

## EFFECT OF COLD STORAGE ON SOME FLORIDA AVOCADOS

**Margaret J. Mustard**

*Division of Research and Industry University of Miami*

### Coral Gables

The increased emphasis on precooling and refrigerated shipment of fruits and vegetables has stressed the need for additional information regarding the proper storage temperatures for Florida-grown avocados. A survey of the available literature of the past forty years shows that different varieties produced in different areas vary widely in their tolerance to refrigerated storage.

Internal browning has frequently been observed in avocados following refrigeration and occasionally following extreme chilling of fruit prior to harvesting (2). This disorder is characterized by a brownish discoloration of areas of the flesh which may be confined to localized areas in the seed cavity; may extend outward from the seed cavity into the surrounding flesh; may be confined chiefly to the vascular bundles; or may be manifested by a combination of the above (Fig. 1). The factors responsible for its development are not fully understood.

As early as 1911, Higgins, Hunn, and Holt (1) noted the occurrence of blackening in the interior of Hawaiian-grown avocados after prolonged storage at temperatures recommended for the storage of Temperate Zone fruits. They found that avocados could endure these temperatures for three to four weeks but recommended that the temperature should not be allowed to fall below 40 degrees F. A few years later, Wilcox and Hunn (9) tested some miscellaneous Hawaiian varieties and found no discoloration of the pulp or loss of flavor after two months storage at 32 or 36 degrees F.

California-grown avocados were found by Overholser (5) to vary both with regard to the temperature and duration of refrigerated storage which they could endure without the occurrence of cold injury. He found, for instance, that the Royal variety could be successfully stored for sixty days at 32 degrees F.; whereas, the Fuerte could be stored for but thirty days at 45 degrees F.

Considerable research has been done by Wardlaw and his associates (6), (7), and (8) in Trinidad on the storage of this fruit. They found only a few West Indian seedlings that could be held at 40 degrees F. for twenty to twenty-five days without the occurrence of cold injury. These investigators have attributed the chilling of avocados, including both skin necrosis and internal browning, to a combination of factors including variety of fruit, temperature of storage, duration of storage, maturity of fruit at time of storage, and the water content of the fruit.

Joachim and Parsons (3) found that the best storage temperature for a Ceylon-grown variety of avocado was 40-45 degrees F. but that its commercial storage life at this temperature was only one week.

Lynch and Stahl (4) working with Florida grown avocados likewise found that different varieties vary with regard to their optimum storage temperatures. For example, these investigators found that the Waldin variety showed signs of cold injury to both pulp and skin after but seven days storage at 48 degrees F.; whereas, the Lula variety could be stored successfully for twenty-eight days at 37 degrees F.

The purpose of this paper is to present some additional information regarding the effect of temperature and duration of storage on several varieties of avocados cultivated in Florida.

## **MATERIALS AND METHODS**

The avocados used in this investigation were obtained either from a local packing house or directly from the growers themselves. The maturity of the fruit approximates that used in commercial shipments. Care was taken to select fruits with a short portion of stem attached to minimize the entrance of decay organisms. Within approximately twenty-four hours from the time of harvesting, the avocados were stored at the temperatures shown below for the respective varieties. These temperatures as well as the relative humidities are the average of daily readings made with a registering maximum and minimum thermometer and a Mason hygrometer. Whenever possible, a total of one hundred and thirty fruit of each variety were obtained and divided into thirteen lots of ten fruit each. Four lots of each variety were placed in each of the three storage rooms and the remaining lot, which served as a check, was held at room temperatures. The fruit was stored in open cardboard cartons containing a cushion of excelsior. At weekly intervals for four succeeding weeks, one lot of each variety was removed from each storage room and allowed to ripen at room temperature. As soon as the fruits ripened, they were cut and examined for signs of internal browning. The individual fruits were checked at frequent intervals throughout the investigation for external symptoms of disease and to determine their degree of ripeness.

## **RESULTS**

### ***Booth 7***

No internal browning was observed in the Booth 7 avocados which were stored throughout the investigation at room temperature. Following ripening at room temperature, no internal browning was observed in the fruit stored for either one or two weeks at 47-50 or 50-56 degrees F. Increasing the refrigerated storage period from two to three weeks resulted in the development of internal browning in 50 percent of the fruit stored at 47-50 degrees F. and in 40 percent of those stored at 50-56 degrees F. Ninety percent of one lot of fruit which was stored for four weeks at 47-50 degrees F. before being transferred to room temperature developed internal browning. These data are summarized in Table 1. The highest percentage of fruit that retained a marketable external appearance until ripe were those which were removed to room temperature after seven days storage under refrigeration. Extending the period of refrigerated storage beyond seven days resulted in a decrease in the percentage of marketable fruit due chiefly to an increase in the incidence of anthracnose and darkening of the skin.

Table 1 shows a summary of these data together with the effect of refrigeration upon the rate of ripening of these fruit.

These results indicate that both from the aspect of incidence of internal browning and external appearance it would seem advisable to limit the storage of Booth 7 avocados to approximately seven days at either of these temperatures.

### **Booth 8**

No internal browning was observed in this variety of avocado when stored until ripe at room temperature or following one week of storage at 51-54 degrees F., 47-48 degrees F., or 43-52 degrees F. Storage for two weeks at 51-54 degrees F. resulted in some internal browning; whereas, none was observed after storage for the same period at the other two temperatures. Extending the period of refrigerated storage beyond two weeks resulted in the development of internal browning at all three temperatures. No explanation can be provided for the higher percentage of internal browning that was observed after three weeks storage at 43-52 degrees F. than after four weeks storage at the same temperature. These data are summarized in Table 1.

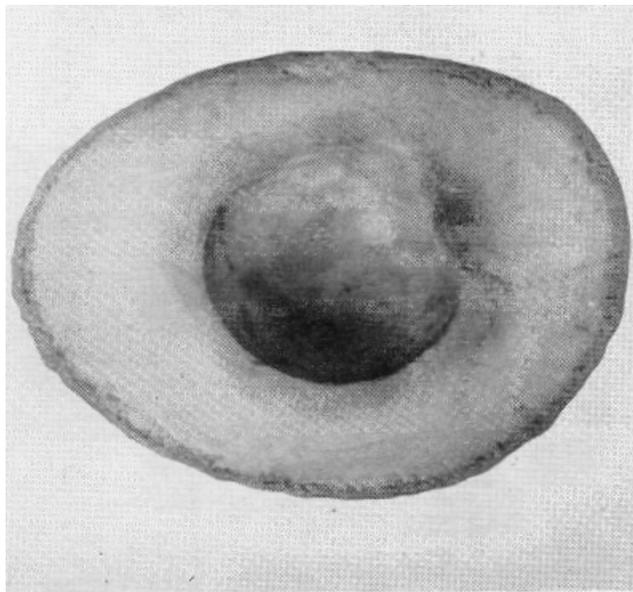


Fig. 1. — Internal browning in an avocado.

TABLE 1. EFFECT OF REFRIGERATION ON SOME FLORIDA-GROWN AVOCADOS.

Facial Origin and Variety	Temperature and Days in Storage	Relative Humidity	No. of Fruit	Total No. of Lays to Ripen	Fruit Showing Internal Browning when ripe	Marketable fruit, judged by external appearance when ripe	Factors Contributing to Unmarketable External Appearance In Order of Prevalence
Guatemalan X West Indian Booth 7	66-78 (R.T.)*	75	10	8-11	0	70	Anthracnose
	50-56+(R.T.)**	84	10	11	0	90	Anthracnose
	7 days		10	14-20	0	0	Darkening of skin, anthracnose, and stem-end rot
	14 days		5	20-23	40	20	Darkening of skin and anthracnose*
	21 days		10	11	0	100	None
	28 days		10	20	0	10	Darkening of skin
	47-50+(R.T.)	84	10	20-23	50	20	Darkening of skin
	7 days		10	27-29	90	40	Darkening of skin and pitting of skin
	14 days		10	11	0	100	Slight pitting of skin
	21 days		10	17-19	10	90	Pitting of skin and darkening of skin
	28 days		10	21-27	10	100	Slight pitting of skin
	47-48+(R.T.)	92	10	21-28	20	40	Pitting of skin, darkening of skin, and anthracnose
	7 days		10	10-12	0	100	Slight pitting of skin
	14 days		10	19	0	80	Pitting of skin and darkening of skin
	21 days		10	25-27	20	--	-----***
	28 days		10	30-31	20	20	Pitting of skin, darkening of skin, and anthracnose
	43-52+(R.T.)	72	10	12	0	100	Slight pitting of skin
	7 days		10	19	0	80	Pitting of skin and darkening of skin
	14 days		10	25-27	60	--	-----***
	21 days		10	30-31	10	20	Pitting of skin, darkening of skin, and anthracnose
28 days		10	30-31	10	20	Pitting of skin, darkening of skin, and anthracnose	
Guatemalan X Mexican Lula	66-78 (R.T.)	75	10	12	0	90	Anthracnose
	50-56+(R.T.)	84	10	12-15	0	100	None
	7 days		10	21-25	0	10	Darkening of skin, anthracnose, and pitting of skin
	14 days		10	25-29	0	10	Darkening of skin and pitting of skin
	21 days		10	25-32	0	40	Pitting of skin, darkening of skin, and stem-end rot
	28 days		10	15	0	90	Anthracnose and stem-end rot
	47-50+(R.T.)	84	10	21-25	0	10	Darkening of skin
	7 days		10	25-29	0	20	Darkening of skin, anthracnose, and pitting of skin
	14 days		10	29-36	0	30	Pitting of skin, darkening of skin, and anthracnose
	21 days		10	15	0	80	Darkening of skin and anthracnose
	28 days		10	25	0	0	Darkening of skin and anthracnose
	44-53+(R.T.)	82	10	25-29	0	60	Darkening of skin and anthracnose
	7 days		10	29-36	0	30	Pitting of skin, darkening of skin, and anthracnose
	14 days		10	12-14	100	0	Darkening of skin, pitting of skin, and stem-end rot
	21 days		10	16-19	100	22	Pitting of skin, darkening of skin, anthracnose, and stem-end rot
	28 days		10	23-26	100	0	Darkening of skin, pitting of skin, anthracnose, and stem-end rot
	47-50+(R.T.)	87	10	28-30	90	10	Darkening of skin and pitting of skin
	7 days		9	12-14	100	11	Darkening of skin, pitting of skin, anthracnose, and stem-end rot
	14 days		9	19-21	100	0	Darkening of skin, pitting of skin, anthracnose, and stem-end rot
	21 days		10	23-26	90	0	Pitting of skin, darkening of skin, anthracnose, and stem-end rot
28 days		10	30-33	100	0	Darkening of skin, pitting of skin, and anthracnose	
42-52+(R.T.)	85	9	12-14	100	0	Darkening of skin, pitting of skin, anthracnose, and stem-end rot	
7 days		9	19-21	100	0	Darkening of skin, pitting of skin, stem-end rot, and anthracnose	
14 days		10	26-28	100	0	Darkening of skin, pitting of skin, and anthracnose	
21 days		10	30-33	100	0	Darkening of skin, pitting of skin, and anthracnose	
28 days		10	9-12	80	50	Pitting of skin, stem-end rot, anthracnose, and darkening of skin	
42-52+(R.T.)	88	10	12-14	100	10	Darkening of skin, stem-end rot, and pitting of skin	
7 days		10	19-21	90	0	Pitting of skin, stem-end rot, darkening of skin, and anthracnose	
14 days		10	23-26	100	0	Pitting of skin, anthracnose, stem-end rot, darkening of skin	
21 days		10	28-33	100	0	Pitting of skin, darkening of skin, stem-end rot, and anthracnose	
28 days		10	12-14	90	20	Darkening of skin, stem-end rot, and pitting of skin	
47-50+(R.T.)	87	10	16-21	90	0	Pitting of skin, darkening of skin, stem-end rot, and anthracnose	
7 days		10	23-26	100	0	Pitting of skin, darkening of skin, anthracnose, and stem-end rot	
14 days		10	28-30	100	10	Pitting of skin, darkening of skin, stem-end rot, and anthracnose	
21 days		10	12-14	100	0	Stem-end rot, darkening of skin, pitting of skin, and anthracnose	
28 days		10	16-19	100	10	Pitting of skin, darkening of skin, anthracnose, and stem-end rot	
42-52+(R.T.)	85	10	21-23	100	10	Pitting of skin, darkening of skin, anthracnose, and stem-end rot	
7 days		10	26-28	100	0	Pitting of skin, stem-end rot, darkening of skin, and anthracnose	
14 days		10	26-28	100	0	Pitting of skin, stem-end rot, darkening of skin, and anthracnose	
21 days		10	26-28	100	0	Pitting of skin, stem-end rot, darkening of skin, and anthracnose	
28 days		10	26-28	100	0	Pitting of skin, stem-end rot, darkening of skin, and anthracnose	

\* Room Temperature

\*\* Stored for 7, 14, 21 or 28 days under refrigeration prior to transfer to room temperature.

\*\*\* Fruit not checked until overripe.

TABLE 1. CONTINUED

Racial Origin and Variety	Temperature and Days in Storage	Relative Humidity	No. of Fruit	Total No. of Days to Ripen	Fruit Showing Internal Browning when ripe	Marketable fruit, judged by external appearance when ripe	Factors Contributing to Unmarketable External Appearance In Order of Prevalence
	Degrees F.	%			%	%	
Astecalen Taylor	64-75 (R.T.)	79	10	5-7	0	50	Anthracnose
	46-50 (R.T.)	83					
	7 days		10	14	0	70	Anthracnose
	14 days		10	17-19	0	50	Anthracnose
	21 days		10	24-27	70	10	Anthracnose, stem-end rot
	28 days		10	27-32	70	10	Anthracnose, stem-end rot
	40-43 (R.T.)	78					
	7 days		10	14-17	0	70	Anthracnose
	14 days		10	17-19	10	50	Anthracnose
	21 days		10	24-27	70	20	Anthracnose
	28 days		10	32-34	40	50	Anthracnose and stem-end rot
	Nabal	66-77 (R.T.)	74	10	8-18	0	0
51-54 (R.T.)		96					
7 days			10	11-18	10	20	Anthracnose and wrinkling of skin
14 days			10	18-19	40	80	Anthracnose and pitting of skin
21 days			10	23-25	90	10	Darkening of skin, anthracnose, and pitting of skin
28 days			10	27-32	70	0	Darkening of skin, anthracnose, and pitting of skin
47-48 (R.T.)		97					
7 days			10	12-22	20	40	Anthracnose, wrinkling of skin, and pitting of skin
14 days			10	18-20	60	90	Wrinkling of skin
21 days			10	23-25	100	30	Darkening of skin and pitting of skin
28 days			10	27-32	100	20	Darkening of skin, pitting of skin, and anthracnose
44-53 (R.T.)		92					
7 days		10	12-22	10	30	Anthracnose and wrinkling of skin	
14 days		10	18-20	90	30	Anthracnose, pitting of skin, and darkening of skin	
21 days		10	23-25	100	20	Pitting of skin, darkening of skin, and anthracnose	
28 days		10	27-32	90	20	Pitting of skin, darkening of skin, and anthracnose	
Linda	66-77 (R.T.)	74	10	8-11	20	50	Anthracnose and stem-end rot
	51-54 (R.T.)	96					
	7 days		10	9-12	70	80	Anthracnose
	14 days		10	13-18	100	20	Anthracnose and stem-end rot
	21 days		10	22-25	100	50	Anthracnose and stem-end rot
	28 days		10	25-33	100	10	Anthracnose and stem-end rot
	47-48 (R.T.)	97					
	7 days		10	11-16	90	80	Anthracnose
	14 days		10	18-22	70	70	Anthracnose
	21 days		10	25-27	90	60	Anthracnose and stem-end rot
	28 days		10	30-33	100	30	Anthracnose and stem-end rot
	44-53 (R.T.)	92					
7 days		10	11-18	40	80	Anthracnose	
14 days		10	18-23	90	70	Anthracnose	
21 days		10	23-26	90	40	Anthracnose and stem-end rot	
28 days		10	27-33	100	20	Anthracnose and stem-end rot	
Schmidt	70-81 (R.T.)	72	10	9-12	50	50	Wrinkling of skin and anthracnose
	51-54 (R.T.)	94					
	7 days		10	14-19	30	10	Wrinkling of skin, anthracnose, darkening of skin, and stem-end rot
	14 days		10	18-21	90	30	Darkening of skin, anthracnose, and wrinkling of skin
	21 days		10	24-26	80	90	Darkening of skin, anthracnose
	28 days		10	31-32	100	0	Darkening of skin, anthracnose, stem-end rot, and pitting of skin
	46-49 (R.T.)	97					
	7 days		10	14-23	70	10	Wrinkling of skin, darkening of skin, and anthracnose
	14 days		10	19-21	100	30	Darkening of skin and anthracnose
	21 days		10	25-26	80	50	Darkening of skin and wrinkling of skin
	28 days		10	32-33	100	10	Darkening of skin, anthracnose, and pitting of skin
	44-57 (R.T.)	88					
7 days		10	16-18	60	10	Darkening of skin, anthracnose, and wrinkling of skin	
14 days		10	19-20	100	20	Darkening of skin and anthracnose	
21 days		10	25-26	100	20	Darkening of skin, anthracnose, pitting of skin, wrinkling of skin	

It can be seen from the data in the accompanying table that refrigerated storage for one to two weeks at any of these temperatures did not detract materially from the external appearance of the ripened fruit.

The results of this study indicate that Booth 8 avocados can be successfully stored for approximately two weeks at any of these temperatures without detracting from their external or internal appearance. Refrigeration for two weeks delayed the ripening of this variety approximately nine days.

## Lula

The data in Table 1 show that the Lula avocado is not subject to internal browning at any of the storage temperatures investigated as none was observed after seven, fourteen, twenty-one, or twenty-eight days storage.

Prolonging the period of storage beyond one week at these temperatures, however, detracted from the external appearance of this fruit. It will be noted from the data in Table 1 that darkening of the skin, anthracnose, and pitting of the skin were the chief factors contributing to this decrease in percentage of marketable fruit.

From these data it would appear that refrigeration for one week can be recommended for this variety of avocado but caution is advised if a longer period of refrigerated storage is used due to the concomitant increase in skin blemishes and anthracnose.

### ***Waldin***

The Waldin variety of avocado is highly susceptible to internal browning as it was observed in twenty percent of the check lot which was never refrigerated. From ninety to one hundred percent of all the refrigerated Waldin avocados showed internal browning upon examination when ripe. These data are summarized in Table 1.

A very small percentage of these fruit retained a marketable external appearance until ripe. Factors contributing to their unmarketable appearance included darkening of the skin, pitting of the skin, anthracnose, and stem-end rot.

It is evident from these results that refrigeration for even one week at any of the storage temperatures used can not be recommended for the Waldin avocado.

### ***Trapp***

This variety like the Waldin is apparently highly susceptible to internal browning. The data in Table 1 show that eighty percent of the fruits of the check lot stored at room temperature developed internal browning. Refrigeration at any of the temperatures tested increased still further the incidence of this breakdown.

It can be seen from the data in the accompanying table that refrigeration at any of the temperatures tested for even seven days decreased materially the percentage of fruit which had a marketable external appearance when ripe.

These results indicate that refrigeration at any of the temperatures studied should not be used for the storage of Trapp avocados.

### ***Taylor***

The data in Table 1 indicate that the Taylor avocado can be held under refrigeration for approximately fourteen days at 46-50 degrees F. or for seven days at 40-43 degrees F. without the occurrence of internal browning. Extending the period of refrigeration beyond fourteen days materially increased the percentage of fruit showing internal browning when ripe.

It was observed that refrigeration for as long as fourteen days did not result in a decrease in the percentage of fruit which retained a marketable external appearance when ripe.

In view of the above and the fact that refrigeration for seven to fourteen days decreased the rate of ripening by approximately eight to twelve days, it would seem that refrigeration for one or two weeks at either of the temperatures tested might be recommended for this variety.

### ***Nabal***

No internal browning was observed in the check lot of fruit stored at room temperature until ripe. Refrigerated storage for one week at 51-54 degrees, 47-48 degrees, or 44-53 degrees F. resulted in the development of internal browning in ten to twenty percent of the fruit as shown in the accompanying table. Extending the period of refrigeration beyond one week resulted in a considerable increase in the incidence of internal browning.

More fruit retained an external marketable appearance until ripe when stored for two weeks at 51-54 degrees, 47-48 degrees, or 44-53 degrees F. than when stored at room temperature. Refrigerated storage for three weeks at any of the temperatures caused a decrease in the percentage of fruit that remained marketable in appearance until ripe. It will be seen from the data in Table 1 that these fruit varied considerably in their maturity at the time of harvest as evidenced by the rather wide variation in their rate of ripening and the occurrence of wrinkling of the skin prior to ripening.

These data indicate that approximately one week of refrigeration might be recommended for the Nabal avocado.

### ***Linda***

It was found that twenty percent of the check lot of Linda avocados stored at room temperature developed internal browning. Refrigeration for one week at 44-63 degrees, 47-48 degrees, or 51-54 degrees F. increased the incidence of this discoloration to from forty to ninety percent.

In most instances, higher percentages of fruit retained their marketable external appearance until ripe when refrigerated for from one to two weeks than when stored at room temperature.

In spite of the effect of refrigeration upon prolonging the external marketable appearance of the fruit and delaying their ripening, refrigeration for even one week cannot be recommended for the Linda avocado due to the accompanying increase in internal browning.

### ***Schmidt***

Fifty percent of the check lot of Schmidt avocados which were stored at room temperature developed internal browning. Storage for one week at 44-57 degrees and at 46-49 degrees F. increased the incidence of internal browning to sixty and seventy percent respectively; whereas, storage for one week at 51-54 degrees F. decreased its incidence. Refrigeration for two weeks at the temperatures studied increased the percentage of internal browning to from 90 to 100 percent. These data are summarized in Table 1.

With the exception of those fruit stored for three weeks at 51-54 degrees F., refrigerated storage did not increase the percentage of fruit which retained a marketable external appearance until ripe.

Based on these data, refrigerated storage cannot be recommended for Schmidt avocados.

## **DISCUSSION**

Examination of avocados ripened at room temperature, following refrigeration for from one to four weeks at temperatures ranging from 40-57 degrees F., showed that Florida grown varieties of avocados differ widely in their tolerance to refrigerated storage. Of the varieties studied, the Lula was found least subject to internal browning as none was observed in the ripened fruit following four weeks storage at the temperatures tested. In contrast, internal browning was found to increase by 20 to 70 percent in the case of the Linda and by 80 percent in the case of the Waldin avocados after refrigerated storage for one week. Ripened fruit of the Trapp and Nabal varieties also showed some increase in internal browning following one week of refrigeration. It was found that the Booth 7, Booth 8, and Taylor avocados could be stored for from one to two weeks at the temperatures tested without material development of internal browning. The tendency for internal browning to increase with the extension of the period of refrigerated storage may be attributed at least in part to a gradual ripening of these fruit during the period of refrigeration. Wardlaw (6) found that avocados were apparently most subject to chilling during the initiation of the ripening processes. These results indicate that if avocados are to be refrigerated, they should be placed in storage as rapidly as possible after harvesting to minimize the danger of internal browning.

The development of internal browning in the check lots of several varieties stored at room temperature is interesting but as yet the factors responsible for its development are not clearly understood. Field observations made on Booth 7 "drops" following the November 29, 1950 freeze supports the suggestion offered by Home (2) that internal browning may sometimes be caused by chilling prior to harvesting. Chilling in the field may offer a possible explanation for its development in the Linda and Schmidt varieties since the temperature fell to 50 degrees F. or below on several occasions during the two month period prior to their harvest. To attribute the darkening in the Trapp and Waldin check lots to this factor hardly seems justified since the average daily temperature during the two months period prior to their harvest was 83 degrees F.

Wardlaw (6) and others have reported that "chilling" may be manifested as a necrotic browning of the skin in certain varieties of avocados. Some of the darkening of the skin that is recorded in Table 1 might therefore be attributed to refrigeration but other factors must also contribute to its development as pitting followed by darkening of the skin was observed in fruits of some varieties stored throughout the investigation at room temperature.

## **SUMMARY**

This investigation was undertaken to determine the effect of refrigerated storage upon some Florida-grown avocados. The results of this study indicate that Waldin, Trapp, Linda, and Schmidt varieties are not well adapted to refrigerated storage; whereas, Booth 7, Lula, and Nabal varieties can be satisfactorily refrigerated for one week and

Booth 8 and

Taylor varieties for two weeks under the storage conditions investigated.

## REFERENCES

1. Higgins, J. E. and others. The avocado in Hawaii. Hawaii Agri. Expt. Sta. Bull. 25. 1911.
2. Horne, W. T. Avocado diseases in California. Cal. Agr. Expt. Sta. Bull. 585. 1934.
3. Joachim, A. W. E. and Parsons, T. H. A note on some preliminary cold storage investigations relating to Ceylon fruits. pp. 353-358. Trop. Agr. (Ceylon) 96. 1941.
4. Lynch, S. J. and Stahl, A. L. Studies in the cold storage of avocados, pp. 79-81. Fla. State Hort. Soc. Proc. 1939.
5. Overholser, E. L. Cold storage behavior of avocados, op. 32-40. Cal. Avocado Assoc. Ann. Rep. 1924-1925.
6. Wardlaw, C. W. and Leonard, E. W. The storage of avocado pears. Low Temperature Research Station Report 1. 1935.
7. Wardlaw, C. W. Tropical fruits and vegetables: An account of their storage and transport. Low Temperature Research Station Memoir 7. 1937.
8. Wardlaw, C. W. Storage investigation with Trinidad avocados. pp. 28-30. Trop. Agr. (Trinidad) 16(2). 1939.
9. Wilcox, E. V. and Hunn, C. J. Cold storage for tropical fruits. Hawaii Agr. Expt. Sta. Press Bull. 47. 1914.