

Physiological Maturity and Percent Dry Matter of California Avocado

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Abstract. A three-year study of major California avocado cultivars was undertaken to evaluate the correlation between physiological maturity and the percent dry matter of the fruit flesh. Guidelines were established for sampling, softening and scoring of both external and internal quality, as well as laboratory methods for percent dry matter determination. Panel scores were used to establish minimum levels of acceptable maturity and used in conjunction with regression analysis to arrive at minimum maturity standards for use by the California avocado industry.

The study demonstrated that there is a measurable relationship between percent dry matter and physiological maturity of the avocado. Although there is variability from year to year and site to site, it is possible to assign a dry matter value for fruit of marketable maturity. It is also evident that this relationship is not area-related within a given production district and not district related within California. A usable procedure has been developed for determining the minimum acceptable harvest level for avocado, based on physiological maturity as expressed by percent dry matter. The minimum maturity standards based on percent dry matter developed for California are: 'Bacon', 18.5%; 'Fuerte', 19.9%; 'Gwen', 25.9%; 'Hass', 21.6%; 'Pinkerton', 23.0%; 'Reed', 19.8%; 'Zutano', 18.8%.

Historically, percent oil content has been used in California as an indicator of minimum fruit maturity in avocado (Anon., 1924). In avocado fruit, oil content is relatively high and its increase is closely related to fruit development. Until the mid-1980's the official method for determining percent oil content in California utilized a refractometric method which involved Halowax oil (monochloro-naphthalene) as a solvent (Lesley and Christie, 1929). Halowax oil is a suspected carcinogen and is no longer available for use in determining avocado percent oil content. In 1983 the California avocado industry (Anon., 1983) adopted percent dry matter as the official method for determining minimum avocado maturity based on the work of Lee *et al.* (1983) which demonstrated the close relationship between percent oil content and percent dry matter during fruit growth and maturation.

In the transition from a maturity standard governed by percent oil content to percent dry matter, questions were raised as to how accurately percent dry matter depicted actual

physiological maturity. To ascertain if percent dry matter could be used as an indicator for maturity, it was necessary to develop a definition for acceptably mature avocados based on the physiological maturity of the fruit, to determine if the definition of maturity could be correlated with percent dry matter by variety, and if so, to determine if the relationship varied from year to year. With this information it would be possible to develop minimum maturity standards that would represent the same level of physiological maturity for each variety. It was hoped that this data would be of benefit in promulgating improved standards, methods and regulations concerning avocado maturity.

Materials and Methods

Varieties and Growing Districts. Sample sites were selected for the Bacon, Gwen, Fuerte, Hass, Pinkerton, Reed and Zutano cultivars. In an attempt to gain some knowledge of the effect of growing area, sites were chosen in the Central Valley District, the North Coastal District and the South Coastal District of California (Fig. 1). The North Coastal District was broken down into three areas, with two sites chosen from each: Ventura-Coastal influence, Ventura-Inland influence, and Santa Barbara. The South Coastal District was divided into three areas with two sites of each variety selected from the areas of Escondido-Pauma Valley, Fallbrook-Bonsall, and Rancho California.

Sampling. Each site was sampled every two weeks until the fruit were past the point of full marketability or until harvested. Only good commercial groves were chosen and any obviously stressed or diseased areas were avoided. For each sampling period, approximately 25 fruit were picked from 25 different trees in one general area of each grove. Careful consideration was given to fruit size and all fruit were picked as close to a single size (48 or 40; 213-269 g or 269-326 g, respectively) as possible (In a given grove, percent dry matter will generally vary with size). The fruit were held until the next day for testing. Each site sample was inspected, and any damaged or obviously over or under sized fruit were discarded. Using the remaining fruit five pairs were chosen, with each pair matched as closely as possible in size, color and shape. One set of five (Group A) was weighed and tested for dry matter. The other set of five (Group B) was placed on a ventilated rack in such a manner that the fruit did not touch and held at 20C (68F) and 80% relative humidity until soft.

Percent Dry Matter. Each individual fruit was cut longitudinally, and opposing eighths (with the seed, seed coat and peel removed) were chopped in a food processor equipped with a chopping blade, to a size 3 mm and smaller. Approximately 5 g of pulp were weighed in a Petri dish cover, placed on a heat-resistant rack and dried in a microwave oven (1050 watts) at 70% power setting. Samples were dried for 12.5 minutes, rotated 180 degrees, dried for another 12.5 minutes, and weighed. The samples were then returned to the oven for additional 10 minute periods until constant weight was attained. The results were recorded as percent of original weight and reported as an average of the five individual values.

Maturity Value. Maturity value was defined as the average of the external and internal panel scores of the five fruit in question. Scoring was done when the sample was determined to be soft enough for use, or in the case of immature fruit, when it appeared that no further softening would take place. Each fruit was individually scored externally by each member of the panel. The fruit was then halved and the scoring repeated internally. Upon completion each panelist noted the overall marketability of the sample ("almost marketable", "just marketable" or "marketable"). A consensus of the panel was used to describe the sample. When the entire panel scored the sample "marketable" an asterisk (*) was placed beside the marketable designation.

As could be expected, given the inherent fruit to fruit variation, the five avocados did not soften evenly. To compensate for this, and to allow the scoring to be done at one time, when a fruit was within one day of scoring it was placed under refrigeration at 5C (41 F) until the day before a scoring session, when it was then returned to the storage rack. In this manner all fruit were the same temperature for scoring and were of reasonably uniform softness.

The definitions used for scoring were as follows:

EXTERNAL

5. Uniformly soft with not more than slight shriveling;
4. Generally soft with some shriveling;
3. Not completely soft with or without noticeable shriveling or noticeable shriveled;
2. Firm with or without heavy shriveling or heavily shriveled;
1. Hard to the touch or rubbery with prune-like shriveling.

INTERNAL

5. Uniformly soft throughout with creamy smooth texture;
4. Generally soft with some evidence of firm and/or grainy texture or slight wateriness;
3. Some firmness or resistance entailing less than 25% and/or signs of excessive wateriness;
2. Rubbery and/or hard spots more than 25%, less than 50%;
1. Rubbery and/or hard spots more than 50%.

Results

The site data was accumulated by crop year, variety and growing district for fruit weight, percent dry matter, maturity value, days to soften, marketability, and percent dry matter corrected to a constant weight of 236 g. This was done by sampling periods with averages calculated for each sampling period.

Figures 2a and 2b are graphical representations for 'Bacon' and 'Fuerte' of the average percent dry matter and average maturity value by sample period for three crop years. The linear relationships developed for each variety were analyzed for yearly variation. There were no significant differences in slopes for all varieties. There was only one difference between years for adjusted maturity value and that was 'Hass', 1986-87, being different at the 5% level from 1987-88 and 1988-89. This difference, however, was not large enough to preclude the use of an average value for the three years. This difference was not confirmed by the other varieties, suggesting causes other than yearly weather variation, most likely site variation, as the same sites were not used every year. With no strong indication of differences due to yearly variations, a single average equation was calculated for each variety from the three yearly formulae developed by regression analysis (Table 1).

Figures 3a and 3b show the same year comparison between the North Coastal and South Coastal Districts for 'Bacon' and 'Hass'. The two comparisons were analyzed for statistical differences. There was no difference in slopes between districts for either variety and a significant, but small, difference in adjusted maturity value for the 'Bacon', which was not confirmed by the 'Hass'. The conclusion was made that no meaningful difference exists between the two districts as to the level of percent dry matter required for a given maturity value for a given variety. This allows a single standard to be used for both districts.

The data for maturity value for each level of marketability were subjected to statistical analysis. There was a high degree of correlation between marketability and maturity value. The averages are presented in Table 2.

Discussion

The consensus of the panel was that fruit scoring between "Just Marketable" and "Marketable", which corresponded to a maturity value of 4.0, resulted in a product that did not contain an excessive amount of unsatisfactory fruit. While either the percent dry matter for a maturity value of 4.0 averaged for the three years of the study or the average percent dry matter for a maturity level of "Just Marketable"/"Marketable" could have been chosen as a level of minimum maturity, it was desired to use something less subjective than general opinions of marketability. Recognizing that all lots of early fruit will have some level of immature fruit, minimum maturity was defined as the percent dry matter that resulted in an acceptable level of unacceptable fruit. Thus, given the maturity value corresponding to unacceptable fruit and the acceptable percentage of that fruit, the percent dry matter that represented this minimum level of acceptable maturity could

be calculated for each variety using the average formula in Table 1 and the coefficient of variation for percent dry matter of each variety in Table 3.

The scoring panel was polled and a maturity value of 3.5 was established as the level below which an individual fruit was determined to be unacceptable. The acceptable level of unacceptable fruit was set at 5%. The percent dry matter that corresponded to 5% of the fruit at or below a maturity value of 3.5 was calculated for the major varieties from the average formula in Table 1. The results were all very close to an equivalent maturity value of 4.0 (3.9 to 4.1). As the 4.0 range on the regression lines gave better year to year agreement than the 3.5 level, a single value of 4.0 was used as the minimum maturity value. This gave percentages of unacceptable fruit from 3 to 9 percent, depending upon variety.

It has been established that there is a measurable relationship between percent dry matter and physiological maturity of avocados. While differences exist from year to year and site to site, the relationship does not appear to be area-related within a given district and not district related within the state, all of which make it possible to assign a single percent dry matter value to each variety for fruit of marketable maturity based on its physiological maturity.

The levels of minimum acceptable maturity developed by this study are presented in Table 4.

It must be stressed that these minimum maturity levels are only valid when considered in the context of this study and of the California Department of Food and Agriculture regulations covering sampling and testing of avocados for acceptable maturity. The major items include: a sample of five fruit from a sized lot of avocados, or the equivalent size range for grove-sampled fruit, the percent dry matter determined within 24 hours of harvest and the sample preparation and drying procedures conforming with the published regulations.

The data developed by this study can be the basis for the establishment of improved regulations, methods and minimum standards covering the early marketing of fruit prior to a general exemption from testing.

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Table 1. Minimum maturity percent dry matter for four avocado cultivars grown in the South Coastal District.

Cultivar	Year	Line of best fit	% Dry matter @ 4.0 maturity value	Avg % dry matter (just marketable and marketable)
Bacon	86-87	MV = 0.2430 %DM - 0.54	18.88	
	87-88	MV = 0.2620 %DM - 0.75	18.12	
	88-89	MV = 0.2542 %DM - 0.68	18.42	
	3-year avg.		18.47	18.67
	Avg. formula	MV = 0.2522 %DM - 0.66	18.46	
Fuerte	86-87	MV = 0.2459 %DM - 0.98	20.23	
	87-88	MV = 0.0821 %DM + 2.44	19.04	
	88-89	MV = 0.1886 %DM + 0.28	19.71	
	3-year avg.		19.66	19.69
	Avg. formula	MV = 0.1722 %DM + 0.58	19.85	
Hass	86-87	MV = 0.2566 %DM - 1.62	21.92	
	87-88	MV = 0.0963 %DM + 1.92	21.20	
	88-89	MV = 0.1550 %DM + 0.68	21.39	
	3-year avg.		21.50	21.64
	Avg. formula	MV = 0.1693 %DM + 0.34	21.62	
Zutano	86-87	MV = 0.2829 %DM - 1.30	18.72	
	87-88	MV = 0.1651 %DM + 0.73	19.83	
	88-89	MV = 0.3399 %DM - 2.20	18.24	
	3-year avg.		18.93	18.53
	Avg. formula	MV = 0.2626 %DM - 0.92	18.75	

Table 2. Average maturity values at various levels of marketability for avocado cultivars grown in the South Coastal District.

Consensus Marketability	Yearly average maturity value (all cultivars)			3-year Average
	86-87	87-88	88-89	
Almost marketable	3.35	3.53	3.42	3.43
Just marketable	3.83	3.94	3.76	3.84
Marketable	4.01	4.22	4.06	4.10
Marketable* ^z	4.24	4.36	4.34	4.31

^z "Marketable*" indicates that the panel was unanimous that the fruit was fully marketable.

Table 3. Coefficients of variation for four avocado varieties grown in the South Coastal District.

Variety	Yearly average			3-year Average
	86-87	87-88	88-89	
Bacon	6.26	6.05	6.71	6.34
Fuerte	8.20	6.37	8.38	7.65
Hass	7.79	8.16	9.51	8.49
Zutano	7.00	7.70	8.20	7.63

Table 4. Minimal acceptable maturities for various avocado cultivars.

Cultivar	Percent Dry Matter
Bacon	18.5
Fuerte	19.9
Gwen	25.9
Hass	21.6
Pinkerton	19.8
Zutano	18.8

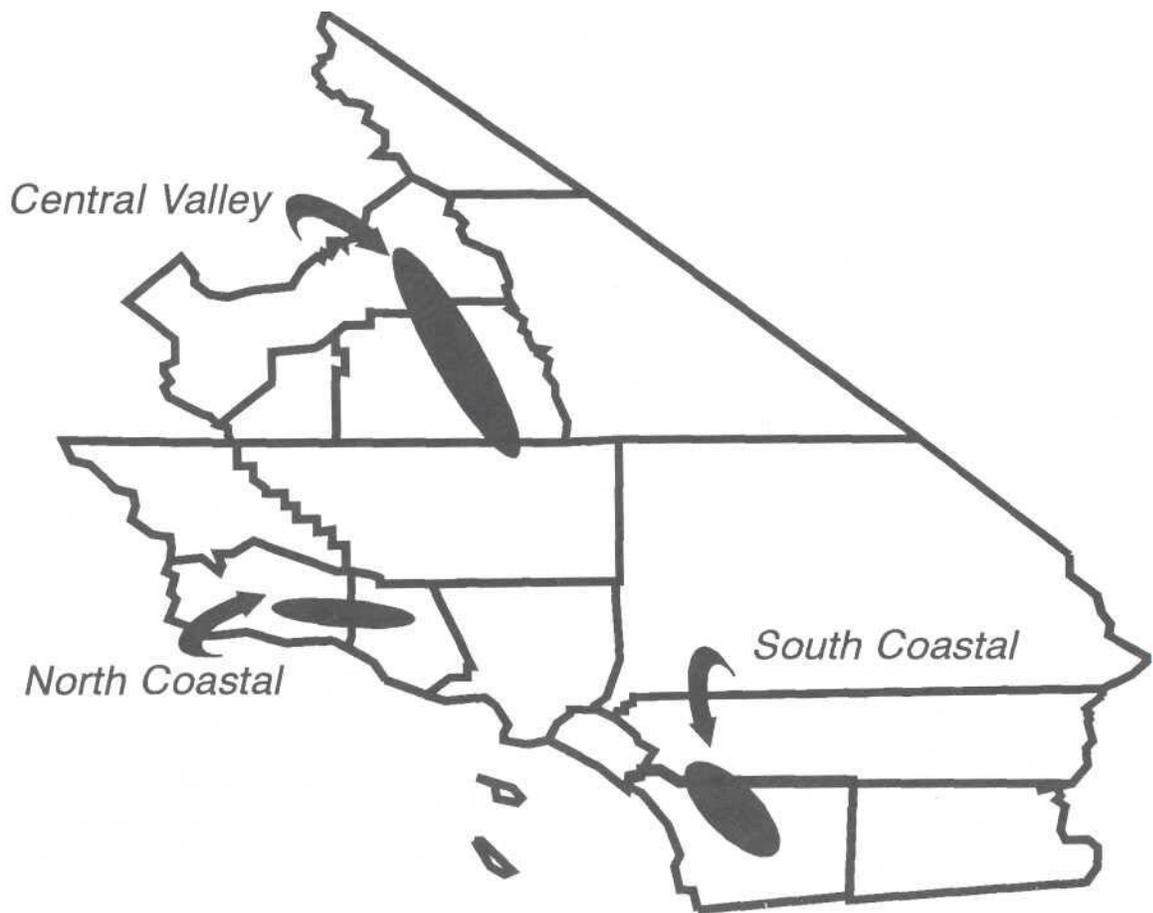


Fig. 1. Avocado production districts in Southern California utilized in maturity study.

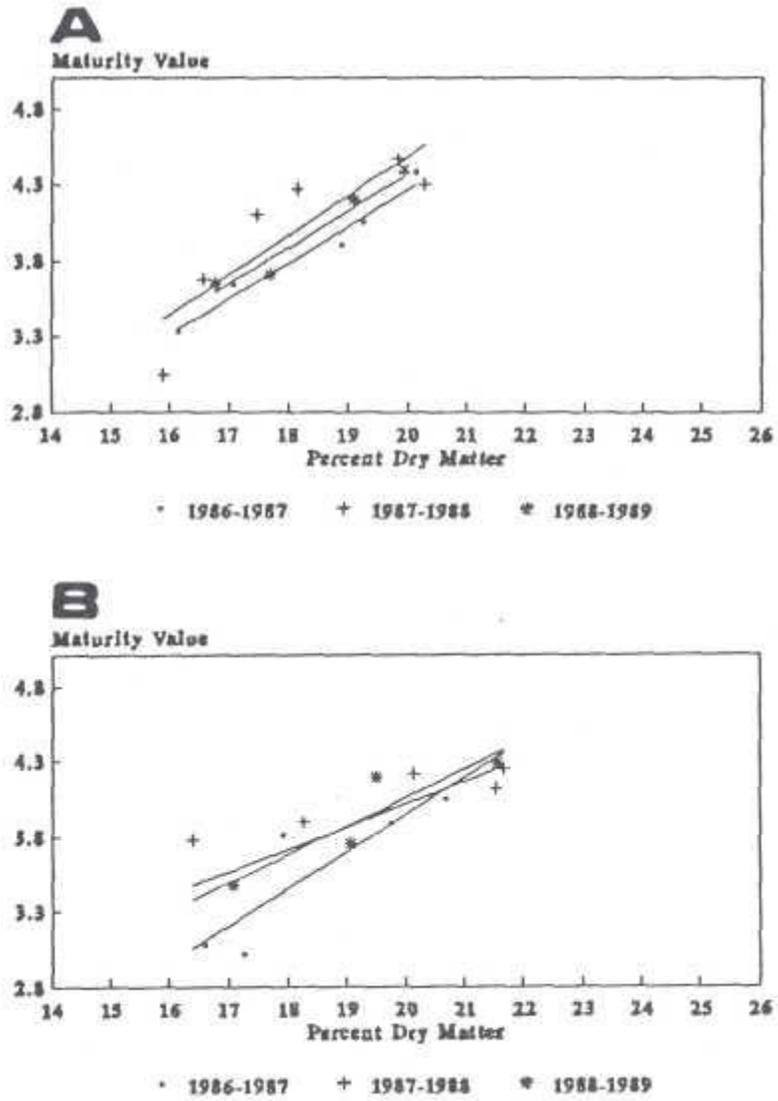


Fig. 2. Changes in percent dry matter in two avocado cultivars compared to maturity value for each sampling year (1986-87; 1987-88; 1988-89): A) 'Bacon'; B) 'Fuerte'. Fruit from South Coastal District only.

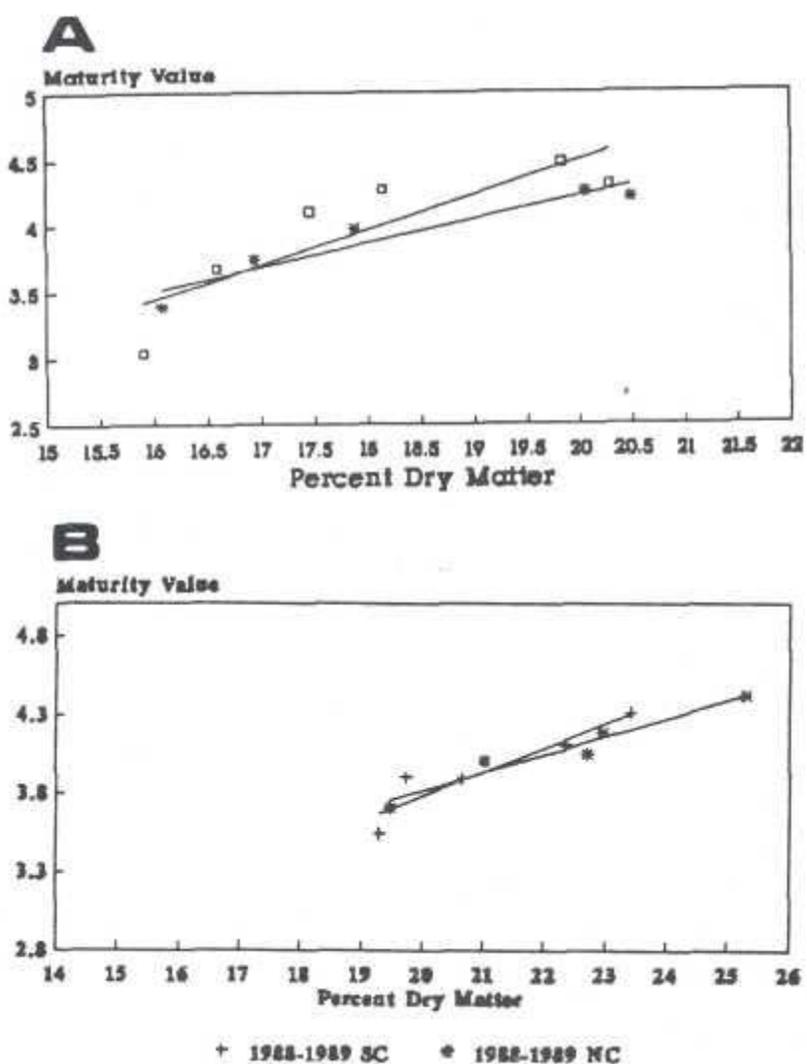


Fig. 3. Changes in percent dry matter in two avocado cultivars compared to maturity value for a single year (1988-89): A) 'Bacon'; B) 'Hass'. Fruit from North and South Coastal Districts.