FRUIT RIPENING RESPONSES TO ETHYLENE IN MODIFIED ATMOSPHERES

G. D. Blanpied and Elmer Hansen
Department of Pomology
Cornell University
Ithaca, New York
(Presented by G. Blanpied)

STABY

Three techniques were used to attain the desired levels for CO_2, O_2 and C_2H_4 in our experiment: commercially premixed gas mixtures were flushed through the containers of fruit; compressed gasses were mixed in the laboratory and flushed through the containers of fruit; fruit was stored in sealed containers with CO_2 levels maintained by N_2 Flushing, O_2 levels maintained by addition of compressed O_2 and C_2H_4 levels maintained by absorption of C_2H_4 on a suitable material (low levels), no specific C_2H_4 adjustment (intermediate levels) or by addition of compressed C_2H_4 gas (high levels). We would like to warn others that we frequently found C_2H_4 was a low level contaminate of compressed gasses, particularly O_2. For zero levels of C_2H_4 it had to be scrubbed from the gas train.

Valery bananas were held at 70°F for 4 days in atmospheres containing air enriched with CO_2 and C_2H_4 (Table 1). The apparent ripening retardation caused by the addition of CO_2 was more than off-set by C_2H_4. Bananas held in air + 10% CO_2 + 100 ppm C_2H_4 ripened faster than bananas held in ethylene-free air. Increasing the C_2H_4 from 100 to 500 and to 1000 ppm had no effect on ripening at 10% CO_2.

In a similar experiment with Anjou pears (Table 2), the retardation of the rate of flesh softening caused by elevated levels of CO_2 was greatly diminished by C_2H_4.

The above experiments indicate that at room temperatures the enrichment of air with CO_2 will not markedly retard ripening unless C_2H_4 is removed from the atmosphere.

Valery bananas were held at 70°F for 4 days in air and in 1% O_2, with and without 500 ppm C_2H_4 (Table 3). The addition of C_2H_4 accelerated the rate of ripening of the bananas in air, but did not appear to influence the rate of ripening in 1% O_2.

Mature green tomatoes were harvested and ripened in ethylene-free air after treatment with 2% O_2 and with 2% O_2 + 500 ppm C_2H_4 at 70°F. The modified atmospheres retarded the rate of ripening when the fruits were subsequently placed in air (Fig. 1). In this experiment the addition of C_2H_4 during the period of low O_2 treatment did not affect the rates of ripening and respiration at low O_2 nor did it affect these indices of ripening when the fruits were subsequently placed in air.

Anjou pears were removed from storage in November and held at 70° for 4 days in air, in 3% and 5% O_2 with and without 500 ppm C_2H_4 (Table 4). At 3% and 5% O_2 the firmness loss and respiration rates were markedly reduced.

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* CA for the Storage * Transport of Hort Crops * Dewey, Herner & Dilley (Eds.) 9:

At the 3 levels of O_2 tested, the rates of flesh softening and respiration were accelerated by the addition of C_2H_4. In comparison with the pears held in air + 500 ppm C_2H_4, flesh softening was retarded when 500 ppm C_2H_4 was applied at 3% O_2, but not at 5% O_2.

The data from the above experiments seemed to indicate: (a) there was an ethylene ripening response at O_2 levels above 3% and (b) C_2H_4 eliminated the low-O_2 retarding effect at 5% or more O_2. To further investigate these observations, the following experiment was carried out.

Anjou pears were removed from storage in December and held at 70°F for 4 days in various levels of O_2, with and without 500 ppm C_2H_4 (Table 5). Contrary to the previous observations of banana and tomato, C_2H_4 stimulated ripening of Anjou pears at all levels of O_2 tested (0-100% O_2). In ethylene-free atmospheres, fruit respiration was related to O_2 level between 1% and 21% O_2; when C_2H_4 was added to the atmospheres, respiration was related to O_2 levels of 1% to 50% O_2. In ethylene-free atmospheres, flesh softening was about the same at all O_2 concentrations between 5% and 100% O_2; the same was true when C_2H_4 was added to the atmospheres.

In a similar experiment with Packham's Triumph pears (Table 6), C_2H_4 stimulated respiration and flesh softening at O_2 levels ranging from 1% to 100% O_2. Contrary to the observations made in the previous experiment, respiration rate was related to O_2 level between 5% and 100% O_2 and flesh softening was related to the level of O_2 between 1% and 50% O_2.

In one further experiment in this series, Anjou pears were held at 70°F for 5 days in air and in atmospheres containing 2 1/2% O_2, 10% CO_2 with different levels of C_2H_4 (Table 7). Flesh softening was proportional to the concentration of C_2H_4 up to 500 ppm. At 500 ppm and 1000 ppm C_2H_4, the firmness loss was almost as great as the firmness loss of the control fruits held in air.

With these data we have shown the CA response of some fruits may be greatly increased by the removal of C_2H_4 from the atmosphere if the fruits are to be held at "ethylene sensitive" temperatures.

Our data on ethylene ripening responses in air at various temperatures confirm previous observations that exogenous ethylene does not appear to increase the rate of ripening at temperatures of 50°F or lower (Table 8). Until 2 years ago we did not study the effect of C_2H_4 on the keeping quality of CA apples, because under commercial conditions the CA storage temperatures for apples were far below the "ethylene sensitive" threshold. Two years ago, however, after a generated O_2 pull-down in one of our 1400 bushel capacity CA rooms, we found 10,000 ppm C_2H_4. This extremely high concentration of C_2H_4 was soon reduced to less than 1000 ppm by the CO_2 water-scrubber, but if lime scrubbing had been employed for that CA room, the very high C_2H_4 concentration may have remained in the room. What would have been the effect on the stored fruit? No one before had worked with such high concentrations of C_2H_4. Therefore, at that time we initiated a study of the effect of C_2H_4 on the keeping quality of McIntosh stored in CA at 38°F.

Our experimental results (not shown) suggest there may be a measurable response of McIntosh to C_2H_4 in CA storage at 38°F. However, we feel duty-

bound to sit on the fence with these data until we are more sure that these responses are commercially significant.

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Table 1. - Effect of air enrichment with CO_2 and ethylene on ripening of Valery bananas held at 70°F for 4 days. 1967.

CO_2 (%)	Ethylene (ppm)			
	0	100	500	1000
	(change in skin color rating)			
air	1.9	-	3.1	-
2 1/2	1.8	-	3.0	-
10	1.3	2.6	2.7	2.6

Table 2. - The effect of CO_2 (added to air) and ethylene (500 ppm) on the firmness loss of Anjou pears removed from storage in January, 1967, and held at 70° for 5 days.

Ethylene (ppm)	CO_2 (%)			
	air	2 1/2	5	10
	(firmness loss in pounds)			
0	17.4	14.7	12.3	9.7
500	17.9	17.8	16.6	14.7

Table 3. - Ethylene response of Valery bananas held for 4 days at 70°F. 1967.

Treatment	Change in	
	Skin color rating	Skin protein N
air	2.4	0.26
air + C_2H_4 (500 ppm)	3.5	0.42
1% O_2	0.4	0.04
1% O_2 + C_2H_4	0.2	0.00

Table 4. - Effect of ethylene on the ripening of Anjou pears held 4 days at 70°F. November, 1966.

Treatment	Firmness loss (lbs)	Avg. respiration (ml CO_2/K/H)
air	4.9	8.4
air + C_2H_2	6.9	10.0
3% O_2	2.1	5.4
3% O_2 + C_2H_4	3.8	6.1
air	5.3	8.1
air + C_2H_2	7.9	11.2
5% O_2	2.5	4.9
5% O_2 + C_2H_4	7.7	6.2

Note: C_2H_4 applied at 500 ppm.

Table 5. - Effect of oxygen level and ethylene on the ripening of Anjou pears held at 70°F for 4 days after removal from storage in December, 1966.

O_2 (%)	C_2H_4 (500 ppm)	Respiration (cumulative CO_2)	Firmness loss (lbs)
0	-	88	0.0
0	+	92	1.3
1	-	49	0.0
1	+	56	3.1
2 1/2	-	52	10.5
2 1/2	+	60	14.0
5	-	78	14.6
5	+	83	16.3
10	-	91	13.5
10	+	104	16.2
air	-	115	14.6
air	+	129	15.9
50	-	112	13.3
50	+	146	16.4
100	-	111	13.7
100	+	147	16.1

Table 6. - Effect of oxygen level and ethylene on the ripening of Packham's Triumph pears held at 70°F for 4 days. April, 1967.

O_2 (%)	C_2H_4 (500 ppm)	Avg. resp. rate (ml O_2/K/H)	Firmness loss (lbs)
1	-	6.2	2.6
1	+	8.1	2.9
2 1/2	-	5.2	4.1
2 1/2	+	5.9	5.6
5	-	5.1	7.6
5	+	6.1	9.2
10	-	7.6	14.8
10	+	7.6	15.6
air	-	14.5	17.4
air	+	16.9	17.7
50	-	15.7	18.1
50	+	19.0	19.2
100	-	18.7	17.5
100	+	19.9	16.9

Table 7. - Effect of ethylene on the softening of Anjou pears held in 2 1/2% O_2-10% CO_2 at 70° for 5 days. 1967.

C_2H_4	Firmness loss
(ppm)	(lbs)
0	0.3
250	3.6
500	8.1
1000	7.0
air control	9.2

Table 8. - Effect of ethylene on the ripening of Anjou pears at various temperatures in air. 1966.

Temp.	Period	C_2H_4	Firmness loss	Respiration
(°F)	(days)	(ppm)	(lbs)	(ml CO_2/K/H)
70	4	0	7.5	12.7
70	4	500	8.8	14.3
60	4	0	6.1	6.7
60	4	500	8.0	8.5
50	19	0	10.7	5.0
50	19	500	10.7	4.8
40	26	0	5.8	3.0
40	26	500	5.6	2.5
32	33	0	1.1	1.4
32	33	500	1.1	1.4

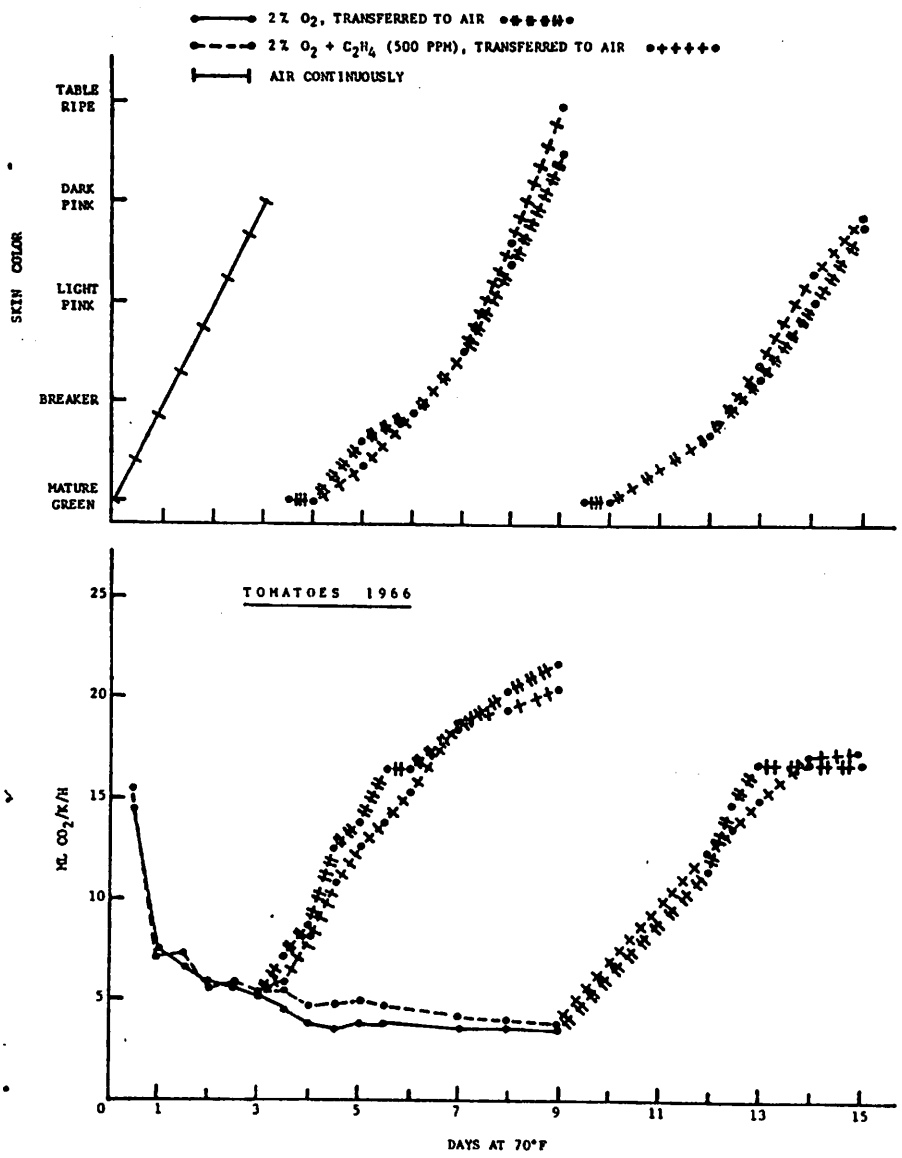

Figure 1. Skin color and respiration rate of tomatoes held in modified atmospheres and in air.