Proceedings of the
AMERICAN SOCIETY FOR HORTICULTURAL SCIENCE
1928 25:371-375

Cold Storage, Ripening, and Respiration Studies of the Fuerte Avocado

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The Fuerte, which appears to be, a hybrid between the Guatemalan and Mexican races is the most important variety of avocado grown in California.

Condit (1915) reported that avocados can be held at temperatures ranging from 0 to 2 degrees C. for a period of two months. Dybowski (1902) stated that with shipments of avocados from the Antilles to France, a temperature of 2 degrees C. was the most satisfactory. Higgins, Hunn and Holt (1911) determined that prolonged storage at temperatures of 0 to 2 degrees C., resulted in the blackening of the interior of avocados. Such temperatures, however, apparently could be endured without injury for three or four weeks. They recommended that the storage temperature be kept not below 4.5 degrees C. Wilcox (1914) reported that avocados may be held without injury at a temperature of 0 degrees C. for two months.

Observations by Overholser (1925) indicated that, with the exception of the Fuerte, most varieties of avocados kept best at about 4.5 degrees C. At temperatures as low as 0 degrees C., with the possible exception of the Royal, the fruit remained firm, but the epidermis and flesh, especially about the vascular bundles, turned brown in color. Furthermore, upon removal to room temperature from 0 degrees C. the fruit subsequently failed to soften, but instead wilted and blackened.

The Fuerte, when stored at 4.5 degrees C., retained the normal external appearance, but the pulp became browned, and remained in a firm unripe condition after removal to room temperatures (18 to 22 degrees C.). At a storage temperature of 7 degrees C., the fruits ripened and became sufficiently soft to indicate the approximate desirable time of removal from storage.

The observations were repeated during the season of 1928 and similar responses of the Fuerte were noted, when the fruit was harvested in a hard to firm stage of ripeness and stored with minimum delay. Depending upon the time of harvest it generally required from 5 to 7 days for the fruits to soften at room temperatures and they remained marketable for from 4 to 6 days longer. The work of three seasons indicated that at 7 degrees C. the fruit kept satisfactorily for three or four weeks. After the fruit had softened either at room temperature or 7 degrees C. it could then be satisfactorily kept for an additional three or four weeks at 0 degrees C. When fruits were stored while hard to firm in degree of maturity at 4.5 degrees C. and lower the tissue remained firm, became somewhat tough, and subsequently failed to soften satisfactorily after removal to room temperatures.

Studies were made of the respiration intensity of Fuerte avocados as measured by the

carbon dioxide production, using the method described by Bennett and Bartholomew (1924). Specimens weighing from 200 to 300 grams were placed in wide mouth glass jars having about five liters capacity. These respiration chambers were closed with No. 14 rubber stoppers containing two brass stop-cocks. Quadruplicate sets were placed at: (a) room temperatures, (19.5 to 22.3 degrees C.); (b) refrigerator car temperatures (7.1 to 8.1 degrees C.) and (c) cold storage temperatures (0.0 to 0.1 degrees C.).

The average duration of the respiration period at the highest temperatures was about 30 hours; at the intermediate temperatures, 108 hours; and at the lowest temperature 165 hours. At the end of each respiration period, duplicate samples of gas from each of the jars were analyzed, by means of a modified Orsat apparatus, for carbon dioxide and oxygen content. The jars were then opened and the fruit aerated for several hours. When again sealed the fruits were surrounded by air having normal content of oxygen and carbon dioxide before the next respiration period was begun. After correcting for temperature and pressure differences the respiration intensity was computed in milligrams of carbon dioxide produced per kilogram of fruit per hour.

In Table I is shown the respiration intensity of Fuerte avocados at room temperatures. The initial respiration intensity at room temperatures was relatively high, averaging about 100 milligrams of carbon dioxide per kilogram of fruit per hour. With each succeeding respiration period, however, it dropped. After 10 periods, averaging approximately 31 hours each, it was only one-half that during the first 36 hours.

TABLE I—The Respiration Intensity of Fuerte Avocados at Room Temperatures

Average Temp. °C.	Duration Respiration Period (Hours)	Average Percent CO_2 Produced	Average Percent O_2 Left	Mgms. CO_2 Per Kilo Per Hour	Repisartion Ratio CO_2/O_2
21.5	36.0	12.8	6.6	100.1	.891
19.7	21.5	8.4	11.2	94.4	.864
21.5	25.5	8.3	9.8	77.0	.806
22.3	22.5	7.3	11.0	74.6	.729
22.0	24.7	6.9	10.3	73.2	.727
21.0	58.1	11.5	5.9	64.1	.754
22.0	24.0	6.8	11.3	67.7	.725
20.3	36.0	9.3	9.4	58.4	.777
21.0	24.5	6.3	13.0	60.1	.751
19.5	31.2	6.6	12.1	50.0	.752
Ave.21.1	31.1	8.3	10.1	72.0	.778

This drop in respiration intensity with succeeding time intervals agrees with unpublished data by Hopkins (1926) for potatoes and Hill (1913) for fruit. Since Hopkins employed the absorption method the carbon dioxide surrounding the tubers did not increase nor the oxygen content decrease, and, therefore neither of these factors appears to account for the decline in respiration intensity.

It is recognized, however, as a result of the work of Kidd (1914) and Kidd, West and Kidd (1927) that the accumulation of carbon dioxide and decrease in oxygen surrounding the avocado from one respiration period to another probably tended to depress respiration intensity. Furthermore, its effect may have been accumulative. As a matter of fact it was observed that the specimens in the respiration chambers remained

firm longer, wilted less, and appeared marketable for a longer period of time than did check specimens in open baskets.

There does not, however, appear to have been any measurable anaerobic respiration, since the respiration ratio, or the per cent of carbon dioxide produced divided by the oxygen consumed, was in every case less than unity. Nevertheless, Kidd, West and Kidd point out that at the higher temperatures oxygen deficiency rather than carbon dioxide increase is likely to be the factor in modifying respiration intensity. It is suggested that the work of Kidd, and West and Kidd might explain some of the data in this paper.

It is known that if fat or oil is the respirable substance primarily consumed, as in the avocado, the respiration ratio is less than unity. According to Liaskowki (1874) the low values are connected with the fact that the fats change over into sugars and thus their respiration is effected. In any case with the avocado more oxygen is absorbed than carbon dioxide is evolved. There may be an independent absorption of oxygen for other purposes simultaneously with the oxygen of respiration.

In Table II is shown the respiration intensity of Fuerte avocados at refrigerator car temperatures (7.0 degrees C.). The respiration intensity at 7.1 to 8.1 degrees C. averaged less than one-third that at 19.5 to 22.3 degrees C. Furthermore, it did not decline as was the case at room temperatures. Kidd, West and Kidd reported that temperatures averaging approximately 7.0 degrees C. were about the optimum to lessen the danger from oxygen deficiency and at the same time result in minimum toxicity from carbon dioxide increase.

TABLE II—The Respiration Intensity of Fuerte Avocados at Refrigerator Car Temperatures

Average Temp. °C.	Duration Respiration Period (Hours)	Average Percent CO_2 Produced	Average Percent O_2 Left	Mgms. CO_2 per Kilo per Hour	Repsiration Intensity CO_2/O_2
7.1	70.3	5.8	13.3	21.30	0.781
7.3	85.3	6.2	13.2	19.01	0.791
7.4	141.0	9.8	8.3	18.44	0.699
7.1	109.3	7.5	10.7	18.09	0.740
7.3	120.5	8.5	9.6	18.14	0.750
7.4	111.2	7.0	11.3	17.44	0.735
8.1	117.2	9.2	8.0	22.40	0.708
Ave. 7.4	107.8	7.7	10.6	19.26	0.743

The respiration ratio also averaged somewhat lower at 7.0 degrees C. than at 21 degrees C. According to Aubert (1892) in the case of succulent tissues, such as fruits, kept at low temperatures, there is an incomplete oxidation of sugar and an intake of a surplus of oxygen with the formation of organic acids. Hence, at lower temperatures the respiration ratio tends to be below unity.

In Table III is shown the respiration intensity of Fuerte avocados at cold storage temperatures (0 degrees C.). While the drop of 14 degrees C. between 21 and 7 degrees C. reduced the respiration intensity to less than one-third, the further drop of only 7 degrees C. resulted in the intensity of 0 degrees C. being less than one-fourth that at 7.1 degrees C. It appeared that a comparatively small drop in temperature below

7 degrees C. was relatively more effective in retarding respiration than was a much larger drop at temperatures of 21 degrees C. Gore (1911) found for different fruits that the average temperature increase required to double the respiration activity was 8.01 degrees C. With prolonged storage at 0 degrees C. the respiration intensity became less than one-fourth that during the first period and, hence dropped to a greater extent than was the case at room temperatures. At 0 degrees C. increases in the percentages of carbon dioxide are according to Kidd, West and Kidd, more toxic than at the higher temperatures.

TABLE III—THE RESPIRATION INTENSITY OF FUERTE AVOCADOS AT COLD STORAGE TEMPERATURES

Average Temp. °C.	Duration Respiration Period (Hours)	Average Percent CO_2 Produced	Average Percent O_2 Left	Mgms. CO_2 per Kilo per Hour	Respiration Intensity CO_2/O_2
0.0	190.0	5.6	14.0	8.8	0.795
0.0	141.0	2.7	17.1	6.0	0.700
0.1	117.5	2.5	17.7	6.4	0.759
0.0	165.7	3.2	16.7	5.8	0.757
0.0	165.5	2.5	17.5	4.0	0.668
0.0	210.5	2.1	17.6	3.2	0.583
0.1	190.0	2.0	18.0	3.3	0.600
0.0	171.0	1.1	18.8	1.8	0.474
0.0	136.0	0.9	18.6	1.9	0.366
Ave. 0.0	165.0	2.5	17.3	4.6	0.634

In agreement with Aübert, at 0 degrees C. the respiration ratio averaged less than at 7 degrees C. It also tended to become progressively lower with succeeding respiration periods and longer time at 0 degrees C. The longer the fruit remained at 0 degrees C. the larger the amounts of oxygen consumed for a given production of carbon dioxide.

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