



DEGREENING OF BARAMASI LEMON {*Citrus limon* (L.) Burm} IN RESPONSE TO ETHEPHON APPLICATION

S.K. Jawandha, Harminder Singh, Jagjit Singh and Rupinder Kaur

Department of Fruit Science, Punjab Agricultural University, Ludhiana – 141 004, Punjab (India)

*e mail: skjawandha@pau.edu

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ABSTRACT

Harvesting of summer crop of Baramasi lemon (*Citrus limon*) coincides with the rainy season that leads to low market demand and poor returns to the growers. Therefore, an experiment was planned for post-harvest degreening of lemon fruits to advance the marketing. Fully mature fruits of lemon cv. 'PAU Baramasi Lemon-1' were treated with different concentrations of ethephon solution viz., 0, 500, 750, 1000, 1250 and 1500 ppm for 5 min. Treated fruits were packed in CFB boxes with paper lining and kept at room temperature. Experimental fruits were analysed for physicochemical characteristics from 4th to 7th day after treatments at 24 h interval. Results revealed that maximum degreening of fruits occurred with ethephon @ 1500 ppm, which was depicted by 'b*' value (49.37, 50.83) of colour flex meter and these results were at par with ethephon @ 1250 ppm treatment. Similar trend was recorded for other parameters viz., physiological loss in weight, sensory quality, juice content, total soluble solids and acid content. It may be concluded that lemon fruits of cv. 'PAU Baramasi Lemon-1' harvested in June can be degreened in 6-7 days at room temperature by dipping in 1250 or 1500 ppm of ethephon so as to advance the marketing of summer crop.

Key words: Degreening, fruit colour, lemon, physiological loss in weight, total soluble solids

INTRODUCTION

Citrus occupies the prime position amongst the fruits grown in India. In citrus fruits, lime and lemon are on third rank after mandarins and sweet oranges in the country with an area and production of 2,59,000 ha and 27,89,000 metric tonnes, respectively (Anonymous, 2017). Among these fruits, lime and lemon have high medicinal value as these are excellent source of vitamin-C and also possess a considerable amount of vitamins B, A and P (Bal, 2015). These fruits can be used in different ways viz., pickles, lemonades, lime cordials as compared to other citrus fruits. In Punjab, Baramasi lemon {*Citrus limon* (L.) Burm} performs well due to its good adaptability to the prevailing sub-tropical climatic (hot and dry summer with cool winters) conditions. Plants of Baramasi lemon bear fruits mainly in two seasons of a year i.e. summer and winter, but sparse flowering and fruiting continues throughout the year. However, the harvesting period of summer crop coincides with the monsoon period that leads to low demand of fruit in market and price crash resulting in low returns to the growers. Income of growers can be increased by advancing the harvesting and marketing period of summer crop. Characteristic colour development governs the marketing of citrus fruits as consumers assess the fresh fruit quality from external appearance.

Ethylene improves the appearance of many fruits by promoting the colour development. External application of ethylene accelerates the development of yellow or orange colour and

degradation of chlorophyll (Saltveit, 1999; Mahajan, *et al.*, 2014). Young *et al.* (1974) reported that pre-harvest spray of ethephon enhanced external colour development in citrus fruit cultivars viz., Nova, Orlando, Hamlin, Temple, Dancy and Murcott. The application of ethephon @ 2000 ppm on pepper (*Capsicum annum*) plants increased the percentage of ripe fruits as compared to the control (Graifenberg and Giustiniani, 1980). Recently, many countries are applying ethylene as growth regulator to enhance fruit colour. Saltveit (1999) reported that the application of ethephon during ripening period of apple intensified fruit colour. In citrus it has been observed that ethylene and ethephon treatments increased β -cryptoxanthin content largely in its peel and developed orange-red colour (Hu, 2018). Keeping the above facts in view, the present study was planned to observe the effect of ethephon on degreening of lemon fruits.

MATERIALS AND METHODS

Fully mature, light green and smooth skinned fruits of lemon cv. 'PAU Baramasi Lemon-1' were harvested in the first week of June during the years 2014 and 2015 alongwith a small pedicle from Fruit Research Farm, Punjab Agricultural University, Ludhiana, India (33°54'N, 75°47'E, 247 m amsl) and immediately shifted to Post-Harvest Laboratory of the Department. Healthy and uniform fruits were immersed in different concentrations of ethephon (Ethrel^R, Sisco Research Laboratories, India) solution viz., 0 (control), 500, 750, 1000, 1250 and 1500 ppm for 5 min. A two-factor experiment (factors; ethephon concentration and days after treatment) was laid out in a completely randomized design. Each treatment was replicated thrice. The treatments comprised of 2.0 kg fruit per replication. A total 24 kg fruit was kept under each treatment for 7 day's study of degreening. Treated fruits were dried under shade at room temperature (32±2°C) and packed in CFB boxes (4 kg) with paper lining and kept under ambient conditions for 7 days. Physicochemical analysis of experimental fruits was done from 4th to 7th day after treatments at 24 h interval. After every 24 h, 2 kg fruits from each replication were drawn and analysed for physicochemical characteristics.

Peel colour (yellowness) of fruits was recorded as b^* coordinate from opposite positions of each fruit by using Color Flex Spectrophotometer (Hunter Lab Color Flex, Hunter Associates Inc., Reston, USA). The physiological loss in weight was calculated on initial weight basis. The percent loss in weight after every 24 h was calculated by subtracting the final weight from the initial fruit weight and then converted into percentage value. For juice content estimation, the fruit juice was extracted with the help of a citrus juicer and strained through mesh and weighed. The juice percentage was calculated on fresh fruit weight basis. Baramasi lemon fruits were rated for sensory quality by a panel of five judges on the basis of external appearance and freshness. A nine point 'hedonic scale' described by Amerine *et al.* (1965) was used for its inference as: 9, extremely desirable; 8, very much desirable; 7, moderately desirable; 6, slightly desirable; 5, neither desirable nor undesirable; 4, slightly undesirable; 3, moderately undesirable; 2, very much undesirable; and 1, extremely undesirable. The total soluble solids (TSS) were determined by digital refractometer (Atago, Pal, model 3810, Japan). The readings were corrected with the help of temperature correction chart at 20°C temperature. Titratable acidity of fruit juice was estimated as per George and Murphy *et al.* (2010). The data obtained were subjected to statistical analysis as described by Singh *et al.* (1998).

RESULTS AND DISCUSSION

Colour is an important fruit quality attribute of lemon. In present study the fruit colour of lemon improved with ethephon application. During both the years, degreening (yellow colour development)

Table 1: Effect of post-harvest treatments of ethephon on colour scale 'b*' of Baramasi lemon

Ethephon concentration (ppm) {T}	2014					2015				
	Days after treatment (D)					Days after treatment (D)				
	4	5	6	7	Mean	4	5	6	7	Mean
500	31.56	32.78	34.23	34.58	33.29	32.76	33.93	35.04	35.13	34.22
750	32.36	34.81	35.72	36.87	34.94	33.84	35.02	36.42	37.08	35.59
1000	34.96	35.92	36.94	37.09	36.23	35.18	36.16	37.18	37.21	36.43
1250	38.24	42.33	47.81	49.39	44.44	38.68	44.03	48.38	50.52	45.40
1500	38.71	43.19	48.70	49.67	45.07	39.28	44.35	48.82	50.83	45.82
Untreated control	31.15	32.58	33.76	34.37	32.97	32.27	33.82	31.85	34.89	33.21
Mean	34.50	36.94	39.53	40.33		35.34	37.89	39.62	40.94	
CD _{0.05}	T: 0.73, D: 0.66, T x D: 1.44					T: 0.62, D: 0.56, T x D: 1.21				

of lemon fruits increased significantly with increase in ethephon concentration up to 1250 ppm, afterwards a non-significant increase in degreening was recorded with 1500 ppm ethephon (Table 1). A significant effect of time period (days after treatment) on degreening was also observed. Change in fruit colour from green to yellow represents the degreening in lemon and it was measured by recording b* value of colour scale. An increasing trend was recorded in b* value with increase in ethephon concentration and degreening time. Maximum b* values for both the years (34.37, 34.89) were recorded with ethephon @ 1500 ppm after 7 days of treatment, which were at par with ethephon @ 1250 ppm. Mean maximum b* values (45.07, 45.82) were also recorded in ethephon @ 1500 ppm treatment and mean minimum (32.97, 33.21) were observed in control fruits. Interaction between ethephon concentration and time for degreening (days after treatment) was found significant for b* value during both the years of study. Similarly, in Brazilian "Murcott" tangor, Jomori *et al.* (2013) reported that ethephon is efficient for postharvest degreening at concentration of 500 mg L⁻¹ and this treatment has great potential for commercial use. Yellow colour development during ripening is related to the accumulation of carotenoids (Medlicott *et al.*, 1988). In mango, Chaplin (1988) and Lizada (1991) also reported improvement in fruit colour with exogenous application of ethephon. External application of ethephon stimulated papaya fruit ripening by skin degreening and yellowing, and carotenoid synthesis (Anand and Paull, 1990). Sposito *et al.* (2006) also reported that in 'Valencia' oranges ethylene application increased SCI (skin colour index) values between +2.0 and +3.0, which were higher than the control SCI values (+1.0).

Physiological loss in weight (PLW) significantly increased with the advancement of degreening period as well as with increase in ethephon concentration. Mean minimum PLW (3.59, 3.68%) was observed in control fruits, but mean maximum PLW (4.30, 4.42%) was recorded in fruits treated with ethephon @ 1500 ppm during both the years of study (Table 2). Increase in weight loss with higher ethephon concentration might be due to rigorous effect of ethephon on

Table 2: Effect of post-harvest treatments of ethephon on physiological loss in weight (PLW) (%) of Baramasi lemon

Ethephon concentration (ppm) {T}	2014					2015				
	Days after treatment (D)					Days after treatment (D)				
	4	5	6	7	Mean	4	5	6	7	Mean
500	2.57	3.46	4.16	4.53	3.68	2.38	3.67	4.09	4.68	3.71
750	2.74	3.54	4.48	4.64	3.85	2.41	3.82	4.31	4.71	3.81
1000	2.91	3.83	4.63	4.89	4.07	2.66	3.94	4.54	4.79	3.98
1250	3.02	3.96	4.76	5.06	4.20	3.11	4.03	4.82	5.11	4.27
1500	3.13	4.08	4.85	5.13	4.30	3.32	4.22	4.93	5.20	4.42
Untreated control	2.46	3.34	4.11	4.44	3.59	2.33	3.58	4.01	4.79	3.68
Mean	2.81	3.70	4.50	4.78		2.70	3.88	4.45	4.88	
CD _{0.05}	T: 0.21, D: 0.26, T x D: 0.43					T: 0.18, D: 0.21, T x D: 0.35				

Table 3: Effect of post-harvest treatments of ethephon on juice content (%) of Baramasi lemon

Ethephon concentration (ppm) {T}	2014					2015				
	Days after treatment (D)					Days after treatment (D)				
	4	5	6	7	Mean	4	5	6	7	Mean
500	24.11	24.84	25.33	26.64	25.23	27.08	27.94	30.92	31.02	29.24
750	25.32	25.66	27.16	29.03	26.79	27.96	28.92	31.70	31.92	30.13
1000	26.16	28.37	31.73	32.67	29.73	28.03	29.18	32.94	34.04	31.05
1250	28.21	31.42	37.77	39.42	34.21	29.65	33.42	36.16	37.56	34.20
1500	28.55	31.74	38.12	40.13	34.64	30.62	34.15	36.98	38.06	34.95
Untreated control	24.08	24.76	25.18	26.01	25.01	26.34	27.36	30.09	30.94	28.68
Mean	26.07	27.80	30.88	32.32		24.81	26.57	29.26	30.08	
CD _{0.05}	T: 1.33, D: 1.08, T x D: 2.68					T: 1.17, D: 1.03, T x D: 2.33				

disorganization of cell wall structure which resulted in higher respiration rate (Singh *et al.*, 1994). Similar increase in weight loss of pear fruit with ethephon treatments has been reported by Dhillon and Mahajan (2011).

Juice content of fruits showed a linear relationship with ethephon concentration and time period (days after ethephon treatment). A significant increase in juice percentage of lemon fruits was recorded with increase in ethephon concentration and advancement of degreening period. During both the years, maximum juice content (40.13, 38.06%) was recorded in ethephon @1500 ppm treated lemons after seven days of treatment which was at par with juice yield from 1250 ppm ethephon treated lemons (Table 3). An increase in juice percentage with increase in ethephon concentration and time may be due to the increase in moisture loss from fruit peel that might have increased the percent value of juice in fruit.

Sensory quality is the factor that governs consumer acceptability for the produce. In lemons, consumer acceptability is more for yellow colour fruits than green colour. During the degreening process yellow colour increased in lemons that further effected the sensory quality rating of fruits. Two years study showed that maximum sensory quality rating (8.16, 8.39) was scored by the lemons treated with 1500 ppm ethephon after 7 days of treatment and it was at par with sensory score registered in 1250 ppm ethephon treated lemons (Table 4). For sensory quality rating, interaction between ethephon concentration and days after treatment was found significant. Development of characteristic colour and aroma of fruit are the major ripening changes which are controlled by ethylene in fruits (Romero *et al.*, 2007).

Table 4: Effect of post-harvest treatments of ethephon on sensory quality rating (1-9)* of Baramasi lemon

Ethephon concentration (ppm) {T}	2014					2015				
	Days after treatment (D)					Days after treatment (D)				
	4	5	6	7	Mean	4	5	6	7	Mean
500	4.86	5.42	5.56	5.71	5.39	4.93	5.50	5.49	5.65	5.39
750	5.12	5.55	5.78	5.83	5.57	5.20	5.71	5.68	5.75	5.59
1000	5.42	5.81	6.03	6.28	5.89	5.51	5.90	6.11	6.39	5.98
1250	5.70	6.67	7.55	8.05	6.99	5.87	6.73	7.78	8.24	7.16
1500	6.11	6.75	7.71	8.16	7.18	6.25	6.85	7.84	8.39	7.33
Untreated control	4.73	5.21	5.40	5.63	5.24	4.85	5.35	5.39	5.58	5.29
Mean	5.32	5.90	6.34	6.61		5.44	6.01	6.38	6.67	
CD _{0.05}	T: 0.22, D: 0.18, T x D: 0.46					T: 0.19, D: 0.17, T x D: 0.36				

*Hedonic scale: 9 = Extremely desirable, 8 = Very much desirable, 7 = Moderately desirable, 6 = Slightly desirable, 5 = Neither desirable nor undesirable, 4 = Slightly undesirable, 3 = Moderately undesirable, 2 = Very much undesirable, and 1 = Extremely undesirable.

Table 5: Effect of post- harvest treatments of ethephon on TSS (%) of Baramasi lemon

Ethephon concentration (ppm) {T}	2014					2015				
	Days after treatment (D)					Days after treatment (D)				
	4	5	6	7	Mean	4	5	6	7	Mean
500	6.63	6.74	6.80	6.90	6.77	6.60	6.63	6.70	6.80	6.68
750	6.71	6.78	6.82	6.90	6.80	6.66	6.70	6.78	6.85	6.75
1000	6.73	6.82	6.90	6.98	6.86	6.71	6.76	6.80	6.87	6.79
1250	6.81	6.94	7.05	7.12	6.98	6.77	6.82	6.87	6.90	6.84
1500	6.87	6.98	7.10	7.15	7.03	6.80	6.87	6.92	6.95	6.89
Untreated control	6.63	6.68	6.77	6.84	6.73	6.58	6.62	6.71	6.77	6.67
Mean	6.76	6.85	6.94	7.01		6.69	6.73	6.80	6.86	
CD _{0.05}	T: 0.08, D: 0.06, T x D: 0.14					T: 0.03, D: 0.04, T x D: ns				

Table 6: Effect of post-harvest treatments of ethephon on acidity (%) of Baramasi lemon

Ethephon concentration (ppm) {T}	2014					2015				
	Days after treatment (D)					Days after treatment (D)				
	4	5	6	7	Mean	4	5	6	7	Mean
500	5.18	5.21	5.25	5.28	5.23	5.15	5.16	5.16	5.14	5.15
750	5.20	5.24	5.28	5.31	5.26	5.15	5.15	5.18	5.19	5.17
1000	5.24	5.27	5.31	5.34	5.29	5.18	5.20	5.20	5.21	5.20
1250	5.29	5.32	5.36	5.39	5.34	5.20	5.23	5.21	5.23	5.21
1500	5.32	5.36	5.38	5.40	5.37	5.18	5.20	5.23	5.22	5.21
Untreated control	5.12	5.15	5.20	5.24	5.18	5.15	5.18	5.20	5.21	5.18
Mean	5.24	5.27	5.31	5.34		5.17	5.19	5.20	5.20	
CD _{0.05}	T: 0.06, D: 0.04, T x D: 0.10					T: ns, D: ns, T x D: ns				

Bio-chemical analysis of fruits showed a slight increase in total soluble solids (TSS) content of juice during degreening process (Table 5). Maximum TSS (7.15, 6.95%) was recorded in ethephon @ 1500 ppm treated fruits after seven days of treatment. Mean minimum TSS (6.73, 6.67%) was found in untreated (control) fruits. Acid content of fruits showed a non-significant increase with increase in degreening time. Among the treatments, mean maximum acid content (5.37, 5.21%) was recorded in ethephon @ 1500 ppm treated fruits and mean minimum was observed in control fruits (Table 6). This increase in total soluble solids of fruit juice might be due to moisture loss from fruits by respiration and transpiration processes. Similar results were reported by Jawandha *et al.* (2016) in mango fruits. However, in Valencia oranges the application of ethylene at concentrations of 5 or 10 $\mu\text{L L}^{-1}$ was found effective for degreening but it did not affect the bio-chemical properties (Jomori, 2016).

Conclusion: Fully mature, light green and smooth skinned fruits of lemon cv. PAU Baramasi Lemon-1 can be degreened in 6-7 days at room temperature by dipping in 1250 or 1500 ppm ethephon solution for 5 min.

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