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ORIGINAL ARTICLE

Application of 1-methylcyclopropene on mango fruit (Cv. Kesar): potential for shelf life enhancement and retention of quality

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Abstract The present investigation was carried out to study the effect of gaseous application of 1-methylcyclopropene (1-MCP) on quality and shelf life of mango fruits of Cv. Kesar. The freshly harvested matured mango fruits were washed, cleaned and treated with fungicide at 500 ppm concentration for 10 min. The fruits were then subjected to 1-MCP treatment at different concentrations (500, 1000, 1500, 2000 ppb) and exposed for 18 and 24 h at 20 °C temperature in an air tight chamber along with control sample. The results indicated that the ripening in the early stages of mango was delayed by 1-MCP and shelf life of the fruits was increased with increase in the concentration of 1-MCP, also the physico-chemical changes such as percent physiological loss in weight of fruit, total soluble solids and colour was slowly increased and ascorbic acid content was effectively reduced. 1-MCP treatment of 2000 ppb for 24 h exposure time gave the best results for percent physiological loss in weight of fruit from 6.1 to 13% and ascorbic acid content from 80.28 to 22.34 mg/100 g, total soluble solids increased from 7.3 to 16.23 °Brix and the colour was improved from 50.9 to 68.6 h with shelf life of 20 days.

Keywords Mango · Fungicide · 1-MCP · Physicochemical properties · Shelf life

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Introduction

Ethylene is effective for the ripening and senescence of climacteric fruits and other horticultural commodities (Lelievre et al. 1997; Klee 2004; Czarny et al. 2006) and the use of ethylene inhibitors for delaying the ripening is common practice now a days (Kebenei et al. 2003; Sisler et al. 2003; Sisler 2006). 1-Methylcyclopropene (1-MCP) has been intensively researched and used as ethylene inhibitor (reviewed in Blankenship and Dole 2003; Watkins 2006; Huber 2008) due to its approved feasible commercial use, easy application, and high efficacy with a large number of horticultural crops. 1-MCP exposure is treated in the form of gas in sealed containers (Serek et al. 1994). 1-Methylcyclopropene (1-MCP) is a recently most effective ethylene antagonist (Sisler and Serek 1997). Ripening and senescence of freshly harvested fruits have been delayed and shelflife is increased by 1-MCP application (Serek et al. 1995; Golding et al. 1998; Jiang et al. 1999; Kim et al. 2001; Pelayo et al. 2003; Aguayo et al. 2006; de Vilas-Boas and Kader 2006; Mao et al. 2007). The 1-MCP has potential to extend the shelf life by delaying the ripening process and also improves post harvest quality of many fruits (Pelayo et al. 2003; de Vilas-Boas and Kader 2006). Exposure of 1-MCP to apple decreased its ethylene production, respiration, softening, colour change and synthesis of aroma compounds (Jiang and Joyce 2002; Perera et al. 2003; Bai et al. 2004; Calderon-Lopez et al. 2005). In pineapple, 1-MCP decreased respiration, browning and increased the shelflife of fruits with improving the physicochemical attributes (Buda and Joyce 2003). Ergun et al. (2006) reported that slices made from 1-MCP treated papayas had double the shelf-life of slices made from untreated papayas.

The objectives of this work were to determine the effects of 1-MCP on shelf life and quality of mango fruit in terms of physicochemical changes such as Physiological loss in weight, colour, TSS, and Ascorbic acid content. Therefore the present study was undertaken to investigate the effect of 1-MCP on shelf life and quality of mango fruit.

Materials and methods

The mango fruits of Cv. *Kesar* were harvested manually at proper stage of maturity from well managed mango orchard near the Aurangabad city. The uniformly matured hard green fruits were brought to Food Technology Laboratory of the University Department with utmost care. The fruits were washed with clean water and then graded on the basis of specific gravity by using 'Float and Sink method'. The graded fruits were then treated with fungicide at 500 ppm concentration in order to control the incidence of stem end rot (SER) and anthracnose (Wills et al. 2000).

1-MCP treatments

Mango (*Kesar*) fruits were treated with gaseous 1-MCP. 1-MCP solution was prepared by diluting 25 mg of 1-MCP powder in 1 L distilled water to obtain at the concentration of 1000 ppb solution from (4% active ingredient, Feiming Chemicals Ltd., China) and different concentrations of 1-MCP such as 500, 1000, 1500 and 2000 ppb were prepared in same manner. Solution was used within 10 min of preparation and all treatments were completed within 10–15 min. The matured and graded mango fruits were subdivided into five groups containing 10 number of mangoes in each group and then subjected to 1-MCP treatment at 500 (T_1), 1000 (T_2), 1500 (T_3), and 2000 ppb (T_4) concentrations respectively while untreated fruits were considered as control (T_0). The fruits were packed in airtight containers along with cup containing known concentrations of 1-MCP solution prepared in lukewarm water. The treatments were given for 18 and 24 h at 20 °C temperature respectively. After treatment, the fruits were kept in CFB boxes and then stored at ambient temperature for further study of shelf life and physico-chemical characteristics like physiological loss in weight (PLW), colour, total soluble solids (TSS), and ascorbic acid content.

Physiological loss in weight (%)

Physiological loss in weight of 10 number of mango fruits of Cv. *Kesar* was calculated by using analytical weighing balance to determine the degree of maturity during the storage of 1-MCP treated and control fruit samples (Nunes 2008).

Colour measurement

Colour value (A) and (B) was determined using a Minolta Colourimeter (Model-CR-10 and Konica Colourimeter, Japan) with a standard CIE illuminant by calculating the hue angle (h°) using formula Tan^{-1} (B/A).

Total soluble solids (TSS)

The total soluble solids (%) in the mango recorded by Agato digital Pocket Refractometer PAL-3 (A.O.A.C. 1990) and expressed in percentage.

Total ascorbic acid content

Total ascorbic acid content was determined by 2, 6 dichlorophenol-indophenol visual titration method in which the dye, which is blue in alkaline solution and red in acid solution, is reduced by ascorbic acid to colourless form. The reaction is quantitative and practically specific for ascorbic acid solution in pH range 1.0–3.5 (Ranganna 1986).

Statistical analysis

The readings for every parameters were taken in triplicates for a particular treatment, they were analyzed separately and the figures were then averaged for calculation of standard deviation of each value of every treatment and expressed as mean ± SD (Das and Giri 1988).

Results and discussion

Application of 1-MCP

Exposure to gaseous 1-MCP at different concentrations (500, 1000, 1500, and 2000 ppb) slowed down the ripening of mango fruits and shelf life was increased effectively as the concentration of 1-MCP was increased. The rate of physiological loss in weight of fruit was decreased with increase in 1-MCP concentration, total soluble solids were initially increased and then decreased with increase in 1-MCP concentration. The rate of change in colour in terms of L*(Lightness) value of mango fruit was improved with increase in the exposure time and concentration of 1-MCP but the rate of reduction in the Ascorbic acid content of fruit was decreased with increase in the exposure time and concentration of 1-MCP.

Physiological loss in weight (%)

The data presented in Table 1 revealed that percent physiological loss in weight (PLW) of mango fruit in all treatments decreased steadily with increase in the 1-MCP concentration and exposure time. The similar observations were reported by Kebenei et al. (2003). The PLW was recorded as 8.7% for 18 h exposure time control treatment and it was spoiled after 4 days. Exposure for 24 h of control sample increased PLW rapidly from 11.40 to 29.47% and samples were spoiled in 8 days. When mango fruits were treated with 500 and 1000 ppb respectively at 18 h exposure time of 1-MCP, the PLW showed a gradual increase from 11.5 to 18.2 and 5 to 21% respectively in 12 days. When the samples were treated at 1500 and 2000 ppb respectively, the PLW changed from 7.4 to 17 and 5.6 to 7.6% respectively in 16 days. The fruits treated at 500, 1000, 1500 and 2000 ppb for 24 h exposure time of 1-MCP did not show significant increase in PLW. 1-MCP treatment at 2000 ppb for 24 h exposure time gave the best results in terms of rate of PLW which was increased at slow rate from 6.1 ± 0.5 to 13 ± 0.5% and shelf life was increased up to 20 days. The present result found were close to those reported earlier. Proximity with Serek et al. 1995; Golding et al. 1998; Jiang et al. 1999; Kim et al. 2001; Pelayo et al. 2003; Aguayo et al. 2006; de Vilas-Boas and Kader 2006; Mao et al. 2007. The reduction in weight loss in 1-MCP treated fruits may be attributed to slow respiration rate (Dong et al. 2002) and maintenance of tissue rigidity of the fruits.

Effect of 1-MCP on color

The data from Table 2 revealed that colour of mango fruits in all treatments improved because the lightness was decreased with increase in 1-MCP concentration and exposure time. Colour was drastically increased from 51.3 ± 1.25 to 64.1 ± 3.0 hue at 18 h exposure time treatment and fruits were spoiled after 8 days in control sample. When mango fruits were treated with 500 and 1000 ppb for 18 h exposure time of 1-MCP, the change in hue angle of colour was not sudden but steady as compared to control sample and the colour increased gradually with steady increase in hue angle in 12 and 16 days respectively. However the change in hue angle increasingly constant in the samples treated at 1500 and 2000 ppb as compared to those treated at 500 and 1000 ppb and the colour in terms of hue angle was increased from 53.93 ± 1.01 to 65.86 ± 1.2 and 53.76 ± 1.7 to 67.45 ± 1.4 in 16 and 20 days respectively. In 24 h exposure time treatment of 1-MCP at 500, 1000 and 1500 ppb concentrations respectively the hue angle responsible for colour was increased spontaneously in 12, 16, 20 days respectively. 1-MCP treatment at 2000 ppb for 24 h exposure revealed the best results in terms of colour because the hue angle and hence the colour was slowly improved from 50.9 ± 1.7 to 68.6 ± 0.8 steadily and at constant rate and shelf life was increased to 20 days. Similar results were reported earlier (Jiang and Joyce 2002; Perera et al. 2003; Bai et al. 2004; Calderon-Lopez et al. 2005).

Table 1 Effect of 1-MCP on physiological loss in weight of mango fruits (%)

Treatment	Exposure time (h)	Storage period (days)				
		4	8	12	16	20
T_0 (control)	18	8.7 ± 0.7	*			
	24	11.40 ± 1.0	29.47 ± 0.6	*		
T_1 (500 ppb)	18	11.5 ± 0.6	15.25 ± 1.0	18.2 ± 1.4	*	
	24	5.83 ± 1.7	6.04 ± 2.5	8.9 ± 2.4	*	
T_2 (1000 ppb)	18	5 ± 0.8	7.4 ± 0.8	21 ± 0.3	*	
	24	2.9 ± 0.6	6.06 ± 1.1	9 ± 0.55	*	
T_3 (1500 ppb)	18	7.4 ± 2.1	11.12 ± 1.7	13.5 ± 3.4	17 ± 1.9	*
	24	5.96 ± 1.2	8.3 ± 0.2	10.5 ± 0.6	14.3 ± 0.9	*
T_4 (2000 ppb)	18	5.6 ± 0.55	6.6 ± 2.5	6.54 ± 1.9	7.6 ± 0.7	*
	24	6.1 ± 0.5	8.1 ± 0.3	11.03 ± 0.3	11.7 ± 0.4	13 ± 0.5

Each value is the average of three determinations and expressed as mean ± SD

T_1–T_4: 1-MCP treatment for 18 and 24 h at ambient temperature

*Fruits discarded due to spoilage

Table 2 Effect of 1-MCP on colour of fruit (hue)

Treatment	Exposure time (h)	Storage period (days)					
		0	4	8	12	16	20
T_0 (control)	18	51.3 ± 1.25	64.1 ± 3.0	*			
	24	52.2 ± 0.38	54.4 ± 0.98	62.33 ± 1.6	*		
T_1 (500 ppb)	18	51.6 ± 2.5	53.5 ± 2.8	63.8 ± 1.2	*	*	
	24	51.43 ± 0.74	50.7 ± 0.74	53.13 ± 0.81	56.8 ± 1.06	*	
T_2 (1000 ppb)	18	55.2 ± 1.98	50.13 ± 2.49	56.8 ± 1.06	58.2 ± 2.5	62.13 ± 1.5	*
	24	52.63 ± 1.6	55.9 ± 1.4	58.4 ± 0.7	60.93 ± 0.6	62.23 ± 1.5	*
T_3 (1500 ppb)	18	53.93 ± 1.01	55.73 ± 1.0	62.36 ± 2.6	64.23 ± 1.3	65.86 ± 1.2	*
	24	50.9 ± 1.2	57.36 ± 1.0	60.6 ± 0.43	63.06 ± 0.8	65.4 ± 1.17	63.8 ± 1.3
T_4 (2000 ppb)	18	53.76 ± 1.7	57.23 ± 1.4	59.66 ± 1.7	64.3.86 ± 1.0	66.4.43 ± 1.4	67.45 ± 1.4
	24	50.9 ± 1.7	57.23 ± 1.3	62.06 ± 0.8	67.6 ± 1.6	66.7 ± 1.6	68.6 ± 0.8

Each value is the average of three determinations and expressed as mean ± SD

T_1–T_4: 1-MCP treatment for 18 and 24 h at ambient temperature

*Fruits discarded due to spoilage

Effect of 1-MCP on TSS

The results presented in Table 3 for the effect of 1-MCP on total soluble solids (TSS) of mango (Cv. Kesar) fruit indicated that TSS of mango fruit was initially increased and then decreased with increase in the 1-MCP concentration and its exposure time. TSS was rapidly increased from 6.9 ± 1.1 to 13.8 ± 1.0 and from 6.4 ± 0.32 to 11.13 ± 0.33 in control fruits for 18 h exposure time within 4 days. In case of mango fruits treated at 500 and 1000 ppb concentration of 1-MCP for 18 h exposure time, gradual increase in TSS was observed in 4 and 8 days respectively for the similar concentration. Nearly similar trend but with steady and gradual increase in TSS was shown by the samples treated at 1500 and 2000 ppb for 12 and 16 days respectively. In 24 h exposure time of 1-MCP treatment at 500, 1000 and 1500 ppb concentrations, TSS was increased from 6.7 ± 0.21 to 13.4 ± 0.35, 7.1 ± 0.29 to 14.4 ± 0.4 and from 7.1 ± 0.29 to 16.3 ± 0.53 in 8,12, 20 days respectively. 1-MCP treatment at 2000 ppb for 24 h TSS was slowly increased from7.3 ± 0.50 to 16.23 ± 0.55 in 20 days. Results were found in close approximity with results obtained by Santos et al. (2004). The increase in TSS and sugars during storage may

Table 3 Effect of 1-MCP on total soluble solids of fruit (°Brix)

Treatment	Exposure time (h)	Storage period (days)					
		0	4	8	12	16	20
T_0 (control)	18	6.9 ± 1.1	13.8 ± 1.0	*			
	24	6.4 ± 0.32	11.13 ± 0.33	*			
T_1 (500 ppb)	18	7.0 ± 0.9	11.5 ± 0.55	*			
	24	6.7 ± 0.21	9.9 ± 0.29	13.4 ± 0.35	*		
T_2 (1000 ppb)	18	6.7 ± 0.7	10.2 ± 1.1	15.4 ± 0.77	*		
	24	7.1 ± 0.29	11.7 ± 0.12	14.3 ± 1.11	14.4 ± 0.4	*	
T_3 (1500 ppb)	18	8.1 ± 0.66	9.4 ± 1.6	14.2 ± 1.3	15.7 ± 0.99	*	
	24	7.1 ± 0.29	9.5 ± 0.49	11.7 ± 0.26	13.13 ± 1.29	15.53 ± 0.5	16.3 ± 0.53
T_4 (2000 ppb)	18	7.5 ± 1.0	9.4 ± 0.75	13.5 ± 0.66	15.4 ± 1.2	15.9 ± 1.1	*
	24	7.3 ± 0.50	8.6 ± 0.44	10.4 ± 0.55	13.6 ± 0.61	15.5 ± 1.04	16.23 ± 0.55

Each value is the average of three determinations and expressed as mean ± SD

* Fruits discarded due to spoilage

T_1-T_4: 1-MCP treatment for 18 and 24 h at ambient temperature possibly be due breakdown of complex organic metabolites into simple molecules. Further it may be attributed to hydrolysis of starch into sugars, on complete hydrolysis of starch no further increase in sugars occurred and subsequently a decline in these parameters is evident as they along with other organic acids are primary substrate for respiration (Wills et al. 1980).

Effect of 1-MCP on ascorbic acid content

Results shown in Table 4 for the effect of 1-MCP on the ascorbic acid content of mango fruits revealed that the ascorbic acid (AA) of mango fruit was decreased with increase in storage period due to increased rate of ripening and its association with 1-MCP concentration and its exposure time. The rate of depletion of AA was comparatively higher in the fruits treated at 500 ppb as compared to rest of the treatments. For the control sample there was significant decrease in AA content as shown in Table 4 for 18 and 24 h exposure time in 8 days and the wholesomeness of fruit started degrading after 8 days. The AA was decreased from 80.6 ± 1.7 to 22.36 ± 1.22 and from 83.72 ± 0.5 to 26 ± 0.67 in 12 days when mango fruits were treated with 500, 1000 ppb concentration of 1-MCP respectively. Similar trend was observed in case of the mango fruits were treated at 1500 and 2000 ppb concentration of 1-MCP for 16 and 20 days respectively, however the rate of AA depletion was steady and was little bit slower in fruits treated at 2000 ppb as compared to rest of the treatments at similar exposure time of 18 h. In case of 24 h exposure time treatment of 1-MCP of 500, 1000 and 1500 ppb concentrations, the AA was decreased from 81.38 ± 1.5 to 21.7 ± 1.7, 80.31 ± 1.3 to 22.58 ± 0.6 and 81.44 ± 1.1 to 16.91 ± 1.1 in 16, 16 and 20 days respectively. 1-MCP treatment of 2000 ppb for 24 h exposure time shown significant results with slow rate of reduction in the ascorbic acid content of mango fruit from 80.28 ± 1.1 to 22.34 ± 1.0 in 20 days. Sisler and Serek (1997) have also reported the similar trend in decreasing the ascorbic acid content in fruits. The decrease in titratable acids during storage may be attributed to marked increase in malic acid utilization during ripening (Hulme 1971). The fruits treated with 1-MCP maintained higher acidity during storage probably due to delay in ripening process. Fan et al. (2002) observed lower acidity loss during storage in peach treated with 1-MCP.

Conclusion

The present study revealed that shelflife and the quality of mango fruit was having strong association with 1-MCP concentration and its exposure time. Shlflife of mango (Cv. Kesar) was increased with increase in concentration of 1-MCP and its exposure time and also the physicochemical properties such as physiological loss in weight of fruit, colour, total soluble solids and ascorbic acid content was significantly influenced by 1-MCP concentration and its exposure time. 1-MCP treatment at 2000 ppb for exposure time of 18 and 24 h found the best results in terms of physicochemical quality and shelf life of mango fruit which was increased to 20 days.

Table 4 Effect of 1-MCP on ascorbic acid content (mg/100 g) of mango fruits

Treatment	Exposure time (h)	Storage period (days)					
		0	4	8	12	16	20
T_0 (control)	18	82.50 ± 1.0	48.8 ± 0.9	*	*		
	24	80.48 ± 0.8	42.4 ± 1.8	23.1 ± 0.8	*		
T_1 (500 ppb)	18	80.6 ± 1.7	47.5 ± 1.4	36.8 ± 0.9	22.36 ± 1.22	*	
	24	81.38 ± 1.5	79.62 ± 0.72	64.20 ± 3.8	45.26 ± 1.7	21.7 ± 1.7	*
T_2 (1000 ppb)	18	83.72 ± 0.5	75.92 ± 1.1	45.32 ± 1.7	26 ± 0.67	*	
	24	80.31 ± 1.3	67.16 ± 1.6	48.2 ± 1.3	26.92 ± 0.4	22.58 ± 0.6	*
T_3 (1500 ppb)	18	80.22 ± 1.14	71.24 ± 1.23	53.4 ± 0.44	33.72 ± 0.54	20.32 ± 1.7	*
	24	81.44 ± 1.1	69.13 ± 1.13	49.37 ± 0.42	24.28 ± 1.0	22.58 ± 0.3	16.91 ± 1.1
T_4 (2000 ppb)	18	82.52 ± 2.6	65 ± 2.9	44.2 ± 1.9	26.52 ± 3.2	21.32 ± 1.8	17.16 ± 1.6
	24	80.28 ± 1.1	72.66 ± 0.6	49.32 ± 1.8	29.14 ± 0.4	23.66 ± 1.6	22.34 ± 1.0

Each value is the average of three determinations and expressed as mean ± SD

T_1–T_4: 1-MCP treatment for 18 and 24 h at ambient temperature

*Fruits discarded due to spoilage

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