

CHANGE IN THE FATTY ACID COMPOSITION OF AVOCADO FRUIT DURING ONTOGENY, COLD STORAGE AND RIPENING

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Abstract

The ratio of saturated fatty acids to unsaturated fatty acids has been implicated in the sensitivity of plant materials to chilling injury. Chilling sensitive plant materials have been reported to have a higher mole percent of saturated fatty acids than plant materials not sensitive to chilling injury. Changes in the fatty acid composition have also been reported for chilling sensitive crops during and following exposure to chilling temperatures and that these changes may be related to chilling sensitivity. The fatty acid composition of 'Fuerte' and 'Hass' avocados was determined during ontogeny, cold storage, and ripening. During ontogeny, oleic acid increased, linoleic and linolenic acids decreased and palmitic and palmitoleic remained essentially constant relative to the percentage of total fatty acids. The fatty acid composition did not change significantly during 2, 4 and 6 weeks storage at 0°, 5° and 10°C or after ripening at 20°C subsequent to the cold storage treatments.

1. Introduction

Avocado fruits are unique in that they store large quantities of lipids in the mesocarp during growth and development. The quantity of lipids in avocado fruit has been the subject of considerable research and the percentage of lipid on a fresh weight basis was used as a maturity standard for years in California and other avocado producing areas in the world. Now the percentage dry weight is used as a maturity standard in California. The fatty acid composition of the avocado lipids has received only limited attention. Mazliak (1965) identified five fatty acids in the lipids from avocado mesocarp and that palmitic (16:0-carbon chain length: number of double bands), palmitoleic (16:1), oleic (18:1) and linoleic (18:2) acids constitute about 95% of the total fatty acids. Kikuta (1968) determined the total lipids and the fatty acid composition of the lipids in 'Fuerte' and 'Hass' avocado fruits during part of the growth and maturation period and found that oleic acid was the primary fatty acid synthesized during the later stages of maturation. Davenport *et al.* (1959) determined the fatty acid content of Australian 'Fuerte' avocados during growth and after ripening at 20°C, not as individual acids, but in categories of saturation; monoene, diene, and triene and found the greatest increase in the monoene fraction during growth which probably consisted primarily of oleic acid. After ripening all categories, except the triene fraction showed small increases.

Avocado fruits are subject to chilling injury. A physical change in membranes which may

be related to the ratio of the saturated to the unsaturated fatty acids, appears to be a primary response to chilling stress (Lyons, 1973; Wang, 1982). After a chilling exposure, Tabacchi *et al.* (1979) reported an increase in the percentage of unsaturated fatty acids for tomatoes, and Kane *et al.* (1978) reported an increase in palmitic acid and a decrease in palmitoleic acid (a change from an unsaturated to a saturated fatty acid) in mango fruits. Therefore, different responses have been reported in response to a chilling exposure.

The objectives of this investigation were to determine the changes in fruit weight, percentage of total lipids and the fatty acid composition of the lipids during growth and maturation and changes in the fatty acid composition of the lipids during a chilling exposure and when ripened after various chilling exposures.

2. Materials and methods

Four trees each of the 'Fuerte' and 'Hass' cultivar were selected in one of the University of California experimental groves in Riverside. Samples consisting of two fruit from each tree (total of eight fruit for each cultivar) were taken the first part of each month beginning on August 8, 1979, and continued until March 3, 1980, for the 'Fuerte' cultivar, and until September 8, 1980, for the 'Hass' cultivar for the growth and maturation evaluations. The experiments to evaluate the effect of chilling exposures on the changes in the fatty acid composition during chilling and after ripening at 20°C were on early-season (legally mature), mid-season and late-season fruit of each cultivar. The fruit were analyzed initially after various chilling exposures and when ripened at 20°C after chilling. The treatments were: initial, direct to 20°C for ripening, and two, four and six weeks at 0°, 5° and 10°C. After the various chilling exposures, one of the eight fruit samples was analyzed immediately and the companion sample was placed in open containers at 20°C and analyzed when ripe.

The sample to determine the lipid content and fatty acid composition of the lipids consisted of 20 grams of mesocarp tissue from the equator of each fruit. The lipids were extracted and purified by the method of Bligh *et al.* (1959). The total lipids were determined by weighing the lipids after the extract was dried under nitrogen. A sample of the lipid was saponified with methanolic KOH (1.12 grams KOH in 100 ml anhydrous methanol), acidified with 1 N HCl, extracted three times with ethyl ether, dried and dissolved in hexane. Methylation of the fatty acids was carried out using sodium methoxide (Alltech Associates, Inc.). Sodium methoxide is a rapid and quantitative methylating agent which avoids the dangers of using methyl fluoride or azide compounds. Although the literature relative to chilling injury refers to the fatty acid composition of mitochondrial lipids, the data presented here are for the whole tissue lipids which have been reported by Maluf *et al.* (1980) and Mazliak *et al.* (1968) to be similar to mitochondrial lipids.

Gas chromatographic analysis of the fatty acid methyl esters were performed under the following conditions: column-2.5 m stainless steel, 6.4 mm OD; packing-15% diethyl glycol succinate on 80/100 mesh gas chromatograph P (Allied Science Laboratories, Inc.); injection port-220°C; column-175°C; detector-240°C; nitrogen carrier gas-60 ml/min using a Varian model 1400 hydrogen flame ionization detector gas

chromatograph connected to a Varian model CDS-111 data system which integrated the data and calculated the percentage composition of each fatty acid component. The individual fatty acids were identified by comparing the retention times with a standard fatty acid solution (Alltech Associates, Inc.) of the fatty acids found in avocado lipids.

3. Results

The fruit weight and percentage total lipids in avocado fruit from August 8, 1979, until March 3, 1980, for the 'Fuerte' cultivar and until September 8, 1980, for the 'Hass' cultivar are illustrated in Figure 1. The fruit weight of 'Fuerte' avocados increased rapidly from August until December and then the increase in fruit weight leveled off. 'Hass' avocado fruit weight increased markedly during August and then increased at a slower but uniform rate until September. The lipid percentage in 'Fuerte' avocado fruit increased gradually from August until November and then the lipid percentage increased rapidly until February and then leveled off. In 'Hass' avocado fruit, the lipid percentage increased at a fairly constant rate from August until May and then decreased slightly until September.

During growth and maturation, myristic (14:0) and stearic (18:0) acids were present in only trace amounts. The changes in the fatty acid composition of 'Fuerte' and 'Hass' avocado fruit lipids are shown in Figures 2 and 3, respectively. In immature 'Fuerte' and 'Hass' avocado fruit, linoleic (18:2) acid is the most prevalent fatty acid which decreases rapidly as the percentage of total fatty acids from August until December and then remains fairly constant until March; but in the 'Hass' cultivar, the decrease continues until April when the percentage increased slowly until September. The percentage of palmitic (16:0) and palmitoleic (16:1) acids remain fairly constant for both cultivars throughout growth and maturation. Linolenic (18:3) acid in both cultivars decreased in percentage from August to October and then remained at a low percentage throughout the experimental period. Oleic (18:1) acid, the major fatty acid in mature avocado fruit increased markedly in percentage in the 'Fuerte' cultivar from August to September, then increased more slowly until February and remained constant until March. In the lipids of the 'Hass' cultivar, the percentage of oleic acid increased rapidly from August until October, increased more slowly until February, and remained constant with a slight decrease between June and September.

The fatty acid content based on grams of fatty acid per 100 grams fruit weight for 'Fuerte' and 'Hass' avocado fruit is illustrated in Figures 4 and 5.

Oleic acid is the major fatty acid in both cultivars. Palmitoleic and linolenic acids display only a small increase in grams per 100 grams fruit weight during growth and maturation. Palmitic and linolenic acids increase slightly in both cultivars beginning in November. In the 'Fuerte' cultivar, oleic acid content increases rapidly beginning in October until February and then remains constant, while in the 'Hass' cultivar the oleic acid increased from September to May and then decreased slightly.

The fatty acid composition of the lipids did not change for either cultivar during ripening when placed directly at 20°C or during storage for two, four and six weeks at 0°, 5° and 10°C and subsequent ripening at 20°C as illustrated for the mid-season 'Fuerte' and

'Hass' cultivars stored at 0° and 5°C (Figures 6 and 7).

4. Discussion

The growth of avocado fruits differ from other fruits in which all the cell division occurs initially and growth consists of only cell enlargement. Schroeder (1953) observed that initially growth involved cell division and enlargement and that cell division continued while attached to the tree. The total lipids in 'Fuerte' increases slowly until essentially maximum size is attained and then increases rapidly. In the 'Hass' cultivar, the total lipids increase fairly gradually until May and then decreases slightly while the fruit maintain a uniform rate of growth. The slight decrease in total lipids after May could be that lipid synthesis has slowed or stopped but the fruit are still increasing in weight. The increase in total lipids is due primarily to the synthesis of oleic acid. The accumulation of total lipids is accompanied by a decrease in water content.

Chilling sensitive tissues have been reported to have a lower mole percentage of unsaturated fatty acids than chilling resistant tissues (Lyons, 1973; Lyons *et al.*, 1964; Wang, 1982). In legally mature avocado fruit, palmitoleic, oleic and linoleic (all unsaturated fatty acids account for about 80% of the total fatty acids with palmitic (a saturated fatty acid) accounting for less than 20% of the total fatty acids. Therefore, as Wang (1982) pointed out, the degree of unsaturation of fatty acids may not be related to sensitivity to chilling.

The composition of the fatty acids in avocado fruit did not change when ripened without chilling, during chilling or when ripened after a chilling exposure. This is in contrast to reported changes associated with ripening and chilling for other chilling sensitive fruit (Tabacchi *et al.*, 1979; Kane *et al.*, 1978).

Avocado fruit appear to have several anomalous characteristics: continued cell division during growth and development, accumulation of large quantities of lipids in the mesocarp, high unsaturated fatty acid content of those lipids while being chilling sensitive and the failure to change the fatty acid composition in response to a chilling exposure.

5. Acknowledgements

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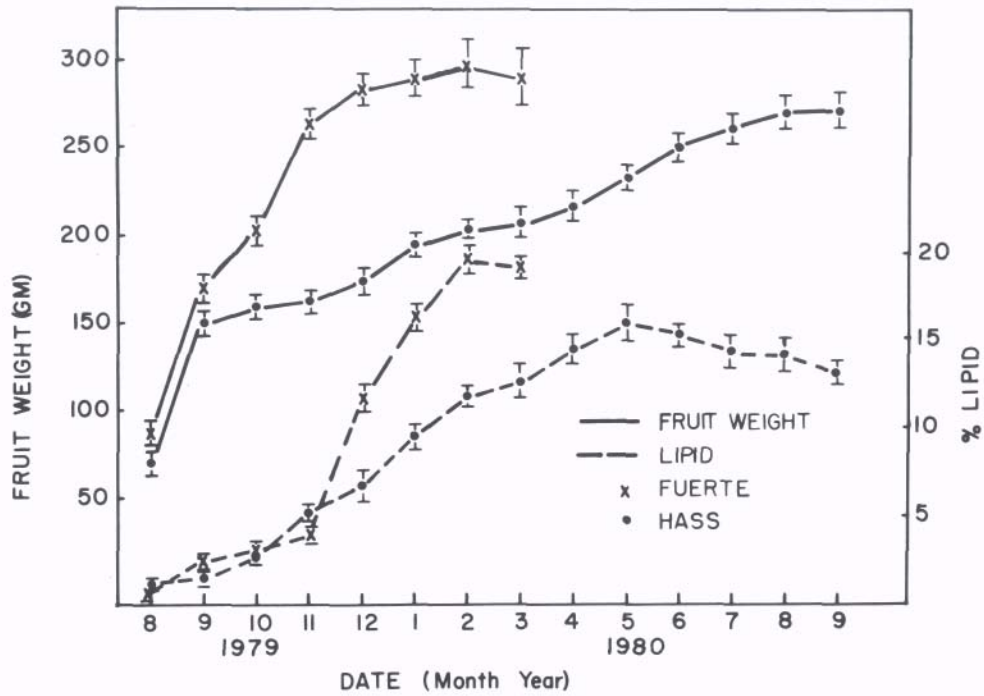


Figure 1. Fruit weight and percentage lipid in 'Fuerte' and 'Hass' avocados during growth and maturation.

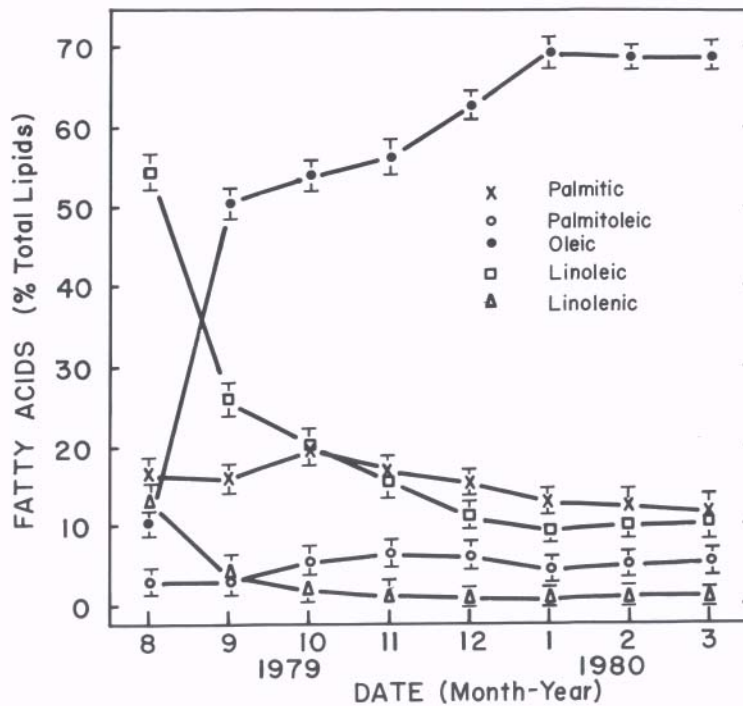


Figure 2. Fatty acid composition as percentage of total lipids in 'Fuerte' avocados during growth and maturation.

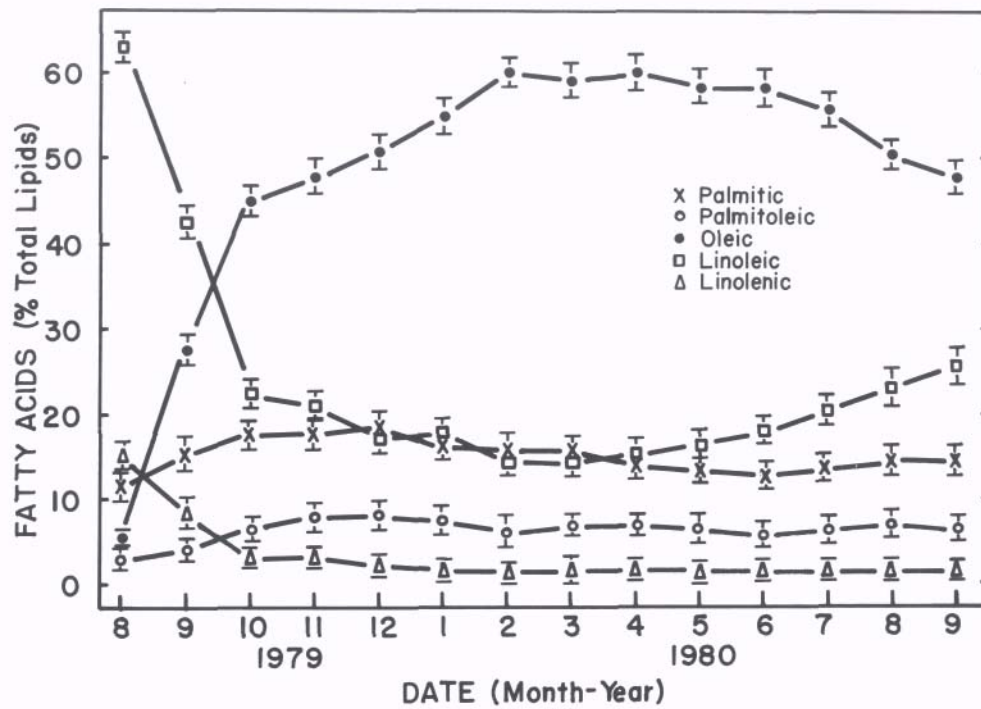


Figure 3. Fatty acid composition as percentage of total lipids in 'Hass' avocados during growth and maturation.

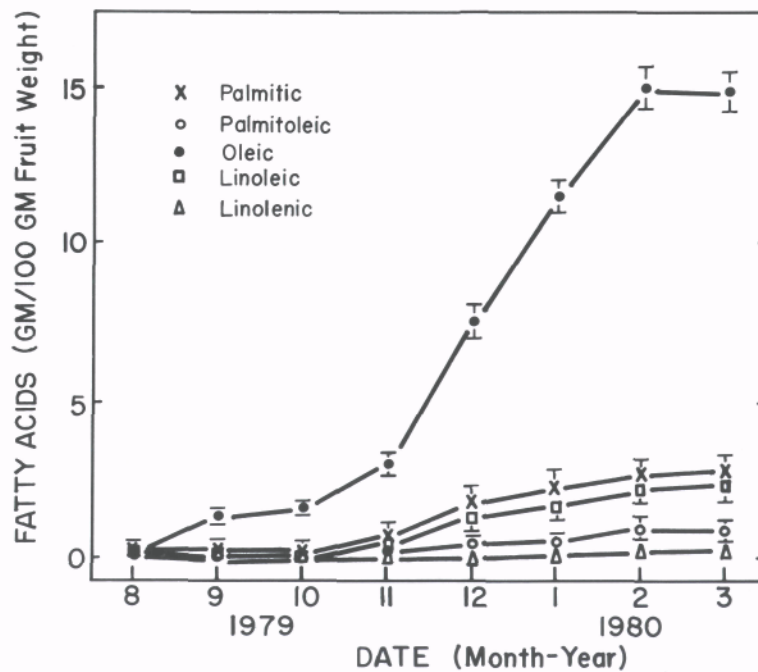


Figure 4. Fatty acid composition as grams per 100 grams fruit weight in 'Fuerte' avocados during growth and maturation.

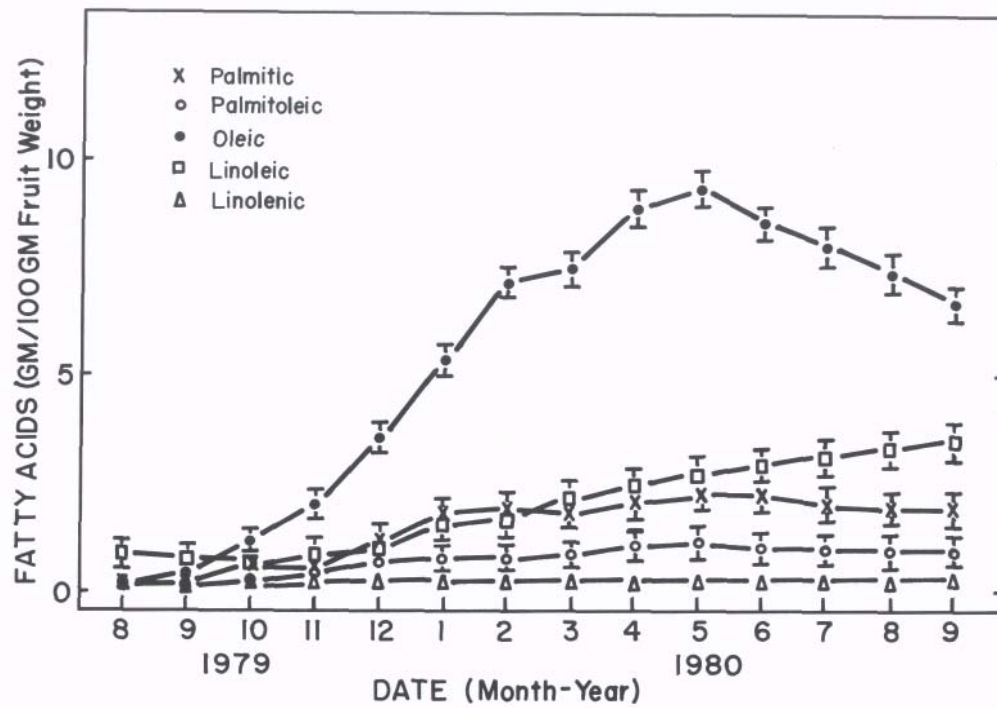


Figure 5. Fatty acid composition as grams per 100 grams fruit weight in 'Hass' avocados during growth and maturation.

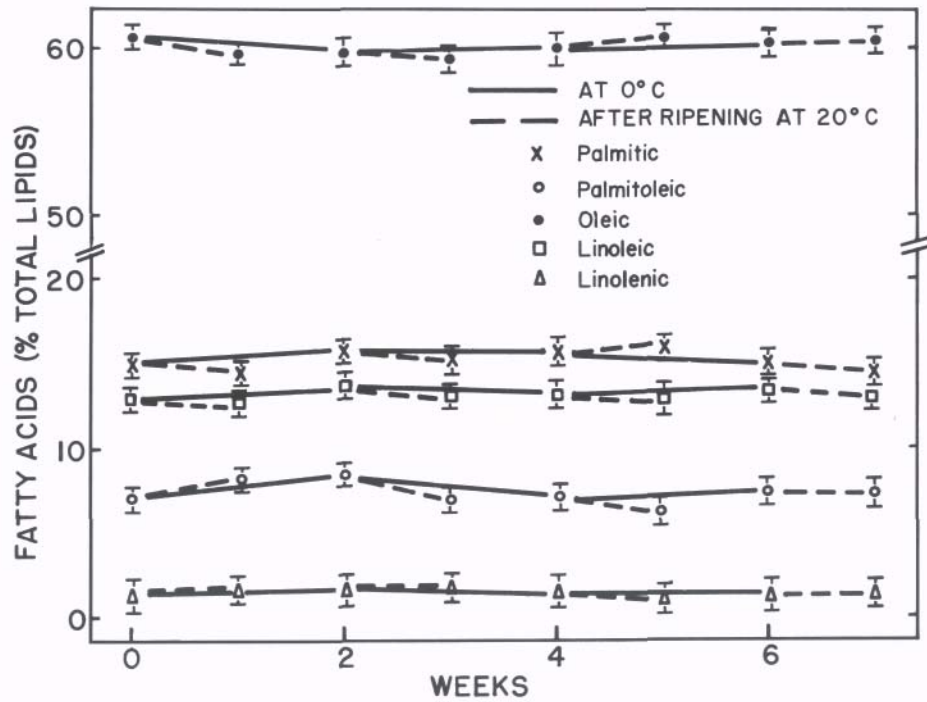


Figure 6. Changes in fatty acid composition as percentage of total lipids of 'Fuerte' avocados after storage for 0, 2, 4 and 6 weeks at 0° and after subsequent ripening at 20°C.

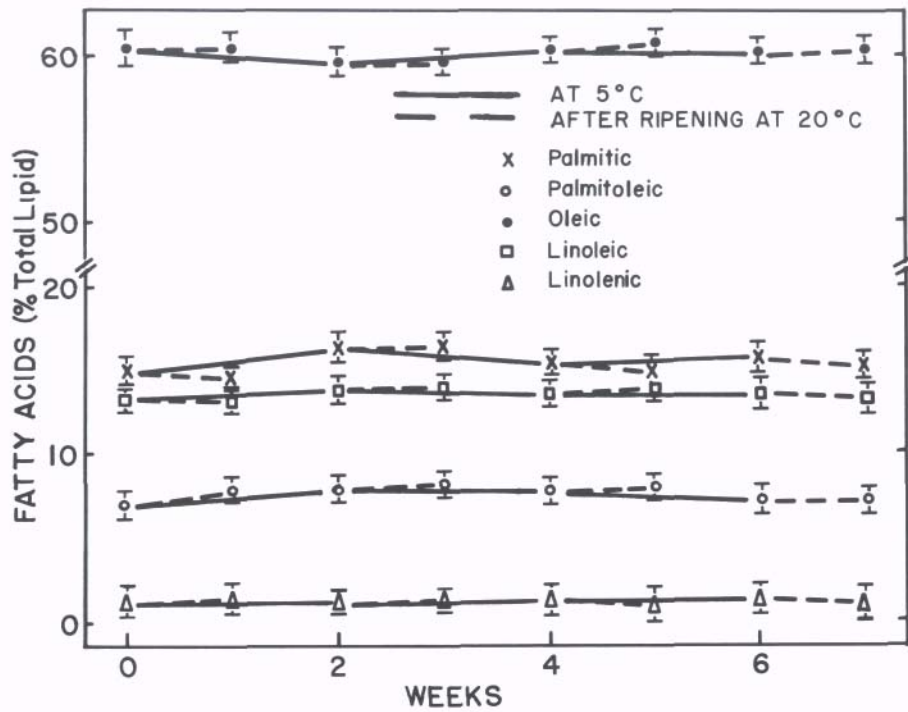


Figure 7. Changes in fatty acid composition as percentage of total lipids of 'Hass' avocados after storage for 0, 2, 4 and 6 weeks at 5° and after subsequent ripening at 20°C.