California Avocado Society 2001 Yearbook 85: 153-178

Development of a New Method for Measuring Minimum Maturity of Avocados

M. L. Arpaia
Dept. of Botany and Plant Sciences, University of California, Riverside, CA

D. Boreham
Avocado Inspection Service, CDFA, Escondido, CA

R. Hofshi
www.avocadosource.com

Summary

The use of the percent dry matter as a maturity indicator for avocado is widely accepted. During a California Avocado Commission funded study to identify a minimum maturity standard for the Lamb Hass variety, we developed a new process for removing samples from the fruit for dry matter determination. After two years of testing and evaluation we have perfected a technique and designed an efficient tool that will allow dry matter testing to be standardized in terms of the sampling method, the sampling location within the fruit, and the quantity of flesh used. Our study shows that:

1) There is great in-fruit variability. When an entire avocado was homogeneously blended and multiple subsamples taken, the dry matter of the subsamples differed by as much as 1.32% (range 0.33 -1.32%).

2) The results from the new method of equatorial cores are not statistically different from the "opposing eighths" method.

3) The "opposing eighths" method is cumbersome, time consuming, dangerous, requires operator training, and is somewhat subjective with respect to the sampling selection of tissue to be tested.

4) An instrument was fabricated that produces uniform samples and expedites sampling. It is easy and safe to use and allows for an estimated 60% reduction in sample preparation time.

Introduction

The California avocado industry converted from oil content to dry matter content as an indicator of maturity for avocados in 1983. This changeover was necessitated by the removal from use due to the carcinogenic nature of the solvent, Halowax oil, the costly and time consuming refractometric method employed in the process of oil content determination. Morris and O'Brien (1980) in Australia reported promising results in the use of dry matter content. Additional research in California demonstrated the close relationship between oil content and dry matter for numerous California avocado varieties, seasons and growing locales (Lee et al, 1983; Coggins, 1984). This work culminated in the adoption of dry matter as the basis for testing of minimum maturity in 1983 (Anon., 1983). Subsequent work (Ranney, 1991; Ranney et al, 1992) that further examined the relationship between production season, dry matter content and fruit acceptability provided the basis for current dry matter standards in California.

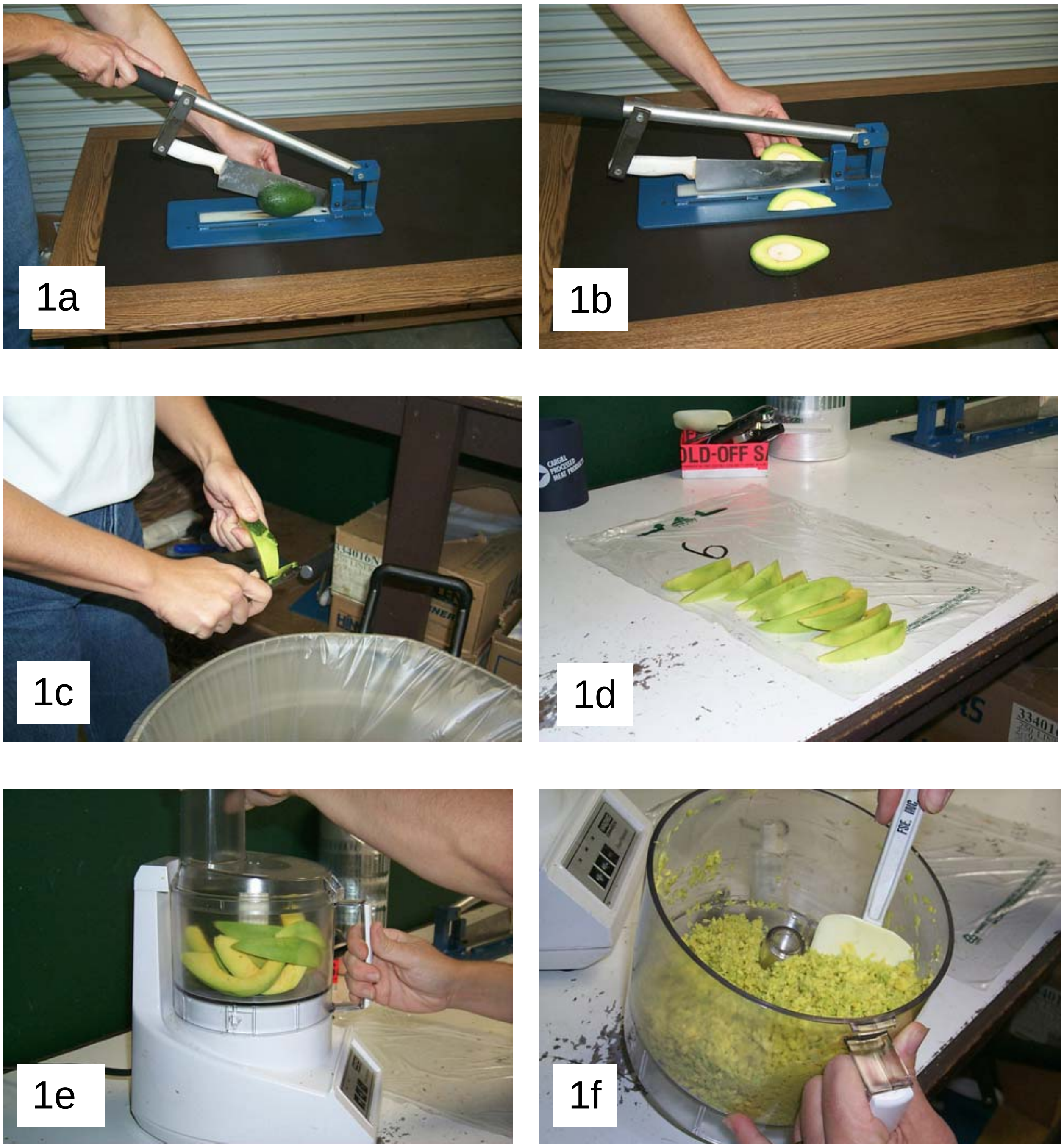
The Avocado Inspection Program (AIP), a part of the California Department of Food and Agriculture (CDFA), conducts two types of maturity testing. The first is called "Informational Testing". The purpose of this testing is to obtain background information on the maturity level of particular avocado orchards. "Informational Testing" uses individual fruit submitted to the AIP by growers or their representatives as the basis of sampling. There is no regulatory action required if the submitted sample does not meet the established minimum maturity standard. The general recommendation for sampling in the grove is to select internal fruit within the tree and avoid sun exposed or blemished fruit.

The second type of testing is called "Official Testing". If a grower wishes to harvest their orchard prior to the release date of a particular variety and size of fruit, then the incoming fruit must be tested to insure that the fruit meets or exceeds the established minimum maturity standard. In this case a CDFA inspector will sample 10 fruit from each size category that has not been released within the harvested lot.

The sample is collected by the inspector at the packinghouse and is random across all bins of a particular lot that have been harvested. A composite sample is taken from five fruit per size and an official test is conducted. If the tested sample meets the minimum standard then the avocados from this size category of a particular lot is released for sale. If this composite sample does not meet the minimum dry matter standard then the second set of five fruit is tested. If the sampled fruit fail the second test then all fruit of that particular size is rejected and not allowed to be marketed. The rejected fruit is either destroyed or sent to an oil or pulp processing plants.

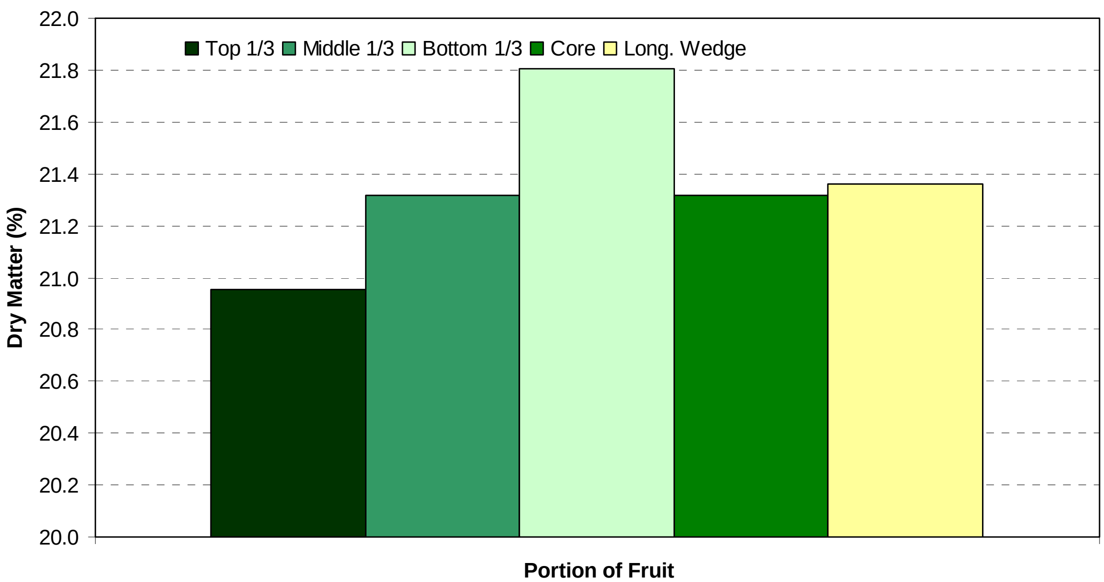
Although the initial adoption of dry matter content was a great simplification of the refractometric method utilized for oil determination, the state guidelines were still somewhat cumbersome, time consuming and required repetitive fruit cutting and use of sharp implements. The method of sampling approved in 1983 required taking opposing eighth wedges from the fruit (Figure 1a-f). In this method, individual fruit were cut into half longitudinally. Two opposing oneeighths samples were then sliced from the fruit halves. The seed coat and peel were then removed. If an informational sample was being processed, the two opposing eighths sections were further processed. For an official test, two opposing eighths sections from five fruit of each size category are used for a total of 10 sections. The 10 sections would be processed together. The sections (either from an individual fruit or a composite sample) would be ground until a uniformly crumbly mixture with particles no larger than 1/8 inch (3.2 mm) was achieved. Once ground; a 5 to 6 gram subsample of the mixture was taken and placed in a microwave and dried until it reached constant weight. The dry matter content was then calculated [(dry weight)/(fresh weight) x 100 = % dry matter].

Figure 1. Overview of 1983 (Anon.) sampling protocol for an official dry matter determination; (a) Individual fruit is first longitudinally cut in half, (b) opposing eighths samples cut, (c) each eighth section peeled and seed material removed, (d) the ten opposing eighths sections from the 5-fruit composite sample, (e) composite sections placed in food processor, (f) ground tissue from the 5-fruit composite sample; a 5 gram sample is taken and dried in a microwave until constant weight is reached.



It was necessary, as part of the 'Lamb Hass' maturity project, to take numerous samples of individual fruit for dry matter determination. This prompted us to consider a more "user-friendly" sampling protocol that would be significantly faster, safer and yield comparable results to the previous standard technique (Anon., 1983). During this consideration we reviewed work by Schroeder (1985, 1987), which reported the gradient of dry matter within an individual fruit as influenced by fruit variety and maturity. Schroeder's studies demonstrated that there were differences in dry matter content between the stem (top) and blossom end (bottom) of the fruit as well as a radial gradient from the peel to the seed. With this in mind we hoped to identify a common sampling area which would be representative of the average dry matter for an individual fruit. Below we report the results of a series of studies conducted to further examine dry matter distribution within the fruit, variability in current methods of sampling and the results of the confirmatory tests conducted from November 2001 February 2002 with multiple varieties.

Figure 2. Within fruit positional effects on dry matter content for ‘Hass’ avocado. Numbers are the average of fruit each from 3 different sources (each tested separately). Ten fruit were individually analyzed per source. Data collected in December 2000. There were no significant differences due to sample position.

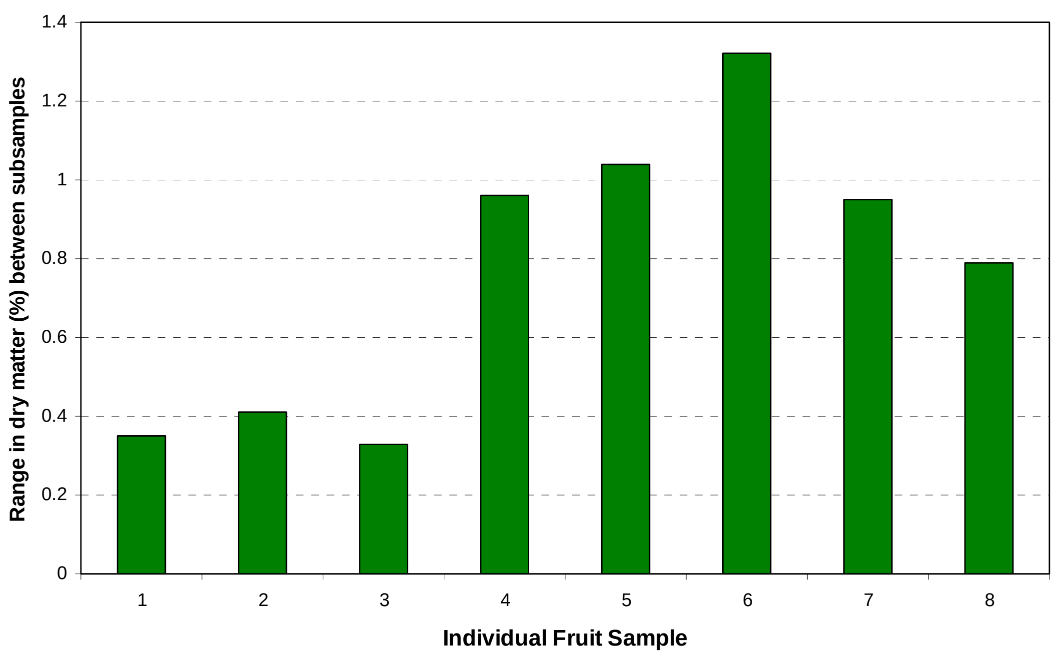


A. Within fruit dry matter distribution.

Thirty uniformly sized unripe 'Hass' avocados from three sources (Moorpark, CA; Fallbrook, CA; and imported Chilean fruit) were collected in early December 2000. The individual fruit were cut longitudinally and opposing quarters were taken. The peel and seed were removed. One quarter was homogenized in a food processor until coarsely ground. The second quarter was divided into three equal pieces representing the stem end, middle and blossom end of the fruit and then ground as individual samples. An additional sample was also taken from the equator of the fruit using a 13.2 mm coring cylinder and prepared in a similar manner.

Approximately 5 grams of the ground mixtures were placed in a microwave (30% power) and dried until constant weight (@ 30-40 minutes), after which the dry matter content was calculated using the standard procedure (Anon., 1983). The data were analyzed as a 2 factor (fruit source x sample position) analysis of variance. Figure 2 illustrates the relationship between sample position and dry matter content. Although there were significant differences in dry matter between the three sources of fruit ($P<0.01$), representing a range in fruit maturity (15.17%, Moorpark; 20.27%, Fallbrook; 28.49% Chile), no significant differences were detected due to sampling position. Note that the top of the fruit (stem end) had a lower dry matter (20.95%) than either the middle (21.24%) or bottom (21.80%) portion of the fruit. This trend is in agreement with the data reported by Schroeder (1985, 1987). The average of these three segments is 21.33% which is statistically the same as the longitudinal wedge (21.36%) and the core sample (21.32%). These results indicated that although there is within fruit variability in dry matter it is possible to subsample fruit to obtain a reasonable estimate of maturity. The results from this study suggest that the mid-section of the fruit will give results which are nearly identical to that of a longitudinal wedge sample.

Figure 3. The range in dry matter content for 5 gram subsamples taken from blended individual 'Hass' fruit. The number of subsamples per fruit ranged from 14 to 25. Data collected in March 2001.

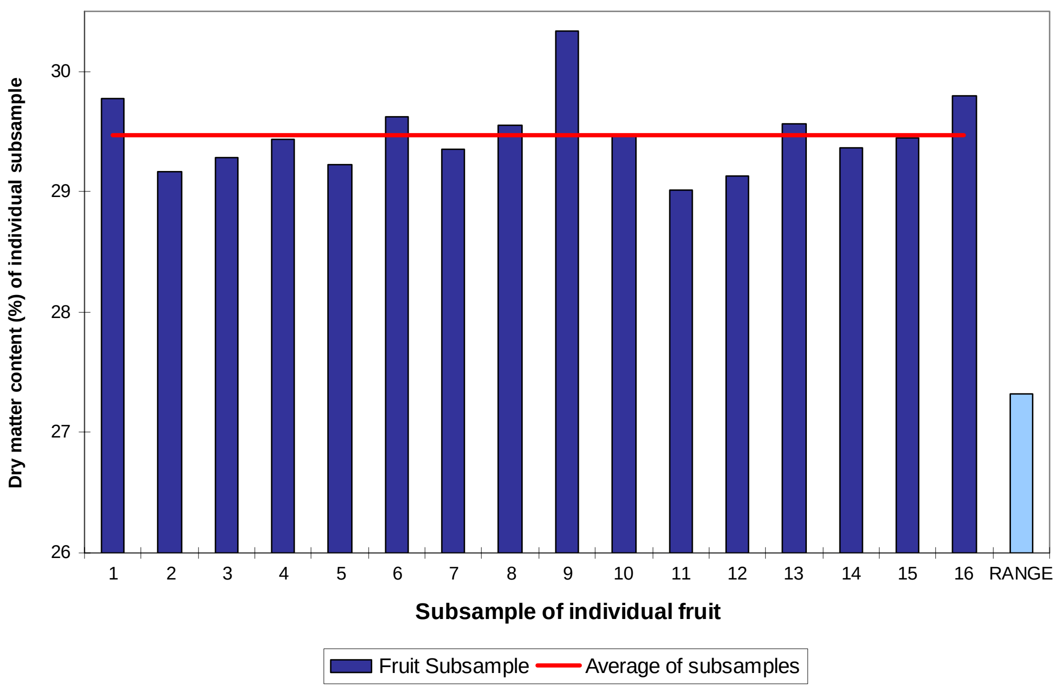


B. Sub-sampling variability within the ground sample

In March 2001, 8 individual 'Hass' fruit were sampled. The peel and seed material were removed and the entire fruit flesh was ground in a food processor until uniformly coarsely ground (about three minutes). The ground sample was divided into approximately 5 gram subsamples and dried in a microwave until constant weight was achieved. The actual number of analyzed subsamples for an individual fruit ranged from 14 to 25.

Figure 3 reports the range in dry matter results for the 8 individual fruit. The range between the high and low dry matter values for an individual fruit varied from 0.33% to 1.32%. Figure 4 is the percentage dry matter for an individual fruit where 16 subsamples were measured. The range between the high and low subsample for this fruit was 1.32%; the average dry matter content was 29.47%. Although, we cannot explain this variability among whole-fruit subsamples; the results indicate that even with a supposedly homogeneous blend, there can be variability in dry matter when subsamples are taken. These results further suggest that the use of a 5 gram sample in the opposing eighth method may have been insufficient and that a larger sample would have given less variability between samples. Alternatively, the observed variability may be indicative of the need for more thorough mixing of the sample for homogeneity.

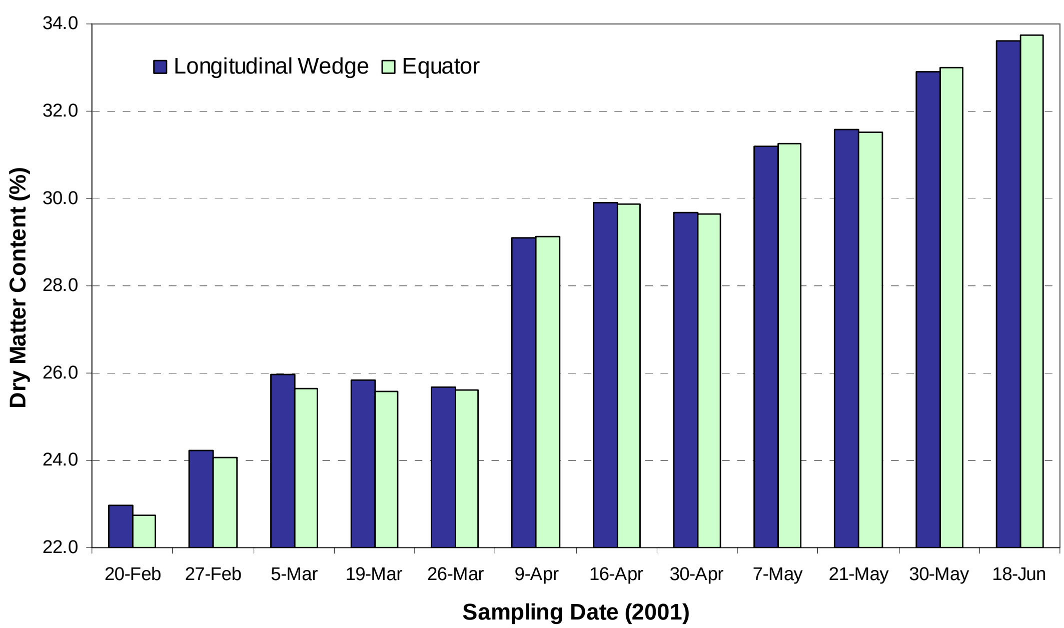
Figure 4. The variability in dry matter content (%) within a single 'Hass' fruit when the entire fruit was ground and 5 gram subsamples taken from the blended tissue. Data collected in March 2001.



C. Comparison of a longitudinal wedge sample to an equator sample

In the spring of 2001 we conducted another study to compare positional effects on dry matter using a longitudinal wedge of fruit tissue as compared to an equatorial fruit sample for seven avocado varieties. For this study we selected 2-3 trees for each variety. These trees were harvested 4 to 12 times from mid-February through mid-June. Five to eight uniformly sized fruit were picked per variety on each sampling date. The individual fruit were divided into quarters. Each quarter was further subdivided longitudinally in half. One half of each quarter was ground in its entirety while, for the matching sample, only the equator portion was ground. Each sample was dried to constant weight and the percent dry matter of each matched pair was calculated. The results for the 'Hass' variety are shown in Figure 5. As would be expected the average dry matter between dates differed significantly ($P<0.001$), but there were no significant differences detected between the two sampling methods for 'Hass' or any of the other varieties. The dry matter differences between the longitudinal wedge and the equator sample for a particular date differed as much as 0.32% and as little as 0.03% for 'Hass'. The average difference between the two methods for all sampling dates and fruit was 0.07% for 'Hass'. Regression analysis of the data showed that there was a significant positive correlation between the longitudinal wedge and equator samples for all varieties (Table 1).

Figure 5. The dry matter content (%) of ‘Hass’ fruit as influenced by sampling method (N=5 fruit for each sampling date; 4 subsamples per fruit). There were no significant differences between sampling method. Significant differences ($P\leq0.001$) detected between sampling dates.



D. Industry testing of the new methodology

Based on the results presented above, we initiated a study in the fall of 2001 to compare, for multiple varieties, fruit sources and dates, the relationship between the standard "opposing eighths" method and our proposed sampling protocol. In the process of planning this study we refined the fruit sampling technique (described below) and the sample preparation methodology. We discovered that when a core sample is taken from the equator region of the fruit more uniform microwave drying is achieved when the sample is cut longitudinally in half rather than ground; thus for this study, samples were either prepared as described in the state code California Code of Regulations (1983) or as described below (Section E) under the new state regulations (2002). During this study, the code for sampling for dry matter content required that a 5 gram sample be utilized for both informational and official testing (1983). For this study, an additional comparison was included. Based on the results of the within fruit variability, we felt that more reliable results might be attained by increasing the ground sample that is tested from 5 grams to approximately 20 grams. This would be more in line with the "coring" method which utilizes the entire cored sample. When individual fruit are sampled (as in California Informational Testing) the combined weight of the two opposing cores is approximately 3 to 5 grams. However, the official maturity testing requires a 5-fruit composite sample. In this case, the entire core samples are completely utilized with a combined weight between 20 to 25 grams.

Table 1. Results of regression and correlation analysis for % dry matter comparing a longitudinal wedge or equator sample for 7 avocado varieties. Four matched pairs per individual fruit.

Variety	# matched pairs (# fruit)	Regression Equation[z]	Coefficient of determination $(r^2)^y$	Coefficient of correlation (r)[x]
Fuerte	92 (23)	y = 2.1008 + 0.9297x	0.9350***[w]	0.9670
Gem	192 (48)	y = -1.1504 + 1.0365x	0.9791***	0.9895
Gwen	216 (54)	y = 0.5630 + 0.9687x	0.9221***	0.9603
Hass	276 (69)	y= -0.6593 + 1.0203x	0.9840***	0.9920
Lamb	276 (69)	y = -0.7230 + 1.0248x	0.9818***	0.9909
Pinkerton	156 (39)	y = 0.1542 + 0.9966x	0.9550***	0.9772
Reed	276 (69)	y = -0.0445 + 1.0017x	0.9448***	0.9720

[z] Regression equation: equator = b + m(longitudinal wedge) where b = y intercept and m = slope.
[y] The coefficient of determination is the "Closeness" between the 2 variables, equator sample % dry matter and longitudinal wedge sample % dry matter. The calculated value is the % variability in data explained by the closeness of data. If there was a perfect fit r^2 would equal 1.
[x] The coefficient of correlation measures the "strength" of the linear relationship between the 2 variables, equator sample % dry matter and longitudinal wedge sample % dry matter. If there was a perfect fit r would equal 1.
[w] ns, *, **, ***; not significant, P ≤ 0.05, 0.01, 0.001, respectively.

A total of 1,386 samples were taken by CDFA personnel from five cultivars that were collected from late October 2001 through early January 2002, of which 359 samples were from informational tests (individual fruit dry matter determination) and 1,027 were official tests (5-fruit composite samples). Tables 2 and 3 summarize the regression analysis conducted to examine the relationship between the "coring" and the "opposing eighths" method. The coefficient of determination (r^2) and the coefficient of correlation (r) are both very high, indicating that there is a very close relationship between the two methods of dry matter determination. Figures 6 and 7 illustrate the linear relationship between the "opposing eighths" method and the "coring" method for the informational and official testing for 'Hass', respectively. We also did a regression and correlation analysis comparing the 20 gram "opposing eighths" to either the "coring" or 5 gram "opposing eighths" method. As shown above, the coefficient of determination (r^2) and the coefficient of correlation (r) are very high, which further supports that the three methods give similar results.

Table 2. Results of regression and correlation analysis for % dry matter comparing sampling by the “opposing eighths” or “coring” methods for informational maturity tests for California avocados. Informational testing uses individual fruit.

Variety	# samples	Regression Equation^z	Coefficient of determination (r^2)^y	Coefficient of correlation (r)^x
Bacon	19	y = -0.415690 + 1.023207x	0.9800***^{w}	0.9900
Fuerte	65	y = 1.051841 + 0.937313x	0.9175***	0.9579
Hass	145	y = -0.080845 + 0.997240x	0.9883***	0.9941
Pinkerton	6	y = 3.532572 + 0.7885234x	0.9294 **	0.9641
Zutano	50	y = -0.705098 + 1.031652x	0.9929***	0.9964
TOTAL Samples	359			

^{z} Regression equation: “coring” method = b + m(opposing eighths) where b = y intercept and m = slope.
^{y} The coefficient of determination is the “Closeness” between the 2 variables, coring method % dry matter and opposing eighth % dry matter. The calculated value is the % variability in data explained by the closeness of data. If there was a perfect fit r^2 would equal 1.
^{x} The coefficient of correlation measures the “strength” of the linear relationship between the 2 variables, coring method % dry matter and opposing eighth % dry matter. If there was a perfect fit r would equal 1.
^{w} ns, *, **, ***; not significant, P ≤ 0.05, 0.01, 0.001, respectively.

Figure 6. Relationship between core dry matter (%) and opposing eighths dry matter (%) of ‘Hass’ fruit sampled statewide from 10/25/01 to 11/15/01 (N=145). Each point represents one fruit. Samples collected as part of the informational maturity testing conducted by CDFA Avocado Inspection Program.

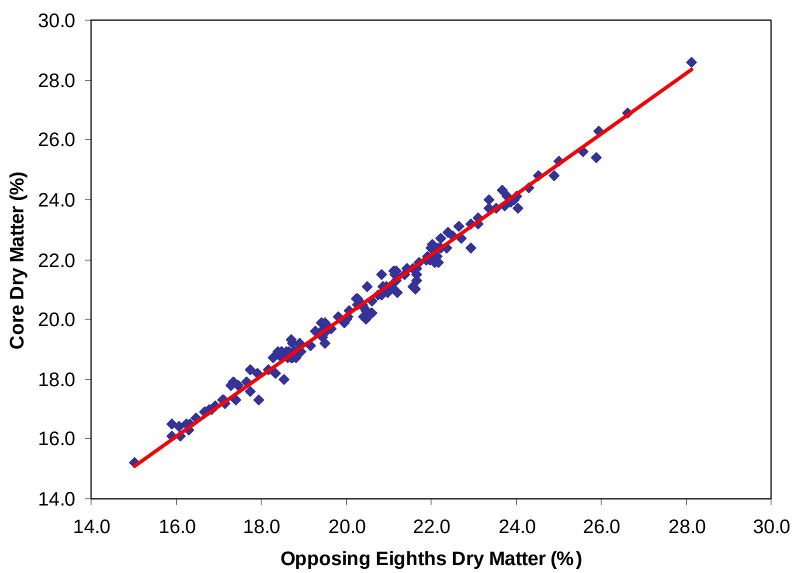


Table 3. Results of the regression and correlation analysis for % dry matter comparing sampling by the “opposing eighths” or “coring” methods for official maturity tests for California avocados. Official testing uses a composite 5-fruit sample.

Variety	# samples	Regression Equation	Coefficient of determination (r^2)	Coefficient of correlation (r)
Bacon	219	y = -0.244561 + 1.010608x	0.9865***	0.9932
Fuerte	32	y = 1.076169 + 0.941638x	0.9484***	0.9739
Hass	722	y = 0.878140 + 0.958850x	0.9673***	0.9835
Pinkerton	4	y = 1.449674 + 0.940074x	0.9420 *	0.9706
Zutano	124	y = -0.341862 + 1.022335x	0.9691***	0.9844
TOTAL Samples	1027			

[z] Regression equation: “coring” method = b + m(opposing eighths) where b = y intercept and m = slope.
[y] The coefficient of determination is the “Closeness” between the 2 variables, coring method % dry matter and opposing eighth % dry matter. The calculated value is the % variability in data explained by the closeness of data. If there was a perfect fit r^2 would equal 1.
[x] The coefficient of correlation measures the “strength” of the linear relationship between the 2 variables, coring method % dry matter and opposing eighth % dry matter. If there was a perfect fit r would equal 1.
[w] ns, *, **, ***; not significant, P ≤ 0.05, 0.01, 0.001, respectively.

Figure 7. Relationship between core dry matter (%) and opposing eighths dry matter (%) of ‘Hass’ fruit sampled statewide from 11/21/01 to 1/04/02 (N=722). Each point represents one 5-fruit composite sample. Samples collected as part of the official maturity testing conducted by CDFA Avocado Inspection Program.

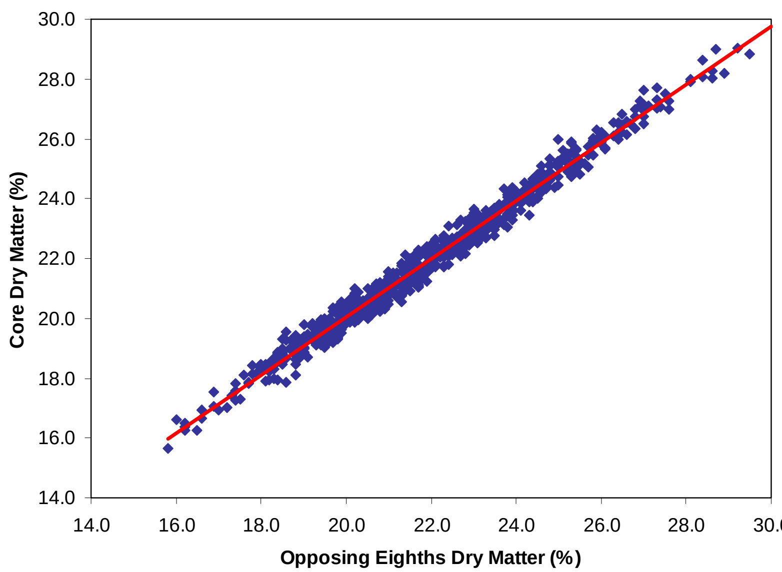


Table 4 and 5 are the by-date analysis of variance for 'Hass' for the three methods compared in the informational and official testing. Occasional differences were observed between the three methods depending on the test (informational or official), variety and date. However, there were no consistent trends in these differences. Based on this data we concluded that the "coring" method could replace the current 5 gram "opposing eighth" method for both informational and official testing.

Table 4. The average dry matter (%) for 'Hass' as sampled for informational testing in Fall 2001 for the 3 sampling methods. Informational testing is done on an individual fruit basis.

DATE	Number of samples	---------- Method --------- Opposing eighths (20 g)	Core (4 – 6 g)	Opposing eighths (5 g)	Significance of F
All	145	20.33 b	20.37 b	20.58 a	***
			Date x Method		***
10/25/01	10	17.67	17.70	17.85	ns
10/26/01	13	22.37 b	22.51 a	22.51 a	*
10/31/01	15	19.08 b	19.23 a	19.25 a	*
11/1/01	3	18.90 b	19.30 a	19.37 a	**
11/5/01	6	19.25	19.17	19.52	ns
11/7/01	16	20.40 ab	20.30 b	20.48 a	*
11/8/01	17	20.73	20.65	20.76	ns
11/9/01	12	21.63	21.75	21.77	ns
11/13/01	19	20.43	20.40	20.49	ns
11/14/01	11	17.98 b	18.05 b	18.26 a	**
11/15/01	23	21.67 b	21.73 b	22.02 a	***

ns, *, **, ***; not significant, $P \le 0.05$, 0.01, 0.001, respectively.

Means within a row with no letter(s) in common are significantly different at $P = 0.05$ on Fisher's Protected LSD test. Analysis of variance done with dates as a factor and for each date separately.

E. The change in sampling methodology

After reviewing the statistical data collected throughout this project the Avocado Inspection Committee (AIC) recommended to the California Department of Food and Agriculture that the California avocado industry adopt this new method as the official protocol to be used by the state's Avocado Inspection Program. This regulation went into effect on September 28, 2002 (Anon, 2002). The new regulation is summarized below.

Percent Dry Matter is defined as the average percent dry matter of five avocados determined by the procedure listed in Section 1408.3. Avocados, Determination of Dry Matter, Title 3.

California Code of Regulations, Title 3. Food and Agriculture, Article 11. Avocados

Section 1408.3 Avocados. Determination of Dry Matter Dry matter of avocados shall be determined by weighing the fresh weight and dry weight of a sample of avocados. The testing procedures and method of calculating the percent of dry matter shall be as follows:

> Percent Dry Matter is defined as the average percent dry matter of five avocados determined by the procedure listed in Section 1408.3. Avocados, Determination of Dry Matter, Title 3.
> California Code of Regulations, Title 3. Food and Agriculture,

Table 5. The average dry matter (%) for 'Hass' as sampled for official testing in Fall 2001 for the 3 sampling methods. Official testing uses a composite 5-fruit sample.

DATE	Number of samples	---------- Method --------- Opposing eighths (20 g)	Core (20 - 25g)	Opposing eighths (5 g)	Significance of F
All	722	22.05 a	22.00 b	22.03 a	**
			Date x Method		***
11/21/01	3	20.03	20.00	20.27	ns
11/27/01	14	23.77 ab	23.64 b	23.92 a	**
11/28/01	54	23.69 a	23.51 c	23.59 b	***
11/29/01	8	22.58 ab	22.53 b	22.76 a	*
11/30/01	1	26.98	26.97	26.80	
12/3/01	88	23.26	23.23	23.27	ns
12/4/01	1	20.52	20.43	20.80	
12/5/01	6	23.80	23.77	23.83	ns
12/6/01	44	22.55 b	22.49 b	22.63 a	***
12/7/01	1	24.93	25.31	25.20	
12/10/01	6	20.85 b	20.95 b	21.22 a	**
12/11/01	50	23.41 b	23.39 b	23.85 a	***
12/12/01	24	21.82 ab	21.74 b	21.95 a	**
12/13/01	12	22.72 ab	22.68 b	22.91 a	*
12/17/01	48	21.61 a	21.55 ab	21.50 b	*
12/18/01	40	21.13	21.07	21.06	ns
12/19/01	52	22.24 a	22.27 a	22.15 b	*
12/20/01	26	21.94	21.96	21.95	ns
12/26/01	44	21.07 a	21.10 a	20.95 b	***
12/27/01	56	20.66 a	20.56 b	20.45 c	***
1/2/02	67	20.62	20.56	20.51	ns
1/3/02	34	21.41	21.40	21.32	ns
1/4/02	43	21.32 a	21.23 a	21.10 b	***

ns, *, **, ***; not significant, $P \leq 0.05$, 0.01, 0.001, respectively.

Means within a row with no letter(s) in common are significantly different at P = 0.05 on Fisher's Protected LSD test. Analysis of variance done with dates as a factor and for each date separately.

Article 11. Avocados

Section 1408.3 Avocados. Determination of Dry Matter

Dry matter of avocados shall be determined by weighing the fresh weight and dry weight of a sample of avocados. The testing procedures and method of calculating the percent of dry matter shall be as follows:

(a) At the widest circumference of the avocado, remove a core from the entire width of the avocado. Discard the seed portion, and remove the seed coat and skin to the depth of the edible portion from the remaining core pieces. Cut each core piece in half. The core sample shall be removed with a coring device having an inside diameter of 5/8 inch (15.88 mm), plus or minus 1/16 inch (1.59 mm).

(b) Repeat the above for the number of sample fruit required by Section 1408.6.

(c)The cored pieces shall be immediately placed in a sealed plastic bag if there is a delay in completing the procedures below.

(d) Weigh a clean petri dish and record the weight (P).

(e) Place all cored pieces on the preweighed petri dish; reweigh the petri dish with the sample and record the weight (F).

(f) Place the petri dish with the sample in a 1,000 watt microwave oven and dry the sample at 50% power for 40 minutes, adjusting the power down as necessary to avoid charring the tissue. Remove the sample from the microwave oven and note the weight. Place the sample back in microwave oven for 5 minutes. Remove the sample again and compare weight. If weight is the same, record it as dry weight. Whenever there is a weight difference, repeat this step until there is no weight loss. After the sample reaches a constant weight, record the weight (D).

(g) Calculate the percent of dry matter using the following example:

(D- P) / (F-P) X 100 = ______% dry matter

All weighings required by this section shall be recorded to the nearest 0.01 gram.

All weighings required by this section shall be recorded to the nearest 0.01 gram.

F. Development of a tool to remove the tissue sample

The initial work described above was done with a small hand held coring cylinder (or "cork borer"). In order to produce a sample we cored the fruit to the seed, wiggled the cylinder to loosen the cored flesh from the rest of the fruit, removed the cylinder from the fruit, removed, with some effort, the core from the cylinder, and then repeated the procedure on the opposing side of the fruit (Figure 8). This took considerable time and effort and bruised the palm of the operator's hand when multiple samples were required. To improve the efficiency of sampling, a tool that could go through the fruit and produce opposing cores with as little effort as possible was needed. The challenges we faced in developing a simple plugging machine were numerous. We needed a tool that:

1. Could penetrate the peel, flesh and seed with ease;
2. Could go through any size avocado at the equator and produce a clean-cut core;
3. Could, with minimal effort, remove the core embedded within the cylinder;
4. The post-cored fruit could be easily removed from the cylinder.

The problems were solved by producing a sharp tipped cylinder attached to a lever and mounted on a shaft, which made the coring of the fruit almost effortless (Figure 9a, b, c). By lowering the cylinder onto the fruit, the lever helps the sharp tipped cylinder produce the desired core. An interior solid shaft, which uses the same lever, helps push the core out of the cylinder when the arm is lifted (Figure 9b). By introducing a hand supported stop above the cored fruit and raising the lever arm, the fruit easily slides off. After several prototypes and testing, the final version was produced. A comparison of the preparation time between the protocols for collecting an official sample for analysis according to the 1983 regulations versus the 2002 regulations is outlined in Table 5.

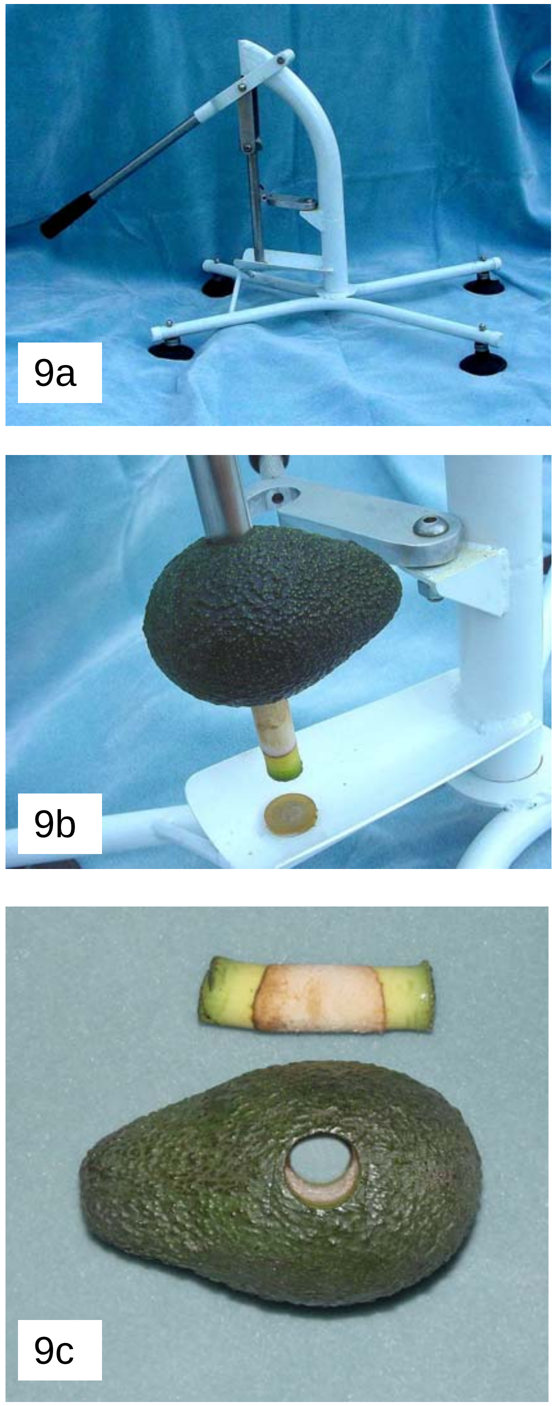
Figure 8. Core sample using a hand held coring tool.

Concluding Remarks

The results we report here confirm that percent dry matter varies within the avocado fruit as reported previously by Schroeder (1985, 1987). We also demonstrated that variability within a blended sample of an individual avocado exists. The lack of homogeneity in blended samples can be overcome by the new sampling method described here. The elimination of grinding of the sample in a food processor may also reduce sampling errors. Although there is a spatial gradient of percent dry matter in the fruit, we showed that an equatorial sample provides similar results as that of a longitudinal wedge. The core sampling method we have described allows for more rapid fruit sampling and is safer and less cumbersome since it requires minimal use of sharp implements.

The samples obtained from the "coring" method can be better used for dry matter determination, fruit nutrient analysis and other purposes. Researchers, marketers, consumers and growers are interested in the dry matter content for diverse reasons. Marketers need to be familiar with fruit maturity for ethylene conditioning and cold storage regimes. They can include fruit maturity as part of their quality assurance program. Consumers can use this information as part of their purchasing decision. Growers can use this information to develop harvest strategies, better understand crop nutrient removal values, i.e. avocados of different maturities have distinct mineral makeup that is removed with the harvested fruit and needs to be replenished. Researchers use dry matter and flesh sampling for various aspects of their research and can benefit from having a common sampling methodology. By having a reliable and easy to use standard sampling method we believe that issues associated with fruit maturity and avocado dry matter will be better understood and communicated.

Figure 9. The tool designed for removing core samples from avocado; (a) an overview of the tool, (b) extraction of core from fruit, (c) the cored fruit and the extracted core sample.



Acknowledgements:

The authors wish to thank Carol Adams, biostatistician, for analysis of the data collected to support the change in California State regulations. Ms. Adams is familiar with the protocols used by the Avocado Inspection Committee for determination of minimum maturity and was associated with previous statistical analysis of similar data. We also wish to thank Bill Berry, engineer, for his insights and ingenuity in the development and manufacturing of the coring tool. Jim Sievert, Kent Fjeld, Sue Collin and Mariska Coetzer (University of California) also provided useful comments that resulted in improvements in sampling methodology and the coring tool prototypes. We are also grateful for the comments, discussions and suggestions on this manuscript of Dr. Alan Woolf and Anne White (HortResearch, New Zealand) and Dr. Peter Hofman (DPI, Queensland, Australia).

References

Anonymous. 1983. Title 3, California Administrative Code of Regulations, Title 3. Food and Agriculture, Article 11. Avocados, Section 1408.3. Avocados, Determination of Dry Matter. California Dept. of Food and Agriculture. Sacramento, California.

Anonymous. 2002. Title 3, California Administrative Code of Regulations, Title 3. Food and Agriculture, Article 11. Avocados, Section 1408.3. Avocados, Determination of Dry Matter. California Dept. of Food and Agriculture. Sacramento, California.

Coggins, Jr., C.W. 1984. Feasibility of using fruit size and percentage dry weight to predict maturity. California Avocado Society Yearbook. 68:145-160.

Lee, S.K. and C. W. Coggins, Jr. 1982. Dry weight method for determination of avocado fruit maturity. California Avocado Society Yearbook. 66:67'-70.

Morris, Rand K. O'Brien. 1980. Testing avocados for maturity. California Avocado Society Yearbook. 64:67-70.

Ranney, C. 1991. Relationship between physiological maturity and percent dry matter of avocados. California Avocado Society Yearbook. 75:71-85.

Ranney, C.E., G. Gillette, A. Brydon, S. Mclntyre, O. Rivers, C.A. Vasquez and E. Wilson. 1992. Physiological maturity and percent dry matter of California avocado, pp 379-385. In: C. J. Lovatt, ed., Proc. of the Second World Avocado Congress. Orange, California. April 21-26, 1991.

Schroeder, C.A. 1985. Physiological gradient in avocado fruit. California Avocado Society Yearbook. 69:137-143.

Schroeder, C.A. 1987. Physiological gradients in flesh pericarp of avocado. Proc. of the World Avocado Congress. South African Avocado Growers' Association Yearbook. 10:32-34.