REQUIREMENTS AND RECOMMENDATIONS FOR EASTERN AND MIDWESTERN APPLES

STABY

G. D. Blanpied
Cornell University
Ithaca, NY

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This paper will be a potpourri of CA observations, problems, data and recommendations for the eastern and midwestern apple industry.

Observations and Problems

Fruit. Our number one problem, which stands head and shoulders above all others in the northeast, is a storage breakdown of McIntosh which has a syndrome of symptoms called the "soft McIntosh problem". The breakdown is not limited to apples stored in CA, but it is associated with CA because it becomes commercially significant in the late winter and spring, after most of the air stored McIntosh have been sold. One of the causes may be calcium deficiency. A commercial solution to this problem has not appeared on the horizon yet.

We have seen storage freezing injury occur in CA each winter for the past several seasons. These losses could have been avoided if distant reading thermometers had been installed in the CA rooms. Unfortunately, most operators still depend upon an alcohol thermometer viewed through the window in the CA door.

Storage scald has appeared on lots of CA apples which had been treated with DPA before storage. A survey of commercial dip tanks indicated the DPA concentrations were usually well below the recommended level. In most cases this problem could have been avoided by replenishing depleated dip tanks with double strength, rather than single strength, DPA.

Finally, for fruit, CO_2 danger levels have not been adequately defined. CA operators who use lime to scrub CO_2 frequently encounter CO_2 levels rising above 3% late in the winter. They and we do not know how long the apples will tolerate 4 or 5% CO_2 at this time of year.

CA Rooms. The flamability of urethane is our greatest problem with CA rooms. Approved fire barriers for urethane are expensive. As a stopgap measure we are recommending that new CA rooms be sealed and insulated with urethane rating "25 flame spread".

High levels of oxygen (4 and 5%) continue to be a problem in some CA rooms. Frequently the leaks are in the floor or at the floor-wall joint. The vacuum and soapsuds method we use successfully to locate leaks in the walls and ceiling frequently doesn't locate holds in the floor. Small holes in the floor can be covered with water or with a water-lime slurry, but a good technique to locate these leaks would be desirable.

Machinery. There are only 2 machinery associated problems worth mentioning. First - the corrosion which occurs when using salt brine for water scrubbing with brinespray defrost evaporators. These corrosion problems are on the decline in the northeast as many of the new storages are being refrigerated with dry coils.

The other machinery-associated problem is the rising cost of electricity. There are several innovations which may reduce power requirements. I'll mention a few. This winter I saw a small packinghouse heated by the refrigeration condensors. At least one operator limits his CA rooms to post-pulldown refrigeration "on" periods of 10 minutes each hour. One of the benefits of this scheme is fewer compressor starts. Some operators have talked of limiting and sequencing the "on" periods for blower fans. One New York CA operator is seriously considering the emulation of his dairy farmer neighbor, who uses a windmill to provide some of his electricity. An imaginative Michigan engineer is investigating the use of outside cold air to provide at least part of the required refrigeration. None of these innovations will single handedly solve our power problems, but combinations of power saving ideas will reduce the bills to tolerable amounts.

Dangers of Recommendations Based on Tests in Small Experimental CA Chambers. For a number of seasons we compared CA Cortland stored in 36 kg (2 bushel) capacity experimental chambers held at 0°C(2-3% CO_2, 3% O_2) and at 3.3° (5% CO_2, 3% O_2). Since the fruit were more firm and had less breakdown at 3.3°, we recommended that temperature to commercial storage operators. In the late 1960's some commercial storage operators started to use 0° for CA Cortland, ie., they stored Cortland with Delicious and not with McIntosh, as we had recommended. In 1972 and again in 1973 we harvested Cortland from several orchards located along a north-south line extending from New Jersey to the New York-Canadian border. These apples were stored in commercial CA rooms at 0 and at 3.3°. In both seasons there was no significant effect of temperature on firmness; the taste panel showed no preference for the one temperature over the other in the first season, but preferred the apples stored at 0° in the second season (Table).

Table 1. Condition of Cortland apples stored at 0° and 3.3°C in commercial Hudson Valley CA rooms.

Storage season	Orchards sampled (no.)	Firmness (kg) 0°C (3-3)	Firmness (kg) 3.3°C (5-3)	Taste panel preference
1972-73	12	4.2	4.2	n.s.
1973-74	11	5.1	5.3	0°C

Bracketed numbers are % CO_2 - % O_2

At this point it seemed that 0° was preferred under commercial conditions, but 3.3° was preferred for storage in small experimental chambers. We thought the conflicting observations of temperature effects on CA Cortland might be due to the method of CO_2 control used for the small experimental chambers. We therefore compared Cortland held in small experimental chambers at 0 and 3.3° with 4 different methods of CO_2 control: chambers continually flushed with premixed gases; excess CO_2 flushed daily with N_2 gas; water scrub excess CO_2; lime scrub excess CO_2. The data in Table 2 show that with each method of scrubbing, the apples held at 3.3° were more firm and had less breakdown than comparable apples held at 0°.

Table 2. Effect of CO_2 scrubbing on firmness and breakdown of Cortland apples removed from experimental 36 kg (2 bushel) CA chambers in March.

CO_2 scrubber	Firmness (kg). 0°C (3-3)	Firmness (kg). 3.3°C (5-3)	Breakdown (%) 0°C (3-3)	Breakdown (%) 3.3°C (5-3)
Flush mixed gas	5.8	6.6	9.3	0.7
N_2 flush	5.7	6.3	7.3	1.3
Water	5.3	5.8	7.5	1.4
Lime	5.0	5.2	19.4	1.6

Source: O. Cadun
Bracketed numbers are % CO_2 - % O_2

Finally, in 2 successive seasons comparisons were made for Cortland stored at 0 and at 3.3° in small experimental chambers and in 28 ton (1400 bushel) capacity CA rooms.

Table 3. Condition of Cortland apples after removal from CA storage in experimental 36 kg (2 bushel) chambers and 28 tons (1400 bushel) capacity CA rooms held at 0° and 3.3°C in 2 seasons.

Chamber capacity	Temp. (°C)	CO_2 (%)	O_2 (%)	Firmness(kg) 1974	Firmness(kg) 1975	Panel Eval. 1974	Panel Eval. 1975	Breakdown (%) 1974	Breakdown (%) 1975
36 kg	0	2-3	3	4.3a	4.6a			73	4
36 kg	3.3	4-5	3	5.4b	5.6b	pref.	pref.	0	2
28 tons	0	2-3	3	4.4a	4.6b	n.s.	n.s.	0	4
28 tons	3.3	4-5	3	4.6a	4.4a			0	4

Statistical notations refer to numbers in pairs.

The data in Table 3 clearly show 3.3° was superior when apples were stored in small experimental chambers and 0° was as good or better than 3.3° when comparable apples were stored in CA rooms. These results convinced us that we should carry out subsequent variety trials only in semicommercial or commercial sized CA rooms. Except for short term treatments, such as CO_2 pretreatment, we have eliminated the use of small experimental chambers

Table 4. Average firmness and taste panel scores for several cultivars of apples stored at 2 levels of CO_2 in 28 ton (1400 bushel) capacity CA rooms in Ithaca, N.Y.

	1973-74		1974-75		1976-77	
	Room 1	Room 2	Room 1	Room 2	Room 1	Room 2
lbs. lime/bu.	0.5	1.0	0.5	1.0	0.5	1.0
kg lime/ton	11.3	22.5	11.3	22.5	11.3	22.5
Avg. CO_2 (%)	2.4	0.9	2.0	1.0	2.6	1.3
Avg. O_2 (%)	2.8	3.3	3.4	2.8	4.2	4.4
	average firmness (kg) after 1 day at 20°					
Macoun	---	---	6.0	6.0	---	---
Cortland	4.4	4.5	4.8	4.9	---	---
Delicious	6.2	6.2	6.3	5.9	5.8	5.6
Goldens	5.2	5.2	5.4	5.3	4.6	4.3
Idared	6.4	6.1	5.6	5.6	4.4	4.3
Rome	---	---	---	---	6.4	5.9
Average	5.3a	5.3a	5.6a	5.5a	5.2b	5.0a
	average firmness (kg) after 1 week at 20°					
Macoun	---	---	4.1	4.6	---	---
Cortland	---	---	4.0	4.1	---	---
Delicious	---	---	5.0	5.5	5.4	5.1
Goldens	---	---	5.1	5.6	4.8	4.4
Idared	---	---	4.6	4.5	4.1	4.1
Rome	---	---	---	---	6.0	5.5
Average	---	---	4.4a	4.8b	5.0b	4.7a
	average taste panel score for ripeness					
Macoun	---	---	16	15	---	---
Cortland	13	13	30	30	---	---
Delicious	15	13	16	11	15	17
Goldens	13	12	16	10	15	19
Idared	12	17	15	12	18	15
Rome	---	---	---	---	13	20
Average	13a	14a	19a	17a	15a	17a

Number of harvest dates in 1973, 1974, 1976: Macoun (0,2,0), Cortland (2,2,0), Delicious (1,2,5), Goldens (1,1,4), Idared (1,2,4,) Rome (0,0,2).

CO_2 Levels in Commercial CA Rooms. A few storage operators control CO_2 by placing bags of lime directly into their CA rooms. Although some control of CO_2 levels can be attained by placing a loose sheet of polyethylene over some of the lime during the early storage period, most of these operators used exposed bags of lime at the rate of 17-23 kg lime per ton of apples (3/4 to 1 lb of lime per bushel), which sometimes results in CO_2 levels below 1% for extended periods of time. In 3 storage seasons we used lime inside 2 of our 28-ton CA rooms to hold the CO_2 levels at approximately 1% and 2% through the season. Several cultivars were used each season. The results of these tests are shown in Table 4. There was no repeatable effect of CO_2 level on firmness; the taste panel was unable to distinguish differences in ripeness in any season.

CO_2 Pretreatment for Delicious. In the fall of 1975 we pretreated Delicious apples with high CO_2 before Ca storage. In comparison with normal CA apples, apples pretreated with high CO_2 and then placed immediately into CA were significantly more firm, higher in acid content, and were judged by a panel to be significantly less ripe after 180 days storage (Table 5). However, when Delicious were CO_2 pretreated and then held in air at 0° for 90 days before placement into CA for an additional 90 days, the firmness, acid content and panel scores for ripeness were significantly lower after 180 days storage. When the experiment was repeated the results were less striking.

Table 5. Effect of prestorage high CO_2 (14% for 14 days) and delayed CA on condition of Delicious apples after 180 days in storage at 0°.

CO_2 Pretreatment	CA period (days)	Firmness (kg)	Acid*	Panel score**
	(1975-76, averages for 4 orchards)			
Yes	90-180	5.5c	.19c	c
Yes	1-180	6.3a	.24a	a
No	1-180	5.9b	.22b	b
	(1976-77, averages for 6 orchards)			
Yes	90-180	5.8b	----	a
Yes	1-180	6.3a	----	a
No	1-180	6.4a	----	a

* g malate/100 ml juice
** statistical significance (0.05)

Delayed CA storage following CO_2 pretreatment resulted in significantly less firm fruit after 180 days storage, but CO_2 pretreatment followed by immediate CA storage did not increase firmness in comparison with normal CA. The taste panel could not distinguish between CO_2 pretreatment + immediate CA and normal CA apples. The panel rated the CO_2 pretreatment + CA after 90 days as more ripe than the other two treatments in only one of the test orchards. Thus, CO_2 pretreatment for Delicious may result in better fruit condition after CA storage, but the benefit from CO_2 pretreatment appears to be contingent upon immediate storage under a CA atmosphere conditions.

Recommendations

The recommended CA conditions for eastern and midwestern apples appear in Table 6. Most cultivars are stored at 0° with 2-3% CO_2 and 3% O_2. McIntosh and Jonathan require special conditions because they are cold sensitive. McIntosh are CA stored continually at 2.2 to 3.3° to avoid browncore. Jonathan are CA stored at 2.2° for one month then 0° to avoid brown heart. Cortland may be stored with McIntosh, with Jonathan, or with other cultivars at 0°. Stayman, York, and Winesap may be CA stored with CO_2 as high as 5% in Virginia.

Table 6. Recommended CA conditions for eastern and midwestern apples.

Cultivar	Temp. (°C)	CO_2 (%)	O_2 (%)
McIntosh	2.2-3.3	2-3 one month then 5	3
Jonathan	2.2 one month then 0	5	3
all others	0	2-3	3