Storage of Pears and Apples in the Presence of Ripened Fruit

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Pears and apples of commercial maturity, grown in the Pacific Northwest, were stored at various temperatures both in fresh outside air and in the presence of measured quantities of ethylenic and nonethylenic emanations from preripened fruit. At 31° F., the commercial storage temperature, there was no difference in the degree of ripeness between the fruit held in fresh outside air and that exposed to emanations from ripe fruit. There was no impairment of cold storage life, texture, flavor, dessert quality, and freedom from physiological disorders during subsequent ripening. Starking Delicious apples were not affected at 31°, 45°, and 65° F. when stored along with ripened apples of the same variety. Anjou pears were not affected at 31° and 45° F. in the presence of the emanations from ripened fruit. The respiratory climacteric of the Anjou pears stored along with ripened fruit of the same variety was hastened by 2 days when experiments were conducted at 65° F.

Conclusive experimental evidence has led to a general recognition that pears and apples evolve ethylene and nonethylenic volatiles after harvest. The amount of emanation depends on the variety, the storage temperature, and the degree of ripeness of the fruit. A belief exists among many cold storage operators that the presence of small quantities of partially ripened pears and apples will hasten the ripening of their entire cold storage tonnage of unripened fruit. Just how detrimental are the volatile emanations of ripened fruits to the successful cold storage of apples and pears? There is considerable disagreement on this question from both a commercial and an experimental viewpoint.

Porritt (*9*) published a comprehensive review of the role of ethylene in fruit storage. Kidd and West (*7*) were able to hasten the respiratory rise in apples with either ethylene or the presence of ripened apples when treatments were applied at 73.4° F.; their experiments (*8*) were negative when repeated at 37.4°. Hansen and Hartman (*6*) obtained an accelerated rise in respiration and Hansen (*5*) reported an increase in soluble pectin in pears during ripening at 65° when they had been treated immediately following harvest with ethylene or the gases from previously ripened fruit. The response to treatment at 65° was greatest in the less mature fruit. This capacity to be stimulated by the presence of ripe fruit at 65° persisted during storage at 31° for 2 weeks to 2 months, depending upon the variety. Hansen and Hartman (*6*) found that ethylene had very little effect upon ripening or respiration of pears held at cold storage temperatures; their results confirmed the earlier studies on apples by Kidd and West (*8*). Uota and Dewey (*13*) also found that the respiration and volatile production of Bartlett pears was not increased by the application of ethylene at 35°.

Smock (*11*) was able to stimulate the respiration and softening of McIntosh apples at 74° F. by the presence of ripe Early McIntosh. He estimated that about 28% of the normal storage life of the fruit was lost during 14 days of such treatment. Even at 40°, Smock (*11*) found that the presence of ripe McIntosh apples stimulated the softening and respiration rates of Rhode Island Greening, Rome Beauty, and Cortland varieties. On the basis of the rate of loss in firmness, this investigator found that the storage life of Duchess of Oldenburg at 33° was shortened by 48% during storage for 1 month with ripe McIntosh apples. No information was presented by Smock as to the texture, flavor, or general dessert quality of these treated and untreated experimental fruits. It is fair to question whether the magnitude of change in firmness which he used to evaluate response to treatment at cold storage temperatures could be detected organoleptically. The literature is in general agreement that apples and pears must be at a definite stage of maturity at harvest to respond to the presence of preripened fruit and that this response declines with the length of subsequent storage.

This paper presents the results of studies wherein pears and apples of commercial maturity, grown in the Pacific Northwest, were stored at various temperatures both in fresh outside air and in the presence of measured quantities of ethylenic and nonethylenic volatile emanations from preripened fruit. The ripening response and storage life of the experimental fruit were evaluated biochemically and organoleptically.

Materials and Methods

Bartlett and Anjou pears and Starking Delicious apples were used in this study during the storage seasons of 1950–51 and 1951–52. Sufficient fruit of each variety was picked from selected trees, thoroughly composited, and placed at 31° F. within 12 hours from harvest. All fruit, with the exception of the second picking of Starking Delicious apples in 1950, was in its preclimacteric stage of respiratory metabolism at harvest, and therefore subject to possible stimulation of ripening from the presence of volatiles of preripened fruit. Information relative to the harvest of the experimental fruit follows:

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Year	Variety	Harvest Date	Firmness, Lb.	Soluble Pectin, %
1950	Bartlett	Aug. 22	16.6	0.069
1950	Anjou	Sept. 13	10.6	0.070
1951	Anjou	Sept. 17	10.9	0.125
1950	Starking Delicious	Oct. 3	16.4	0.045
1950	Starking Delicious	Oct. 23	14.8	0.057
1951	Starking Delicious	Sept. 24	17.9	0.045

During the season of 1950–51, all lots of experimental fruit were stored at 31° F. and all treatments with the volatile emanations from preripened fruit were also applied at that temperature. Usually about 12 kg. of each lot of fruit under test was placed in a suitable airtight container and aerated continuously at 20 liters per hour with one of three atmospheres as follows: (1) fresh outside air conditioned as to temperature, humidity, and freedom from fruit volatiles, (2) air from the regular station cold storage room wherein was held a miscellaneous group of apples and pears, and (3) volatile-laden air from preripened fruit of the same variety as that treated at 31°. Atmospheres 1 and 2 were applied continuously throughout the storage season. Atmospheres in the third treatment were supplied intermittently during the storage season to the same lot of test fruit. Usually the fruit used as a source of the volatile stimulant (6 kg.) was nearly fully ripened at 65° prior to movement to 31° to serve as the origin of atmosphere 3.

Respiration, firmness, and soluble pectin determinations and dessert evaluations of the fruit stored in the three atmospheres were made at irregular intervals during the season. The concentration of the ethylene and the nonethylenic volatiles in the air stream of atmosphere 3 was measured each time a fresh lot of ripened fruit was used as a source of the volatile emanate. The amount of these volatiles in the aeration stream was kept at a concentration somewhat similar to that previously found in many commercial fruit storages (*3*, *10*). In some instances the concentration of the nonethylenic volatiles was considerably higher in the aeration stream than that observed in atmospheres of commercial fruit storages.

In the second season's work, 1951–52, approximately 80 kg. each of Starking Delicious apples and Anjou pears was stored in a large metal cabinet at 31° F. immediately following harvest. This cabinet was aerated continuously with fresh outside air at a rate sufficient to provide four air changes a day and an atmospheric concentration of less than 0.5% of carbon dioxide. The fruit in this cabinet served as a reservoir for the subsequent intermittent withdrawal of experimental lots of fruit to be treated at 31°, 45°, and 65° with the volatile emanations from preripened fruit. Determination of the volatiles in the aeration stream, biochemical analyses, and organoleptic tests of the experimental fruit during storage and during ripening were similar to those made the previous season.

The methods used for the measurement of the respiration of the fruit, soluble pectins, and the volatile assay by absorption and cerate oxidimetry were similar to those described previously (*3*). Conversion of ethylene from milligrams per cubic foot of air to parts per million can be made by multiplying the former by 27.3. The nonethylenic volatiles are expressed as milligrams of ceric sulfate reduced per cubic foot of storage air; this is a relative unit which merely permits comparison between samples and cannot be used to determine the actual specific constituents in this group. A taste panel usually of four members evaluated the appearance, condition, and dessert quality of the different lots of fruit after experimental treatment.

Experimental Atmospheres, 1950–51

Concentration of Volatiles

Information as to the time of application and the composition of the aeration stream originating from the preripened fruits is summarized in Table I. In the pear stimulation studies, the concentrations of the nonethylenic volatiles in the air stream from ripened pears were much greater than those found in many commercial pear storages, while the concentrations of ethylene were in line with those found commercially. The aeration stream from the ripened apples carried concentrations of ethylene and nonethylenic volatiles entirely similar to those of most commercial apple rooms. Previous assay of commercial pear and apple storages (*10*) showed approximately 0.1 and 2.0 mg. of ethylene and nonethylenic volatiles, respectively, per cubic foot of storage air for Bartlett pear rooms in November and from 0.3 to 0.4 mg. of ethylene and 9 to 18 mg. of nonethylenic volatiles for apple rooms at mid-season storage.

No volatiles were detected in the aeration stream of atmosphere (fresh outside air) by quantitative measurement during the experiments; the volatiles in atmosphere 2 (station cold storage room) approximated 0.1 and 4.9 mg. per cubic foot of air, respectively, for ethylene and nonethylenic volatiles.

Response of Fruit

How did unripened pears and apples stored at 31° F. respond to various atmospheric concentrations of fruit volatiles? Were their biochemical and physiological processes stimulated and their storage life shortened by the presence of volatile emanations from previously ripened fruit?

Data in Table II show that it made little difference in the firmness or soluble pectin contents of pears and apples at 31° F., whether they were held in volatile-free outside air or subjected to an atmosphere laden with volatiles emanating from previously ripened fruit. The

Table I. Handling Procedure and Atmospheric Concentration of Volatiles from Preripened Fruit Applied to Unripened Pears and Apples

Year	Variety	Temp. during Treatment of Unripened Fruit, ° F.	Treatment with Volatiles from Ripened Fruit: Date	Days	Concn. Range of Volatiles in Aeration Stream, Mg./Cu. Foot Air: Ethylene	Nonethylenic[a]
1950–51	Bartlett pear	31	Sept. 18–25	7	0.10–0.77	15.2–171.5
			Oct. 7–23	16	0.04–0.03	43.0–97.2
			Nov. 16–Dec. 8	22	0.04–0.08	57.0–78.3
	Anjou pear	31	Oct. 30–Nov. 30	31	0.06–0.11	2.6–3.0
			Jan. 29–Feb. 28	30	0.09–0.12	11.0–13.0
	Starking Delicious apple					
	First picking	31	Oct. 30–Nov. 28	29	0.25–0.37	4.8–8.3
			Dec. 3–Jan. 17	45	0.35–0.49	5.2–10.1
			Jan. 29–Mar. 1	31	0.40–0.49	10.9–8.2
	Second picking	31	Nov. 6–30	24	0.15–0.43	10.7–21.6
			Jan. 29–Mar. 1	31	0.21–0.18	10.0–17.7
1951–52	Anjou pear	31, 45, 65	Nov. 29–Dec. 11	12	0.05–0.18	37.0–90.3
		45, 65	Jan. 31–Feb. 14	14	0.16–0.44	75.0–207.0
	Starking Delicious apple	31, 45, 65	Oct. 24–Nov. 7	14	0.20–0.30	11.4–45.9
		45, 65	Jan. 31–Feb. 14	14	0.17–0.38	26.0–66.4

[a] Expressed as mg. $Ce(SO_4)_2$ reduced per cu. foot air.

Table II. Relation of Firmness and Soluble Pectin Content of Apples and Pears to Kind of Storage Atmosphere

Year	Variety	Date Sampled	Storage Temp., ° F.	Kind of Atmosphere[a]	Period of Treatment, Days[a]	Firmness, Lb.	Soluble Pectin, %
1950	Bartlett pears	Oct. 25	31	1		16.1	0.071
				2		16.3	0.070
				3	7	16.2	0.066
		Nov. 14	31	1		15.0	0.131
				2		15.1	0.130
				3	23	15.6	0.126
		Dec. 8	31	1		14.0	0.213
				2		14.5	0.192
				3	45	14.7	0.172
1950–51	Anjou pears	Dec. 26	31	1		11.1	0.061
				2		10.8	0.070
				3	31	11.0	0.073
		Feb. 13	31	1		10.2	0.072
				2		9.0	0.089
				3	61	10.3	0.078
		Apr. 4	31	1		9.3	0.102
				2		8.0	0.115
				3	61	8.8	0.117
	Starking Delicious apples First picking	Dec. 26	31	1		13.4	0.047
				2		13.3	0.046
				3	29	13.4	0.051
		Feb. 15	31	1		12.1	0.053
				2		12.1	0.048
				3	74	12.5	0.052
		Apr. 4	31	1		11.8	0.082
				2		11.4	0.079
				3	105	11.1	0.080
	Second picking	Dec. 26	31	1		12.2	0.045
				2		12.2	0.046
				3	24	12.5	0.042
		Feb. 15	31	1		10.6	0.058
				2		11.0	0.061
				3	55	10.7	0.062
		Apr. 4	31	1		10.0	0.062
				2		10.0	0.059
				3	55	10.0	0.056
1951–52	Anjou pears	Dec. 18	31	1		11.2	0.135
				3	12	11.0	0.115
			45	1		5.8	0.350
				3	12	5.5	0.361
			65	1		..	0.525
				3	12	..	0.495
		Feb. 14	45	1		4.5	0.380
				3	14	4.0	0.390
	Starking Delicious apples	Nov. 15	31	1		16.2	0.050
				3	14	16.2	0.063
			45	1		13.1	0.105
				3	14	13.1	0.105
			65	1		11.1	0.145
				3	14	11.4	0.155
		Feb. 14	45	1		13.7	0.120
				3	14	13.5	0.115

[a] 1. Fresh outside air continuously.
2. Fruit storage air continuously.
3. Continuous aeration with fresh outside air when not under subjection for specified days to vapors from ripened fruits.

respiratory intensity of a fruit is an accepted indication of its rate of ripening. Data of this nature shown in Figure 1 indicate that the kind of storage atmosphere had little influence on the respiration of pears and apples stored at 31° F. Both varieties of pears and Starking Delicious apples of the first picking in 1950 were in their so-called preclimacteric stage of metabolism at harvest (as determined by respiratory measurement) and according to general concept should have been susceptible to stimulation of their ripening processes by the presence of the volatile emanation from ripe fruit.

Samples of the various lots of fruit of the 1950–51 season were removed at irregular intervals from their cold storage atmospheric environments (Table I) and ripened at 65° F. to determine whether dessert quality, storage scald, and breakdown could be correlated with their past storage history. The data obtained are summarized by variety as follows.

Bartlett Pears. Fruit of the Bartlett variety of pear from the three atmospheres (fresh outside air, fruit storage room air, and ripe fruit volatile-laden air) was ripened on October 25. Fruit of all three lots was full yellow and almost eating ripe after 3 days at 65° F.; it was of prime dessert quality after 4 to 7 days, overripe by the eighth day, and discarded on the ninth day because of severe core breakdown.

When ripened on November 14, fruit of all three lots showed considerable yellow color upon removal from 31° F. All fruits had lost their capacity to ripen normally; they were considered as ripe as they would ever be after 4 days in the ripening room and were granular in texture and of poor dessert quality. In all lots approximately 50% of the fruit developed core breakdown and were discarded after 6 days of ripening.

It is recognized that December is too late to store Bartlett pears successfully. Ripening observations, however, were purposely made at this late date to detect any difference in the cold storage life and loss of ripening capacity of the fruit, not observed in November, that might be correlated with the composition of its cold storage atmosphere. When ripened at 65° F. on December 8, fruits of all three lots were firm, full yellow in color, and free from pear scald upon removal from 31°. They failed to ripen normally in 4 days and were granular in texture and of poor dessert quality. No pear scald was present, but some core breakdown had developed. All three lots of fruit were discarded after 6 days because of severe core breakdown.

In none of the three lots of experimental Bartlett pears was it possible to distinguish any consistent differences in the ripening response, dessert quality, freedom from physiological storage disorders, or shelf life of fruit ripened in the three tested cold storage atmospheres.

Anjou Pears. This variety was withdrawn from the three different cold storage atmospheres and ripened at 65° F. on December 26, February 13, and April 4, in an attempt to discern whether the presence of ripe fruit volatiles in 31° storage affected the storage life and ripening characteristics of the various lots of fruit.

Pears of all three lots removed from the three kinds of storage atmospheres (Table II) on December 26 ripened with excellent dessert quality in 7 days; they remained in this condition for 5 additional days. All were free from Anjou scald and slightly mealy after 14 days of ripening; they were discarded after 18 days because of core breakdown. At the second withdrawal for ripening, on February 13 fruits of all three lots were of uniformly excellent appearance and free from Anjou scald. Fruit in all lots had developed severe Anjou scald after ripening for 7 days; it had softened but was not considered of optimum dessert quality at this time. All fruit from the different storage atmospheres was juicy and smooth in texture and of excellent taste and flavor from the 9th to the 12th day of ripening; fruit in all lots was mealy after 17 days and discarded because of core breakdown. At the last withdrawal for ripening, Anjou pears scalded badly after being held for 5 days at 65°; some softening had occurred, but normal ripening capacity was absent in fruit of all three lots, as evidenced by lack of juiciness and distinct granularity in texture. All fruit was discarded because of core breakdown after 12 days of ripening.

At none of the withdrawals for ripening was it possible to detect any significant differences in the storage life, ripening capacity, or dessert quality of Anjou pears of the various lots that could be correlated with the presence of fruit volatiles from preripened fruit in the air in which unripened pears were stored at 31° F.

Starking Delicious Apples. Samples of Starking Delicious apples of the first picking from the three cold storage atmospheres (Table II) were initially withdrawn for ripening and dessert evaluation on December 26. All lots of apples were crisp to yielding and of good flavor after 6 days of ripening at 65°; they were yielding in texture and of acceptable dessert quality after 14 days. Some apple scald had developed in all lots at this time. All samples were stale in flavor after 17 days and were discarded after 23 days of ripening, because of mealiness and poor dessert quality. At the second withdrawal from cold storage, on February 15, all fruits except those in oil paper wraps had developed some apple scald. The fruit from all three storage treatments was crisp to yielding after 5 days of ripening and was of good texture and flavor for 12 days, and finally on the eighteenth day of ripening it was discarded because of poor dessert quality. The final withdrawals of Delicious apples of the first picking were made on April 4. At this time fruits of all three lots had developed severe apple scald in cold storage; they were yielding in texture and of good dessert quality after 8 days of ripening and mealy with a stale flavor in 15 days, at which time all fruits were discarded. None of the fruit had developed internal breakdown at this time; there was no difference in the condition, appearance, and dessert quality among the apples in the three test lots.

Starking Delicious apples of the second picking were harvested at an advanced maturity; most fruits were severely water-cored and eating ripe at harvest. This stage of maturity was purposely chosen to determine whether the amount of fruit volatiles in the air at 31° F. would influence the rate of disappearance of water core and the incidence of internal breakdown. When withdrawn from cold storage on December 26, fruits of all three lots were still heavily water-cored; they were mealy after 6 days of ripening and were discarded at 14 days, because of internal breakdown of the water-cored tissue. By February 15 water core had disappeared in all samples of fruit in storage. Apples in all lots were mealy after 5 days of ripening and discarded on the twelfth day, because of breakdown. Flavor of all fruits was excellent; even the fruit in the lot subjected to the atmosphere laden with volatiles from preripened fruit had developed no staleness.

At none of the withdrawals for ripening of Starking Delicious apples of the first picking was it possible to distinguish any difference in the ripening behavior, dessert quality, shelf life, or intensity of apple scald that could be attributed to the atmospheric environment in which the fruit had previously been stored at 31° F. The disappearance of water core during storage and the development of internal breakdown during ripening in Starking Delicious apples of advanced maturity at harvest was also not related to the concentration of fruit volatiles in the atmosphere during storage at 31°.

Experimental Atmospheres, 1951–52

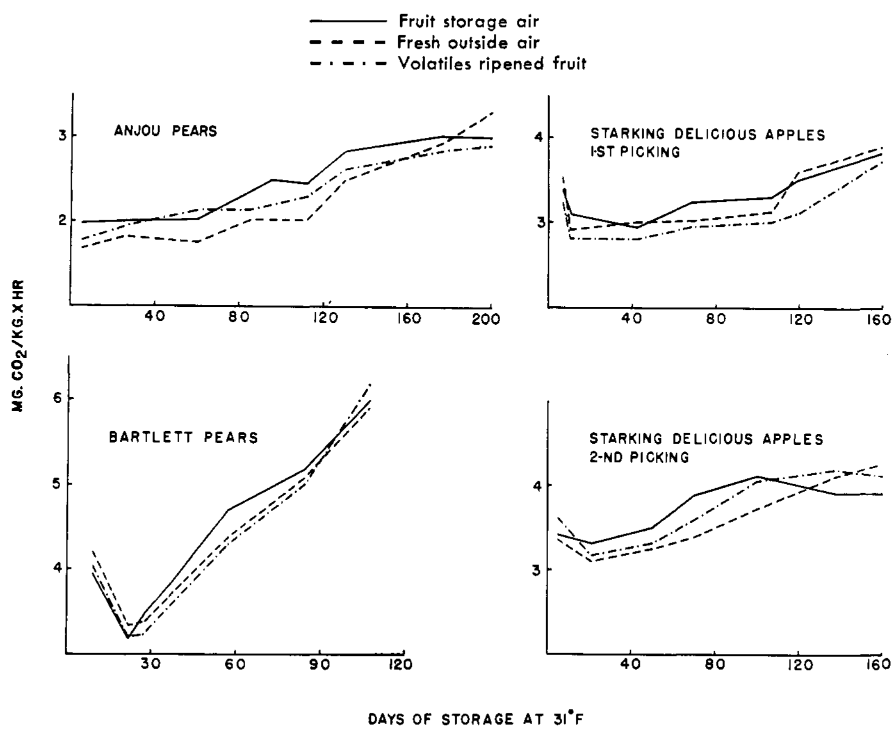
Response of Fruits

Since the keeping quality of unripened pears and apples at 31° F. was not adversely affected in 1950–51 by the presence of preripened fruit, studies of this nature were repeated the following season, wherein volatiles from preripened fruit were also applied at 45° and 65°. Treatments of shorter duration and greater concentrations of nonethylenic volatiles were used as shown in Table I. Anjou pears and Starking Delicious apples again served as test varieties. They were harvested and stored prior to treatment as described.

Anjou Pears. The first withdrawal of the experimental fruit and exposure to the volatiles from preripened pears were made on November 29; the second occurred on January 31. Respiration measurements on the fruit were made during and following each treatment and at each storage temperature; these values for the first withdrawal are shown in Figure 2. At 65° F., there was an earlier onset of the climacteric rise in respiration and maximum respiratory intensity was attained about 2 days earlier as a result of treatment with the volatiles from preripened fruit. The cumulative production of carbon dioxide for both treated and untreated lots at 65° was similar. The data in Figure 2 show that no stimulation of the respiratory activity of Anjou pears occurred at temperatures of 45° and 31° as a result of the presence of ripened fruit.

The data in Table II show no significant difference in the firmness or soluble pectin of Anjou pears at 45° or 31° F. as a result of treatment with emanations of ripe fruit. At 65° fruits of both the treated and the untreated lots were fully ripe after 12 days; they were too soft for pressure-test readings; their contents of soluble pectin, however, were similar. The observed stimulatory effect of the respiratory activity in the treated lot at

Figure 1. Respiration of pears and apples as influenced by source of storage atmosphere, 1950–51



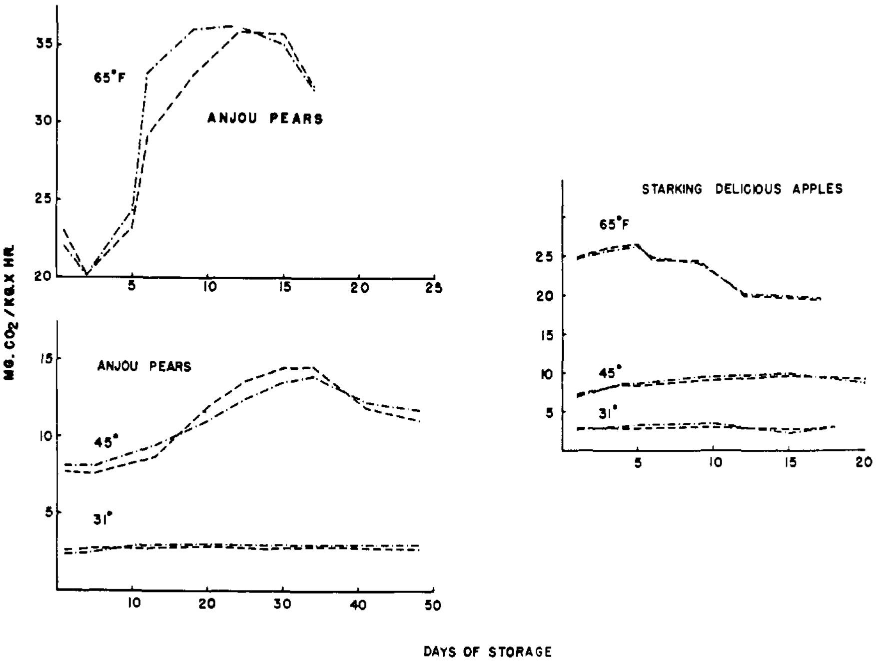


Figure 2. Respiration of pears and apples at various temperatures as related to source of storage atmosphere, 1951–52

– · – · – · – · Volatiles ripened fruit
– – – – – Fresh outside air

65° (Figure 2) was not manifested in the degree of ripeness of the fruit at this time.

Organoleptic examination was made of the experimental pears held at different temperatures while exposed to volatiles from the ripened fruit. Both the treated and untreated fruit held at 65° F. were overripe, mealy, and of poor dessert quality when ripened for 6 additional days following termination of treatment. There was no difference in the texture, flavor, or dessert quality of the treated and untreated pears held at 45°. Fruits of both lots had softened after 18 days at this temperature; they were fully ripe and of excellent dessert quality after 34 days. When unripened pears were subjected to the volatile emanate from ripened fruit at 31°, firmness and color of the treated and untreated samples were similar as long as the fruit remained at 31°; upon subsequent removal to 65°, those in both lots ripened normally with excellent dessert quality and evidenced similar ripening characteristics regardless of their previous storage history.

Starking Delicious Apples. Starking Delicious apples were withdrawn on October 24 and January 31 from their storage reservoir at 31° F. and treated at 31°, 45°, and 65° with the volatiles from preripened fruit as indicated in Table I. The respiration rates for the treated and untreated apples of the first withdrawal are shown in Figure 2. The volatile emanation from the preripened fruit had no stimulatory influence, at any of the temperatures tried on the respiration of the experimental fruit. Information relative to the firmness and soluble pectin content of all test fruit after treatment at 31°, 45°, and 65° in November and again at 45° in February is presented in Table II. Changes in firmness and soluble pectins are often used to evaluate progressive ripening in fruits. Data in Table II indicate that presence of preripened fruit at temperatures tested had no deleterious influence on unripened Starking Delicious apples as measured by these indexes.

Certainly a ratio of about 1 to 2 of ripened to unripened fruit was sufficient to preclude the possibility that the quantity of ripe fruit emanation in these studies was a limiting factor in the failure of the treated Starking Delicious apples to respond to their atmospheric environment. Quantitative measurements of the volatiles in the air stream around the treated fruit (Table I) indicate that the level of the nonethylenic component was considerably higher than the 9 to 18 mg. per cubic foot found in most commercial apple storages.

A taste panel evaluated the texture and flavor of all lots of untreated Starking Delicious apples and those subjected to the volatiles from preripened apples. When the apples were examined immediately following treatment at 65° F. in November and in February, no difference existed in the condition or dessert quality of the treated and untreated fruits; fruits in both lots were yielding to slightly mealy in texture and possessed a full varietal flavor. There was no discernible difference in texture and flavor of experimental fruit in the two lots immediately following treatment at 45° or even when portions of the treated and untreated samples were transferred from 45° to 31° and examined in April. As in 1950–51, the texture, flavor, and condition of Starking Delicious apples were similar in the treated and untreated lots at 31°. This observation was true when dessert qualities were compared immediately following treatment in November or when delayed until April. Both the treated and the untreated fruit were hard to firm in texture and starchy in taste in November, and fruits in both lots were considered full ripe and of good texture and flavor when sampled at 31° in April.

It was not possible, at the temperatures used during 1951–52, to demonstrate by chemical measurement, visual examination, or taste panel, any deleterious effect on ripening behavior or storage life of Starking Delicious apples of presence of ripened fruit of the same variety.

Discussion

All commercial apple and pear storages in the Pacific Northwest endeavor to maintain temperatures of 29° to 31° F. It is in this temperature range then that one must evaluate any possible deleterious effect on the regular storage tonnage of the presence of some fruit of varying degrees of ripeness.

Most informed fruit storage operators are conscious of the fact that their commodity evolves fruity odors, which comprise two general kinds of volatile emanations—ethylene and the nonethylenic fraction composed of aldehydes, esters, and alcohols. Smock (*12*) stated that the presence of the nonethylenic volatiles, rather than ethylene, offers the chief hazard to the successful cold storage of apples. Investigators (*5, 7, 11*) have shown that the emanations from ripe fruit can hasten the ripening of unripe fruit under certain specific conditions wherein the variety, the stage of maturity at harvest, the temperature during exposure to ripe fruit, and the duration of prior cold storage are important factors.

It is not logical to assume that because an unripe apple or pear may ripen faster in the presence of a ripened fruit at 70° F., a similar phenomenon will occur at 30°. A major portion of published research indicates that it will not. Certainly the results from the present study definitely show that the volatile products from ripened pears and apples at 31° have no discernible influence on the storage life or dessert quality of specified unripened varieties grown in the Pacific Northwest. Ripening of Anjou pears even at 45° or of Starking Delicious apples at 65° was not hastened by the presence of ripened fruit. These results explain why different investigators (*1, 2, 4*) have met with failure in their attempts to prolong cold storage life of apples and pears by use of air-purification equipment.

It is not the intent of the authors to encourage careless handling and cold storage practices for apples and pears in the Pacific Northwest. They do feel, however, that the popular conception of the possible hazard presented by a few ripe apples in commercial fruit cold storages has been distorted beyond its true economic significance; and that prompt handling, adequate refrigeration capacity to cool the fruit quickly, proper air distribution to get uniform temperatures throughout the room, and maintaining favorable temperatures and humidities are the really important factors in successful cold storage of pears and apples.

Summary

Unripe Bartlett and Anjou pears and Starking Delicious apples were stored continuously at 31° F. during 1950–51 in volatile-free atmospheres and in those containing measured quantities of ethylene and nonethylenic volatiles from ripened fruits of similar variety. Certain indexes associated with the rate of ripening (respiration, firmness, and soluble pectins) failed to reflect any significant difference in the degree of ripeness between the fruit held in fresh outside air and that exposed to the emanations from ripe fruit. A qualified panel of judges was unable to distinguish any impairment in the cold storage life or the texture, flavor, dessert quality, and freedom from physiological disorders during subsequent ripening of the pears and apples, as a result of their previous storage along with ripened fruit.

Storage temperatures of 31°, 45°, and 65° F. were employed in the 1951–52 experiment wherein ripe and unripe Anjou pears were held in the presence of each other, as were also Starking Delicious apples. The presence of ripe fruit hastened the respiratory climacteric in Anjou pears by about 2 days when the experiments were conducted at 65°. This stimulatory effect was not detected organoleptically. The ripening of Anjou pears at 45° and 31° was not hastened by the presence of previously ripened fruit. Starking Delicious apples were not adversely affected at any of the temperatures tested when they were stored along with ripened fruit of the same variety.

The commercial implications of these and related studies are discussed with regard to the successful storage of apples and pears at 31° F.

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Received for review September 2, 1954. Accepted January 8, 1955.

FOOD DISCOLORATION

Darkening of Food Purees and Concurrent Changes in Composition of Head-Space Gas

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Studies on the nonenzymatic browning of foods have shown that carbon dioxide and oxygen are involved in these reactions. In an attempt to clarify further the relationship between composition of head-space gas and change in color, the concentration of these gases in the head space of sealed tubes of puréed fruits and vegetables was determined periodically. Reflectometric measurements of the color of the purées were made concurrently. Oxygen was absorbed and carbon dioxide evolved by all the food studied. There was a significant correlation between oxygen absorption and discoloration in all foods except pears. The correlation between carbon dioxide evolution and discoloration was significant only for beets, carrots, green beans, and squash. Significant correlation between oxygen absorption and carbon dioxide evolution was observed for all except spinach purée. Development of nonenzymatic discoloration in the puréed vegetables closely paralleled absorption of oxygen, indicating that inhibition of darkening in these puréed foods may be assisted by maintenance of low oxygen levels.

Oxygen and carbon dioxide may be involved in the development of nonenzymatic darkening in foodstuffs. The present study was undertaken to try to clarify the relationship between gas changes and changes in color. The rates of oxygen absorption and carbon dioxide production by eight puréed foods were studied. Darkening occurred concurrently in most of these purées and was evaluated by a reflectometric method. Correlation coefficients between changes in composition of head-space gas and discoloration are presented.

Although Maillard (*9*) noted that the

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