

LOW ETHYLENE CA STORAGE FOR 'EMPIRE' APPLES

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Essential Elements in a Low Ethylene CA Program for 'Empire'

Some New York storage operators have reaped the benefits of low ethylene (<1.0 ppm) CA for 'Empire' apples in three storage seasons. Lessons learned from the successes and the failures have indicated that a program for low ethylene CA 'Empire' must include all of the elements listed in Table 1. The first and last entries are the subject matter of this paper. The other items are briefly discussed in the next paragraph.

Table 1. Essentials for low ethylene CA 'Empire'.

early harvest
postharvest drench for storage scald control
electric forklift in enclosed area
3-day cooling rate (maximum)
rapid CA to 3% O₂ (use N₂)
very tight CA room
external CO₂ scrubber (lime)
C₂H₄ scrubber

The postharvest drench for control of storage scald may not be necessary for apples stored under low ethylene CA conditions. The drench is recommended, however, as protection against scald in the event the low ethylene atmosphere cannot be maintained. Electric forklifts should be used to handle low ethylene CA apples in enclosed areas because there is frequently 500ppm C₂H₄ in the exhaust from fossil fueled forklifts. The fast cooling rate is needed to reduce the rates of C₂H₄ production during loading. Rapid CA is required to quickly reduce the rates of C₂H₄ production and to minimize the length of the period of maximum C₂H₄ sensitivity. N₂ gas is recommended for flushing the O₂ from the room because most fossil fueled atmosphere generators produce at least trace amounts of C₂H₄. The CA room must be extremely tight because the slowly respiring apples consume very little O₂. An external CO₂ scrubber is required because the CO₂ should be maintained at a high safe concentration (2-3%) to inhibit C₂H₄ production. Lime scrubbers are recommended because they do not add O₂ to the CA room atmosphere.

Evaluations of Harvest Maturity

Michael Knee, working with 'Bramley's Seedling' and F. W. Liu, working with 'McIntosh' have reported that response to low ethylene CA required picking the apples before the C₂H₄ climacteric began to develop in the orchard.

The initiation of the climacteric rise in ethylene production (ICREP) has been described as the calendar date on which the average internal C₂H₄

exceeded a specified concentration, eg., 0.20 ppm, or the calendar date on which a specified percentage of the crop, eg., 10%, exceeded a threshold C_2H_4 concentration for ICREP, eg. 0.50 ppm. Internal C_2H_4 analyses of attached 'Empire' indicated a very highly significant and constant relationship between these two indicators of ICREP (Fig. 1). In the studies

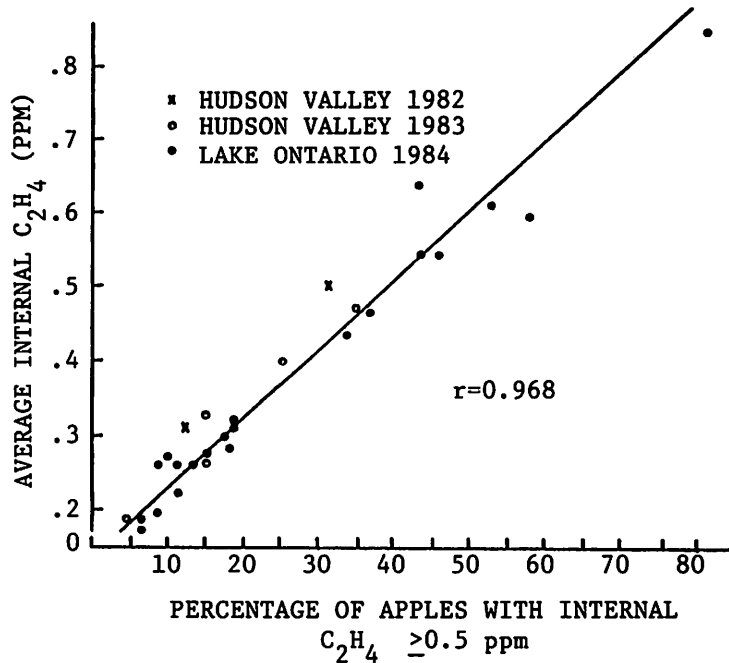


Fig. 1. Relationship between average internal C_2H_4 and percentage of 'Empire' apples with internal $C_2H_4 \geq 0.5$ ppm. (C_2H_4 concentrations >1.0 ppm recorded as 1.0 ppm).

reported here, ICREP was the calendar date the average internal C_2H_4 was 0.20-0.25 ppm \approx the calendar date 10 percent of the crop had internal $C_2H_4 \geq 0.5$ ppm.

A 1980-81 harvest maturity study indicated that 'Empire' picked pre-ICREP on October 2 and at ICREP on October 8 responded to low ethylene CA, but apples picked post-ICREP on October 15 did not (Table 2). The lack of response by the October 15 harvested apples was assumed to be related to the advanced stage of ICREP at harvest. In the next season

Table 2. Relationship between 'Empire' harvest date, average internal C₂H₄ at harvest, and flesh firmness after low ethylene CA. 1980-81.

Harvest date		
October 2	October 8	October 15
average internal C ₂ H ₄ (ppm) at harvest		
0.08	0.21	0.31
poststorage firmness - N (LBF)		
68.0(15.3)	66.7(15.0)	48.5(10.9)

apples were picked on an early calendar date, September 28, from two Hudson Valley farms. Internal C₂H₄ analyses indicated apples from Farm A were at ICREP (0.20 ppm) and apples from Farm B were definitely post-ICREP (0.51 ppm). Apples from both farms responded to low ethylene CA (Table 3). The unexpected good response to low ethylene CA by apples from Farm B raised a question about the usefulness of ICREP as the harvest maturity index for low ethylene CA 'Empire'. Each of the several previous studies of harvest maturity for low ethylene CA had included apples from a single orchard block. In these studies the late harvest dates were associated with high internal C₂H₄ and poor response to low ethylene CA. None of the previous studies included several orchards, each at a different stage of ICREP on a given calendar date. The study described below was designed to determine if earliness/lateness of calendar date or stage of ICREP should be used as the index of harvest maturity for low ethylene CA 'Empire'.

Table 3. 'Empire' internal ethylene at September 28 harvest and poststorage flesh firmness. 1982-83.

	Farm A	Farm B
internal C ₂ H ₄ (ppm)	0.20	0.51
poststorage firmness - N (LBF)		
slow CA	48.0(10.8)	53.8(12.1)
rapid CA	58.7(13.2)	59.2(13.3)
low ethylene CA	63.6(14.3)	64.1(14.4)

Three closely situated orchards with different ICREP dates (Fig. 2)

were harvested, at 4-day intervals from September 26 to October 16. Samples of apples were stored until April in low ethylene CA and in normal CA. Postharvest firmness and panel evaluations are summarized in Table 4. Best harvest dates for these blocks were judged to be the calendar dates assoc-

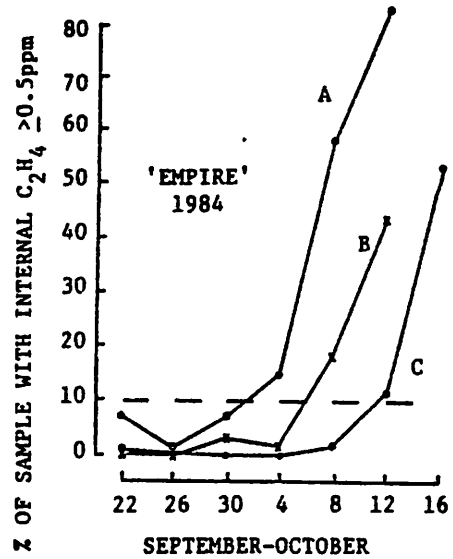


Fig. 2. Development of the C_2H_4 climacteric in attached 'Empire' apples. Three Orleans County orchards, n=60 (A & B) or 240 (C) apples.

Table 4. Flesh firmness, firmness difference, and panel score for 'Empire' apples stored in low ethylene CA storage until April.

Orchard	Quality evaluation	September - October harvest date					
		26	30	4	8	12	16
A	firmness (N)	67.6	68.9	61.4	56.9	52.5	50.3
	" difference (N) ¹	4.8	8.0	11.5	7.6	3.1	3.1
	(LBF) ¹	1.1	1.8	2.6	1.7	0.7	0.7
	panel score ²	c	c	ab	a	ab	bc
B	firmness (N)	71.6	70.3	65.8	60.5	49.8	50.3
	" difference (N)	9.8	8.9	18.2	13.7	1.3	2.7
	(LBF)	2.2	2.0	4.1	3.1	0.3	0.6
	panel score	b	b	a	a	a	b
C	firmness (N)	71.6	71.6	61.4	58.3	55.6	56.5
	" difference (N)	11.5	11.5	11.1	12.4	7.6	8.5
	(LBF)	2.6	2.6	2.5	2.8	1.7	1.9
	panel score	c	c	b	a	a	b

1. firmness in low ethylene CA minus firmness in normal CA storage.
 2. statistical notation (5% level) for average panel evaluation of eating quality (firmness & texture) and fruit appearance (color & brightness).

iated with the highest panel score ("a" in Table 4) and a 8.8 N (2 LBF) flesh firmness advantage over normal CA. The best harvest dates for orchards A, B, and C were October 4-8, October 4-8, and October 8-12 respectively. The C_2H_4 status of apples on these dates is shown in Fig. 3. On the best harvest dates the apples in orchard A were post-

ICREP, in orchard B were at ICREP, and in orchard C the apples were pre-ICREP. An October 8 harvest for all 3 orchards would have assured high quality and a significant firmness advantage over normal CA. This study indicated that calendar date is a better harvest maturity index than ICREP for low ethylene CA 'Empire'. Previous observations for 'Empire' grown in this area (Table 5) appear to verify the reliability of the October 8 date.

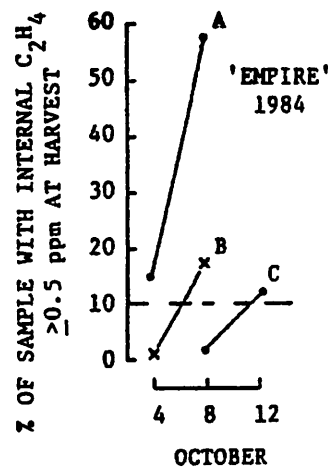


Fig. 3. Internal C_2H_4 status of attached 'Empire' apples (3 orchards) on the best harvest dates for low ethylene CA.

Table 5. Best harvest dates¹ for 'Empire' apples, Lake Ontario area, 1972-77.

Best harvest	Observations	
	Number	Percent
Before Oct. 5	6	25
Oct. 5-9	16	67
After Oct. 9	2	8

1. Based on poststorage panel evaluations and flesh firmness.

C_2H_4 Scrubber

One New York storage operator is using the Swingtherm heated catalyst C_2H_4 converter discussed in the paper by Wojciechowski et al. This C_2H_4 scrubber requires a high initial capital investment but its long term operating costs have been estimated to be below the estimated operating costs for C_2H_4 chemisorption. C_2H_4 chemisorption requires a very low

initial capital investment and therefore was the logical system for testing the efficacy of low ethylene CA in commercial rooms.

When several proprietary forms of ethylene chemisorption beads (ECB) were tested under laboratory conditions, it was observed that only 'Purafil' maintained a high rate of C_2H_4 chemisorption under the high relative humidity conditions that exist in apple storage rooms. A subsequent comparison was made under commercial CA conditions using 85 kg charges of 'Ethysorb' and 'Purafil'. The test results (Fig. 4) verified

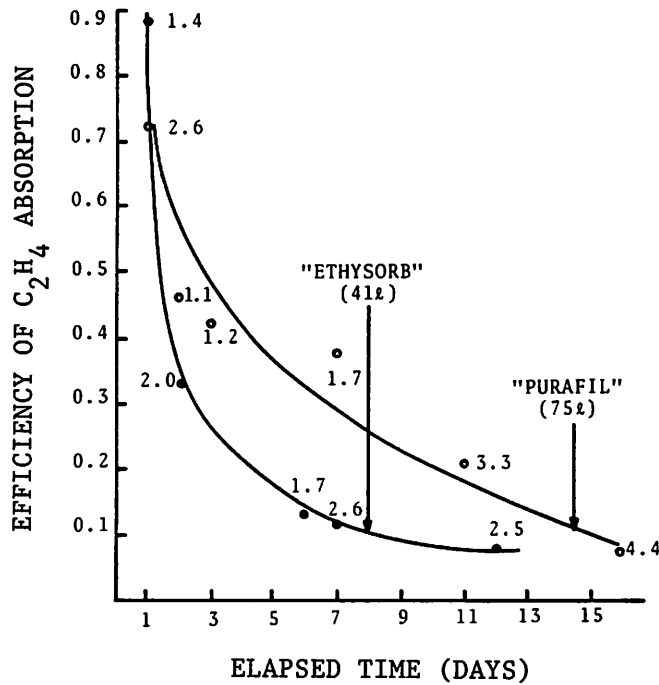


Fig. 4. Efficiency of C_2H_4 absorption by 85 kg charges of 2 C_2H_4 chemisorbants. Numbers adjacent to the dots indicate the C_2H_4 concentration (ppm) at the scrubber inlet (see Fig. 5). Numbers in () indicate the total liters of C_2H_4 absorbed when efficiency reached 0.10.

the laboratory observations concerning the relative efficacy of these two ECB. In addition, this test demonstrated the decline of ECB efficiency with time and demonstrated the independence of this decline from C_2H_4 concentration at the scrubber inlet.

The cabinet (Fig. 5) we are using to hold the ECB is located outside

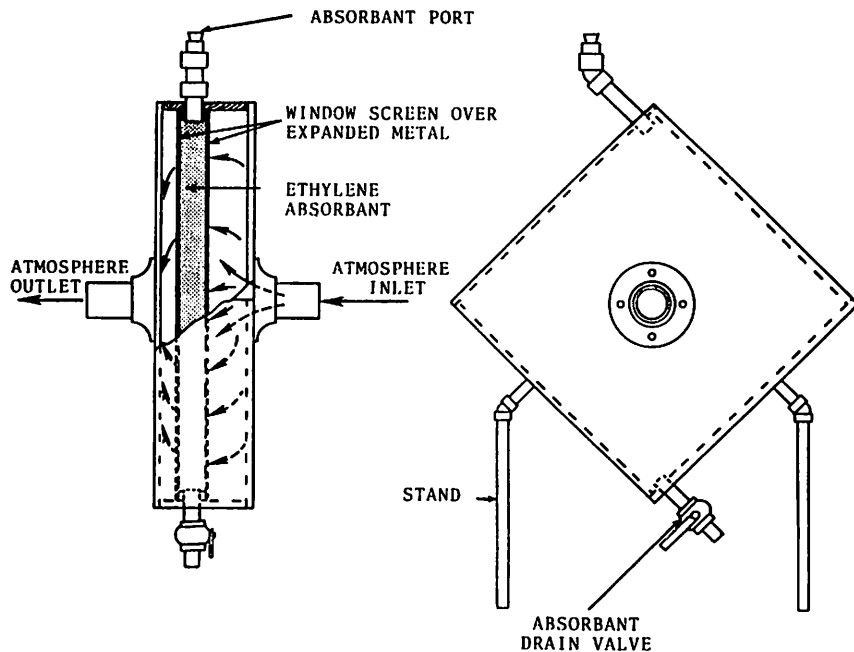


Fig. 5. Vertical-bed cabinet for C_2H_4 absorbing beads. Cabinet located outside and blower fan located inside the CA rooms.

the CA room where it can easily be serviced. The atmosphere pump is located inside the CA room and is plumbed to the scrubber cabinet with 4 inch plastic pipe. The atmosphere, which is blown (not sucked) through the cabinet keeps the cabinet under slight pressure, permitting the easy detection of leaks with soapy water. The bed of ECB is 10 cm thick and $0.9m^2$ for 200 ton rooms and $1.2m^2$ for 400 ton rooms. Approximately 1000 m^2/hr are pumped through the small scrubber, 1500 m^2/hr through the large scrubber. Each week the ECB are visually inspected by draining an aliquot of ECB from the bottom of the cabinet. If the crushed beads are still purple, the aliquot is dumped back into the top of the cabinet. If the beads are brown, the charge is replaced. Removal of the aliquot of ECB results in a redistribution of the ECB in the bed, thus minimizing the possibility of the atmosphere forming channels through the bed of beads.

The system is very simple and does not require C_2H_4 analyses of the CA storage atmosphere. The charge of ECB (85 kg for 200 ton rooms, 170 kg for 400 ton rooms), should last 4 weeks. If the crushed ECB are brown after 2-3 weeks, the rate of C_2H_4 production has exceeded the capacity of the scrubber. The expense of continued C_2H_4 scrubbing would be prohibitive and would probably not maintain the C_2H_4 below 1 ppm in the CA room.

Five New York State storage operators started low ethylene CA 'Empire' rooms in October 1984. One was cancelled very soon after sealing because the operator used an atmosphere generator to maintain the O_2 at the

desired concentration of 2.0-2.5%. The atmosphere generator quickly raised the C_2H_4 to above 3000 ppm in the CA room. Two leaky CA rooms (1 & 2 in Table 6) had to be run as normal CA after midwinter because the high O_2 in the rooms stimulated C_2H_4 production. In the fourth room (#3 in Table 6) the C_2H_4 production exceeded the C_2H_4 scrubber capacity in March. The operator of this room had delayed harvest to obtain more red color and also took too long to establish the desired O_2 concentration. The operator of the last room scrupulously used the entire program outlined in Table 1 and maintained his C_2H_4 below 0.10 from harvest until June 1, when the last C_2H_4 analysis was made.

Table 6. ECB usage in four low ethylene CA rooms. 1984-85.

CA room #	Tons Capacity	ECB usage		Date	$C_2H_4 \geq 3$ ppm	
		kg/ton	lbs/bu.		Date	Reason
1	200	2.4	0.11	Jan 17	$O_2 > 3\%$	78 days
2	400	2.0	0.09	Feb 6	$O_2 > 3\%$	65 days
3	200	2.0	0.09	March 4	late pick,	slow CA
4	200	<2.0	<0.09	June 1	last analysis	

Conclusion.

Low ethylene CA has made it possible for several New York storage operators to sell high quality 'Empire' in excellent condition, free of senescent breakdown, in June and July. Continued growth of this CA strategy during the next few years will probably be dependent upon a strong late season market. Once low ethylene 'Empire' have established a favorable reputation on that market, premiums will probably be paid for them earlier in the marketing period, also.