1-Methylcyclopropene Can Differentially Affect the Postharvest Life of Strawberries Exposed to Ethylene

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Abstract. Strawberry (*Fragaria* × *ananassa* Duch.) fruit were fumigated for 2 hours at 20 °C with 1-mcp at concentrations from 5 to 500 nL·L⁻¹, then held at 20 and 5 °C in air containing 0.1 µL·L⁻¹ ethylene. Fumigation with 1-mcp at 5 to 15 nL·L⁻¹ extended the postharvest life by ≈35% at 20 °C and 150% at 5 °C, but at higher 1-mcp concentrations there was an accelerated loss of quality with a 30% to 60% decrease in postharvest life at 500 nL·L⁻¹ at both 20 and 5 °C. Chemical name used: 1-methylcyclopropene (1-mcp).

Strawberry fruit are popular with consumers, but marketing is limited by a short postharvest life. The postharvest life can be extended by storage at low temperatures and in an atmosphere containing high levels of carbon dioxide (Harris and Harvey; 1973; Larsen and Watkins, 1995; Smith, 1992; van Doren et al., 1941) or low concentrations of ethylene (El-Kazzaz et al., 1983; Wills and Kim, 1995). Methods for preventing ethylene accumulation or inhibiting ethylene action on strawberries would thus be of considerable commercial interest. Fumigation with 1-methylcyclopropene (1-mcp) gas has been reported to inhibit ethylene action in various plant tissues (Serek et al., 1995; Sisler and Serek, 1997; Sisler et al., 1996). Our objective was to determine if 1-mcp could extend the postharvest life of strawberries.

Materials and Methods

Organically grown 'Tioga' and 'Seascape' strawberries were obtained from a farm in Ourimbah, NSW, Australia, and hydroponic 'Selva' and 'Parker' strawberries from the Sydney wholesale markets over a 3-month period. Berries that were clean, bright, and free from physical damage and deterioration were selected for experimental use. A treatment unit consisting of ≈300 g of strawberries

was sealed in a 2-L glass jar. Randomized block designs were used for experiments with a minimum of three replicate jars per treatment. 1-Mcp gas (100 mL at a concentration of 75 mL·L⁻¹) was supplied by Floralife (Burr Ridge, Ill.). This was diluted to 375 µL·L⁻¹ with air for use as a stock mixture. Appropriate volumes of the stock mixture were injected into the sealed glass jars to obtain the desired 1-mcp concentrations, which were maintained for 2 h at 20 °C. Control strawberries were held in sealed jars in air. All strawberries were then held in air containing 0.05 to 0.1 µL·L⁻¹ ethylene at either 5 or 20 °C to simulate conditions that might be encountered in commercial marketing (Wills and Kim, 1995). Ethylene in the headspace of the glass jars was sampled by a 1-mL gastight syringe twice a day and analyzed using a flame ionization gas chromatograph (Gow-Mac Model 580, Bound Brook, N.J.) equipped with a stainless steel column (1.8 m × 3 mm i.d.) packed with activated alumina (80–100 mesh). Detector, column, and injector temperatures were 110, 90, and 70 °C, respectively, and the gas flow rates (mL·min⁻¹)

were 30, 30, and 300 for N₂, H₂, and air, respectively. The quality of strawberries in each jar was assessed visually by a single observer at 0900 and 1700 hr each day. Berries showing loss of freshness or gloss, softening, rotting, or mold growth were considered unacceptable and discarded. The percentage of acceptable strawberries remaining was calculated at each assessment. A linear regression of the change in percentage of acceptable berries was determined for each treatment. The time for quality to decline to 80% acceptable strawberries was calculated from the equation and assigned as the postharvest life. Statistical procedures for storage life values were performed using SPSS version 7.5 (Chicago). Least significant differences (LSD) at $P \leq 0.05$ were calculated to compare differences between means, and the appropriate regression equations were fitted.

Results and Discussion

The postharvest life of strawberries at 20 and 5 °C was reduced by fumigation with 1-mcp (Table 1), with significant linear regressions found for the four strawberry cultivars as the concentration was increased up to 500 nL·L⁻¹ ($P \leq 0.05$). Fumigation with 500 nL·L⁻¹ 1-mcp reduced the storage life by ≈40% compared with nontreated fruit. The loss of quality was due mostly to the onset of rotting. The relatively short postharvest life is explained by the stringent quality standards applied to individual berries, the low number of defective berries required for sample rejection, and addition of ethylene to the atmosphere to better simulate commercial conditions.

The data in Table 1 also suggested that exposure to 10 nL·L⁻¹ 1-mcp might increase postharvest life. Subsequent trials with 'Selva' strawberries exposed to 1-mcp concentrations in the range 5–50 nL·L⁻¹, then stored at 20 or 5 °C (Table 2), showed a highly significant curvilinear regression at both temperatures [$y = 30.4/(1 + 0.0004)(x - 18.5)^2$ at 20 °C and $y = 237.6/(1 + 0.004)(x - 27.7)^2$ at 5 °C; $P \leq 0.001$; where y = storage life, and x = 1-mcp concentration]. Thus, postharvest life was extended following fumigation with 1-mcp at 5–15 nL·L⁻¹, but declined as the concentration increased to 50 nL·L⁻¹.

Table 1. Effects of fumigation with 1-mcp on postharvest life of fruit of four strawberry cultivars held at 20 and 5 °C.

1-Mcp concn (nL·L ⁻¹)	Postharvest life (h)			
	cv: Tioga temp: 20 °C	Seascape 20 °C	Parker 20 °C	Selva 5 °C
0	12.0 a ^z	9.6 a ^z	24.7 ab ^z	67.9 ab ^z
10	---	---	25.6 a	103.6 a
50	---	7.4 b	19.5 bc	68.1 ab
100	6.0 bc	6.8 b	---	---
200	---	6.8 b	18.5 c	---
280	7.5 b	---	19.1 c	46.3 b
500	4.3 c	---	16.1 c	38.6 b
LSD _{0.05}	±2.75	±2.01	±5.57	±40.6
No. replicates	3	3	6	5
Linear regression	$y = 10 - 0.012x^*$	$y = 9 - 0.013x^*$	$y = 23 - 0.016x^*$	$y = 81.0 - 0.094x^*$
Correl. coeff., r	-0.68	-0.66	-0.35	-0.46

^zMean separation within columns by LSD_{0.05}.

*Significant at $P \leq 0.05$.

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Table 2. Effects of fumigation with low concentrations of 1-mcp on postharvest life of 'Selva' strawberry fruit at 20 and 5 °C.

1-Mcp concn (nL·L ⁻¹)	Postharvest life (h)	
	20 °C	5 °C
0	24.0 bc ^z	54.8 b ^z
5	32.2 a	72.2 ab
10	30.5 ab	124.5 a
15	28.2 abc	122.6 a
50	22.2 c	73.6 b
LSD _{0.05}	±7.09	±52.7
No. replicates	6	4

^zMean separation within columns by LSD_{0.05}.

Our observations that 1-mcp can accelerate deterioration has not been previously reported for any horticultural commodity. The effect of 1-mcp in extending the life of horticultural produce has been ascribed to 1-mcp competing with ethylene for attachment to enzyme receptor sites that initiate ripening (Sisler and Serek, 1997), but Tian and Gong (1997) have suggested that ethylene receptors in strawberries may differ from those in climacteric fruit. The deleterious action of 1-mcp appears to be either through inhibition of some beneficial metabolic system or stimulation of some undesirable system. Since deterioration was primarily related to decay, high concen-

trations of 1-mcp may interfere with a natural defense system in strawberries that confers resistance. The deleterious effect of 1-mcp may, however, be unrelated to ethylene action.

The postharvest life of strawberries fumigated with low 1-mcp concentrations was doubled at 5 °C and increased by ≈30% at 20 °C. The benefits of 1-mcp application, together with the small amount of 1-mcp required, suggest that its use may have commercial importance. However, the narrow range over which the benefit is realized could present operational difficulties, as the application system must apply a designated 1-mcp concentration with small tolerances for deviation. The reliability of 1-mcp fumigation to maintain strawberry quality needs to be assessed under commercial operating conditions.

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