Postharvest Physiology of Avocado

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Abstract

The avocado is a climacteric fruit and the ripening process is associated with an increase in respiration, referred to as the climacteric rise. During the ripening of avocado, ethylene production parallels the pattern of respiration. Fruit softening is generally discernible 1 to 2 days, and edible ripeness 1 to 3 days after the climacteric peak, respectively.

As for the fatty acid composition of the lipids of the avocado pericarp, major fatty acids are oleic acid, followed by palmitic, linoleic, palmitoleic and linolenic acids.

Storage at a low temperature of 4°C and relative humidity of 80-90% is limited to about 2 to 4 weeks.

Removal of ethylene from controlled-atmosphere storage (2% O_2, 10% CO_2, 7.2°C) prolongs the marketable life of avocados.

Other storage methods include packaging of fruit and low pressure storage.

Introduction

The avocado is a fruit of Central America and Mexico, though its precise origin is obscure due to its long history of utilization. Avocado fruit is currently produced throughout most of the tropical and subtropical areas. The avocado tree belongs to the family Lauraceae in the genus *Persea*. Avocado has undergone an evolution into three distinct races named Mexican, Guatemalan and West Indian (Bergh, 1975).

Avocados are grown in the United States, Mexico and Brazil for commercial production. Other producing areas are Central and South America, the Caribbean Island, South Africa and Israel.

In Japan, avocado is planted along the Pacific Ocean in the southern part of the country which enjoys a warm climate. Avocado can be grown in areas of 31° to 35° North latitudes. Some of the major planting areas are Kagoshima in Kyushu Island, Ehime and Kouchi in Shikoku Island, Wakayama and Shizuoka in Honshu Island. The planting of avocado in these areas covers only about 10 ha.

1. Respiration and ethylene production

Avocado is a climacteric fruit and the ripening process is associated with an increase in respiration, referred to as the climacteric rise (Adato *et al*., 1974; Awad *et al*., 1979). The respiration pattern is divided into three stages, the preclimacteric minimum when the respiration of fruit is low, the climacteric maximum during which the fruit respiration is maximum and the postclimacteric stage, with a decline in respiration (Fig. 1, 2) (Biale *et al*., 1971; Ahmed *et al*., 1980; Salunkhe *et al*., 1984; Seymour *et al*., 1993). During the ripening of avocado, ethylene production parallels the pattern of respiration (Gazit *et al*., 1970; Lee *et al*., 1984; Inoue *et al*., 1991). Fruit softening is generally discernible one to two days, and edible ripeness one to three days after the climacteric peak, respectively.

2. Fatty acid composition

Although the fatty acid composition of the lipids or oil content of fruit varies among cultivars, stage

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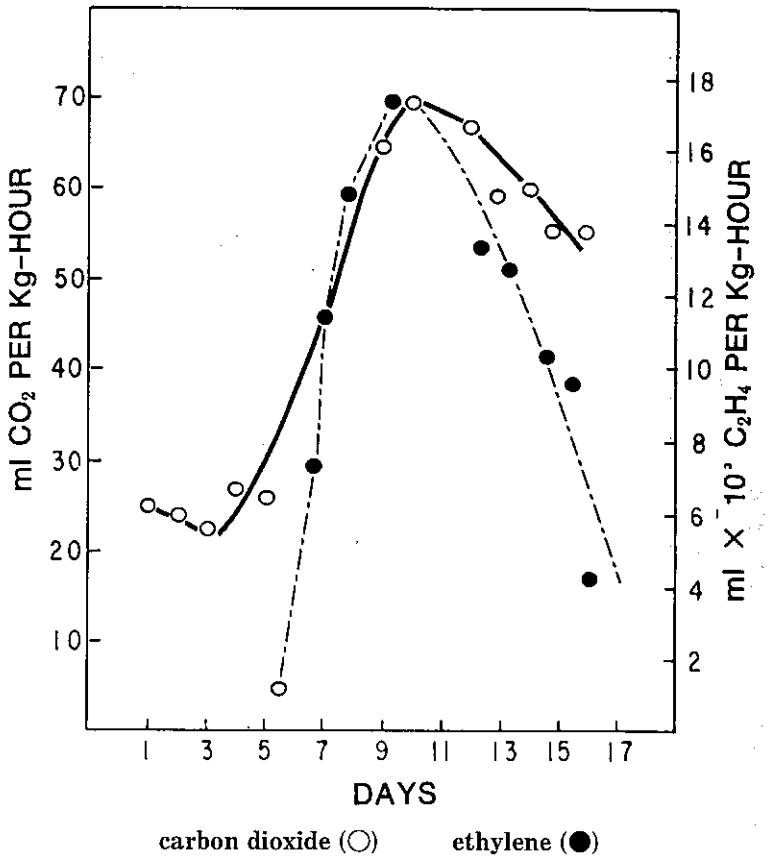

Fig. 1 Fruit respiration and ethylene production by Fuerte avocado following harvest (Biale *et al*., 1954)

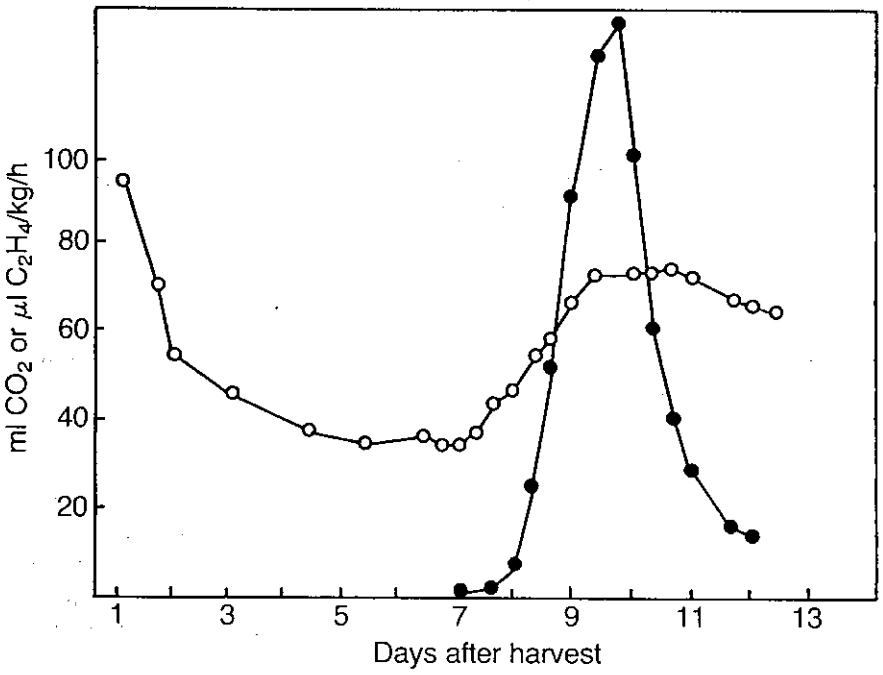

Fig. 2 Postharvest trends in carbon dioxide (○) and ethylene (●) production in an individual Fuerte avocado fruit (Awad and Young, 1979)

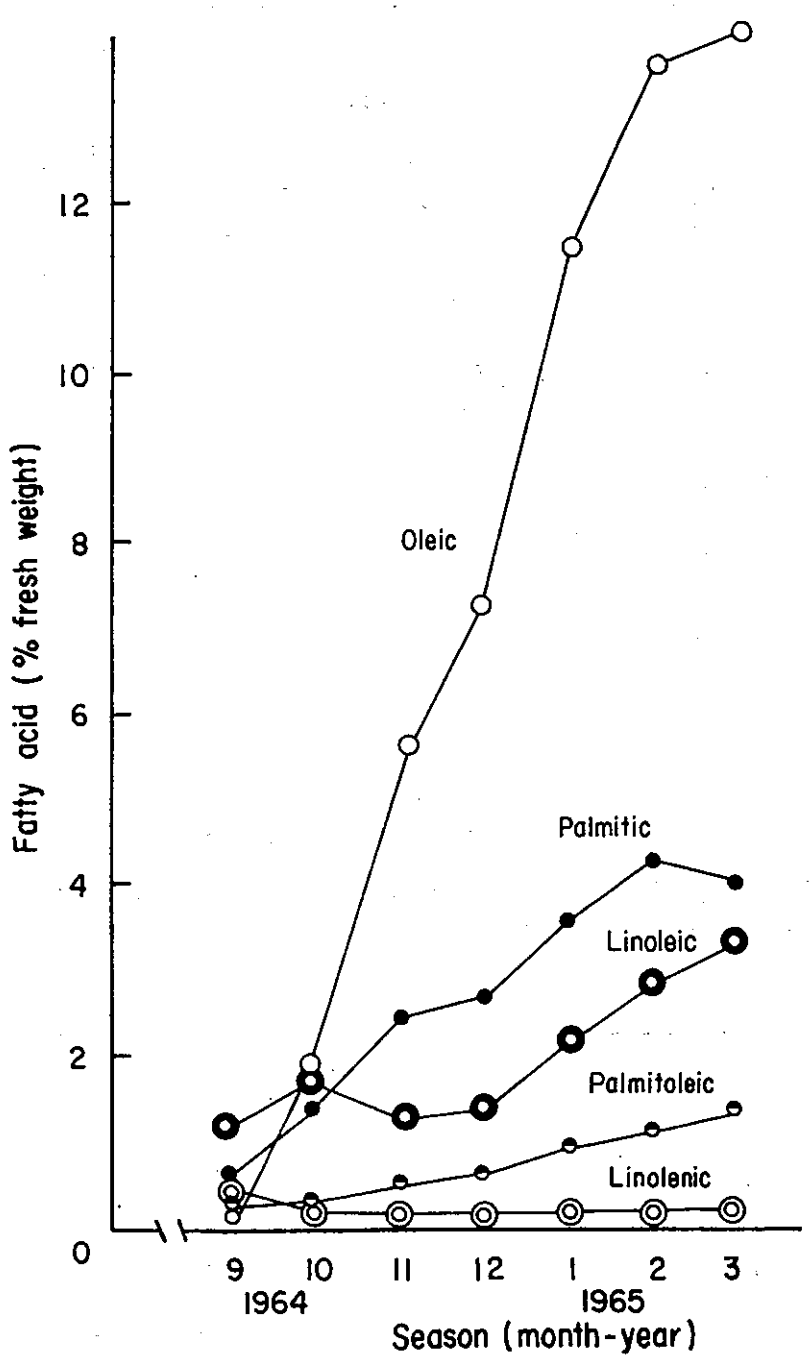

Fig. 3 Seasonal changes of fatty acid composition in Fuerte avocado fruit (Kikuta and Erickson, 1968)

of ripening and growth location, major fatty acids in the pericarp of fruit consist of oleic acid, followed by palmitic, linoleic, palmitoleic and linolenic acids (Fig. 3) (Kikuta *et al.*, 1968; Kaiser *et al.*, 1994). The fatty acid composition of the lipids of the pericarp of the cultivar 'Fuerte', an avocado fruit harvested in Japan was the same as that of the avocados grown in California. Major fatty acids are oleic acid, followed by palmitic, linoleic, palmitoleic and linolenic acids (Fig. 4) (Inoue *et al.*, 1994). Ripening of avocado results in an increase in the content of fatty substances and free fatty acids.

Kikuta and Erickson (1968) reported that in 'Fuerte' avocados there were some changes in the lipids during ripening, including increases in the monoglyceride and free fatty acid fractions, which may result

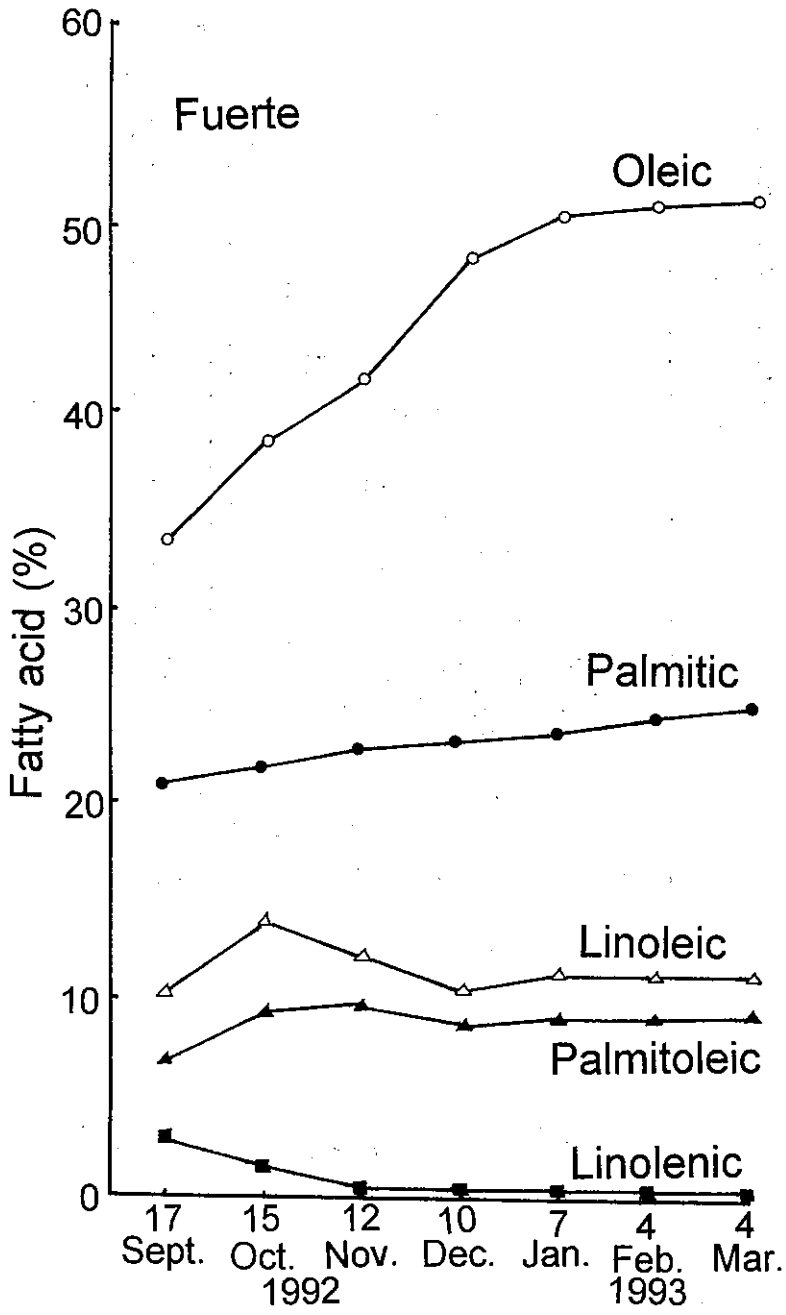

Fig. 4 Seasonal changes of fatty acid composition in Fuerte fruit (1992–'93) (Inoue *et al.*, 1994)

from the degradation of triglycerides (Fig. 5). Thus the storage lipids may be involved in some way in the metabolic processes taking place during ripening.

3. Fruit ripening

Fruit ripening to a stage suitable for consumption does not occur on the tree; fruit must be picked and ripened off the tree. Only mature fruits develop a good eating quality as they soften after harvesting. Fruit ripening may proceed from less than 7 days at 27°C to one month at 5°C. However, lower temperatures may not be conducive to a good flavor and internal quality.

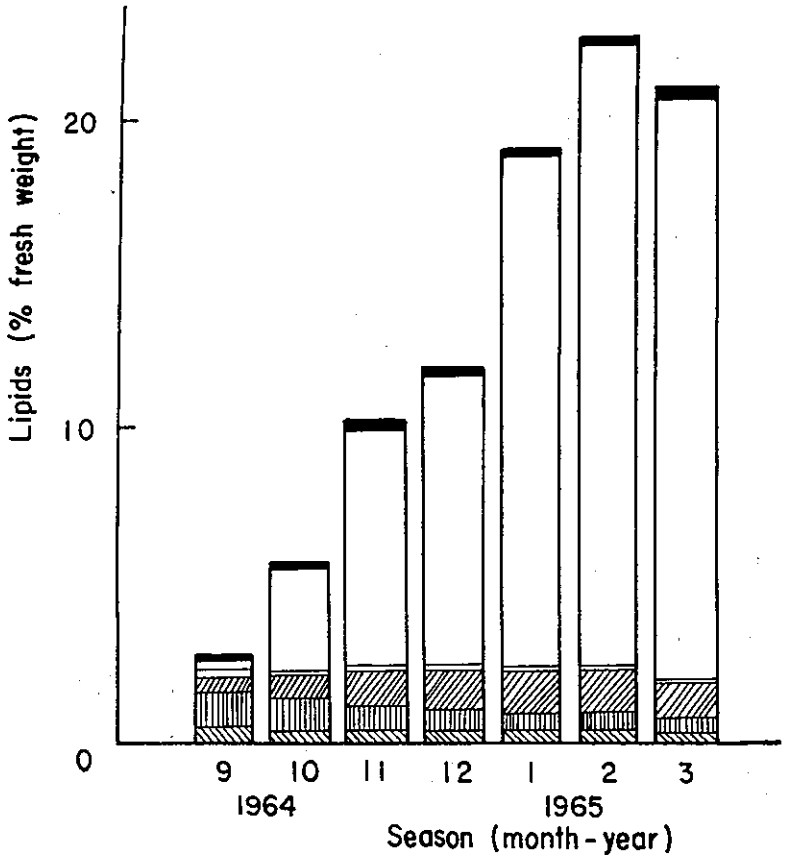

Fig. 5 Seasonal changes of lipid classes in the mesocarp of Fuerte avocado fruit

Fractions from top to bottom in each histogram: hydrocarbons, triglycerides, free fatty acids, diglycerides, monoglycerides and phospholipids. (Kikuta and Erickson, 1968)

Table 1 Harvest date, average fruit weight, average oil content, peak of ethylene production for untreated fruit and days from harvest to softening

Harvest date	Fruit weight (g)	Oil content (%)	Peak of ethylene production (μl/kg・hr)	Days to softening	
				Control	Treated[z]
Aug. 28	82	1.3	100	18.5a[y]	17.5a
Sept. 18	108	1.6	120	16.3b	15.8bc
Oct. 6	128	2.5	150	14.8cd	12.7fgh
Nov. 10	135	4.2	155	14.5de	11.9hi
Dec. 8	142	6.7	160	13.9ef	10.8ij
Jan. 10	154	9.8	175	13.1fg	9.3kl
Feb. 6	169	12.0	188	12.8fgh	8.8lm
March 6	188	13.2	210	12.2gh	8.3mn
April 10	204	14.8	215	10.1jk	7.1o
May 15	217	15.8	215	9.4kl	6.3p
June 5	226	16.5	220	8.2mn	5.1q

[z] Treated for 2 days, beginning 1 day after harvest, with 1000 ppm propylene.

[y] Mean separation within treatments and harvest dates by Duncan's multiple range test, 5% level. (Eaks, I. L., 1980)

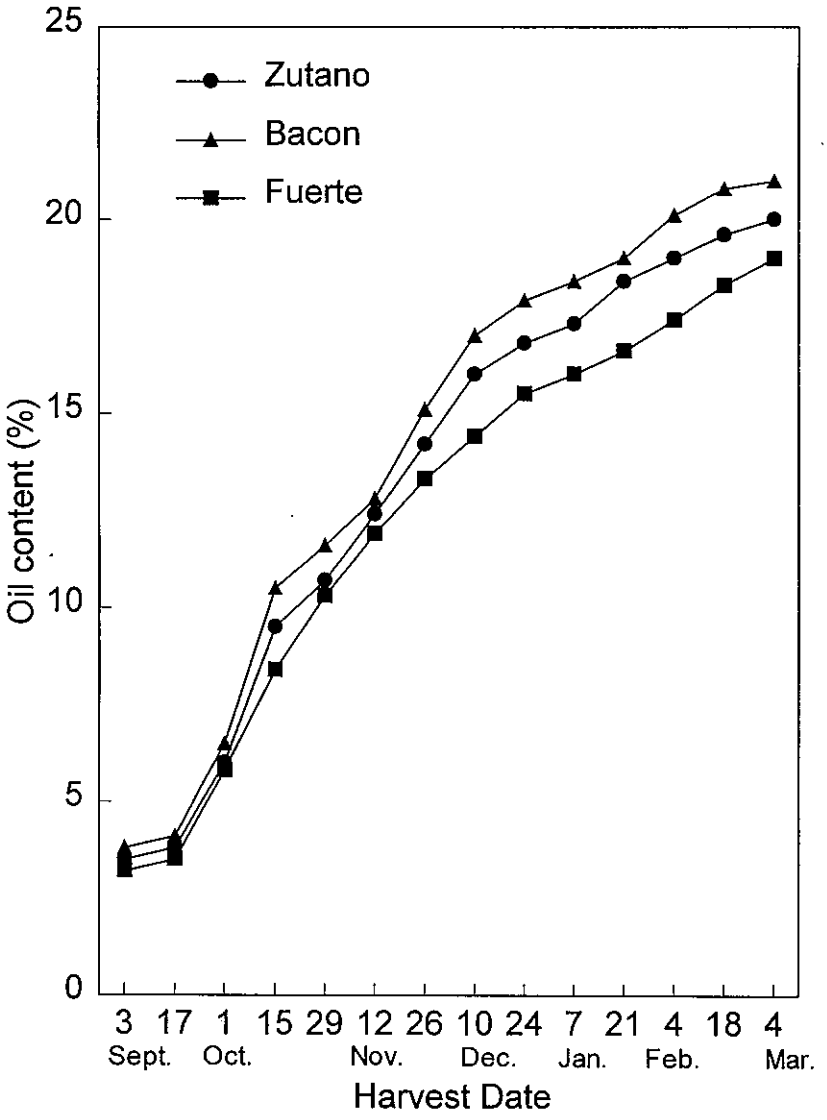

Fig. 6 Oil content of Zutano, Bacon and Fuerte avocado fruits harvested in Japan (1990-'91) (Inoue *et al.*, 1991)

In California, fruit harvest begins when the oil content reaches 8%. The peak rate of ethylene production of untreated fruit increases until March as fruit maturation proceeds and remains at nearly the same rate through June. The days from harvest to softening for the untreated fruit decreased from 18.5 days for fruit harvested in August to 8.2 days for fruit harvested in June (Table 1) (Eaks, 1980). In Japan, harvest time begins when the fruit has reached a 12% oil content, then optimum harvest time takes place from December to March in Japan (Fig. 6) (Inoue *et al.*, 1991). The peak rate of ethylene production increased as the fruit matured until December 10, at nearly the same rate through March in Japan (Inoue *et al.*, 1991).

4. Postharvest technology

Low temperature storage of cultivars of the West Indian race is 12.8°C and for the Guatemalan and Mexican cultivars 4°C and 8°C, respectively. 'Fuerte' avocados can be stored at 7.2°C. The storage at low temperature (4°C) for 'Fuerte' and 'Hass' cultivars is limited to about 2 to 4 weeks. Relative humidity of about 80-90% is necessary for the storage of avocado at a low temperature (Eaks, 1979). The storage of avocado in CA has been studied by various groups both in California and Florida (Barmore *et al.*, 1976).

Table 2 Effect of storage time and treatment on the total postharvest life of stored avocados

Storage time (days)	Treatment	Total postharvest life (days)
5	Control	8
5	Polyethylene bag	11
5	Polyethylene bag plus $KMnO_4$	11
10	Control[a]	8
10	Polyethylene bag	16
10	Polyethylene bag plus $KMnO_4$	16

[a] Oversoft at first examination.
(Chaplin, G. R. and Hawson, M. G., 1981)

Table 3 Fruit quality of avocados after storage in CA or air

Storage time, temperature (°C)		Acceptable fruit		Softening time (days at 21°C)	
		Air[a]	CA[b]	Air[a]	CA[b]
Cultivar Booth 8					
No storage		100	–	6.5	–
20 days	4.5	80	93	4.8	5.8
	10.0	33	60	1.6	5.2
40 days	4.5	17	73	–	6.4
	10.0	0	43	–	3.8
Cultivar Luna					
No storage		100	–	6.4	–
20 days	4.5	80	100	3.3	6.0
	10.0	47	100	3.1	6.0
40 days	4.5	0	100	–	5.1
	10.0	0	100	–	5.4

[a] Air at 2.5°C.
[b] Controlled atmosphere of 2% O_2 and 10% CO_2.
(Spalding, D. H. and Reeder, W. F., 1972)

The optimum temperature for CA storage varies with the cultivars, the maximum storage time for any cultivar being 60 days. These authors showed that the use of controlled atmosphere (2% O_2 plus 10% CO_2) at 7.2°C doubles the normal storage life of avocado under refrigeration alone. The maximum storage life for 'Booth 8' and 'Lula' cultivars was about 6 to 8 weeks (Table 3) (Spalding *et al.*, 1972).

These investigators further observed that the total postharvest life of avocados was a function of storage. The extension of the postharvest life achieved by the storage of fruit in polyethylene bags during transportation may enable to prevent losses resulting from premature softening (Table 2) (Chaplin *et al.*, 1981).

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Discussion

Participant: You mentioned that you were able to extend the shelf life of avocado by 16 days when the fruits were placed in ethylene bags for 11 days in storage. What was the temperature?

Answer: 25°C

Moriguchi, T. (FTRS): Which enzymes play an important role in the softening (ripening) of avocado fruits?

Answer: I did not study this problem.

Uritani, I. (Japan): Did you investigate possible changes in the composition of the fatty acids of the phospholipids of the membranes of avocado during storage at low temperatures? It is indeed possible that the content of unsaturated fatty acids increase.

Answer: I did not carry out such studies.

Comment: Herregods, M. (Belgium): The changes in the content of fatty acids in the phospholipids of cellular membranes have been studied for various commodities. I could provide you with the results obtained during such studies.