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STORAGE BEHAVIOR OF MODIFIED ATMOSPHERE PACKED TOMATO (*SOLANUM LUCOPERSICUM* L.) TREATED WITH AQUEOUS 1-METHYCYCLOPROPENE

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Abstract

A two year study was carried out to know the storage behavior of 1-Methylcyclopropene treated tomato (cv. Punjab Ratta) in modified atmosphere package during their storage at 13±2^{0}C and relative humidity of 85-90%. Modified Atmosphere packed tomato fruits were treated with aqueous solutions of 1-methylcyclopropene at 6mg/L, 12mg/L and 18mg/L and untreated control (without 1-MCP) and evaluated for various quality attributes at weekly intervals at 1st, 8th, 15th, 22nd, 29th and 36th day of storage. Study revealed that tomato treated with higher concentrations of 1-methycyclopropene resulted in significant lower ripening index, higher hue angle, titratable acidity and firmness compared to control (without 1-MCP) at different days of storage. Significant higher titratable acidity was recorded at the end of the storage (36th day of storage) when tomatoes treated with 1-MCP at 18mg/L over other treatments. Till 29th day of storage, tomato treated with 1-MCP at 12mg/L retained the fruits in acceptable red stage than by other 1-MCP treatments. However, at the end of the storage (36th day of storage), tomato treated with 1-MCP at all concentrations recorded higher hue angle above 40^0 (overripe stage) than in control (below 40^0). Similarly, modified atmosphere packed tomato fruits treated with 1-methycyclopropene at 18 mg/L recorded significant higher firmness (N) at all the days of analysis compared to other 1-MCP treatments and control.

Key words: Tomato; 1-MCP; MAP; Storage; firmness; hue angle

Introduction

Tomato is a climacteric fruit and its senescence starts with the onset of ethylene depended ripening and quickly deteorates after harvesting due to its high moisture content. Improper handling of the produce results in fresh produce losses to the tune of 6-16% (Indiresh *et al.,* 2010) and so the modern techniques and methods should be followed to maintain the quality while, minimizing losses during storage and distribution. However, integrated handling operations, sanitation program and other emerging techniques can decrease these post-harvest losses. Modified atmosphere packaging (MAP) of fresh vegetables is a technique that matches the respiration of the product with the O_2 and CO_2 permeability of packages in order to modify the oxygen and carbon dioxide concentrations of the atmosphere to desired levels within the package. The level of O_2 decreases during the storage while, CO_2 increases inside the package due to respiration of the fruit and the higher CO_2 levels reduce the respiration rate and can inhibit the deteriorating effects of ethylene and reduces the weight loss, softening and fungal infection of fruits (Tano *et al.,* 2007). A delay in ripening resulted in the greatest longevity of 58 days was realized when packing banana fruits in sealed polyethylene bags with gaseous 1-MCP at 0.5 or 1.0 µL/L (Jiang *et al*., 1999). 1-methylcyclopropene (1-MCP), a chemical compound known to inhibit 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

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quality (Sisler and Serek, 1997 and Bower and Mitcham, 2001). Basic effects of 1-MCP on tomato are 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 (Guillen *et al.,* 2005; Moretti *et al.,* 2005; Guillen *et al.,* 2007; Choi and Huber, 2008). However, some studies showed that soluble solid content and weight loss were not affected by 1-MCP treatment (Wills and Ku, 2002; Krammes *et al.,* 2003; Opiyo and Ying, 2005). Similarly, MA packing of 1-MCP treated tomato resulted in significant delayed changes in fruit ripening parameters such as skin color, lycopene, higher titratable acidity and lower ripening index (SSC/TA) in both pink and light red ripening stages of tomato Sabir and Agar (2011).

The present investigation was carried out to study the storage behavior of 1-MCP treated fresh tomato at different concentrations (6mg/L, 12mg/L and 18mg/L) when packed in LDPE@40µ thickness along with untreated tomato as control (MAP without 1-MCP) during cold storage at 13±2°C and RH of 85-90%.

Materials and Methods

Tomato fruits (*var.* Punjab Ratta) of uniform size and weight were harvested at mature green to breaker stage from an unreplicated experimental plot raised at Vegetable Research Farm, Punjab Agricultural University, Ludhiana, Punjab, India during 2012-13 and 2013-14 and brought to Food Packaging and Tranportation Laboratory, Central Institute Post-Harvest Engineering and Technology, Ludhiana, Punjab, India and washed by dipping in normal tap water to remove the field heat and blemishes on the fruits. Then fruits were air dried for 5 minutes and kept overnight at 20°C in cold store. Next day, aqueous solutions of 1-MCP were prepared and treatments were imposed.

1-MCP treatments

A 10 litre 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 of distilled water were prepared and taken in 3 plastic tubs separately and in control there was no 1-MCP. A small stirring with plastic rod was given so as to mix and dissolve the 1-MCP chemical completely in distilled water. After 10 minutes of solution preparation, tomato fruits were dipped separately in each tub. 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 no later than 30 min after preparation. 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, air dried for five minutes and packed with LDPE film of 40µ thickness and double sealed with paddle operated sealer machine. The LDPE MA packs were made with 3 pin holes of 0.3mm diameter. Tomato fruits of 500± 50 grams was being used per each MA pack and in each treatment there were six MA packs which were drawn one at a time for quality analysis. The MA packed fruits were kept in cold store at 13±2^{0}C and relative humidity of 85-90% for further storage studies and evaluated for various physico-chemical parameters at weekly interval *i.e.* on 1st, 8th, 15th, 22nd, 29th and 36th day of storage for total soluble solids (TSS) content, titratable acidity (%), ripening index (TSS/TA), colour strength (a* value, hue angle), firmness (N) and decay % and average of 2012-13 and 2013-14 seasons data was presented.

The present experiment during 2012-13 and 2013-14 arranged in a Completely Randomized Design and was replicated five times. Averaged data of two year was analysed for ANOVA using SAS (v.9.3, SAS Institute, Cary, NC, USA) and means separated by Tukey's test at P = 1% significance levels.

Titratable acidity (TA) and Ripening index (TSS/TA)

Titratable acidity (TA) was determined by titrating the 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 (measured in ^{0}Brix with handheld digital Refractometer, PAL-1, 0-53%, ATAGO Make, Japan) with that of corresponding values of titratable acidity and considered as ripening index (Sabir and Agar, 2011).

a* value and Hue angle (h^0)

Changes in surface colour of tomato were determined using Mini Scan XE Plus (D/85) Hunter colorimeter (45/0-L) 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. Likewise, per each treatment three fruits were used and again average values were recorded. Hue angle is the most indicative of the colour status of the tomato fruit during ripening and 55° or lower hue angle was regarded as acceptably red and hue angle of 40^0 regarded

as overripe stage of tomato (Hurr *et al.,* 2005).

Firmness

Firmness was measured using TA-HDi (Stable Micro Systems, UK) texture analyzer equipped with a 50 kg load cell (Choi *et al.,* 2008) and 5mm-diameter plunger set to pierce 5 mm deep from the fruit surface. For the penetration of the tomato fruit 5 mm diameter flat head stainless steel cylindrical probe was used. Test speed during penetration test was 1 mm/s. three fruits were taken per treatment and puncture test was done two times at opposite sides of the equatorial area of the fruit and average value was taken as the firmness of the fruit. The force required for the plunger was recorded by texture analyzer software and expressed in Newtons.

Results and Discussion

Titratable Acidity (% Citric Acid) and Ripening index (TSS/TA)

Irrespective of treatments, it was observed that titratable acidity is in decreasing trend from the initial value of 1.08% citric acid as storage period proceeded except from 15th to 22nd day of storage (table 1). Fruits treated with 1-MCP showed significant higher titratable acidity than in control (MAP without 1-MCP) at all days of storage. Among the 1-MCP treatments, fruits treated with 1-MCP at 18 mg/L showed significant higher titratable acidity over control throughout the storage period and at the end of the storage, showed highest significant titratable acidity (0.79 % citric acid). The reason for decrease of titratable acidity in all the treatments is attributed to conversion of acids into sugars whereas, higher titratable acidity might be due to delayed ripening by higher concentrations of 1-MCP of 18 mg/L and 12 mg/L which is in accordance with results of Wills and Ku (2002) and Opiyo and Ying (2005).

Fruits treated with 1-MCP at 18 mg/L showed significant lower ripening index throughout the storage period than any other treatments studied (table 2) which could be attributed to reduced lossess in titratable acidity during ripening. These results indicate that 1-MCP@18 mg/L concentration delayed the ripening of tomato fruits effectively than other treatments studied (Guellen *et al.,* 2006).

Table 1: Effect of 1-MCP on titratable acidity (% citric acid) of MA packed tomato stored at 13±2^{0}C and RH of 85-90%

Particulars	Day of storage					
	1st	8th	15th	22nd	29th	36th
MAP+ No 1-MCP	1.08	0.74b	0.57c	0.77b	0.52c	0.43c
MAP+1-MCP 60mg/10L	1.08	0.65c	0.88b	0.92ab	0.86a	0.68b
MAP+1-MCP @120mg/10L	1.08	1.03a	0.95a	0.96ab	0.82ab	0.70b
MAP+1-MCP @180mg/10L	1.08	1.07a	0.92ab	1.08a	0.77b	0.79a

(Data in column followed by different superscript letters are significantly different at $P = 1$ %)

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

Particulars	Day of storage					
	1st	8th	15th	22nd	29th	36th
MAP+ No 1-MCP	4.74	7.47a	9.01a	6.60a	9.46a	10.45a
MAP+1-MCP 60mg/10L	4.74	7.85a	5.70b	5.38b	5.99b	6.57b
MAP+1-MCP @120mg/10L	4.74	5.56b	4.97c	6.78a	5.65b	6.58b
MAP+1-MCP @180mg/10L	4.74	5.14c	4.99c	4.14c	6.17b	5.59c

(Data in column followed by different superscript letters are significantly different at $P = 1\%$)

Table 3: Effect of 1-MCP on a* value of MA packed tomato stored at 13±2°C and RH of 85-90%

Particulars	Day of storage					
	1st	8th	15th	22nd	29th	36th
MAP+ No 1-MCP	-1.35	5.93a	28.48a	33.31a	35.94a	37.31a
MAP+1-MCP 60mg/10L	-1.35	1.34b	6.89b	14.91b	31.42b	31.26a
MAP+1-MCP @120mg/10L	-1.35	-2.91d	-0.95c	9.77c	24.98c	26.92a
MAP+1-MCP @180mg/10L	-1.35	-1.97c	-1.87d	8.37d	30.92b	28.62a

(Data in column followed by different superscript letters are significantly different at $P = 1\%$)

a* value and Hue angle

Data in table 3 indicated that, significant lower a* values were observed in all the 1-MCP treatments than in control upto 29th day of storage but, at the end of the storage, non-significant differences were observed between the 1-MCP treatments and control. Fruits treated with 12 mg/L and 18 mg/L of 1-MCP showed a* values in negative till the 15th day of storage (-0.95 and -1.87 respectively) initial value being -1.35 whereas, in fruits treated with 1-MCP at 6 mg/L and in control (MAP without 1-MCP), a* values turned positive at 8th day of storage itself indicating higher concentrations of 1-MCP delayed ripening and so the a* values in negative

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

Particulars	Day of storage					
	1st	8th	15th	22nd	29th	36th
MAP+ No 1-MCP	92.80	81.01d	52.93d	45.56d	42.90c	37.24c
MAP+1-MCP 60mg/10L	92.80	87.91c	80.46c	71.23c	50.42b	44.96b
MAP+1-MCP @120mg/10L	92.80	94.97a	91.75b	76.86b	59.12a	46.81a
MAP+1-MCP @180mg/10L	92.80	93.78b	93.69a	79.49a	51.91b	46.88a

(Data in column followed by different superscript letters are significantly different at $P = 1\%$)

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

Particulars	Day of storage					
	1st	8th	15th	22nd	29th	36th
MAP+ No 1-MCP	30.55	23.04b	21.79c	14.94c	12.66d	2.85b
MAP+1-MCP 60mg/10L	30.55	23.44b	26.51a	23.03b	16.57c	2.89b
MAP+1-MCP @120mg/10L	30.55	29.69a	22.66c	26.25a	18.50b	3.16ab
MAP+1-MCP @180mg/10L	30.55	28.25a	24.52b	27.10a	20.17a	3.81a

(Data in column followed by different superscript letters are significantly different at $P = 1\%$)

representing greenness of tomato fruits. Guellen *et al.,* (2006) also reported that application of 1-MCP significantly delayed changes in a* values in tomato fruits harvested at breaker stage.

As ripening period proceeded, three was decreasing trend in hue angle in all the treatments during storage of the tomato fruits at 13±2^{0}C and RH of 85-90%. In all the 1-MCP treated fruits hue angle was above 55^0 (acceptable red stage) till 22nd day of storage from the initial hue angle of 92.80^0. But, at 29th day of storage, tomato treated with 12 mg/L of 1-MCP (hue angle of 59.12^0) are in acceptable red stage (55^0) than the fruits treated with other 1-MCP concentrations and control (MAP without 1-MCP). However, at 36th day of storage, tomato fruits treated at all 1-MCP treatments recorded hue angle of above 40^0 (overripe stage) whereas, in control (37.24^0), hue angle of tomato fruits was below the hue angle of over-ripe stage. These results are in accordance with Choi and Huber (2008) who reported that hue angle reduction was strongly delayed in tomato fruits treated with 400 and 600µg/L of aqueous 1-MCP.

Firmness (N)

As storage period proceeded (table 5), observed decrease of firmness in all the treatments. Among the 1-MCP treatments, fruits treated with 1-MCP at 18 mg/L recorded significant higher firmness values (initial being 30.55N) at all the days of storage than in control indicating higher dose of 1-MCP treatment delayed the softening thereby slowing down the rate of ripening during storage and keeping the tomato fruits firmer for longer days (Indiresh *et al*., 2010). Tadesse *et al.,* (2012) also reported higher firmness in 1-MCP treated red and breaker stage tomato fruits than in untreated control.

Conclusion

Storage of the fruits in modified atmospheric package helped the produce to maintain for longer days during storage with minimum losses in quality because of higher CO_2 levels and lower O_2 levels being maintained in the package. Similarly, earlier studies also indicated that quality loss was very less in the fruits treated with 1-MCP than in the untreated fruits. So, when the fruits treated with higher concentrations of 1-MCP (18 mg/L and 12 mg/L) are packed in suitable MAP films, expect a synergistic effect of modified atmosphere package and 1-MCP chemical which further helps in prolonging the shelf life and quality of tomato fruits during storage and was evident from the present study.

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