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Effect of Aqueous 1-Methylcyclopropene on Quality Attributes of Polypropylene Packed Tomato (*Solanum lycopersicum* L.) during Cold Storage

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Present investigation was carried out at Punjab Agriculture University, Ludhiana to know the effect of aqueous 1-methylcyclopropene (1-MCP) application on storage behavior of mature green to breaker stage tomato fruits (cv. Punjab Ratta) packed in polypropylene (40µ) bags stored at 13±2°C and relative humidity of 85-90% on various quality attributes at weekly intervals *i.e* on 1st, 8th, 15th, 22nd, 29th and 36th day of storage. Study revealed that when tomato fruits were treated with 1-MCP at 18 mg/L resulted in significant lower ripening index at 15th, 22nd and 36th day of storage. Tomato fruits were in acceptable red ripe stage (hue angle 55.16^0) throughout the storage period (36 days of storage) compared to control. However, significant higher firmness (Newtons) was recorded throughout the storage period when fruits treated with 1-MCP at 6, 12 or 18 mg/L concentrations over control (without 1-MCP).

Key words: Tomato, 1-MCP, MAP, Quality attributes

Tomato is a climacteric fruit and post-harvest behaviour of tomato is classified as moderate based on the level of ethylene emitted by fruits, which is from 1.0 and 10 µLkg^{-1} h^{-1} at 20°C (Kader 2002) with respiration rates of 10 and 20 mg CO_2 kg^{-1} h^{-1} at 5°C (Rizvi 1981). Modern techniques and methods should be followed to maintain the quality while minimizing losses during storage and distribution. Modified atmosphere packaging (MAP) of fresh vegetables results in decreased levels of O_2 and increased levels of CO_2 inside the package and the higher CO_2 levels reduce the respiration rate, can inhibit the deteriorating effects of ethylene, reduces the weight loss, softening progress and fungal infection of fruits (Tano *et al.,* 2007). Modified atmosphere packaging of tomato fruits in bioxially oriented polypropylene @50µ, harvested at breaker stage resulted in longer shelf life of 23 days when stored at 25°C (Kumar *et al.,* 2012).

One methylcyclopropene (1-MCP) is a chemical compound, which inhibits either ethylene synthesis or ethylene perception. It is a gas with a molecular weight of 54 (C_4H_6), which blocks ethylene binding and interferes with ethylene induced fruit ripening and affects on fruit quality. Bower and Mitcham (2001) proposed the ethylene inhibiting action in plants. Basic effects of 1-MCP on tomatoes is the prolonged storage life by a decrease in 1-aminocyclopropane-1-carboxylic acid (ACC) synthesis, ACC oxidase activities, ethylene production, respiration rate, loss of firmness and titratable acidity including lycopene accumulation or chlorophyll degradation (Choi and Huber, 2008). A delay in ripening resulted in the greater longevity of about 58 days was realized by packing banana fruits in sealed polyethylene bags with gaseous 1-MCP at either 0.5 or 1.0 µL/L (Jiang *et al.,* 1999). Hence, the present investigation was carried to study the effect of MAP (Polypropylene @40µ thickness) on tomato fruits treated with aqueous application of 1-MCP at different concentrations (60mg/10L, 120mg/10L and 180mg/10L) on quality attributes of tomato harvested at mature green to breaker stage during cold storage at 13±2°C and RH of 85-90%.

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Materials and Methods

The tomato crop cv. Punjab Ratta was raised in an unreplicated experimental plot at Vegetable Research Farm, Punjab Agricultural University, Ludhiana, Punjab, India during 2013-14 and storage studies were carried at Food Packaging and Tranportation Laboratory, Central Institute Post-Harvest Engineering and Technology, Ludhiana, Punjab, India. Fruits of uniform size and weight were picked at mature green to breaker stage and washed by dipping in normal tap water to remove the field heat and blemishes on the fruits. Then fruits were air dried on the table and kept overnight at 20°C in cold store. On the next day the fruits were dipped in aqueous solutions of 1-MCP and then MA packed.

1-MCP treatments

For this purpose, 10L each of aqueous solutions of 1-MCP ("Soyoung"@3.2% active ingredient, Shanghai Soyoung Biotechn.Inc., China) at 6 mg/L, 12 mg/L and 18 mg/L were prepared in 3 plastic tubs separately, corresponding to three treatments M_1, M_2 and M_3 respectively and in control there was no chemical added. After 10 minutes tomato fruits from each treatment were dipped one by one separately. Care was taken that each fruit was fully dipped in the solution for one minute only. The solution was used no sooner than 10 min and not later than 30 min after preparation and treatment procedure was completed within 10–15 min. The entire procedure of 1-MCP treatment was done as per the procedure followed by Choi *et al.,* (2008). After one minute dip, the fruits were taken out and air dried.

Then the fruits were MA packed into polypropylene @40 µ films and double sealed with paddle operated sealer machine. The polypropylene packaging film (MAP pack) was made with 3 pin holes (0.3mm diameter), two at opposite corners of the lower side of the MAP pack and 3rd one on top right corner of the pack. A sample size of tomato fruits of 500± 50 grams was maintained in each treatment and per treatment there were six MAP packed samples to be drawn one at a time for destructive analysis. The MAP packed fruits were kept in cold store at 13±2°C and relative humidity (RH) of 85-90% and evaluated for physico-chemical parameters at weekly intervals *i.e* on 1st, 8th, 15th, 22nd, 29th and 36th day of storage for total soluble solids (TSS) content, titratable acidity (TA), ripening index (TSS/TA), hue angle and firmness (Newtons).

The TSS of the tomato fruit juice squeezed from the fruits of each treatment was measured with handheld digital Refractometer (PAL- 1, 0-53%, ATAGO Make, Japan) and measured in degree Brix. Titratable acidity (TA) was determined by titrating 2 ml of squeezed tomato juice with 2 drops of phenolphthalein indicator against 0.1 N NaOH and expressed as % citric acid. A ratio was calculated by dividing the values of TSS with that of corresponding values of titratable acidity and considered as ripening index (TSS/TA). Changes in surface colour of tomato were determined using a Mini Scan XE Plus Hunter colorimeter (45/0-L, Hunter Associates Laboratory Inc, Reston, VA, USA) with a standard C illuminant taking the b* value as a measure of degree of yellowing, L* value as a measure of surface lightness, while a* being the measure of red colour. The values were expressed by the CIE L*a*b* system and hue angle was calculated using the formula $h^0 = \tan^{-1}(b^*/a^*)$. Readings were taken around the equatorial point of the fruit at four places and average was taken.

Firmness was measured using TA-HDi (Stable Micro Sysytems, UK) texture analyzer equipped with a 50 kg load cell (20) and 5mm-diameter plunger set to pierce 5 mm deep from the fruit surface. A 5 mm diameter flat head stainless steel cylindrical probe was used with test speed of one mm/s. For the analysis of texture, three tomatoes of each ripening degree were taken and each tomato was punctured two times at opposite sides of the equatorial area of the fruit and average value was taken as the firmness of the fruit. Statistical analysis was performed using Texture Analyzer software and the force required for the plunger was recorded and expressed in Newtons. The present experiment was laid out in Completely Randomized Design and statistical design for ANOVA was done using the SAS GLM (v.9.2, SAS Institute Inc, Cary, NC, USA) and means separated by the Tukey's test at P ≤ 1% significance level.

Results and Discussion

Total Soluble Solids, Titratable Acidity (% Citric Acid) and Ripening index (TSS/TA)

Data in Table 1 showed that there was an increase in TSS (°Brix) content upto 15th day of storage from the initial value (5.03) in all the 1-MCP treated treatments and thereafter, decreased gradually from 15th day of storage onwards till the end of the storage period (36th day of storage). Whereas, in control it reached peak at 8th day of storage and then gradually decreased till the end of the storage period. Treating the tomato fruits with 1-MCP at all concentrations resulted

Table 1. Effect of aqueous 1-MCP on TSS (°Brix) of tomato stored at 13±2°C and RH of 85-90%

		Day of storage					
Treatment	Particulars	1st	8th	15th	22nd	29th	36th
MAP+M0	PP + without 1-MCP	5.03	6.66a	5.50d	4.53d	5.40a	4.93a
MAP+M1	PP + 1-MCP @ 6 mg/L	5.03	5.60b	5.80c	4.83c	4.80c	4.80b
MAP+M2	PP + 1-MCP @ 12 mg/L	5.03	5.63b	5.93b	5.36b	5.16b	4.53c
MAP+M3	PP + 1-MCP @ 18 mg/L	5.03	5.70b	6.16a	5.60a	4.40d	4.46c

(Data in column followed by different letter superscripts are significantly different at P ≤ 1%)

Table 2. Effect of aqueous1-MCP on titratable acidity (% citric acid) of tomato stored at 13±2°C and RH of 85-90%

		Day of storage					
Treatment	Particulars	1st	8th	15th	22nd	29th	36th
MAP+M0	PP + without 1-MCP	1.1	0.62c	0.54b	0.79b	0.66c	0.39c
MAP+M1	PP + 1-MCP @ 6 mg/L	1.1	0.93b	0.88a	1.02ab	0.94a	0.62b
MAP+M2	PP + 1-MCP @ 12 mg/L	1.1	1.22a	0.98a	1.18a	0.69c	0.59b
MAP+M3	PP + 1-MCP @ 18 mg/L	1.1	0.99b	0.92a	1.29a	0.76b	0.72a

(Data in column followed by different letter superscripts are significantly different at P ≤ 1%)

in significant higher TSS content in the fruits during 15th and 22nd day of storage while, significant lower TSS content observed at later part of the storage period (29 and 36th day of storage) over control (without 1-MCP). Among 1-MCP treatments, at 29th and 36th day of storage, the lowest TSS content was recorded in fruits treated with 1-MCP at 18 mg/L. Higher TSS can be attributed to the conversion of sugars into soluble ones during ripening (Kader *et al.,* 1989 and Park *et al.,* 1999) and reduced enzymatic activities responsible for quality deteoration resulting in lower TSS (Ryall and Pentzer, 1982).

Table 3. Effect of aqueous 1-MCP on ripening index (TSS/TA) of tomato stored at 13±2°C and RH of 85-90%

		Day of storage					
Treatment	Particulars	1st	8th	15th	22nd	29th	36th
MAP+M0	PP + without 1-MCP	4.57	10.79a	10.20a	6.54a	8.17a	12.52a
MAP+M1	PP + 1-MCP @ 6 mg/L	4.57	5.96b	6.55b	5.03b	5.11d	7.63b
MAP+M2	PP + 1-MCP @ 12 mg/L	4.57	4.59b	6.05bc	4.70c	7.45b	7.59b
MAP+M3	PP + 1-MCP @ 18 mg/L	4.57	5.75b	5.84c	4.34d	5.73c	6.16c

(Data in column followed by different letter superscripts are significantly different at P ≤ 1%)

Data shown in Table 2 depicts that the titratable acidity (TA) content was significantly higher in 1-MCP treated fruits at all concentrations than in the control (without 1-MCP). However, non-significant higher values were obtained during 22nd day of storage in fruits treated with 1-MCP@6 mg/L and on 29th day of storage in fruits treated with 1-MCP@12 mg/L. The higher TA content in 1-MCP treated fruits than in control could be attributed to lesser conversion of acids to sugars and delayed ripening by 1-MCP and similar reports of higher titratable acidity in turning stage and pink fruits of tomato treated with 500 nl/l 1-MCP during 18^{0}C storage were also reported by Baldwin *et al.,* (2011).

Table 4. Effect of aqueous 1-MCP on hue angle (h°) of tomato stored at 13±2°C and RH of 85-90%

		Day of storage					
Treatment	Particulars	1st	8th	15th	22nd	29th	36th
MAP+M0	PP + without 1-MCP	92.76	74.06b	56.53d	37.71d	45.61c	37.14d
MAP+M1	PP + 1-MCP @ 6 mg/L	92.76	93.31a	87.50c	57.94c	61.14b	44.01c
MAP+M2	PP + 1-MCP @ 12 mg/L	92.76	92.44a	89.84b	72.99b	60.7b	45.51b
MAP+M3	PP + 1-MCP @ 18 mg/L	92.76	93.35a	92.75a	89.03a	78.88a	55.16a

(Data in column followed by different letter superscripts are significantly different at P ≤ 1%)

It was observed (Table 3) that the 1-MCP at all concentrations recorded low ripening index throughout the storage period than in control (without 1-MCP), which could be attributed to reduced losses in titratable acidity in 1-MCP treatments and delayed ripening of tomato fruits (Sabir and Agar, 2011). Among the treatments, 1-MCP at 18 mg/L resulted in significant lower ripening index at 15th, 22nd and 36th day of storage except at 29th day. Khan and Singh (2008) who also reported similar kind of significant reduction in SSC/TA by 1-MCP application in MA packed plums.

Table 5. Effect of aqueous 1-MCP on firmness (N) of tomato stored at 13±2°C and RH of 85-90%

		Day of storage					
Treatment	Particulars	1st	8th	15th	22nd	29th	36th
MAP+M0	PP + without 1-MCP	30.35	23.99b	16.09c	17.38c	15.85c	2.60b
MAP+M1	PP + 1-MCP @ 6 mg/L	30.35	29.47a	25.59a	23.20a	19.84b	3.43a
MAP+M2	PP + 1-MCP @ 12 mg/L	30.35	26.63ab	24.12b	19.52bc	22.12a	3.33a
MAP+M3	PP + 1-MCP @ 18 mg/L	30.35	25.87ab	26.69a	22.50ab	21.33ab	3.41a

(Data in column followed by different letter superscripts are significantly different at P ≤ 1%

Hue angle

Hue angle is the most indicative of the colour status of the tomato fruit during ripening. A hue angle of 55^o or lower was regarded as acceptably red and 40^0 as overripe stage of tomato (Hurr *et al* 2005). Data in Table 4 indicated that with advancement of storage period, hue angle significantly reduced in all the treatments of storage at 13±2^{0}C and RH of 85-90%. But, in 1-MCP treatments, there was a gradual decrease in hue angle while, sharp decrease in early days of storage under control. Fruits treated with 1-MCP at 18 mg/L maintained acceptable redripe stage (hue angle 55.16^0) upto 36th day of storage while, 1-MCP treatments at 6 mg/L and 12 mg/L maintained the fruits in acceptably redripe stage (hue angle 60.7^0 and 61.14^0) till 29th day of storage. However, fruits in control were at acceptable redripe stage upto 15th day of storage only. Similarly, Samir and Agar (2011) also reported maximum hue angle in 1-MCP treated tomato fruits (74.48°) at the end of the storage (21 days).

Firmness

With the advancement of storage period, there was a decrease in firmness of fruits in all the treatments including control (Table 5). However, there existed a gradual decrease of firmness values in all the 1-MCP treatments, whereas in control (without 1-MCP) a sharp decline was noticed. Under control, fruits firmness was reduced by almost 42.74 to 47.78% during 15th and 29th day of storage; while, in 1-MCP treatments, firmness was reduced by a maximum of 35.69% during the same period. At the end of storage period, 1-MCP treated fruits retained significantly higher firmness values than the untreated fruits in control. MA packed litchi (Mauritius and McLean's red cultivars) fruits treated with 1-MCP at 500 or 1000 nLL^{-1} showed significantly higher fruit firmness than 1-MCP at 300 nLL^{-1} and control after 21 days of storage (Reuck *et al.,* 2009).

It can be concluded that treating tomato fruits with 1-MCP at 18 mg/L or 12 mg/L and packing in MAP polypropylene film 40µ could help to maintain longer storage due to ethylene inhibiting action of 1-MCP during storage at 13±2°C and RH of 85-90%.

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