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TOWARDS IMPROVED MATURITY STANDARDS FOR 'FUERTE' AVOCADO (*Persea americana* Mill.) FRUIT IN A COOL SUBTROPICAL CLIMATE

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Abstract

Fruit maturity is a key issue for harvesting and post-harvest handling and avocado fruit are no exception. Physiological maturity may be defined as that stage of development at which the fruit, once detached from the tree, will ripen and result in a product desirable for eating. Immature fruit are known to be bland and likely to shrivel as they ripen and in extreme cases the fruit may not even soften. In addition, 'Fuerte' avocado fruit have been shown to be more prone to post-harvest physiological disorders especially later in the season, than are 'Hass' fruit. Consequently, it is imperative that maturity standards, both minimum and maximum be set for these fruit. Presently, in South Africa the lipid and reciprocal moisture percentages are used to determine minimum fruit maturity. The current investigation examined lipid accumulation, fruit firmness and pectin methylesterase (PME) activity over two seasons and found that PME activity was too variable between and within replications in both 1994 (sed = 0.005) and 1995 (sed = 0.011). Lipid content proved to be the most accurate marker and 'Fuerte' fruit should have been picked at the latest for export on Everdon Estate, Howick at lipid concentrations of about 16.5 % on a fresh mass basis or 60 % on a dry mass basis.

1. Introduction

'Fuerte' avocados are one of the main Californian cultivars grown in South Africa for export to European markets. Harvesting of 'Fuerte' fruit begins in the hotter Northern Province in February and continues until July in the cooler Kwazulu-Natal midlands. The Californian maturity standard has been adopted by the South African industry and fruit may not be picked before the lipid percentages have reached a minimum of 8% on a fresh mass basis. Although some cultivars e.g. "Hass" may be left to hang on the tree for extended periods of time without subsequent deterioration of fruit quality (Kaiser and Wolstenholme, 1994), others may not be suited to delayed harvesting as fruit senescence while on the tree is probably a limiting factor. The fact that 'Fuerte' avocado fruit especially late in the season are more prone to post-harvest physiological disorders than are 'Hass' fruit (Witney et al., 1990) is supporting evidence for this.

In the past, the only reliable maturity standard for avocado fruit was found to be total lipid content (Eaks and Sinclair, 1978) and this is still the case today (Kaiser, 1994).

Since the total lipids and moisture content are reciprocal and sum to a constant for any one cultivar (Swarts, 1976) the moisture content is still used extensively by the South African industry as a maturity standard. However, the moisture content varies according to the prevailing orchard conditions. Consequently, for accurate readings, lipid concentrations should be determined on a dry mass basis. On a different note however, Zauberman and Schiffmann-Nadel (1972) examined pectin methylesterase activity (PME), the enzyme responsible for the initiation of the ripening process, in, 'Fuerte' fruit at various stages of development and ripening and found that PME activity on the day of harvest decreased with an increase in the stage of fruit development. In younger fruit, PME activity decreased rapidly while in mature fruit, PME activity decreased moderately and they suggested from these data that PME activity may be a possible maturity indicator. Apparently however, no further work has been done in this regard. Consequently, the present study was undertaken to determine whether PME activity is a suitable maturity marker for 'Fuerte' fruit.

2. Materials and Methods

During 1994, 232 'Fuerte' fruit of count 16 (236g to 265g) from well managed orchards on the farm Everdon Estate (30º16ºE and 29º27ºS) near Howick, a cool subtropical area were harvested on a weekly basis between 17 May 1994 and 6 July 1994. Sixteen fruit were sampled on the day of harvest and fruit firmness, fruit and seed masses were recorded. The moisture content of the fruit flesh was determined gravimetrically and lipid percentages were determined using a soxhlet apparatus and plotted over time (figure 1). In addition, PME activity of radial sections was monitored by modification of the method developed by Hagerman and Austin (1986). Meanwhile, 80 fruit were placed in the laboratory and allowed to ripen at room temperature (21ºC). Eight fruit were sampled on each of the subsequent 10 days of storage and fruit firmness, fruit and seed masses, and PME activity were recorded. The change in PME activity was analyzed statistically and plotted over time (figure 2). The remaining fruit were stored at four different temperature regimes. These storage regimes were identical to treatments 2,4,6 and 9 (table 1) of Donkin et al. (1995). During each week of storage, 8 fruit were removed from each treatment and fruit firmness recorded. These values were averaged for each week and the data plotted over time.

Table 1 - Storage temperatures (°C) for treatments 2,4,6 and 9 over 4 or 5 weeks of regular atmosphere storage.

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5
2	8.5	8.5	7.5	6.5	-
4	7.5	7.5	6.5	5.5	-
6	5.5	5.5	5.5	5.5	-
9	7.5	7.5	6.5	5.5	5.5

During 1995, 144 'Fuerte' fruit of count 16 were harvested at the same site on a weekly basis between 23 May 1995 and 26 June 1995. Sixteen fruit were sampled on the day of harvest and fruit firmness, fruit and seed masses were recorded. The moisture content and lipid percentages were determined as above and the results plotted over time (figure 3). In addition, 80 fruit were placed in the laboratory and allowed to ripen at room temperature (21ºC), and 8 fruit were sampled on each of the subsequent 10 days of storage. Again the change in PME activity was

analyzed statistically and plotted over time (figure 4). The remaining fruit were again stored at the same temperature regimes (treatments 2,4,6 and 9) and the firmness of 16 fruit was recorded each week. These weekly values were averaged and the data plotted over time.

3. Results and Discussion

During 1994, lipid percentages increased over the season from about 11% on a fresh mass basis (or 53% on a dry mass basis) on 17 May 1994 to slightly more than 20% on a fresh mass basis (or about 65% on a dry mass basis) on 6 July 1994 with some minor fluctuations between these times (figure 1). During 1995, a similar trend was seen where lipid percentages increased over the season from about 12 % on a fresh mass basis (or 54.5 % on a dry mass basis) on 23 May 1995 to slightly more than 19 % on a fresh mass basis (or about 64 % on a dry mass basis) on 27 June 1995 (figure 4).

In most instances during both 1994 and 1995, PME activity usually increased the day after harvest but then declined steadily while the fruit was ripening. No definite trends in initial activity nor the rate of change of activity could be observed across either season. Consequently, PME activity is not a suitable maturity marker. Two definite decreases in initial activity were however, observed between 17 May 1994 and 1 June 1994 in the first instance and 7 June 1994 and 6 July 1994 in the second instance (figure 2). Two similar trends were observed during 1995 between 23 May 1995 and 13 June 1995 in the first instance and 20 June 1995 and 26 June 1995. PME activity was thus modeled against fruit firmness using a simple linear regression model. The relationship between fruit firmness and PME activity was highly significant ($P < 0.0001$). Consequently, firmness definitely increased with decreasing PME activity however, the r-value was only 22.8%, which means that PME activity only describes 23% of the variability in fruit firmness. This implies that PME activity is not a very good marker for fruit softening either.

Of the four temperature trials, treatment 6 (5.5ºC, 5.5ºC, 5.5ºC, 5.5ºC) the industry norm, proved the best in both seasons where fruit softness was concerned. None of the fruit receiving this treatment exceeded the maximum 35 kPa firmometer readings after 4 weeks of storage (figure 5). During the 1994 season however, fruit from treatment 6, harvested after 21 June 1994 were beginning to soften after 4 weeks in storage but still had an acceptable firmness. Indeed, some of the fruit harvested in Kwazulu-Natal left Durban harbour on Vessel 906 on 25 June 1994, and arrived in Europe soft. It appears that the optimum harvesting date for 'Fuerte' fruit in the Kwazulu-Natal midlands was up to 21 June 1994. Indeed, this was confirmed by Donkin et al. (1995) who found that there was a definite increase in physiological and pathological disorders after this date. Fruit harvested at that time had a lipid content of about 57% on a dry mass basis (or 15% on a fresh mass basis). A similar trend was seen in 1995 when post-harvest physiological problems were seen in several of the fruit cut after 20 June 1995. Here, the lipid content was about 60% on a dry mass basis (or 16.5 % on a fresh mass basis).

Fruit from treatments 2, 4 and 9 were only firm after four weeks of cold storage for the first two weeks of harvest in 1994. Whereas during 1995, fruit which underwent these same treatments, had an acceptable firmness after until the last week of harvest but was significantly higher than treatment 6 (sed= 0.997). Consequently, treatment 6 resulted in the firmest fruit after four weeks of cold storage.

4. Conclusions

'Fuerte' fruit harvested in the Kwazulu-Natal midlands at Everdon Estate, Howick during the 1994 and 1995 seasons stored best in regular atmospheric cold storage at a constant 5.5ºC over 4 weeks when compared to other stepped-up or stepped-down temperature regimes where fruit softness was concerned. The experimental fruit stored at this regime in South Africa were still relatively firm even when harvested after 21 June 1994 however, some of the commercial consignments of fruit (on Vessels 906 and 907), which underwent similar storage conditions arriving in Europe 4 weeks after that date were soft. During 1995 however, all fruit were firm after 4 weeks at a constant 5.5ºC. For the first three weeks of storage during 1994 (17 May 1994 until 01 June 1994) and the first 5 weeks of storage during 1995 (23 May 1995 until 20 June 1995) however, there were no marked differences in fruit firmness where treatments 2,4,6 and 9 were concerned. Consequently, it is recommended that fruit are stored a constant 5.5ºC for 4 weeks to reach the European markets firm.

Lipid content, still the most reliable maturity standard for avocados to date, plateaued on 21 June 1994 at approximately 58% on a dry mass basis (or 16% on a fresh mass basis). After that time it declined to about 57 % on a dry mass basis (or 15 % on a fresh mass basis) by 29 June 1994. This together with the fact that physiological browning disorders of the mesocarp (Donkin et al. 1995) and distal-end browning (Kaiser et al., 1995) increased after 21 June 1994 indicates a maximum fruit maturity date. In 1995, a similar trend was seen where post-harvest physiological disorders appeared in fruit harvested after 20 June 1995. Here, fruit lipid content was 60% on a dry mass basis (or 16.5 % on a fresh mass basis). Consequently, based on these results it is recommended that 'Fuerte' fruit from Everdon Estate, Howick should all be harvested when lipid concentrations reach a maximum of 60% on a dry mass basis (or 16.5% on a fresh mass basis). During 1994 and 1995, this coincided with the last week of June.

Analysis of PME activity showed two definite decreases in initial activity in both 1994 and 1995 (figures 2 and 4) however they were not coincidental. Consequently, PME activity is not a good fruit maturity marker. Finally, modeling of PME activity showed that PME activity only describes 23% of the variability in fruit firmness.

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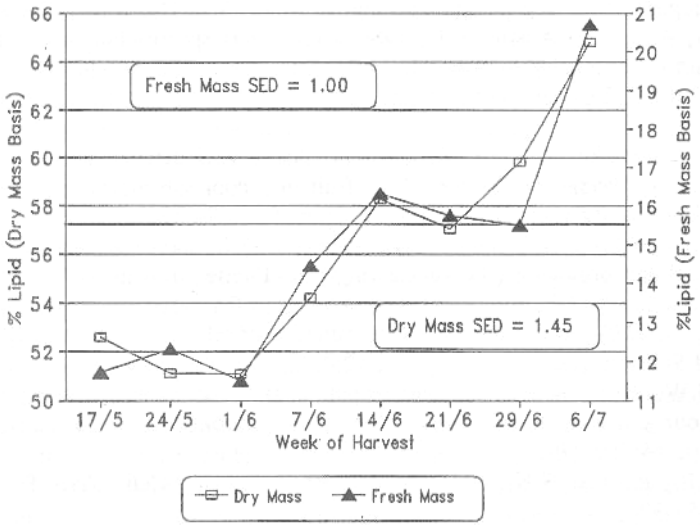

Figure 1. Average lipid content (%) on a dry and a fresh mass basis for 'Fuerte' fruit harvested between 17 May 1994 and 06 July 1994 at Everdon Estate (Howick)

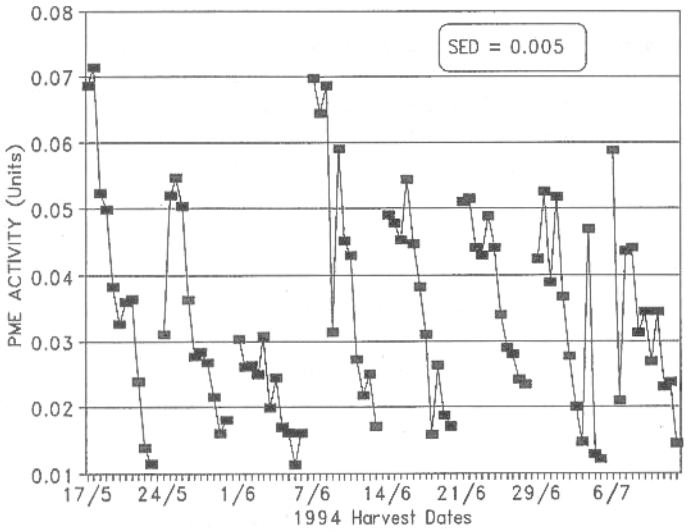

Figure 2. Average values of pectin methylesterase activity for 'Fuerte' fruit harvested during 1994 at Everdon Estate (Howick) between 17 May 1994 and 06 July 1994 and allowed to ripen at room temperature (21°C)

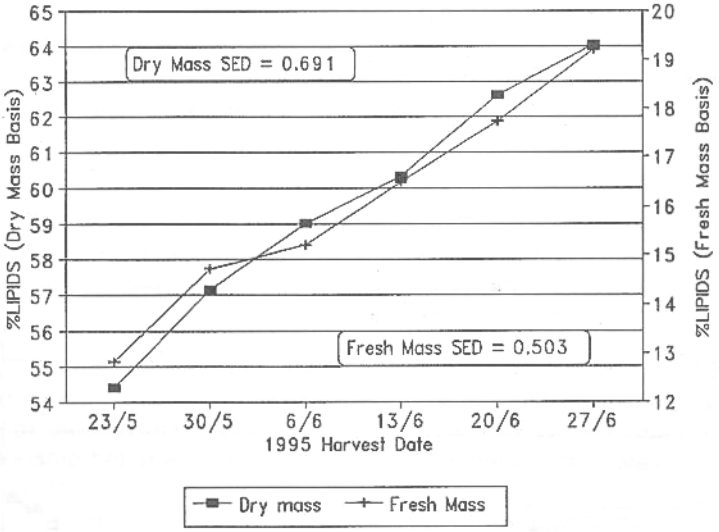

Figure 3. Average lipid content (%) on a dry and a fresh mass basis for 'Fuerte' fruit harvested between 23 May 1995 and 26 June 1995 at Everdon Estate (Howick)

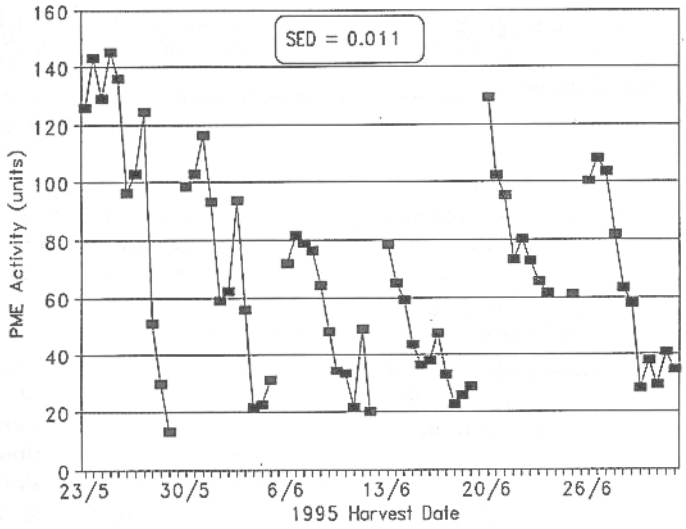

Figure 4. Average values of pectin methylesterase activity for 'Fuerte' fruit harvested during 1995 at Everdon Estate (Howick) between 23 May 1995 and 26 June 1995 and allowed to ripen at room temperature (21°C)

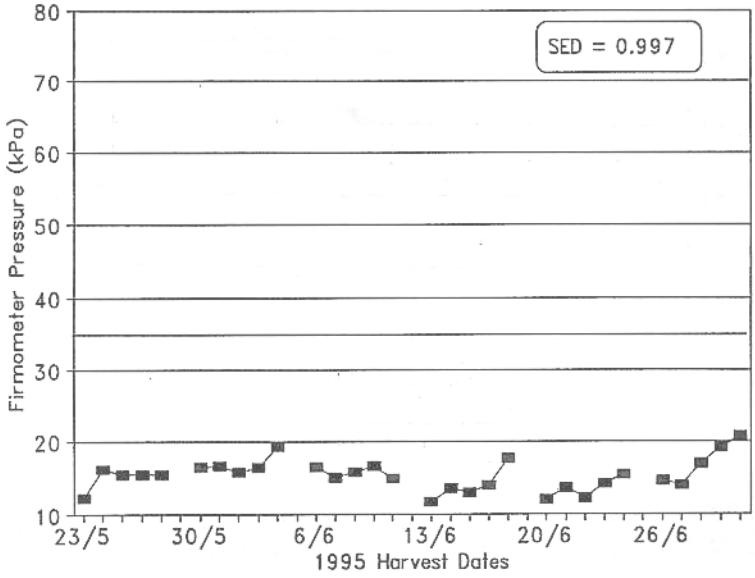

Figure 5. Firmometer readings (kPa) for fruit harvested weekly at Everdon Estate in 1995 and kept in cold storage for 4 weeks at temperatures of 5.5°C, 5.5°C, 5.5°C, 5.5°C respectively (Treatment 6)