

Relationship Between Physiological Maturity and Percent Dry Matter of Avocados

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Introduction

In the transition from a California maturity standard for avocados governed by percent oil content, as estimated by the "Halowax Method", to one based on percent dry matter, there have been many questions raised as to how accurately either depicts actual physiological maturity. There was also a feeling in the industry that the relationship between physiological maturity and percent dry matter might vary enough from year to year to require a change every season in the minimum percent dry matter required for harvest. To ascertain if percent dry matter could be used as an indicator for maturity, four items needed to be accomplished:

1. Develop a definition for acceptably mature avocados based on the physiological maturity of the fruit, eliminating the subjectivity of taste to the maximum extent possible.
2. Determine if this definition of maturity can be correlated with percent dry matter by variety.
3. If there is a measurable correlation, determine if the relationship varies from year to year; and if so, by how much.
4. If there is a yearly change, establish if it is large enough to preclude using a constant value of percent dry matter from year to year.

With this information, it would be possible to adjust the minimum maturity standards to accurately represent the same level of physiological maturity for each variety. It was also hoped that these data would be of benefit in promulgating improved standards, methods, and regulations concerning avocado maturity.

Results of a preliminary study made during the 1985-86 "maturity season" strongly indicated that a measurable relationship existed between physiological maturity and the percent dry matter of the pulp. *The objective of this study was to define and quantify this relationship.* These results also indicated that establishing the relationship between

percent dry matter and maturity each year prior to harvest was not practical, since the time needed to soften and score the fruit was such that if a delay in harvest was indicated, it would not be known until after harvest had started. Given this problem, it was hoped that the relationship between percent dry matter and physiological maturity would be constant enough from year to year that yearly testing would be unnecessary.

Since there was strong industry interest in the pre-season establishment of harvest dates by size and variety, the study was designed to collect data that would be helpful in the future development of such a program.

Materials and Methods

Since the then current procedure for the determination of percent dry matter used by the State of California entailed a sample of five avocados, a sample size of five fruit was chosen for this study.

The general approach was to match, as closely as possible, five pairs of fruit, all falling within a narrow weight range; determine the percent dry matter individually on one set of five; and assign a "maturity value" to the other set. When the second set reached an acceptable level of physiological maturity, the average percent dry matter of the first set could be considered the appropriate minimum value for the variety and year in question.

The sampling periods were chosen in an attempt to encompass a broad maturity range, from unmarketable to fully marketable.

Each sample site (variety, district) was sampled every two weeks until past the point of full marketability, or until harvested. Only good commercial groves were chosen as sample sites, 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. It was attempted to pick all fruit as close to a single size (48 or 40) as possible, since in a given grove percent dry matter will generally vary with size.

The fruit was brought back to the Avocado Inspection Service office in Escondido and held until the next day for testing.

Each site sample was inspected, and any damaged or obviously over-or under-sized fruit was 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, 1-5) was tested for dry matter, and the other set of five (Group B, 1-5) was allowed to soften and was then scored for maturity.

Each fruit was weighed (gram weights) the day following harvest.

Dry Matter was run on the individual fruit of Group A immediately after weighing.

Group B was placed on a ventilated rack in such a manner that the fruit did not touch and was held at 20°Celsius (68 °F) and 80% Relative Humidity.

Percent Dry Matter

Percent Dry Matter is defined as the average percent dry matter of five avocados determined by the procedure listed in 1408.3 of the Administrative Code - Title 3 of California.

In an effort to improve the test's reproducibility, the following changes were made in the official procedure:

1. Opposing eighths from each fruit were used as the sample instead of slices from the face of a single half.
2. The sample was chopped to approximately 3 mm. in a food processor instead of using individual slices.
3. The sample was dried for 25 minutes and then to constant weight at 5 minute intervals instead of 10 minutes and 1 minute intervals.

Maturity Value

Maturity Value is defined as the average of the external and internal panel scores of the five fruit in question. (The panel consisted of eight persons during the course of this study, with a core group of five persons present at 95 percent of the sessions.)

Scoring was done when the sample was determined to be soft enough to 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 scored internally. Upon completion, each panelist noted the overall marketability of the sample as a whole and expressed it as "almost marketable", "just marketable", or "marketable". A consensus of the panel was used to describe the sample. When the entire panel felt the sample was 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 uniformly. To compensate for this, and to allow scoring to be done at one time, when a fruit was within one day of scoring, it was placed under refrigeration at 5 degrees Celsius (41 °F) until the day before a scoring session, when it was returned to the storage rack. In this manner, all fruit was at the same temperature for scoring and were reasonably uniform in their softness. The number of days that a given fruit had been under refrigeration was noted, and the assumption was made that it had not softened during that time.

The definitions used for scoring were as follows:

EXTERNAL

- 5 = Uniformly soft, with no more than slight shriveling.
- 4 = Generally soft, with some shriveling.
- 3 = Not completely soft, with or without noticeable shriveling or noticeably 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 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% and less than 50%.
- 1= Rubbery, and/hard spots more than 50%.

Results and Discussion

Figures 1a through 1d are graphical representations for Bacon, Fuerte, Hass, and Zutano of the average Percent Dry Matter and average Maturity Value by sample period for the three crop years that comprised the entire period of the study. Only data representing Maturity Values of 3.0 and above (from the scoring tables *supra*) have been included in the graphical presentations. The values below 3.0 are of no economic importance, and the linear correlation is improved by their omission.

The graphs confirm the early indication that a measurable relationship between dry matter and physiological maturity exists.

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 in Hass, 1986-87 being different at the 5% level from 1987-88 and 1988-89. The difference 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, since the same sites were not used every year.

With no strong indication of differences due to yearly variations, a single equation was developed for each variety (Table 5).

Figure 1a
MATURITY VALUE vs PERCENT DRY MATTER
 Bacon - South Coastal

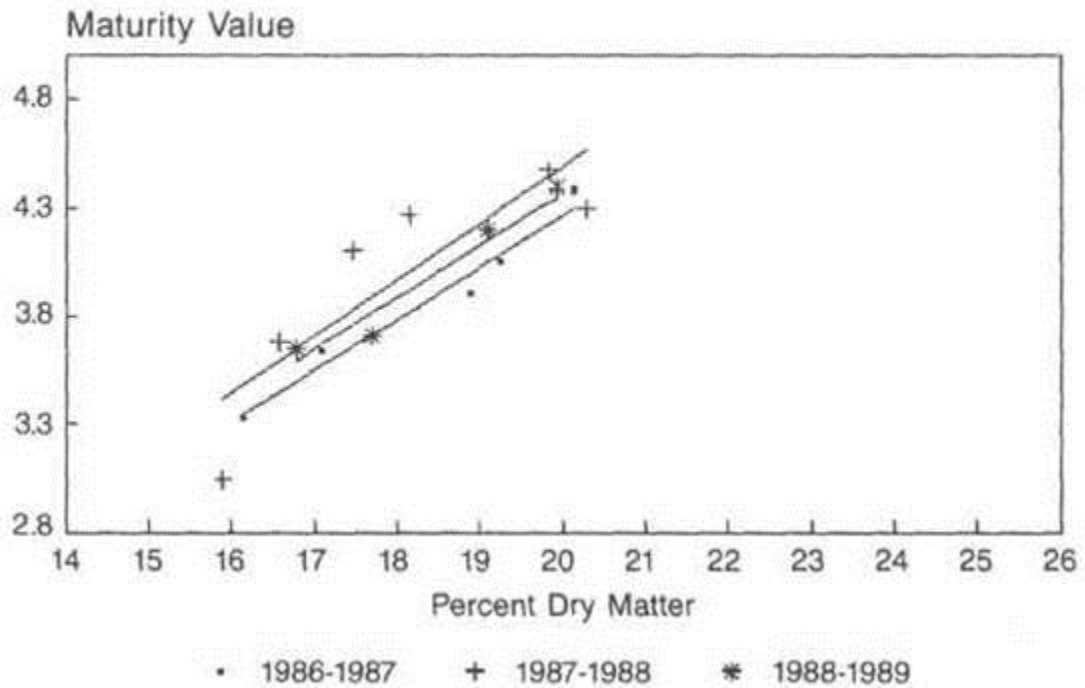


Figure 1b
MATURITY VALUE vs PERCENT DRY MATTER
 Fuerte - South Coastal

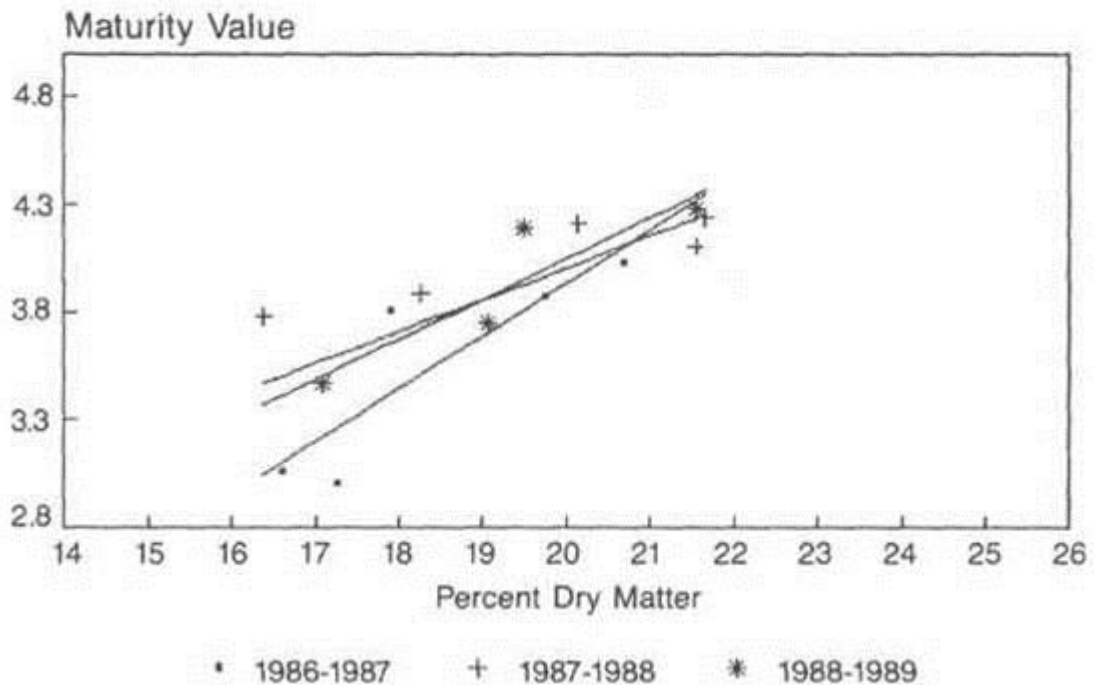


Figure 1c

MATURITY VALUE vs PERCENT DRY MATTER
Hass - South Coastal

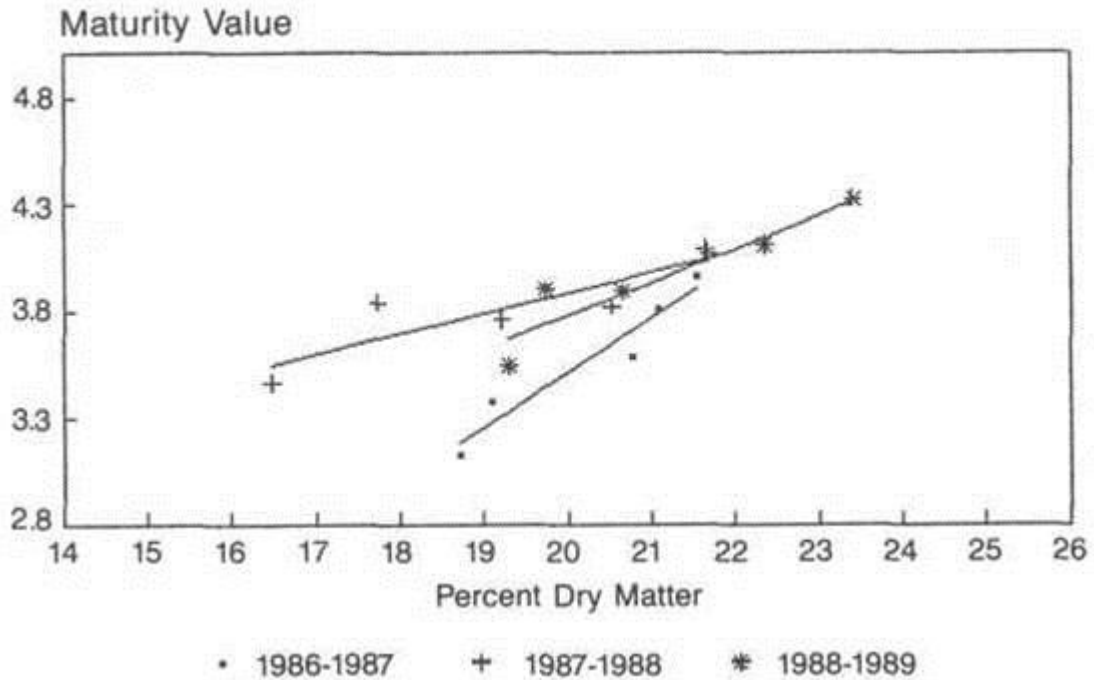
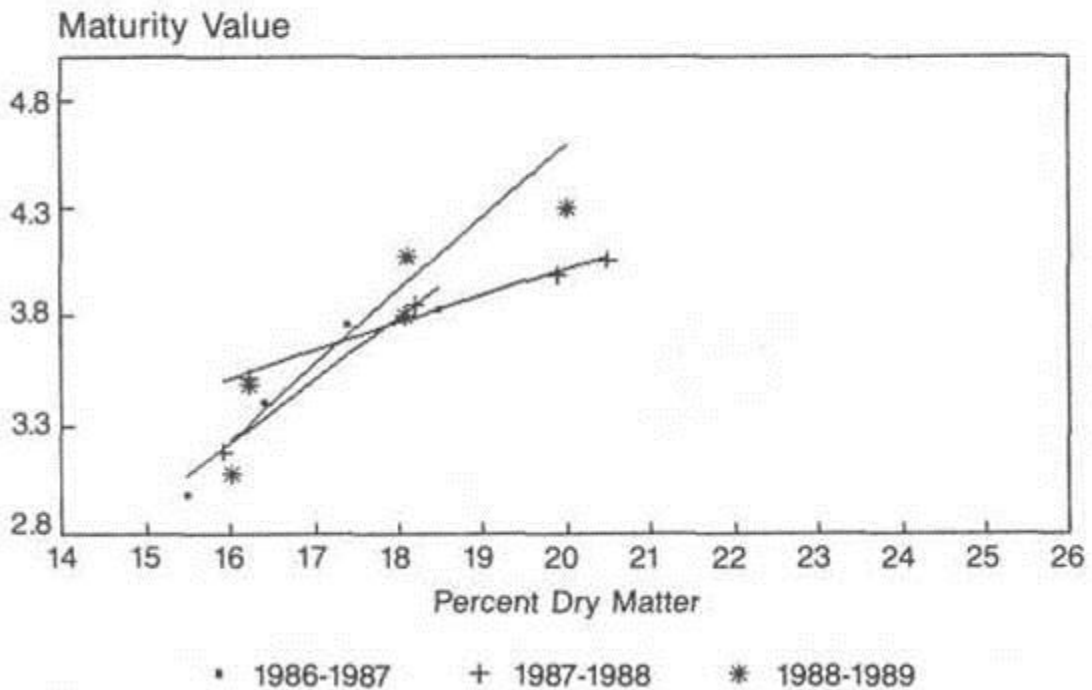


Figure 1d

MATURITY VALUE vs PERCENT DRY MATTER
Zutano - South Coastal



Figures 2a and 2b show the same year comparison between the North Coastal and South Coastal Districts for Bacon and Hass.

The comparisons between the North Coastal and South Coastal Districts 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.

Figure 2a
MATURITY VALUE vs PERCENT DRY MATTER
Bacon - North & South Coastal

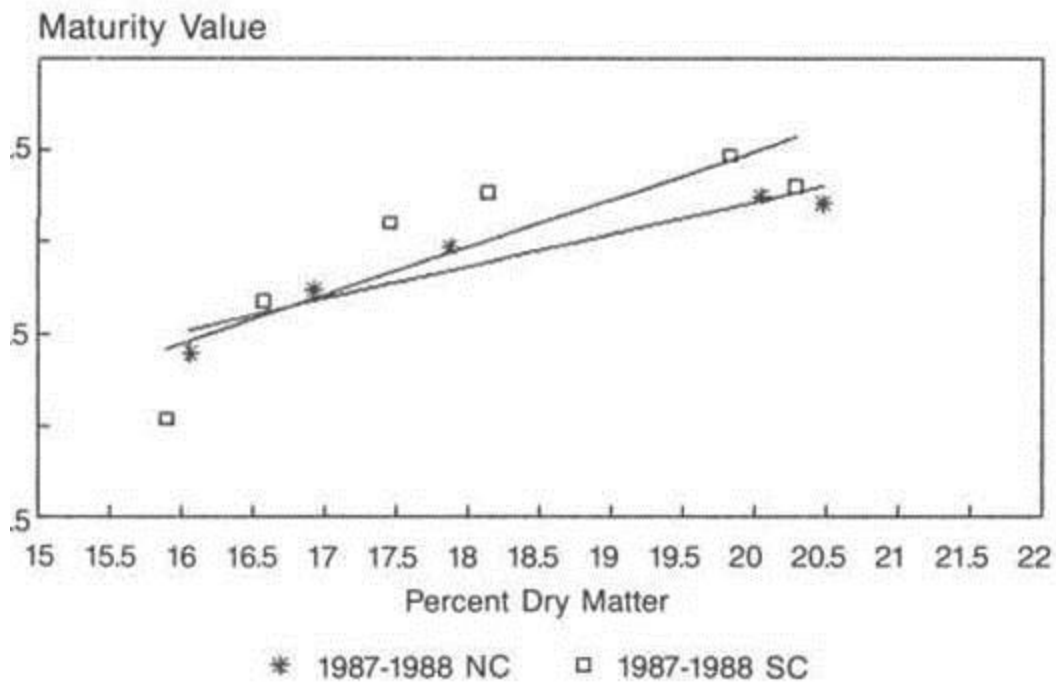
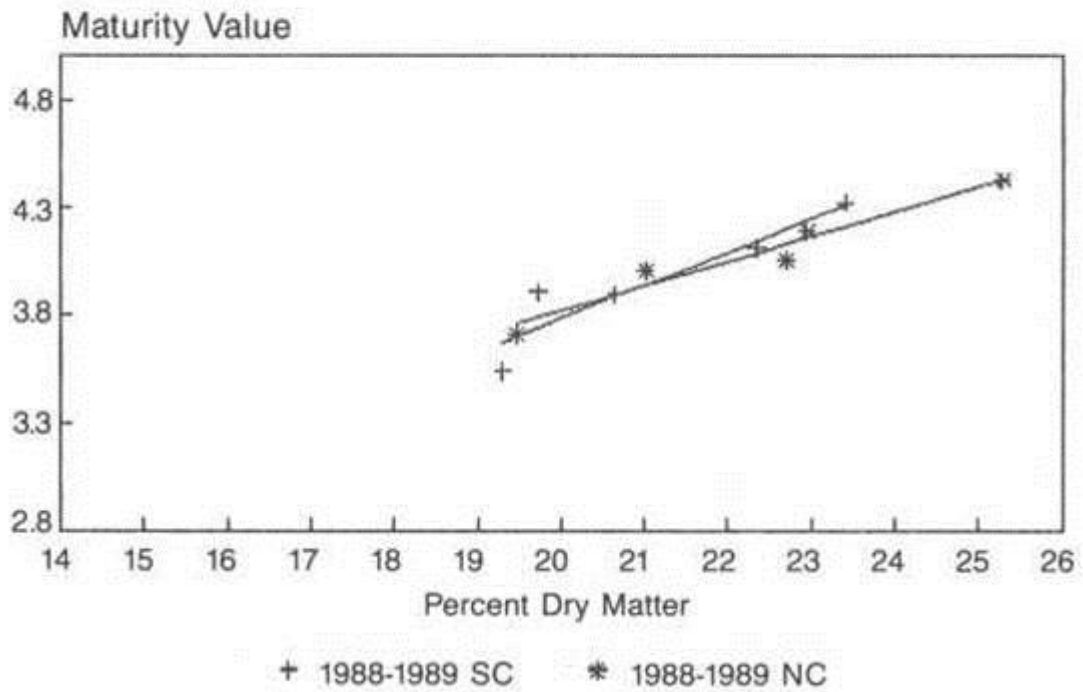


Figure 2b

MATURITY VALUE vs PERCENT DRY MATTER Hass - South & North Coastal



It was not possible to collect adequate data for Central Valley Zutano since, in most years, harvest was completed before full marketability levels were attained.

Table 1 lists the Average Maturity Values by variety for each level of marketability taken from the tables in the Appendix.

Table 1. Average maturity values at various levels of marketability.

VARIETY	CONSENSUS MARKETABILITY	Average Maturity Value			
		86-87	87-88	88-89	AVERAGE
Bacon -NC	Almost Marketable		3.33		NA
	Just Marketable		3.92		NA
	Marketable		4.28		NA
Bacon-SC	Almost Marketable	3.33	3.32	3.38	3.34
	Just Marketable	3.87	3.94	3.73	3.85
	Marketable	3.94	4.31	4.05	4.10
	Marketable*	4.32	4.51	4.38	4.40
Fuerte-SC	Almost Marketable	3.31	3.64	3.41	3.45
	Just Marketable	3.87	4.01	3.61	3.83
	Marketable	4.12	4.33	4.07	4.17
	Marketable*	4.29	4.37	4.47	4.38
Gwen-SC	Almost Marketable			3.41	NA
	Just Marketable			3.70	NA
	Marketable			4.08	NA
	Marketable*			4.37	NA
Hass-NC	Almost Marketable (a)			3.50	NA
	Just Marketable			3.87	NA
	Marketable			4.13	NA
	Marketable*			4.37	NA
Hass-SC	Almost Marketable	3.40	3.69	3.50	3.53
	Just Marketable	3.85	3.96	3.86	3.89
	Marketable	4.04	4.15	4.11	4.10
	Marketable*	4.15	4.30	4.34	4.26
Pinkerton-NC	Almost Marketable			3.55	NA
	Just Marketable			3.84	NA
	Marketable (a)			4.06	NA
	Marketable* (a)			4.32	NA
Reed-SC	Almost Marketable			3.64	NA
	Just Marketable			3.85	NA
	Marketable			4.11	NA
	Marketable*			4.28	NA
Zutano-CV	Almost Marketable	3.47	3.47	3.21	3.38
	Just Marketable	3.76	3.62	3.40	3.59
	Marketable	3.97	4.05		NA
Zutano-SC	Almost Marketable	3.37	3.48	3.38	3.41
	Just Marketable	3.72	3.85	3.85	3.81
	Marketable	3.92	4.10	4.02	4.01
	Marketable*	4.20	4.26	4.18	4.21

(a) one or two values only

A point to be made is that the categories of marketability were only consensus levels of the panel with no numerical values assigned. This means that a sample with a four to three Marketable/Just Marketable score was assigned the same marketability level as a sample with a score of six to one having a higher level of marketability and a higher Maturity Value. Maturity Value is therefore the descriptor to use in defining marketability.

It is interesting to compare the average Maturity Values at equal levels of marketability for each variety. The consistency is encouraging, given the large differences, and the resultant difficulty in scoring, between a smooth skin, non-wrinkling variety such as Bacon and one of opposite characteristics such as Gwen. This gives a high level of confidence in using Maturity Value in conjunction with the regression formula for the determination of percent dry matter for various levels of marketability.

Table 2 lists the Average Percent dry matter by variety for each level of marketability determined from the study data. For the Marketable category, these levels of dry matter are close to the levels developed in 1984 by the Fruit Quality and Maturity Committee based on tests conducted by the University of California at Riverside. This result is not illogical since one would expect good flavored fruit to be physiologically mature.

The data for both Maturity Value and percent dry matter for each level of marketability were subjected to statistical analysis. For each variety, it was found that there was a high degree of correlation between marketability and Maturity Value or percent dry matter, although there are some "irregularities" where only a limited number of observations were obtained.

Table 3 presents the average of all varieties from Table 1.

The three year average values of Table 3 will be those used in the following discussions of Maturity Value and marketability.

The panel felt that fruit scoring between Just Marketable and Marketable, corresponding 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 be used 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 for the relationship shown in Figures 1a-1d and the coefficient of variation for percent dry matter for each variety.

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 this fruit was set at 5 percent. Calculations were made for the major varieties, and the results were all very close to an average Maturity Value of 4.0 (3.9 to 4.1). Since the 4.0 range on the regression lines gave better year-to-year agreement than at the 3.5 level, it was decided to use a single value of 4.0 as the minimum Maturity Value. This gave percentages of unacceptable fruit from 3 % to 9%, depending upon variety.

Table 2. Average percent dry matter at various levels of marketability.

VARIETY	CONSENSUS MARKETABILITY	Average Percent Dry Matter			AVERAGE
		86-87	87-88	88-89	
Bacon -NC	Almost Marketable		16.51		NA
	Just Marketable		17.83		NA
	Marketable		19.74		NA
Bacon-SC	Almost Marketable	16.67	15.86	17.25	16.59
	Just Marketable	18.82	17.31	17.37	17.83
	Marketable	19.30	19.46	19.75	19.50
	Marketable*	20.04	19.28	19.52	19.61
Fuerte-SC	Almost Marketable	18.00	18.10	19.92	18.67
	Just Marketable	19.09	19.69	17.81	18.86
	Marketable	21.33	20.57	19.67	20.52
	Marketable*	20.51	21.02	21.15	20.89
Gwen-SC	Almost Marketable			24.61	NA
	Just Marketable			24.77	NA
	Marketable			25.69	NA
	Marketable*			26.53	NA
Hass-NC	Almost Marketable (a)			19.67	NA
	Just Marketable			21.45	NA
	Marketable			21.97	NA
	Marketable*			24.36	NA
Hass-SC	Almost Marketable	20.20	18.48	19.10	19.26
	Just Marketable	21.24	20.62	20.88	20.91
	Marketable	25.80	19.79	21.50	22.36
	Marketable*	20.75	21.74	23.05	21.85
Pinkerton-NC	Almost Marketable			20.27	NA
	Just Marketable			20.45	NA
	Marketable (a)			21.59	NA
	Marketable* (a)			27.59	NA
Reed-SC	Almost Marketable			18.50	NA
	Just Marketable			19.03	NA
	Marketable			20.44	NA
	Marketable*			20.33	NA
Zutano-CV	Almost Marketable	17.99	18.57	17.14	17.90
	Just Marketable	18.28	18.29	20.23	18.93
	Marketable	19.84	21.26		
Zutano-SC	Almost Marketable	16.78	16.96	16.38	16.71
	Just Marketable	18.03	18.87	17.68	18.19
	Marketable	18.92	19.66	18.04	18.87
	Marketable*	18.20	18.50	19.69	18.80

Table 3. Average maturity values at various levels of marketability.

VARIETY	CONSENSUS MARKETABILITY	Average Maturity Value (B-F-H-Z SC)			3 Yr AVERAGE
		86-87	87-88	88-89	
All	Almost Marketable	3.35	3.53	3.42	3.43
All	Just Marketable	3.83	3.94	3.76	3.84
All	Marketable	4.01	4.22	4.06	4.10
All	Marketable*	4.24	4.36	4.34	4.31

The data in Table 4 and Table 5 were used to make the calculations of percent unacceptable fruit and the percent dry matter corresponding to a 4.0 Maturity Value.

Table 4 lists the Average Coefficient of Variation for three years by variety derived from study data sheets.

Table 5 lists the minimum maturity percent dry matter values obtained by using the average formula for each variety, and compares these with those derived from the three year average at 4.0, and of Just Marketable-Marketable levels.

It is interesting to note that, by using the conversion factors developed by the University of California at Riverside and confirmed by D. H. Swarts of South Africa, the percent dry matter at 3.5 for Hass corresponds to an oil content of 7.0 percent. Thus, even with a completely different approach to the level of unacceptability, we still arrive at the value of 7 percent oil content contained in the regulations in effect at the beginning of this study. The basic change is the recognition that, from statistical and practical points of view, this level cannot be set at zero.

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 from 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 makes it possible to assign a single percent dry matter value to each variety for fruit of marketable maturity based on its physiological maturity.

For the three varieties (Gwen, Pinkerton, and Reed) on which only single year data were collected, a three year average was calculated on their relationship to the major varieties for the year in question.

The levels of minimum acceptable maturity developed by this study are as follows:

Variety	Percent Dry Matter
Bacon	18.5
Fuerte	19.9
Gwen	25.9
Hass	21.6
Pinkerton	23.0
Reed	19.8
Zutano	18.8

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 the sampling and testing of avocados for acceptable maturity. This includes 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 procedures followed in this study.

Table 4. Coefficient of Variation.

VARIETY	<u>Yearly Average</u>			3 Yr AVERAGE
	86-87	87-88	88-89	
Bacon - SC	6.26	6.05	6.71	6.34
Fuerte - SC	8.20	6.37	8.38	7.65
Hass - SC	7.79	8.16	9.51	8.49
Zutano - SC	7.00	7.70	8.20	7.63

Table 5. Minimum Maturity Percent Dry Matter
 (From lines of Best Fit for Maturity Value and Percent Dry Matter).

VARIETY	YEAR	LINE BEST FIT	% DRY MATTER @ 4.0 MAT VALUE	AVERAGE % DM J MARKETABLE / MARKETABLE
Bacon-SC	86-87	MV = 0.2430 DM - 0.54	18.88	18.67
	87-88	MV = 0.2620 DM - 0.75	18.12	
	88-89	MV = 0.2542 DM - 0.68	<u>18.42</u>	
	3-Yr Avg Avg Frmla	MV = 0.2522 DM - 0.66	18.47 18.46	
Fuerte-SC	86-87	MV = 0.2459 DM - 0.98	20.23	19.69
	87-88	MV = 0.0821 DM + 2.44	19.04	
	88-89	MV = 0.1886 DM + 0.28	<u>19.71</u>	
	3-Yr Avg Avg Frmla	MV = 0.1722 DM + 0.58	19.66 19.85	
Hass-SC	86-87	MV = 0.2566 DM - 1.62	21.92	21.64
	87-88	MV = 0.0963 DM + 1.92	21.20	
	88-89	MV = 0.1550 DM + 0.68	<u>21.39</u>	
	3-Yr Avg Avg Frmla	MV = 0.1693 DM + 0.34	21.50 21.62	
Zutano-SC	86-87	MV = 0.2829 DM - 1.30	18.72	18.53
	87-88	MV = 0.1651 DM + 0.73	19.83	
	88-89	MV = 0.3399 DM - 2.20	<u>18.24</u>	
	3-Yr Avg Avg Frmla	MV = 0.2626 DM - 0.92	18.93 18.75	

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

Use of Study Data to Establish Date and Size

Throughout this study, data were collected that could be used to track the change of percent dry matter with time for the various varieties and geographic sites selected.

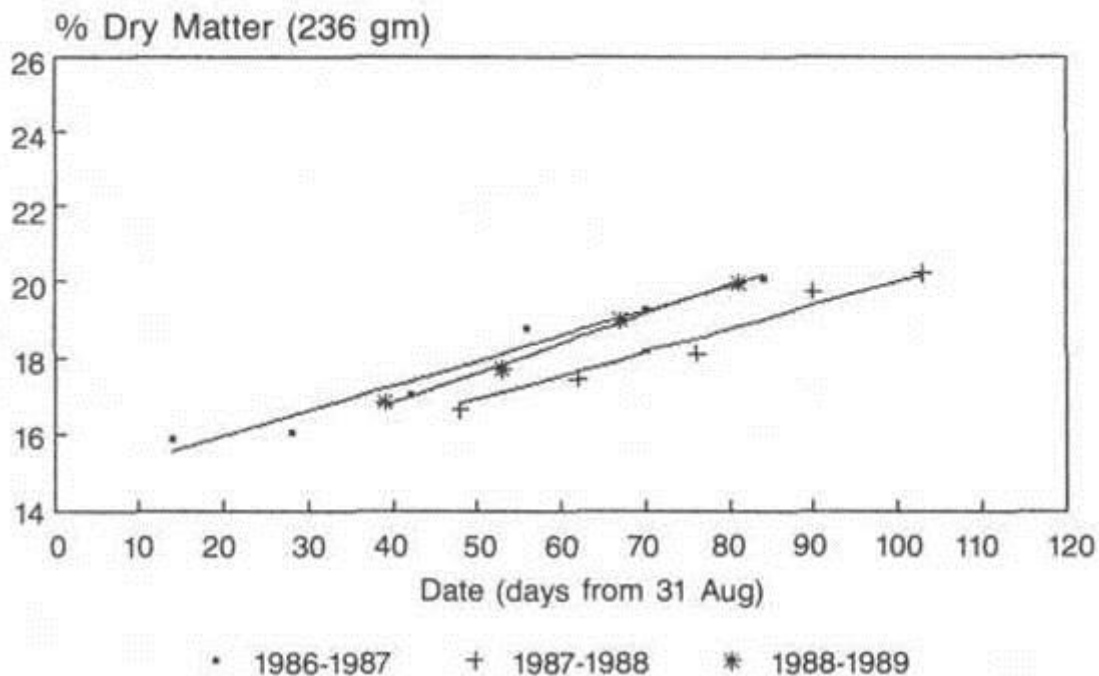
Statistical analysis showed a high degree of correlation between the change in percent dry matter and time. There were no statistical differences between the years as to the rate of change for each variety, but there were differences between varieties. There were statistical differences between the years for all varieties as to the date that a given variety reached a given percent dry matter.

To use the above relationships, it is necessary to establish a release date based on a percent dry matter that is consistent with procedures used by the Avocado Inspection Service in establishing release dates.

This release dry matter could be established as the average percent dry matter at which 85 percent of the sites would be above the minimum maturity standard. With this value, the date at which each variety would attain this percent dry matter could be used as the release date. Since there is a yearly variation, to customize this date for each year requires information on the level of maturity sometime before the release date. Attempts should be made to establish the "earliness" or "lateness" of each year. If this can be done before the harvest of the earliest variety, then early adjustment of all varieties can be accomplished.

Figure 3

PERCENT DRY MATTER AT VARIOUS DATES Bacon - South Coastal



The other possibility is to use an average date for all years. This would be acceptable if the variation between an "early" and "late" year did not result in serious deviations from the acceptable level of unacceptable fruit used to establish the release percent dry matter.

The first pre-season prediction attempt with Hass during the 1989-90 maturity season gave inconsistent results. Another attempt will be made using Bacon in the 1990-91 maturity season.

If the predictability of "earliness" or "lateness" is not possible, the constant date approach could be considered, even though the observed spread of dates ranges from 11 to 20 days. This large range requires that any single date be such that in the "late" year, fruit will be of acceptable maturity at general release.

Figure 3 is typical of the results obtained on the relationship between percent dry matter and time. This illustrates that the 1987-88 year was a "late" year. This was confirmed by the other three varieties.

Table 6 lists the regression formula for the three years of the study for Bacon, Fuerte, Hass, and Zutano.

Table 6. Lines of Best Fit for Percent Dry Matter and Days from 31 August

VARIETY	YEAR	FORMULA
Bacon-SC	86-87	DM = 0.0653 Days + 14.68
	87-88	DM = 0.0612 Days + 13.89
	88-89	DM = 0.0754 Days + 13.89
	Average	DM = 0.0673 Days + 14.15
Fuerte-SC	86-87	DM = 0.0660 Days + 15.57
	87-88	DM = 0.0793 Days + 13.87
	88-89	DM = 0.0985 Days + 13.42
	Average	DM = 0.0813 Days + 14.27
Hass-SC	86-87	DM = 0.0565 Days + 17.09
	87-88	DM = 0.0796 Days + 13.05
	88-89	DM = 0.0774 Days + 14.85
	Average	DM = 0.0712 Days + 14.99
Zutano-SC	86-87	DM = 0.0563 Days + 14.22
	87-88	DM = 0.0769 Days + 12.33
	88-89	DM = 0.0578 Days + 13.63
	Average	DM = 0.0637 Days + 13.39

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Lastly, the sincere appreciation of the author and the Quality Control Subcommittee must be expressed to those numerous individuals and corporations whose efforts made the study possible. Without the spirit of cooperation shown by the entire industry, this project could not have been completed successfully.

Note: Although the foregoing report does not include the data summaries that were essential to calculations and conclusions, that information may be obtained by interested parties from:

California Avocado Commission Attention: Amanda Duva 1251 East Dyer Road,
Suite 200 Santa Ana, California 92705

Raw data developed during the study may be reviewed at the same location.