Proc. of Second World Avocado Congress 1992 pp. 435-442

The Influence of Harvest Maturity, Type of Packing and Temperatures on Avocado Quality

L. Antonio Lizana, Mariano Salas, and Horst Berger
Centro Estudios Postcosecha, Univ. of Chile, Casilla 1004, Santiago, Chile

Abstract. **Fruit of avocado *(Persea americana* Mill.) cv. Fuerte were harvested at 3 different dates (August 17, September 8, October 13) and packed with and without Ethysorb^{R} during 3 periods of storage to determine the optimum harvest maturity rates for best fruit quality in postharvest. Fruits harvested with 14-16% oil content and 75% pulp moisture maintained commercial quality during storage for 28 days at temperature of 7C. The use of two temperatures for storage (7C and 2C) results in better storage quality than using only one (7C); however, once the pulp is exposed to air, it spoils faster than the one kept only at 7C. No significant differences were found in maturity rates between the fruit packed with and without Ethysorb.**

Proper harvest maturity and subsequent fruit handling constitutes essential operations to insure the best fruit quality when exporting avocados to distant markets. Since this fruit ripens after harvest, picking them at an immature physiological state of development may result in irregular ripening, off flavors and physiological disorders (Swarts, 1979; Vakis *et al.,* 1985; Zauberman *et al.,* 1977).

Due to the high cost of air freight, the ocean/ground transport seems more convenient, but there is an increased transit time that may also affect final fruit quality. Ethylene gas control becomes essential together with other fruit conditioning such as temperature, ventilation and type of packing (Berger *et al.,* 1978, 1982).

The objectives of this work were to determine the influence of different harvest maturities, different storage temperatures and ethylene absorbers on the postharvest quality of the fruit.

Materials and Methods

Avocado fruit cv. Fuerte were harvested at three different dates: August 17, September 8 and October 13 from an orchard located in Mallarauco near Santiago (33 °Lat, 71 ° Long.).

After harvest the fruit were immersed for 5 min in a fungicide solution: Benlate (50%) 600 ppm and Manzate (88%) 1800 ppm, and then packed in a single layer in standard perforated export cartons with and without Ethysorb", an ethylene absorber. Individual fruit were used as replicates. There were 6 replicates per treatment at each evaluation

period. The fruit were stored under two different regimes: 1) constant storage at 7C and 87% R.H. for 35 days; and 2) stored at 7C and 87% R.H. for 14 days and then transferred to 2C and 95% R.H. for the remaining 21 days (September 8 and October 13 harvests only).

Fruit were evaluated after 0, 14, 28 and 35 days storage plus a simulated market treatment of 5 days at ambient temperature. Water and oil content were determined at harvest. Oil was determined by extracting dry pulp samples with ethyl ether in a Soxhelet. Water content was calculated as the difference between fresh and dry weight (Luza, *et al.,* 1979).

Fruit were evaluated for flesh firmness using a Effegi pressure meter (7.8 mm tip). Two measurements were taken on opposite sides of each fruit after removal of the skin. Results are expressed in kilogram force (kgf). Peel color was determined by an arbitrary scale from the Munsell Color Chart. Fruit diameter was determined using a Cranston sizer at the fruit equator. Physiological disorders were rated using a scale from 1 to 5, where 1 was healthy fruit and 5 was severely damaged fruit. The browning of the vascular fibers were evaluated as presence or absence of vascular browning.

Following the 5-day simulated marketing period, the fruit was analyzed for sweetness, fibrosity and flavor by a Sensory Evaluation Panel using an Hedonic Scale from 1 to 9.

Fruit respiration (mg CO_2/kg/h) was measured using an Infrared Gas Analyzer HB-model URAS.

Fruit from the second harvest (September 8), which were stored for 28 days without Ethysorb at 7C, were grouped according to the presence or absence of pulp browning. Fruit with browning were separated according to the browning characteristics: distal zone browning and generalized browning. Oil content was determined in the whole fruit and separately in the affected areas.

Results and Discussion

Fruit Characteristics at Harvest. The main parameters used to characterize harvest maturity indicate that the fruit harvested at the three different dates (August 17, September 8 and October 13) were at different physiological states, thus at different harvest maturity (Table 1).

Oil content increased 2.05% between the first and second harvest and 5.04% between the second and third harvest. As expected, moisture content values were inverse to those of oil content. Moisture content decreased 0.38% between the first and second harvest and 1.16% between the second and third harvest. For both parameters, the changes are more pronounced after the second harvest. Avocado fruit dry matter was not statistically different for all harvest dates. The average for the three harvests was 11.10%. This suggests that oil and moisture contents are the only compositional changes occurring when the fruit are on the tree.

In all cases, flesh firmness was very high at the time of harvest. Fruit from the last harvest were significantly firmer than fruit obtained from the first two harvests. The standard deviation decreased from 10.38 Kgf for the first harvest to 0.81 for the second and to 0.57 for the third harvest.

Fruit diameter increased from 65.37 mm at the first harvest to 66.45 mm at the second and to 71.30 mm at the third harvest. The weekly increase in fruit diameter between the first and the second harvest was 0.34 mm and between the second and third harvest, 0.97 mm, which indicates a significant size increase from the second harvest date (Table 1).

Peel color was always the same at harvest time with olive green being moderate (Munsell's 5GY 4/3).

Sensory evaluation conducted with random fruit sampled 5 days after removal from cold storage showed no differences in acceptability, sweetness, fibrosity and flavor for any of the harvest dates. There were differences detected between fruits from the first harvest and those from both the second and third harvest in relation to texture. This may be related to the changes in moisture and oil content. The increase in oil would produce a softer texture.

Trial 1. The influence of three different harvest maturities and an ethylene absorber (Ethysorb) on the quality of avocado cv. Fuerte stored at 7C and 87% RH. Pulp integrity measured as pulp resistance is one of the best indices to monitor the postharvest behavior of fruits. There was no difference in pulp integrity ($P<0.05$) between the harvest maturities despite the presence of the Ethysorb although there was a slight tendency towards higher pulp integrity in fruit stored with ethylene absorbers (Table 2).

In general, pulp pressure of the fruit decreased during storage at 7C in a similar pattern for all three harvest dates (Table 2). During the first 14 days of storage the fruit from the earliest harvest maintained a slightly higher pulp integrity than the other two harvests. The main decrease in flesh firmness occurred between 14 and 28 days of harvest. For the first and the second harvest maturity, there were no significant differences in flesh firmness between 28 and 35 days of cold storage; the final values ranged from 1.36 to 2.09 kgf (Table 2).

The fruit in storage reached an acceptable condition for consumption between days 28 and 35, being optimum at 35 days. Nevertheless, the fruit at this stage, with the exception of those of the first harvest maturity, were too soft for adequate handling and transport.

As in the work of Berger *et al.* (1978), Lizana and Luza (1979) and Luza *et al.* (1979), the results show that fruit can soften in storage to eating ripeness within 14 to 28 days at 7C. Zauberman *et al.* (1977) had reported previously that avocado fruit stored

between 6 and 8C could not be ripened unless subsequently subjected to a higher temperature.

The origin of the fruit and the climatic conditions under which the fruit is grown may also have some influence on its storage durability. In other reports, 'Fuerte' grown in other production areas of Chile maintain higher flesh firmness for longer periods of time at the same storage temperature (7C). Fruit from Peumo which was harvested July 18 was 9.78 kgf after 35 days of storage (Luza *et a*l., 1979). Fruit from Santiago which was harvested September 14, had an average flesh firmness 7.45 kgf after 35 days in air storage and 16.09 kgf after controlled atmosphere storage (Berger *et al.,* 1982).

Fruit stored for 14 days at 7C can reach adequate edible maturity after three days at 18C. If kept for a longer period, some overripe characteristics may develop, mainly physiological disorders.

Physiological disorders. Four physiological disorders were detected in the fruit of the 'Fuerte[1] avocado: external or superficial browning, generalized pulp browning, spotted pulp browning, and pulp vascular browning.

Peel or superficial browning of the avocado fruit appeared in two forms: either as slightly depressed spots or as nondepressed irregular brown areas. Both appeared always on the distal end of the fruit. When the symptoms were severe there would also be browning on the proximal end of the fruit. Sometimes the severe superficial browning also included the first few layers of cells underneath the skin which appeared reddish in color.

Superficial browning of either type did not develop significantly during the storage of the avocado fruit at 7C until the fruit had been in storage for 28 days (harvest 2 and 3) or 35 days (harvest 1). Superficial browning which was observed after 28 days storage was very incipient (not impairing the fruit quality for a normal marketing process). After 35 days of storage, however, browning was an important limiting factor to the appearance and to general fruit quality. In general, the later the harvest, the higher the incidence of browning in prolonged storage. Fruit that reached edible maturity in storage (7C) at day 28 showed superficial browning when ripened for 5 days at ambient temperature.

The pulp browning was manifested in three different ways: a generalized pulp browning, a spotted pulp browning, and browning of the vascular tissue. The first two were located almost exclusively in the yellow zone of the pulp at the calyx or distal end of the fruit. The generalized pulp browning, when severe, extended to the rest of the pulp generally coinciding with a superficial or peel browning.

Spot browning usually affected areas of no more than 5 mm in diameter although they sometimes occurred in bigger portions of the pulp as a consequence of several spots together, usually gray to brownish-gray. In most of the cases, this disorder appeared after cutting the pulp and exposing it for some minutes to air at ambient temperature. The occurrence of this disorder could not be related to time of harvest and length of

storage. There also was no relationship between the type of packing (with or without ethylene absorber).

The first symptoms of vascular browning appeared as light brown streaks in the vascular tissue at the distal end of the fruit. When very severe, they could extend throughout the fruit and change to dark brown or black. There was an increase in vascular browning with the length of storage. But in this work most of it was only incipient with the exception of the fruit from the third harvest after 35 days of storage (Table 3).

Relationship between oil content and the degree of pulp browning.

It was frequent to find fruit with browning and fruit without any symptoms, both from the same harvest period and the same postharvest treatments. There is a possibility that fruit maturity could be the main factor in this erratic behavior. For this reason, the oil content of sound fruit (without browning) and fruits with severe pulp browning, both under the same treatments, was determined. Results showed initially that fruit with browning had less oil than sound fruit: an average of 10.53% and 16.39%, respectively. After repeating sampling of the fruit, however, the results were not significantly different. Nevertheless, there was less oil in the distal part of the fruit, where browning occurs more frequently, than in the proximal part of the fruit (Table 4). Although there is a lower oil content in the distal portion of the fruit there is no firm evidence relating this to pulp browning.

Some fruit decay was present, commonly associated with advanced browning and always superficial and at the proximal end of the fruit. The fungi found in the pedicel area was *Penicillium* sp, and *Fusarium* sp. The mycelium found in the fruit skin was identified as *Alternaria* sp.

Trial 2. The influence of harvest date, the use of an ethylene absorber (Ethysorb) and combination of two storage temperatures (7C and 2C) on the final quality of 'Fuerte' avocado.

The criteria used for the timing in the change in storage temperature was the maximum climacteric respiration, which coincided with a low pulp pressure (2.27 kgf). The avocado fruit is more tolerant to low temperatures once the maximum climacteric respiration has occurred (Kosiyachinda and Young, 1976).

In the respiration trials of the avocado fruit, the preclimacteric rise at room temperature occurred in a period of less than 20 h; and there was a simultaneous drop in pulp pressure from near 11.36 kgf to close to 2.27 kgf.

The range of flesh firmness of the avocado fruit stored for 14 days at 7C was from 5.41 to 18.45 kgf. The change in temperature from 7C to 2C was done when the fruit were near the assumed maximum climacteric respiration. There are some indications of low temperature susceptibility at maximum metabolic activity at ambient temperatures.

Therefore, we assumed that if the climacteric progresses at temperatures lower than normal (7C), the susceptibility to low temperatures could also be less. In addition, in order to store and handle avocado fruit there must be a minimum pulp resistance, or the damage of the fruit is large.

In general, there was a slight positive effect of the ethylene absorber on the flesh firmness only when the fruit was stored permanently at 7C. When the fruit were stored at 7C followed by 2C, there was no significant difference in flesh firmness due to the ethylene absorber (Table 5).

In all cases, after 28 and 35 days of storage, the combination of storage temperatures (7C and 2C) resulted in firmer fruit as compared to fruit stored only at 7C (Table 5). This tendency was maintained during the simulated marketing period after storage. In all cases, softening progressed very fast. Within two days fruit were extremely soft.

Physiological disorders. External or superficial browning was "slight" and "moderate" after 28 and 35 days of storage, respectively, in all treatments. Nevertheless, the fruit harvested on September 8th and submitted to the 7 and 2C combination, showed less than "incipient" peel browning after 35 days of storage and only "slight" browning after 5 days at ambient temperature. Fruit from all other storage treatments showed "severe" peel browning when exposed to ambient temperatures.

Pulp browning was "moderate" in the fruit harvested on Oct 13 and stored for 35 days at 7C as compared to those stored under 7 and 2C treatment which showed only "incipient" pulp browning.

Temperature treatments strongly influenced vascular browning than fruit held continuously at 7C. Fruit harvested on September 8 showed higher levels of vascular browning after 28 days storage as compared to the third harvest (Table 6). Nevertheless, when fruit from any of the treatments were held at ambient temperature, the vascular browning increased similarly, becoming the most important physiological disorder to impair fruit quality.

Appearance and acceptability was evaluated high only in the fruit that was stored for 14 days and in some of the fruit stored for 28 days that were free of physiological disorders. Texture, flavor and fibrosity were rated moderate to good.

Conclusions

'Fuerte' avocado fruit held under the conditions of this work, when harvested with 14 to 16 % oil content and about 75 % moisture, could be stored at 7C for 28 days without decreasing fruit quality. However, when warmed to ambient temperatures, their quality deteriorated rapidly.

A combination of storage temperatures (14 days at 7C followed by 2C) increased the storage ability of the fruit, compared with those at 7C only. But again, when exposed to

ambient temperature, quality deteriorated readily and faster than for fruit treated with a combined temperature treatment.

Literature Cited

Berger, H., J.G. Luza and L. Peralta. 1978. Almacenaje de palta 'Fuerte' y 'Hass'. Proc. Amer. Soc. Hort. Sci., Trop. Reg. 22:30-39.

Berger, H., C. Auda and E. Gonzalez. 1982. Almacenamiento de paltas *(Persea americana* Mill) cv. 'Fuerte' y 'Hass' en atmosfera controlada, modificada y refrigeracion comun. Simiente 52:55-60.

Kosiyachinda, S. and R.E. Young. 1976. Chilling sensitivity of avocado fruit to different storage temperatures. J. Amer. Soc. Hort. Sci. 101:665-667.

Lizana, L.A. and J.G. Luza. 1979. Caracterizacion frutal de paltos raza Mexicana, cultivados en Chile. Proc. Amer. Soc. Hort. Sci., Trop. Reg. 23:133-138.

Luza, J.G., H. Berger and L. A Lizana. 1979. Almacenaje en frio de paltas *(Persea americana* Mill) cvs Negra La Cruz, Ampolleta Grande y Fuerte. Simiente 49:42-47.

Swarts, D. H. 1979. A method for determining ripening of avocados S. A. Avocado Growers' Assn. Yrbk. 3:70-73.

Vakis, N. J., C. Gregorion and L. Pandemetrion. 1985. Maturity and picking data of avocado under Cyprus conditions. Calif. Avocado Soc. Yrbk. 69:81-87.

Zauberman, G., M. Shiffmann-Nadel and V. Yanko. 1977. The response of avocado fruit to different storage temperatures. HortScience 12: 353-354.

Table 1. Oil content, moisture content, dry matter, pulp firmness, fruit diameter and peel color in avocado fruit cv. Fuerte harvested at three different dates (August 17, September 8 and October 13).

	Harvest dates		
Parameter	August 17	September 8	October 13
Oil content (%)	13.99 a [z]	16.04 a	21.08 b
Moisture content (%)	74.55 b	73.35 b	67.52 a
Dry matter (%)	11.41 a	10.52 a	11.38 a
Pulp firmness (Kgf)	19.92 a	20. 34 a	21.04 b
Fruit diameter (mm) [y]	65.37 a	66.45 b	71.30 b
Peel color [x]	5GY-3/4 a	5GY-3/4 a	5GY-3/4 a

[z] Different letters on the same line indicate significant differences using Duncans' Multiple Range Test, P<0.05.
[y] Fruit diameter measured at fruit equator.
[x] Munsell Tables values at Nickerson color charts.

Table 2. Evolution of pulp pressure resistance (kgf) in avocado fruit cv. Fuerte harvested at three different maturities and stored at 7C, 87 % RH with and without an ethylene absorber (Ethysorb) for 35 days.

		Storage period (Days)			
Harvest date	Package type	0	14	28	35
August 17	WE [Z]	19.45 a [y]	14.59 b	2.09 c	1.73 c
	NE	19.48 a	13.45 b	1.32 c	1.64 c
September 8	WE	20.36 a	6.50 b	1.64 c	1.68 c
	NE	20.36 a	6.18 b	1.59 c	1.36 c
October 13	WE	21.05 a	8.45 b	3.05 c	0.91 d
	NE	21.05 a	5.41 b	2.41 c	0.68 c

[z] WE= with Ethysorb; NE= without Ethysorb.
[y] Different letters in the same line indicate significant differences using Duncans' Multiple Range Test, $P \leq 0.05$.

Table 3. Different types of pulp browning affecting fruit (in %) harvested at three different periods and stored at 7 C for 14, 28, and 35 days with and without an ethylene absorber.

Harvest date	Package type	Storage Period (days)								
		14			28			35		
		GB[z]	SB	VB	GB	SB	VB	GB	SB	VB
August 17	WE[y]	0.0	0.0	0.0	2.3	0.0	27.7	23.6	27.0	27.7
	NE	0.0	0.0	0.0	20.8	9.8	27.7	23.7	20.1	44.4
September 8	WE	0.0	52.8	0.0	6.9	12.3	30.8	23.6	8.0	38.8
	NE	0.0	31.0	22.0	20.8	17.1	33.3	22.2	8.1	22.2
October 13	WE	0.0	9.0	0.0	12.5	22.5	0.0	66.6	19.3	50.0
	NE	0.0	22.3	0.0	18.0	9.9	5.5	73.5	22.5	77.7

[z] GB= Generalized pulp browning; SB= spot browning; VB= vascular browning.
[y] WE= With Ethysorb; NE= Without Ethysorb.

Table 4. Oil content (%) in different portions of the pulp of 'Fuerte' avocado fruit with and without pulp browning.

Type of fruit	Distal	Proximal	Average
Sound Fruit	21.5	23.5	22.5
Only Distal Portion Browning	22.5	23.0	22.7
Generalized Pulp Browning	20.0	24.5	22.2
Average	21.3	23.7	22.5

Table 5. Changes in flesh firmness (kgf) in 'Fuerte' avocado fruit harvested at two different times and stored for 14, 28 and 35 days at 7C, or a combination of 14 days at 7C and 14 or 24 days at 2C. Fruit were packed either with or without an ethylene absorber.

Harvest date	Package type	Storage Period (days)					
		0	14	28		35	
				7C	7C + 2C	7C	7C + 2C
September 8	WE[z]	20.36	6.50	1.64 3[y]	3.73 b	1.68 a	3.73 b
	NE	20.36	6.18	1.59 a	4.18 b	1.36 a	3.68 b
October 13	WE	21.05	8.45	3.05 a	5.27 b	0.91 a	2.86 b
	NE	21.05	5.41	2.41 a	5.86 b	0.68 a	3.23 b

[z] WE= With Ethysorb; NE= Without Ethysorb.
[y] Different letters in the same line indicate significant differences using Duncans' Multiple Range Test ($P \leq 0.05$).

Table 6. Percentage of fruit affected by pulp and vascular browning harvested at 2 different dates and stored at 7C for 14 days and subsequently at 2C for 28 or 35 days with and without an ethylene absorber.

Harvest date	Package type	Storage Period (days)							
		28				35			
		GB[z]		VB		GB		VB	
		7C	7C + 2C	7C	7C + 2C	7C	7C + 2C	7C	7C + 2C
September 8	WE	8.3	0.0	38.8	0.0	24.0	0.0	38.8	5.0
	NE	21.1	0.0	33.3	0.0	22.1	12.2	22.2	5.5
October 13	WE	11.0	0.0	0.0	0.0	68.0	31.0	50.0	16.6
	NE	22.0	0.0	5.4	0.0	71.3	31.0	77.6	16.6

[z] GB= Generalized pulp browning; VB= vascular browning.
[y] WE= With Ethysorb; NE= Without Ethysorb.