0.01	4.54 ± 0.03
Titrable acidity (% citric acid)	Control	0.312 ± 0.002	0.314 ± 0.003	0.318 ± 0.002	0.321 ± 0.003
	T1	0.311 ± 0.001	0.312 ± 0.002	0.319 ± 0.003	0.316 ± 0.001
	T2	0.309 ± 0.003	0.308 ± 0.002	0.321 ± 0.001	0.318 ± 0.002
	T3	0.342 ± 0.004	0.369 ± 0.002	0.345 ± 0.001	0.371 ± 0.002
	T4	0.315 ± 0.002	0.324 ± 0.003	0.319 ± 0.001	0.318 ± 0.002
Ascorbic acid content (mg/100 g FW)	Control	22.21 ± 0.04	12.36 ± 0.02	23.32 ± 0.03	13.65 ± 0.01
	T1	23.12 ± 0.02	11.34 ± 0.03	22.31 ± 0.02	12.32 ± 0.02
	T2	21.35 ± 0.04	12.14 ± 0.02	23.21 ± 0.04	12.31 ± 0.03
	T3	18.36 ± 0.01	22.31 ± 0.04	19.38 ± 0.03	23.26 ± 0.04
	T4	21.32 ± 0.03	12.17 ± 0.01	21.31 ± 0.04	12.36 ± 0.01

T_1 = 1 mM; T_2 = 2 mM; T_3 = 3 mM and T_4 = 4 mM.

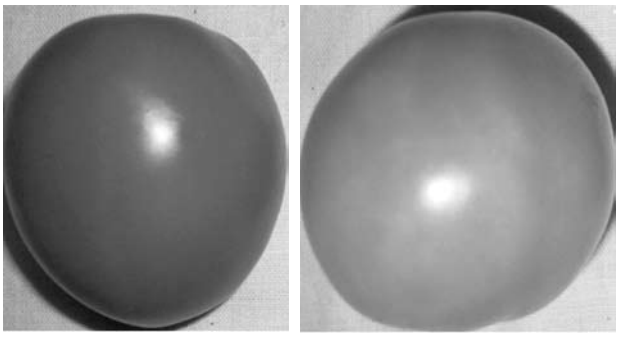
compared to the 3 mM treatments. Zheng *et al.* (13, 14) reported that OA reduced ion leakage, maintain flesh firmness, lower respiration as compared with control in peach and mango.

Oxalic acid dip treatment at 3 mM maintained firmness compared with control and other treatments at 15 days in case of Pusa Rohini (Fig. 1A) and at 17 days in case of Pusa Gaurav (Fig. 1B). The control treatment had the lowest ability in maintaining firmness followed by the lower concentration of 1 mM dip treatment, where they did not showed any significant difference among each other. The desired effect of OA dip treatment at 3 mM on maintaining fruit firmness may be due to the stabilizing and strengthening the cell walls because OA delayed peak activity of cell wall hydrolyzing enzyme particularly polygalacturonase and pectin methyl esterase (Wu *et al*., 10). Similar results were also observed in case of mango (Zheng *et al*., 15), jujube (Wang *et al*., 9) and peach (Zheng *et al*., 13). Zhang *et al*. (11) showed that OA (20 g/l) solution on kiwi fruit through dip method treatment at 20°C kept fruit firm and controlled russet in comparison to control.

In general, the colour of the pericarp changed from green at harvest to red at the end of ripening. Oxalic acid (3 mM) treated fruit reddened slowly and showed a lower peel colouration than control fruit during ripening in Pusa Rohini (Fig. 1A) and Pusa



(A) Pusa Rohini: Firmness and peel colour



(B) Pusa Gaurav: Firmness and Peel colour

Fig. 1. Effects of oxalic acid (3 mM) on firmness and peel colour change in two different tomato cultivars : (A) Pusa Rohini at 15 DAT. (B) Pusa Gaurav at 17 days after treatment.

Gaurav (Fig. 1B). Wu *et al.* (10) reported that colour development on plum fruit were retarded significantly using OA treatment compared with the control due to retardation of anthocynin synthesis.

Significant decrease in SSC was observed for OA dip treatments at 3 mM than other treatment at 1, 2 and 4 mM (Table 2). The effect of OA in decreasing SSC content of fruits was probably due to slowing down of respiration and metabolism activity hence, retarding the ripening process. The slower respiration also slows down the synthesis and use of metabolites resulting in lower SSC due to the slower change from carbohydrates to sugars. Our results are in line with the results obtained by Zheng *et al*. (15) who reported that the concentration of free sugars progressively increased with shelf-life, this increase was quite markedly delayed by OA treatment for mango cultivars. It has been suggested that the application of OA on litchi fruit (Zheng and Tian, 12) and on kiwi fruit (Zhang *et al*., 11) influenced several postharvest senescence changes involving free sugars, organic acids, anthocyanin content and texture of fruits.

pH value of tomato fruits first decreased from immature green to pink stage and then start to increase and reached a peak at deep red stage in control as well as treated ones (Table 2). This may be due to formation of organic acids from immature to pink and then consumption of same due to rise in climacteric respiration. In fact, no significant change in pH occurred as a result of OA treatment in comparison to control (Table 2). Therefore, the experimental treatments did not cause a leaking of OA into the mesocarp of fruit. These results are consistent with findings of Zheng *et al*. (12, 13) who reported that the postharvest application of OA in litchi and peach fruits showed no significant difference in pH between treated and control.

Oxalix acid (3 mM) treated fruits had the higher TA level compared with control and other treatments (Table 2). The lowest level of TA was obtained with untreated fruits followed by 1 mM dip treatment. Zheng *et al*. (14) suggested that OA treated mango maintained higher TA level as compared with control during ripening period. Ascorbic acid content in 3 mM treated fruits was found to be higher than control and other treatments (Table 2) and maintaining of this quality delayed the ripening of fruits. Similar results were reported by Ding *et al*. (2) in mango. Previous work suggested that once fruits reach ripe stage, ascorbic acid content start to decline in tomato and fruit ripen rapidly.

In the present study, it was found that PG (Fig. 1A) and PME (Fig. 1B) activities tend to increase significantly ($p \leq 0.05$) during their ripening period in control, but the activity of these enzymes was lower in the fruits treated with 3 mM OA at 15 days and 17 days in Pusa Rohini and Pusa Gaurav, respectively. The other treatments did not reduce PG and PME activities significantly in comparison to their control at 15 days in case of Pusa Rohini and 17 days in case of Pusa Gaurav during their ripening period (Fig. 1A and B), after that PG and PME degraded in control while its maximum activity was found in 3 mM treated fruits at 19 days and 21 days in Pusa Rohini and Pusa Gaurav, respectively (Fig. 1A and B). Previous research work suggested that OA reduced the activities of PG and PME in mango (Zheng *et al*., 16) and plum (Wu *et al*., 10) and delayed the ripening and senescence process significantly.

This work suggests that postharvest application of OA (3 mM) on tomato fruits increased shelf-life and maintains quality characteristics. Therefore, the OA with different concentrations combined with adhesive agent needs to be further investigated at molecular level in terms of its ability to enhance shelf-life and maintaining quality of tomato fruits.

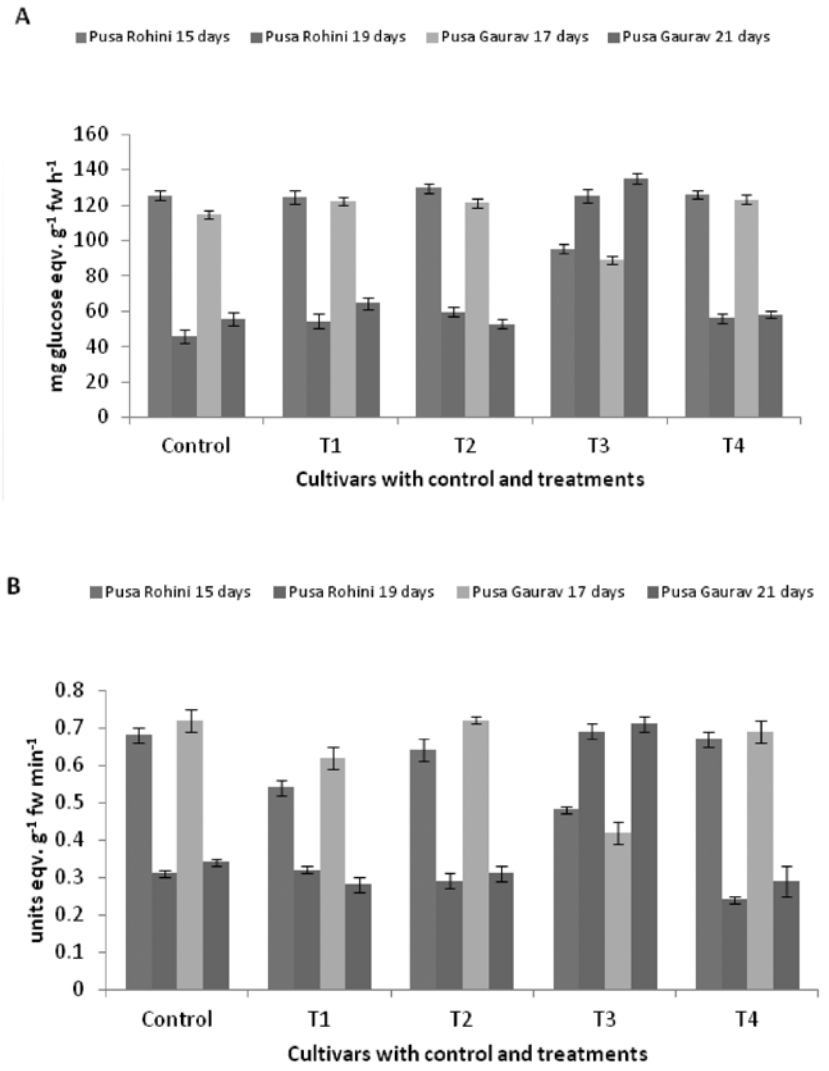


Fig. 2. Effect of oxalic acid on cell wall hydrolyzing enzymes: (A) PG and (B) PME, in two tomato cultivars (Pusa Gaurav and Pusa Rohini). Control, T_1- 1 mM; T_2 - 2 mM; T_3 - 3 mM and T_4 - 4 mM).

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