RIPENING AND STORAGE of FLORIDA AVOCADOS

Marketing Research Report No. 697

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

PREFACE

This report is part of a continuing program to reduce marketing losses and to extend the marketing season of agricultural products. Information in this report is intended as a guide only; it should not be construed to apply to all avocados under all conditions.

Acknowledgment is made to the staff members of the University of Florida Sub-Tropical Experiment Station for technical assistance; and to various growers and shippers for supplying test fruit.

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Washington, D. C. Issued August 1965

RIPENING AND STORAGE OF FLORIDA AVOCADOS

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SUMMARY

The best ripening temperature for Florida avocados was 60° F., but temperatures ranging from 55° to 75° were usually satisfactory. At 60° individual fruit softened over a long span of time; whereas, at higher temperatures fruit softened more concurrently. West Indian avocados, such as Fuchs, Pollock, and Waldin, eventually suffered chilling injury at 55°. Ripening avocados at temperatures of 80° and above frequently resulted in off-flavor, skin discoloration, uneven ripening, and decay.

The optimum storage temperature was 40° F. for cold-tolerant avocados, such as Booth 1, Booth 8, Lula, and Taylor. Many cold-tolerant avocados stored for over a month at this temperature were still in excellent condition after ripening at 70°.

The optimum temperature for cold-intolerant avocados was usually 55° F., but in some cases it was 50°. Cold-intolerant avocados include West Indian varieties, such as Fuchs, Pollock, and Waldin. The Booth 7 avocado, which is a "hybrid" variety, was intermediate in cold tolerance. Booth 7 avocados stored well up to 2 weeks at either 40° or 45° but not for longer periods.

Wide variations in the extent of chilling injury occurred in avocados of the same variety stored at identical temperatures and lengths of time. The causes of this variation are not known.

Precooling delayed the ripening of avocados and thus extended the market life; this indicated that the removal of field heat immediately after harvest is advantageous.

The percentage weight loss of avocados varied directly with ripening temperature and length of storage period.

INTRODUCTION

The primary objectives of this investigation were to obtain additional information on the behavior of Florida avocados during ripening and storage and to more clearly define the effects of temperature and duration of storage on several Florida-grown varieties.

Over 40 varieties of avocados, *Persea americana* Miller, are grown commercially in Florida. They comprise three general groups: varieties of the West Indian race; varieties of the Guatemalan race; and "hybrid" varieties which are mostly crosses of West Indian and Guatemalan *(7)*.[2] West Indian avocados, which are native to the tropical American lowlands, are grown commercially in the continental United States only in southern Florida. They mature during the summer and early fall. "Hybrid" varieties, many of unknown parentage, constitute nearly 90 percent of the Florida crop; they mature during the fall and winter. The Guatemalan varieties also mature during fall and winter months, especially the latter; however, these varieties account for only a small part of the total crop. These studies were limited to the few varieties representative of each group, or race, that make up most of the commercial crop in the State.

The commercial shipping season for Florida avocados covers a span of approximately 8 months, beginning in June and ending in February. The heaviest volume of shipments is usually from September through January. During the 1963–64 season over a half million bushels of Florida avocados were shipped.[3]

Avocados are consumed only when ripened to the soft state, but they are picked and shipped when the fruit is mature but still firm. Avocados may be in transit 1 or 2 days to 2 or 3 weeks before reaching the consumer. For distant markets refrigeration is necessary to delay ripening; this is especially important during warm weather. After the fruit reaches the markets, handlers and distributors of avocados often extend the market life by further refrigeration. Proper storage and ripening procedures are necessary to assure the consumer high-quality avocados.

Reports dating from the early 20th century showed avocados being successfully shipped from the Antilles to Paris *(5)* and from Hawaii to New York *(3)*. Immediate refrigeration after harvest, not below 40° F., was emphasized for Hawaiian avocados in 1911 *(9)*. Conversely, in 1914 Hawaiian avocados were reported to be adapted to storage for at least 2 months at temperatures ranging from 32° to 36° *(24)*. In 1915, Condit reported that the length of time California avocados kept varied with the different varieties *(4)*. Overholser *(15, 16)* determined the best storage temperature for most California avocado varieties was 40° but that 45° was best for the Fuerte variety. West Indian type avocados were investigated in Trinidad by Ward-

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[2] Italic numbers in parentheses refer to Literature Cited, p. 9.

[3] Since the 1954-55 season, the Avocado Administrative Committee, Homestead, Fla., has published annually the volume of commercial shipments, according to variety.

law in 1933 *(20)* and by Wardlaw and Leonard in 1934 *(22)*. They reported that only a few tolerated a temperature of 40° for 20 to 25 days without sustaining low-temperature injury and that higher temperatures resulted in fruit softening during storage. These results were subsequently confirmed in Jamaica *(19)*. Joachim and Parsons *(10)*, in 1941 in Ceylon, reported that, for one variety of avocado, the optimum storage temperature was 40° and the commercial storage life was 2 to 3 weeks.

Lyle *(11)* reported his storage work at the University of Florida in 1933 on three Florida-grown varieties. He concluded that Trapp and Taylor avocadoes could be successfully stored at 48° and 42° F., respectively, while the Winslowson avocado was sensitive to temperatures below 54°. Storage work on seven varieties during the 1938–39 season by Lynch and Stahl *(12)* indicated that different Florida avocados require different storage temperatures for optimum results. In 1948, Mustard and Stahl *(14)*, working primarily on wrapping materials, observed no skin browning on Waldin and Trapp avocados after 16 days at 45° but that browning occurred after transfer of the fruit to room temperature. In 1952, Mustard *(13)* reported wide differences in tolerance of several Florida-grown varieties of avocados to refrigerated storage.

In 1959, Pennock reported from Puerto Rico on a method of obtaining a refrigeration tolerance index for avocados. The resulting indices reflected marked clonal differences and suggested fairly consistent performance within the clone *(17)*. The latest and most comprehensive bulletin describing Florida avocados and the Florida avocado industry, in general, was by Ruehle in 1963 *(18)*.

MATERIALS AND METHODS

Storage and ripening studies of avocados were conducted during a 7-year period—from the 1957–58 crop year through the 1963–64 crop year. Over 7,000 individual fruits from more than 30 groves were tested (table 1).

TABLE 1.—*Number of fruit, groves, tests, and crop years involved in Florida avocado ripening and storage studies*

Variety	Total fruit	Groves[1]	Tests	Crop years
	Number	*Number*	*Number*	*Number*
Booth 1	505	5	5	4
Booth 7	467	4	6	4
Booth 8	1,495	9	14	7
Fuchs	434	3	5	4
Lula	1,654	8	17	7
Pollock	479	5	8	4
Taylor	637	3	4	3
Waldin	1,102	3	11	6
Other varieties[2]	903	7	13	4

[1] In some cases different varieties were from the same grove.

[2] 9 varieties (Booth 3, Collinson, Herman, Hickson, Ruehle, Simmonds, Simpson, Tonnage, and Winslowson) were tested 1 to 3 times.

Most avocados were harvested from groves in Dade County. A few Taylor avocados were obtained from groves in Palm Beach and Highlands Counties; some Lula and Tonnage avocados were from Highlands County.

An average of eight tests per variety was made of eight avocado varieties. These varieties represented over 75 percent of the total Florida production. Lula and Booth 8 avocados, the two most important varieties grown in Florida, represent approximately 50 percent of the total Florida crop.

Fruit was picked at a mature stage; this complied with the legal shipping schedules specified in the Florida Avocado Marketing Agreement.[4] It was transported in field crates to the U. S. Department of Agriculture laboratory at Miami, weighed, and placed in wooden flats in the various temperature chambers. Most avocados were placed at desired test temperatures within 4 hours after picking. Care was taken to select fruit with a minimum of skin blemishing. Fruit was usually selected with a short portion of stem attached, to minimize the entrance of decay organisms.

The number of avocados per test varied. During preliminary tests in 1957–58 and 1958–59, as many as 60 avocados were tested at each temperature. After tolerance levels of temperature and duration became better established, the number of avocados were reduced to as few as 10 at each temperature.

Temperatures of 35°, 40°, 45°, 50°, 55°, 60°, 70°, and 80° F. were used in most tests; in addition, temperatures of 65°, 75°, 85°, and 90° were used in a few tests. Temperatures were arbitrarily tabulated into two classes—ripening temperatures and storage temperatures. The basis for this classification is related to the softening characteristics of avocados. Temperatures of 55° and higher were considered as ripening temperatures. Avocados were allowed to soften at these temperatures. Temperatures of 50° and lower were considered as storage temperatures. All avocados at 50° or lower, except for a few that softened during the storage period, were periodically transferred from these temperatures and allowed to soften at 70°. Fruit was considered ripe when it attained uniform edibility and softness as indicated by slight finger pressure. Relative humidity in the chambers ranged from 70 to 95 percent, but usually it was above 85 percent.

In this publication "ripening" refers to the process by which a firm mature avocado when held under suitable conditions becomes soft and edible. The terms "ripen" and "soften" are considered as being synonymous. A mature avocado is a fruit that has attained such a stage of development on the tree that it will ripen or soften with acceptable eating quality after picking.

[4] Commercial shipping schedules have been published annually by the Avocado Administrative Committee, Homestead, Fla., since the 1954–55 season.

Individual avocados were checked daily and removed from the ripening room as soon as they became soft. Soft fruits were examined for external condition, including general appearance and presence and extent of decay, and chilling injury. The number of days required to soften was recorded. Some avocados were weighed when soft for weight loss determinations.

Next, fruits were cut in half longitudinally and examined and rated for quality factors, which included presence and extent of decay and chilling injury,[5] appearanee, and palatability. Chilling injury ratings were based on percentage of surface affeeted (appendix table 5). Appearance ratings were based on internal and external defects, including general appearance, decay and chilling injury (appendix tables 4 and 5). Palatability was evaluated and classified on the merits of individual fruits (appendix tables 4 and 5). Avocados classified unacceptable in appearance often had severe chilling injury or decay and were not tested for palatability but were given a rating of unpalatable.

The term "optimum storage temperature" as used in this publication refers to that temperature that resulted in the best quality, appearance, and extended marketable shelf life for any given variety of avocado after removal from storage. "Prolonged storage" refers to extended storage, usually beyond 3 weeks.

[5] Chilling injury is described on p. 4.

RESULTS AND DISCUSSION

Ripening

Ripening studies are summarized in appendix table 4.

The best ripening temperature for all varieties of avocados was 60° F.; fruit softened at this temperature was excellent in appearance and palatability and free of decay and discoloration.[6] At 60° individual avocados softened over a longer span of time than at higher temperatures (table 2). The rate of softening was slower at 60° than at higher temperatures, which made it easier to select fruit at a precise state of softness; thus, overripe fruit with related deeay was avoided.

TABLE 2.—*Rate of softening of Pollock avocados at 60°, 70°, and 80° F., 1958*

[Values are not cumulative]

Ripening temperatures (° F.)	Days to soften—					
	3	4	5	6	7	8
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
60	0	6	19	19	25	31
70	19	44	31	6	0	0
80	50	50	0	0	0	0

A ripening temperature of 70° F. was very good, although not quite so satisfactory as 60° so far as general appearanee of the fruit was eoncerned. No difference was deteeted in flavor or extent of decay between fruit ripened at 60° and 70°. The approximate temperature of 70° prevailing in retail markets could be considered as a satisfaetory ripening temperature.

Limited ripening data indicated that temperatures of 65° and 75° F. were also very good. Ripening temperatures of 80° and higher were frequently questionable or unsatisfactory. Avocados ripened at 80° were usually aeceptable, but they were generally poorer in appearance and flavor than those softened at lower temperatures. At 80° rapid and occasionally uneven softening occurred, some decay and discolorations appeared, some individual fruits were unpalatable because of off-flavors, and shriveling was occasionally present. The discolorations at 80° were manifested as small brown spots on the skin and darkening of the flesh. At 85° and 90° most of the characteristics found at 80° became more apparent and accentuated. In addition, at 90° a scaldlike discoloration of the skin oceurred, the flesh was rubbery, and fruit was mostly unacceptable in quality. A common peculiarity of ripening avocados at 85° and 90° was the delay of softening; sometimes avocados required longer to soften at 85° and 90° than at 80° or lower.

Avoeados will eventually soften at 55° F.; for this reason it was classified as a ripening temperature. This temperature may also be considered as a storage temperature, since softening can be considerably delayed; thus, the market life is extended. For ripening, this temperature was good for some varieties, but not so satisfactory for general appearance as 60° to 70°. For West Indian avocados, such as Fuchs, Pollock, and Waldin, extended exposure at 55° for 2 to 3 weeks often resulted in chilling injury, yet for shorter storage periods 55° was the optimum temperature for these varieties (appendix table 4).

Considerable differences were apparent in the rates of softening of different varieties at any specific ripening temperature; this was primarily caused by differences in maturity of the fruit. Generally, for any given variety, the more mature the fruit, the fewer days required for softening *(6)*.

Storage

Storage studies are summarized in appendix table 5.

Since decay and chilling injury were primary factors restricting the length of time avocados were kept at the various storage temperatures, descriptions of the two are given.

[6] Decay is described on p. 4.

Description of Storage Decay

The most prevalent storage decay observed was anthracnose, *Colletotrichum glocosporioides* Penz., which usually enters the fruit as a secondary organism after *Cercospera* spot or avocado scab. An occasional stem-end decay may be attributed to *Diplodia natalensis* Pole-Evans or to *Diaporthe citri* Wolf. For storage, especially for prolonged periods, the selection of fruit free of decay and blemishes is of utmost importance. A direct relationship exists between absence of decay in fruit and successful storage. The susceptibility of different avocado varieties to anthracnose and other diseases should be considered when contemplating storage.

Description of Chilling Injury

Chilling injury in avocados is characterized by several symptoms that may occur in combination or singly in various ways in different varieties. The most common symptom is a grayish-brown discoloration of the flesh, especially in the vascular tissue (pl. 1). The extent of discoloration may vary from trace areas in the flesh that are inconspicuous to severe cases where all the flesh is discolored. In severe cases, abnormal ripening, development of undesirable flavors and odors, pitting, and a scald-like browning or darkening of the skin commonly occur. Sometimes fruit may appear satisfactory while in storage but display chilling injury when allowed to soften at higher temperatures. Chilling injury of avocados has previously been variously described *(2, 8, 11, 12, 13, 14, 15, 17, 20)*.

General Storage Behavior

West Indian avocados as a group were susceptible to chilling injury even at the relatively high storage temperature of 55° F. The rapid softening characteristics of West Indian avocados and the susceptibility of fruit of this group to chilling injury during extended storage at 55° indicate little advantage of 55° over 50°. West Indian avocados are produced primarily during the warm summer months in Florida and are often shipped in mixed loads with mangos and limes, which are frequently transported at temperatures between 50° and 55°. Hybrid avocados varied greatly in their storage behavior; some were susceptible to cold injury and some were tolerant. The only Guatemalan variety included in these studies, Taylor, was cold-tolerant. However, Wardlaw *(21)* stated that, contrary to expectations, a pure Guatemalan type grown in Trinidad was found to be very susceptible to chilling injury in storage. These studies confirm previous reports that different varieties or selections had various optimum storage temperatures *(12, 15, 20)*. The poor shipping characteristics of West Indian avocados, due to their susceptibility to chilling injury, has also been reported from Trinidad *(22)* and Jamaica *(19)*.

For prolonged storage, 40° F. was optimum for cold-tolerant varieties such as Lulu and Taylor. Although prolonged storage was usually not possible for cold-intolerant varieties such as Fuchs, Pollock, and Waldin, they could be stored for a limited time at 55° (appendix table 4). For limited storage, all varieties responded well to temperatures of 55° and 50°. The most serious deterrents to extending the storage of avocados were chilling injury and decay. Although relatively low storage temperatures such as 35° and 40° usually inhibited the development of decay, chilling injury became the limiting factor, especially at 35°. Less chilling injury occurred at temperatures of 45° and 50°, but softening and the development of decay were accelerated. As long as fruit was firm decay was somewhat inhibited, but during the softening process decay usually developed rapidly.

Wide variation in extent of chilling injury frequently occurred in avocados of the same variety stored at identical temperatures and for the same length of time, especially in prolonged storage. Such variation, evident during the entire range of time in storage, is illustrated by the diverse descriptions in appendix table 5. Avocados from the same source were more likely to be similar in storage behavior than avocados from different sources. Also avocados from the same source were more similar in storage behavior during any given season than from one season to the next *(2)*. For example, Booth 8 avocados stored for 18 days at 40° F. during the 1963 crop year displayed no chilling injury, whereas comparable fruit tested in the 1962 crop year displayed slight chilling injury after similar storage. Environmental factors, such as precipitation, cultivation, fertilization, and crop year, are only a few of many conditions possibly contributing to variation in storage behavior of avocados. Wardlaw *(21)* reported that a variety that had previously been selected for its cold resistance in storage was observed during a wet year to be characterized by excessive wateriness and susceptibility to chilling injury. This indicates the importance of soil and climatic factors in this physiological relationship. Wardlaw and Leonard *(22)* reported that avocados were subject to chilling injury during the climacteric stage of the ripening process. This would suggest that, if avocados are to be refrigerated, they should be placed in storage as rapidly as possible after harvest to avoid chilling injury.

Storage beyond 2 weeks at 55° F., especially until all fruits became soft, was an adaptable method for establishing the cold-tolerance of avocado varieties. Prolonged storage at 40° was also found to be adaptable for establishing cold-tolerance, which confirms Pennock's suggestion *(17)*. He suggested a storage temperature of 40° as sufficiently low to establish differences in cold-tolerance for commercial varieties. Possibly the simultaneous use of 40° and 55° to establish cold-tolerance of avocado varieties would give faster and more precise results. Of primary importance, how-

ever, is the need of further research to determine those factors responsible for extremes of variation in storage behavior.

At storage temperatures, the ripening processes slowly continued; and at temperatures of 45° F. and higher, some fruit ultimately softened. Generally, the longer the storage period or the higher the storage temperature or both, the shorter the time required for ripening after removal from storage. Some exceptions occurred, especially in prolonged storage at 35° and 40°, when apparently the fruit was injured and the fruit required a longer time to soften than those stored for a shorter period. Biale (*1*) stated that the longer avocados are kept in storage the higher the respiration value when taken out; as a result the fruit becomes soft sooner after prolonged storage than otherwise.

Few changes in palatability occurred during storage, and those that occurred were usually directly related to the extent of decay or chilling injury. Occasionally a bitter flavor was detected in avocados having chilling injury. Avocados classified unacceptable in appearance often had severe chilling injury or decay and were not tested for palatability but were given a rating of unpalatable.

Precooling

Removal of field heat from avocados as soon as possible after harvest appears to be important in extending market life. Removal of field heat is especially advantageous during the summer and early fall when temperatures are high. Precooling before holding at 70° F. delayed the softening of avocados (table 3).

TABLE 3.—*Softening rate of precooled Lula avocados, 1958*

[Values are not cumulative]

Cooling conditions (° F.) [1]	Days from harvest until fruit was soft-ripe—					
	4	5	6	7	8	9
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
70 (no cooling)	10	55	30	5	0	0
50 for 24 hours	0	35	45	10	10	0
50 for 72 hours	0	0	0	10	70	20
35 for 24 hours	0	0	26	58	16	0
35 for 72 hours	0	0	0	0	50	50

[1] After cooling avocados were ripened at 70° F.

As mentioned previously, in general, the more mature the fruit, the fewer days are required for softening. Avocados in an advanced stage of maturity can be safely stored and early softening avoided provided fruit temperature is lowered immediately after harvest and low temperature is maintained until the fruit is ready for softening. Precooling at 35° F. for 72 hours did not cause chilling injury to cold-tolerant avocados; however, occasionally the skin had a dull appearance. The desirability of rapid cooling confirms previous work by Overholser in California, who emphasized that any delay in placing fruit in storage shortened the storage life of the fruit (*15*).

Loss in Weight During Ripening and Storage

Weight-loss data are presented to give an approximation of expected loss in fruit weight under various storage and ripening conditions (appendix tables 4 and 5). Percentage weight loss was often variable between tests, but generally the higher the ripening temperature, the greater was the weight loss (appendix table 4). Factors other than temperature, such as duration of exposure at each temperature, relative humidity, and presence of decay, affected weight loss. In 1934, Wardlaw (*20*) showed the effect of temperature, humidity, and number of days stored on the percentage weight loss of avocados. He reported a loss of about 4 percent after 20 days at 40° F., about 5 percent after 18 days at 53°, and about 7 percent after 10 days at 70°.

Wells (*23*) found that Hass avocados in California held at 45° F. lost from 120 mg. per 100 grams per day (0.12 percent) at 95 percent relative humidity to 280 mg. per 100 grams per day (0.28 percent) at 78 percent relative humidity. He also found that loss of weight varied inversely with the size of the fruit. Other studies have confirmed this relationship (*7*).

Varietal Ripening and Storage Behavior

The responses of avocados to ripening temperatures were considerably more consistent than responses to storage temperatures. Chilling injury never occurred at temperatures of 60° F. and higher. Decay was infrequent at temperatures from 60° through 75°, provided fruit did not become overripe.

For prolonged storage, 40° F. was the optimum temperature for cold-tolerant avocados, such as Booth 1, Booth 8, Lula, and Taylor. These varieties could also be stored at 45°, 50°, or 55°; however, early softening of the fruit usually precluded prolonged storage.

For limited storage, 55° F. was the optimum temperature for cold-intolerant avocados, such as Fuchs, Pollock, and Waldin. These varieties were not adaptable to prolonged storage at any temperature, primarily because of the rapid development of chilling injury at temperatures below 50° and the softening of the fruit as well as chilling injury at 50° and 55°.

Booth 7 avocados were intermediate in cold tolerance. Equally good results were obtained when the fruits were stored at 40° and 45° F. for about 14 days.

Booth 1 (Hybrid)

At 40° F., some lots of fruit were in excellent condition after 35 days in storage; however, a few

lots displayed chilling injury, especially darkening of the skin, after 25 days.

Fruit stored at 50° F. began to soften after 12 days, but the softening time averaged 14 days. After 18 days at 55° all fruit became soft (appendix table 4), decay became prevalent, and little or no subsequent market life remained.

Fruit stored at 45° F. began to soften after 20 days. At 35°, fruit stored well for 14 days, but the skin possessed a dull appearance; beyond 14 days, chilling injury, especially darkening of the skin, frequently occurred.

Booth 7 (Hybrid)

At 40° and 45° F., Booth 7 avocados were in excellent condition after about 14 days' storage. Longer storage often resulted in chilling injury, especially browning of the flesh and some darkening of the skin; decay developed in fruits stored at 45° but not in those stored at 40°.

Because chilling injury was not observed in fruit softened at 55° F., this temperature was safer than 50°. Fruit stored at 50° began to soften at 14 days, although the average required 23 days. Fruit softened at 50° frequently incurred chilling injury. At 35°, chilling injury was observed in fruit after 8 days' storage. Fruit that displayed chilling injury after storage at 35°, 40°, and 45° often softened unevenly.

Booth 8 (Hybrid)

Some lots of fruit were in excellent condition after 40 days' storage at 40° F. However, a 24-day period was the usual limit for fruit to remain in excellent condition; thereafter chilling injury was often observed. Slight chilling injury was occasionally detected after 14 days at 40°.

Although little or no market life remained, Booth 8 avocados were sometimes in excellent condition after storage for as long as 30 days at 50° and 55° F. At 50° softening of the fruit began at 17 days, and slight chilling injury sometimes appeared after 20 days; no chilling injury occurred at 55°, and the fruit began to soften after 15 days.

Storage at 45° F. beyond 24 days frequently resulted in chilling injury. Softening of the fruit began at 23 days.

One lot of fruit was in good condition after storage for 35 days at 35° F. without exhibiting chilling injury; however, the dull appearance of the skin, usually manifested under these conditions, was present. Fruit stored well for 8 days at 35° without evidence of chilling injury.

Chilling injury was most frequently manifested as a browning or darkening of the skin. Of the varieties studied, Booth 8 avocados were the most variable in storage and ripening behavior.

Fuchs (West Indian)

At 55° F. Fuchs avocados usually stored well for 14 days before chilling injury was present; however, most of the fruit had softened before this time (appendix table 4).

Storage at 50° F. was sometimes excellent; however, slight chilling injury was occasionally observed after 4 days and severe chilling injury usually occurred after 11 days (appendix table 5). At 50°, most fruit became soft in storage after 9 to 11 days, and some began to soften as early as 5 days.

At 35°, 40°, and 45° F., chilling injury developed after 2 or 3 days.

Fruit softened rapidly at ripening temperatures, especially after being held in storage for a few days (appendix tables 4 and 5).

Lula (Hybrid)

Lula, the leading variety produced in Florida, possessed better storage characteristics than any other variety studied. At 40° F., some lots of fruit were stored for 60 days in good condition without internal chilling injury; such extended storage, however, usually resulted in some skin discoloration and little or no subsequent market life. Numerous lots of fruit were stored for 38 days in excellent condition; although after 21 days a slight discoloration of the skin was occasionally observed (appendix table 5).

Storage at 45° F. was not so satisfactory as at 40°, because of softening of the fruit and increased decay and skin discoloration. At 45°, softening of fruit began after 25 days. Individual fruits were stored in good condition for 42 days at 45°.

At 35°, Lula avocados were usually in excellent condition after 20 days, although after 14 days an occasional fruit had a dry and flaky flesh. This flaky condition was characterized by thin separated layers of flesh, which became more prevalent as storage time increased. Beyond 27 days' storage at 35°, fruit often softened unevenly after exposure to ripening temperatures.

Although little or no subsequent market life remained, Lula avocados were sometimes in excellent condition after storage for more than 30 days at 50° and 55° F.; but fruit began to soften after 12 days at 55° and after 17 days at 50°.

Accelerated ripening of fruit at temperatures of 80° F. and higher often resulted in brown spotting of the skin.

Pollock (West Indian)

At 55° F., Pollock avocados usually stored well for 18 days before chilling injury was present; early softening of the fruit, however, often occurred before 18 days (appendix table 4).

Pollock avocados stored at 50° F. were in excellent condition for 6 days (appendix table 5). Softening of the fruit began after 6 days, but the softening process required an average of 13 days. Chilling injury in this variety was previously reported after 13 days at 50° (*2*).

At 35° F., chilling injury usually developed after 5 days; at 40° and 45°, it usually developed after 6 days. Chilling injury was characterized by in-

ternal browning, graying of vascular tissue, and darkening of the skin (pl. 1).

Taylor (Guatemalan)

Individual fruits were in good condition after storage at 40° F. for 45 days; such extended storage, however, usually resulted in little or no subsequent market life for the fruit. Fruit stored for 31 days at this temperature was in excellent condition.

Storage at 45° F. was almost as satisfactory as 40° except that softening of fruit occurred and decay developed at 45° (appendix table 5). At 45°, softening of fruit began after 24 days. Fruit stored at 35° was in excellent condition for 13 days; however, beyond 13 days skin discolorations became apparent.

For limited storage, 50° and 55° F. were usually excellent temperatures but early softening was the primary limitation. For example, at 50° softening began after 9 days and the average fruit required 17 days to soften. Storage beyond 20 days at these temperatures resulted in decay and practically no subsequent market life for the fruit.

Ripening temperatures of 80° F. and higher often resulted in black spotting of the skin.

Waldin (West Indian)

At 50° F., softening of some fruit occurred as early as 13 days and some skin discoloration, especially browning of the skin, became apparent after 10 days. However, several lots of fruit stored at 50° F. remained in excellent condition for 15 days without chilling injury or softening of the fruit. Softening of the fruit occurred earlier and chilling injury was detected later at 55° than at 50° (appendix tables 4 and 5). The average time required for softening of Waldin avocados was 24 and 26 days at 55° and 50°, respectively; however, most fruit had internal as well as external chilling injury before this time.

At temperatures below 50° F., external chilling injury, which had a scaldlike appearance, usually developed within a few days.

Other Varieties

A few tests were made with nine other varieties. These varieties of avocados ripened best at 60° F., although temperatures from 55° to 75° were usually satisfactory; temperatures of 80° and higher usually resulted in fruit with poor or unsatisfactory quality. Chilling injury often developed in Ruehle and Simmonds avocados (West Indian) when allowed to soften at 55°; these varieties had little tolerance to temperatures below 50°. The remaining varieties were "hybrid" avocados, and their storage behavior varied from those having little tolerance to temperatures below 50° to those that were tolerant. Booth 3, Herman, and Simpson appeared to be cold-tolerant; whereas, Collinson, Hickson, and Winslowson appeared to be cold-intolerant. Tonnage avocados appeared to be intermediate in cold tolerance.

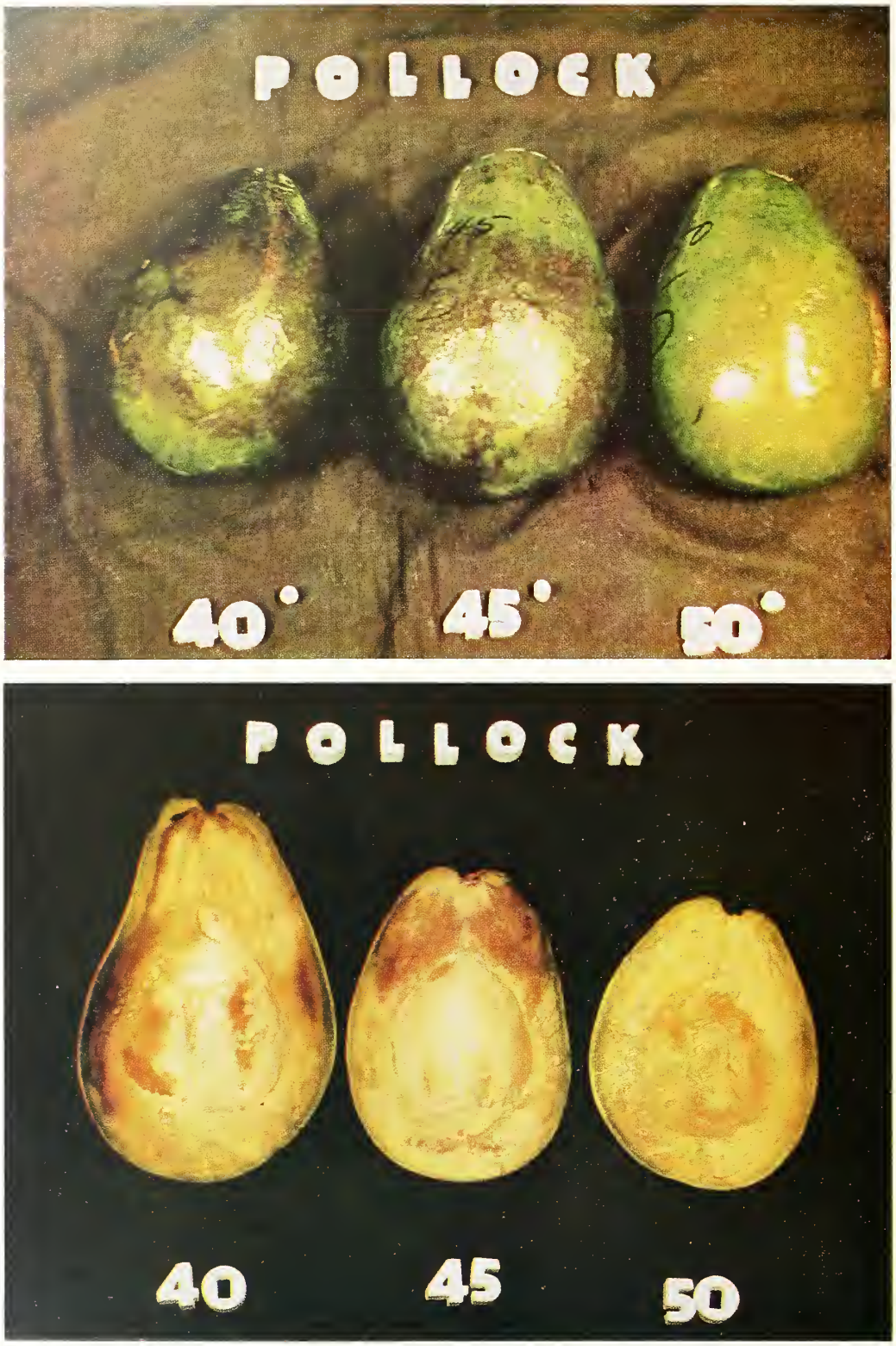

PLATE 1.—External and internal chilling injury of Pollock avocados stored at 40°, 45°, and 50° for 11 days and softened at 70° F.

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APPENDIX

TABLE 4.—*Time to soften, loss in weight, appearance, and palatability of some Florida avocados softened at various ripening temperatures, 1957–64*

Variety and parentage	Temperature	Time to soften		Loss in weight		Appearance [1]	Palatability [2]
		Average	Range	Average	Range		
	° F.	*Days*	*Days*	*Percent*	*Percent*		
Booth 1 (hybrid).	55	15	9 to 18	....	.....	Excellent to good.	Excellent.
	60	9	4 to 17	....	.....	Excellent.	Do.
	65	8	4 to 9	....	.....	Excellent to good	Do.
	70	5	4 to 7	6.8	3.2 to 11.9	do.	Do.
Booth 7 (hybrid).	55	17	11 to 21	4.3	3.8 to 4.9	do.	Do.
	60	14	9 to 19	6.3	4.5 to 7.8	Excellent.	Do.
	65	12	9 to 14	....	.....	Excellent to good.	Do.
	70	6	5 to 12	7.6	5.0 to 8.6	do.	Do.
Booth 8 (hybrid).	55	17	15 to 30	3.6	2.9 to 5.2	do.	Do.
	60	10	4 to 19	....	.....	Excellent.	Do.
	65	9	4 to 14	....	.....	Excellent to good.	Do.
	70	6	3 to 13	5.9	3.7 to 11.3	do.	Do.
	75	6	3 to 9	4.8	2.8 to 6.1	do.	Do.
	80	5	2 to 8	9.2	5.4 to 13.3	Good to poor.	Palatable.
	85	5	1 to 8	....	.....	Poor.	Palatable to unpalatable.
Fuchs (West Indian).	[3]55	7	4 to 14	5.7	4.0 to 7.9	Excellent to good.	Excellent.
	60	5	2 to 9	4.8	4.0 to 6.1	Excellent.	Do.
	65	4	2 to 7	....	.....	Excellent to good.	Do.
	70	3	1 to 5	6.1	4.7 to 11.0	do.	Do.
	80	2	1 to 3	7.0	5.7 to 8.2	Good to poor.	Palatable.
Lula (hybrid).	55	23	12 to 34	5.6	3.6 to 7.1	Excellent to good.	Excellent.
	60	10	7 to 25	4.9	2.4 to 7.8	Excellent.	Do.
	65	9	6 to 14	....	.....	Excellent to good.	Do.
	70	6	3 to 10	7.1	3.1 to 12.5	do.	Do.
	75	6	3 to 9	7.5	5.9 to 8.9	do.	Do.
	80	6	3 to 8	9.8	5.8 to 15.5	Good to poor.	Palatable.
	85	4	3 to 6	....	.....	Poor.	Palatable to unpalatable.
	90	6	4 to 8	13.9	8.8 to 17.7	Unacceptable.	Unpalatable.
Pollock (West Indian).	[3]55	11	4 to 26	4.3	2.9 to 7.2	Excellent to unacceptable.	Excellent to unpalatable.
	60	7	2 to 14	3.6	1.6 to 4.6	Excellent	Excellent.
	65	6	2 to 12	....	.....	Excellent to good.	Do.
	70	4	2 to 8	5.6	4.6 to 8.5	do.	Do.
	80	2	1 to 3	4.4	1.9 to 7.1	Good to poor.	Palatable.
Taylor (Guatemalan).	55	14	7 to 21	4.3	4.2 to 4.6	Excellent to good.	Excellent.
	60	8	6 to 15	5.4	4.3 to 6.1	Excellent.	Do.
	70	5	2 to 9	6.2	2.8 to 10.3	Excellent to good.	Do.
	80	4	2 to 6	....	.....	Good to poor.	Palatable.
	85	11	9 to 13	....	.....	Poor.	Palatable to unpalatable.
Waldin (West Indian).	[3]55	26	10 to 28	....	.....	Excellent to unacceptable.	Excellent to unpalatable.
	60	12	6 to 16	5.1	3.7 to 6.2	Excellent.	Excellent.
	65	11	5 to 14	....	.....	Excellent to good.	Do.
	70	6	3 to 10	6.9	4.2 to 13.8	do.	Do.
	75	5	3 to 8	....	.....	do.	Do.
	80	4	3 to 7	4.5	3.3 to 6.2	Good to poor.	Palatable.
	90	5	4 to 6	5.9	2.1 to 9.8	Poor to unacceptable.	Unpalatable.

[1] Excellent, fruit of high quality with no defects; good, fruit with minor defects that do not affect commercial quality; poor, fruit with sufficient defects to affect commercial quality; and unacceptable, fruit of no commercial value.

[2] Excellent, fruit of distinctly excellent flavor; palatable, fruit of satisfactory flavor and which meets consumer acceptance; unpalatable, fruit of unacceptable flavor.

[3] Chilling injury was detected at 55° F. only in Fuchs, Pollock, and Waldin avocados after 14, 18, and 23 days, respectively.

TABLE 5.—*Characteristics of some Florida avocados stored at various temperatures and ripened at 70° F., 1957–64*

Variety and parentage	Storage temperature	Time stored [1]	Time to soften at 70° F.		Total time to soften from harvest		Loss in weight		Appearance [2]	Chilling injury [3]	Palatability [4]
			Average	Range	Average	Range	Average	Range			
	° F.	*Days*	*Days*	*Days*	*Days*	*Days*	*Percent*	*Percent*			
Booth 1 (hybrid).	35	11	5	3 to 6	19	17 to 20	...	.....	Good	.....	Excellent.
		17 to 27	4	2 to 5	29	21 to 32	...	.....	Poor to unacceptable	None to severe	Palatable to unpalatable.
	40	14 to 25	4	2 to 7	20	16 to 30	...	.....	Excellent	.....	Excellent.
		26 to 35	4	3 to 5	35	29 to 40	...	.....	Excellent to unacceptable	None to severe	Excellent to unpalatable.
	45	[5]14 to 21	3	0 to 3	17	15 to 24	...	.....	Excellent	.....	Excellent.
		22 to 35	1	0 to 2	32	22 to 37	...	.....	Poor to unacceptable. Occasional decay and shrivel.	None to moderate	Excellent to unpalatable.
	50	[5]12 to 14	2	0 to 5	15	12 to 17	...	.....	Excellent	.....	Excellent.
		25 to 33	0	0 to 1	29	25 to 33	...	.....	Good to unacceptable. Occasional decay.	None to slight	Excellent to unpalatable.
Booth 7 (hybrid).	35	8 to 13	6	5 to 7	15	14 to 20	6.2	4.2 to 8.6	Good to poor	None to trace	Excellent.
		14 to 19	5	4 to 10	20	18 to 27	5.5	3.0 to 8.9	Poor to unacceptable	None to severe	Excellent to unpalatable.
	40	9 to 13	5	4 to 7	14	13 to 18	6.3	3.4 to 8.9	Excellent	.....	Excellent.
		14 to 18	4	3 to 6	18	17 to 24	5.8	3.6 to 9.0	Excellent to unacceptable. Slight skin discoloration.	None to severe	Excellent to unpalatable.
	45	9 to 14	4	2 to 5	16	13 to 18	5.0	2.9 to 7.2	Excellent	.....	Excellent.
		15 to 23	4	2 to 8	22	20 to 27	...	.....	Excellent to unacceptable. Occasional decay and slight skin discoloration.	None to severe	Excellent to unpalatable.
	50	[5] 9 to 14	3	0 to 4	15	14 to 17	4.9	1.6 to 7.4	Excellent	.....	Excellent.
		15 to 29	2	0 to 7	23	15 to 36	...	.....	Poor to unacceptable. Frequent decay.	None to severe	Palatable to unpalatable.
Booth 8 (hybrid).	35	3 to 8	4	3 to 6	10	7 to 14	...	.....	Excellent	.....	Excellent.
		9 to 14	4	3 to 9	16	12 to 21	5.4	2.2 to 9.1	Good to poor	None to slight	Excellent to palatable.
		15 to 35	4	3 to 7	29	18 to 40	4.5	2.4 to 7.0	Good to unacceptable	None to severe	Excellent to unpalatable.
	40	3 to 8	4	3 to 6	9	6 to 12	...	.....	Excellent	.....	Excellent.
		9 to 14	4	3 to 8	14	12 to 20	5.6	3.7 to 8.0	Excellent to good. Occasional slight skin discoloration.	.....	Do.
		15 to 24	4	2 to 9	22	17 to 29	4.9	2.2 to 7.5	Excellent to poor	None to slight	Excellent to palatable.
		25 to 40	4	3 to 13	33	29 to 43	...	.....	Excellent to unacceptable	None to severe	Excellent to unpalatable.
	45	3 to 14	3	1 to 7	14	6 to 19	6.1	4.2 to 8.7	Excellent	.....	Excellent.
		[5]15 to 24	3	0 to 5	21	16 to 28	5.2	2.5 to 8.1	Excellent to poor. Occasional decay.	.....	Excellent to palatable.
		25 to 35	3	2 to 7	31	27 to 40	...	.....	Excellent to unacceptable. Frequent decay.	None to moderate	Excellent to unpalatable.
	50	[5] 3 to 20	3	0 to 7	17	6 to 27	5.6	4.1 to 9.3	Excellent	.....	Excellent.
		21 to 31	1	0 to 4	25	22 to 32	3.2	2.1 to 5.3	Excellent to poor	None to slight	Excellent to palatable.
		32 to 38	1	0 to 3	37	32 to 39	...	.....	Poor to unacceptable. Frequent decay.	None to severe	Palatable to unpalatable.
Fuchs (West Indian).	35	1 to 2	3	2 to 5	5	3 to 7	...	.....	Good to poor. Slight skin discoloration.	.....	Excellent.
		3 to 8	3	2 to 5	8	5 to 12	7.5	5.4 to 8.9	Poor to unacceptable	Trace to severe	Palatable to unpalatable.
	40	1 to 2	3	1 to 4	4	2 to 6	...	.....	Good	.....	Excellent.
		[5] 3 to 9	3	0 to 4	9	7 to 13	6.7	4.8 to 8.0	Poor to unacceptable	None to severe	Palatable to unpalatable.
	45	1 to 3	2	1 to 2	5	2 to 5	...	.....	Good	.....	Excellent.
		[5] 5 to 11	2	0 to 4	10	5 to 14	7.2	1.5 to 11.4	Poor to unacceptable. Occasional shrivel.	None to severe	Palatable to unpalatable.
	50	1 to 3	1	1 to 2	4	2 to 5	...	.....	Excellent	.....	Excellent.
		[5] 4 to 11	1	0 to 2	7	4 to 13	5.2	1.0 to 9.6	Excellent to poor	None to slight	Excellent to palatable.
Lula (hybrid).	35	3 to 14	5	3 to 7	16	7 to 20	5.8	3.4 to 8.8	Excellent	.....	Excellent.
		15 to 20	6	2 to 7	21	17 to 25	...	.....	Excellent to good. Occasional flaky flesh texture.	.....	Excellent to palatable.
		21 to 27	5	3 to 7	29	24 to 31	...	.....	Excellent to poor. Flaky flesh texture; dull-colored skin.	.....	Do.
		31 to 41	6	3 to 8	43	34 to 49	...	.....	Excellent to unacceptable. Flaky flesh texture; dull-colored skin.	None to moderate	Excellent to unpalatable.
	40	3 to 20	4	2 to 6	16	7 to 25	5.5	1.4 to 7.2	Excellent	.....	Excellent.
		21 to 31	4	3 to 6	29	24 to 37	...	.....	Excellent to poor. Occasional slight skin discoloration.	.....	Do.
		32 to 38	4	2 to 5	35	36 to 41	...	.....	Excellent to poor. Occasional decay.	.....	Excellent to palatable.

	45	3 to 16	3	2 to 6	14	6 to 20	6.3	3.3 to 10.8	Excellent		Excellent.
		17 to 23	3	1 to 6	24	22 to 26	...	...	Excellent to good. Occasional slight skin discoloration.		Do.
		[5]24 to 28	4	0 to 5	28	25 to 32	...	...	Excellent to poor. Occasional decay and slight skin discoloration.		Excellent to palatable.
		31 to 42	4	0 to 6	41	33 to 47	...	...	Excellent to unacceptable. Frequent decay and moderate skin discoloration.		Excellent to unpalatable.
	50	3 to 15	3	1 to 5	14	7 to 18	4.9	3.1 to 10.3	Excellent		Excellent.
		[5]16 to 22	2	0 to 5	22	21 to 25	...	...	Excellent to poor. Occasional slight skin discoloration.		Do.
		24 to 33	2	0 to 6	27	24 to 35	...	...	Excellent to unacceptable. Occasional decay and slight skin discoloration.		Excellent to unpalatable.
Pollock (WestIndian).	35	3 to 5	5	3 to 7	9	7 to 12	...	...	Good to poor. Slight skin discoloration.		Excellent.
		6 to 11	4	2 to 8	10	8 to 17	4.4	2.2 to 5.7	Poor to unacceptable	Slight to severe	Palatable to unpalatable.
	40	3 to 6	3	1 to 4	8	4 to 10	4.0	1.4 to 5.8	Good		Excellent.
		7 to 11	4	4 to 8	14	11 to 17	...	...	Poor to unacceptable	Slight to moderate.	Palatable to unpalatable.
	45	3 to 6	2	1 to 3	8	4 to 9	4.5	3.1 to 5.5	Good		Excellent.
		[5] 7 to 16	3	0 to 5	17	13 to 19	...	...	Poor to unacceptable	Slight to moderate.	Palatable to unpalatable.
	50	[5] 3 to 6	2	0 to 3	5	6 to 9	5.1	1.3 to 7.3	Excellent		Excellent.
		10 to 14	2	0 to 5	15	10 to 19	5.1	2.4 to 7.8	Excellent to poor	None to slight	Palatable.
		15 to 25	1	0 to 7	18	15 to 26	...	...	Poor to unacceptable	Slight to severe	Palatable to unpalatable.
Taylor, (Guatemalan).	35	8 to 13	4	3 to 6	19	14 to 19	...	...	Excellent		Excellent.
		15 to 19	4	3 to 6	20	18 to 23	5.2	3.7 to 7.5	Good. Slight skin discoloration		Do.
		21 to 31	5	4 to 6	35	25 to 37	...	...	Good to poor. Moderate skin discoloration.		Excellent to palatable.
	40	13 to 19	3	2 to 4	18	17 to 23	4.5	2.2 to 7.1	Excellent		Excellent.
		21 to 31	4	3 to 6	36	25 to 37	...	...	..do		Excellent to palatable.
	45	13 to 15	2	1 to 5	16	15 to 20	4.2	1.9 to 6.1	..do		Excellent.
		[5]16 to 31	2	0 to 5	27	20 to 36	...	...	Excellent to good. Occasional decay.		Do.
	50	[5] 9 to 20	1	0 to 2	17	9 to 22	2.9	1.8 to 4.9	Excellent		Do.
Waldin (West Indian).	35	1 to 3	5	4 to 8	8	7 to 11	...	...	Good to poor. Skin discoloration		Excellent.
		4 to 7	6	4 to 9	12	8 to 16	6.5	5.6 to 8.0	Poor to unacceptable	Slight to severe	Palatable to unpalatable.
	40	3 to 5	6	4 to 8	9	8 to 11	...	...	Excellent to poor. Skin discoloration.		Excellent.
		6 to 8	5	2 to 7	12	9 to 15	5.7	4.9 to 7.1	Good to unacceptable	None to moderate	Excellent to palatable.
	45	3 to 7	4	3 to 6	9	7 to 11	...	...	Excellent to poor. Skin discoloration.		Excellent.
		8 to 12	4	3 to 5	12	11 to 16	5.7	4.8 to 6.8	Poor to unacceptable. Skin discoloration.	None to slight	Palatable to unpalatable.
	50	3 to 10	3	2 to 6	10	8 to 15	...	...	Excellent		Excellent.
		[5]11 to 15	3	0 to 6	17	13 to 19	...	...	Excellent to poor. Skin discoloration		Do.
		16 to 22	5	0 to 8	22	20 to 28	4.8	3.4 to 7.3	Poor to unacceptable	None to severe	Palatable to unpalatable.

[1] Number of days greater than those listed were not included because fruit was considered to be generally unacceptable. Omitted number of days were those not included in the tests.
[2] Excellent, fruit of high quality with no defects; good, fruit with minor defects that do not affect commercial quality; poor, fruit with sufficient defects to affect commercial quality; and unacceptable, fruit of no commercial value.
[3] Trace, barely perceptible; slight, up to 25 percent of fruit affected; moderate, 25 to 50 percent; severe, over 50 percent.
[4] Excellent, fruit of distinctly excellent flavor; palatable, fruit of satisfactory flavor and which meets consumer acceptance; unpalatable, fruit of unacceptable flavor.
[5] Ripening began.