Measuring avocado maturity; ongoing developments

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As with many biological issues, defining terms such as maturity can be quite complex. In terms of the avocado, this may mean "physiological maturity", i.e. the ability to ripen normally once harvested. However, in terms of taste acceptability, other measures are required, and these can be difficult to define.

Dry Matter and Maturity

In order to have a maturity index to determine when a fruit should be harvested some measurable parameter must change during fruit development. An example of this is the rapid increase in soluble solids concentration in kiwifruit as the starch in the fruit is degraded. For avocados, dry matter content (or its related measures, oil or water content) is the accepted worldwide standard on which timing of harvest is based. Dry matter is measured by taking a known weight of avocado flesh tissue, and drying it to a point where no further weight loss occurs. Oil content is highly correlated with dry matter but measuring oil content was found to be slow and expensive when compared to dry matter analysis (Lee et al, 1983), and therefore has fallen out of favour.

With increasing volumes of New Zealand avocados being exported to the USA, the "export window" has shifted markedly from that of the past.

For example, November was considered "early season" for our exports to Australia in the early 1990's. Now early September is considered "early season", and all the fruit for the USA market is harvested by the end of November. This market drive for early season fruit raises the question of what the minimum commercial harvest maturity should be.

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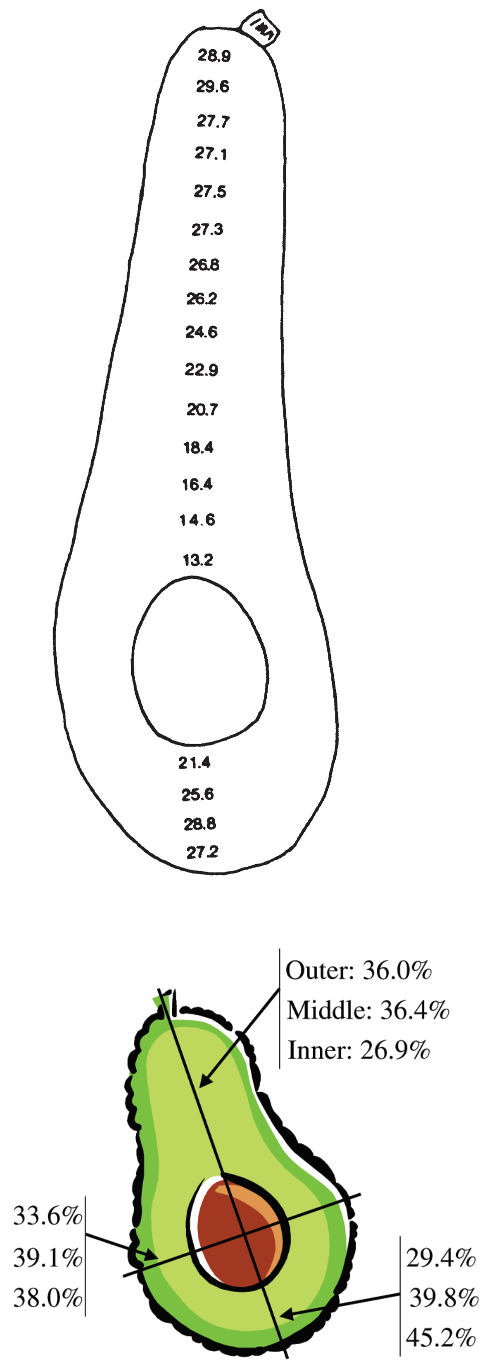
Figure 1A &1B: Diagrams of average distribution of dry matter around avocado fruit A) 'Pinkerton' (Schroeder, 1985) and B) New Zealand 'Hass' (Phetsomphou, 2000).



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Limits on harvest maturity should be set in order to achieve standardisation of fruit quality across an export-based industry. Lee et al. (1983) examined the relationship between dry weight, oil, and sensory perception. They concluded that regional release dates were

not appropriate. There is also discussion as to whether the same dry matter level means the same "taste acceptability" in different countries, or even possibly regions within a country – is a Bay of Plenty avocado at dry matter 24% of the same taste acceptability as one from the Far North?

Dry Matter Variability

So what are the key issues in measuring dry matter? Basic points include harvesting fruit from representative positions on the tree, harvesting early in the day (when fruit are most likely to be fully hydrated), and holding fruit in plastic bags for dry matter analysis to be carried out as soon as possible. An interesting consideration is the variability in dry matter within a fruit (Schroeder, 1985). Figure 1A shows this variability for 'Pinkerton'. Similar trends were identified for 'Hass' in New Zealand (Phetsomphou, 2000) with higher dry matter at the stem end than above the seed, and a gradient of higher to lower dry matter moving from the outside to the inside of the fruit from the sides and bottom of the fruit (Figure 1B). This variability within a fruit led the Californians to prescribe the use of two longitudinal slices (or wedges) of tissue which were then grated and a sub-sample dried. This is, however, relatively time consuming, and in New Zealand an alternative method was developed where a potato peeler is used to cut slices of tissue from a quarter of a fruit (similar to that described by Lee and Coggins, 1982). In all cases, skin and seed coat tissue must be removed, a slow process which can affect dry matter accuracy depending on the level of care taken to remove only skin and seed coat tissue.

The Hofshi Coring Machine

The length of time taken to process avocado samples for dry matter determination has led to the development of an alternative technique (pers. comm. R. Hofshi and M.L. Arpaia). This method involves sampling a "plug" or core of flesh from the equator of the fruit (Figure 2A). The machine pushes a sharpened 15.88 mm metal tube completely through the equator of the fruit (Figure 2B), yielding a core of tissue (Figure 2C). The two plugs of flesh generally weigh about 5 g (depending on the fruit size). The skin and seed coat tissue are easily removed from the flesh plugs, and the flesh then sliced and dried. In our laboratory, the time taken to process (but not dry) 20 individual fruit was about 100 minutes for the old Californian system, 60-70 minutes for the NZ slice system, and 20 minutes for the Hofshi core system.

Given that the distribution of dry matter around the fruit is not uniform (Figures 1A & B), the question arises whether a sample from the equator gives the same measure of the overall dry matter of the fruit. Comparisons between the opposing 1/8ths (two longitudinal slices) and plug method have shown extremely high correlations ($r2 > 0.92$) between the two methods (Arpaia et al., 2002). Figure 3 shows the high level of correlation between the two techniques over a range of growing sites and times in the season. This work has led to legal changes in the sampling and measurement of dry matter in California (Anon. 2002). Preliminary measurements of fruit from three New Zealand orchards at two times in the season also found no significant statistical difference between use of the Hofshi corer, standard New Zealand, and old Californian techniques (Table 1).

Aongatete Coolstores Ltd saw the potential of this system to significantly reduce the labour involved and have registered a modified corer design in New Zealand. The ability to rapidly measure dry matter of individual fruit means that a higher level of accuracy can be achieved by using more fruit (if so desired). Given the time saving and increased safety of this technique, it appears a number of other countries will be moving to this system for dry matter measurement.

Dry Matter Variability between Fruit

Due to fruit to fruit variability, how many fruit need to be sampled to achieve a representative sample? Figure 4 shows the distribution of dry matter sampled from one Katikati orchard for 80 individual fruit. In October the average dry matter was 27.2%, with dry matter values ranging from 18 to 38%. In January, when fruit have an average dry matter of 34.7%, values ranged from 28

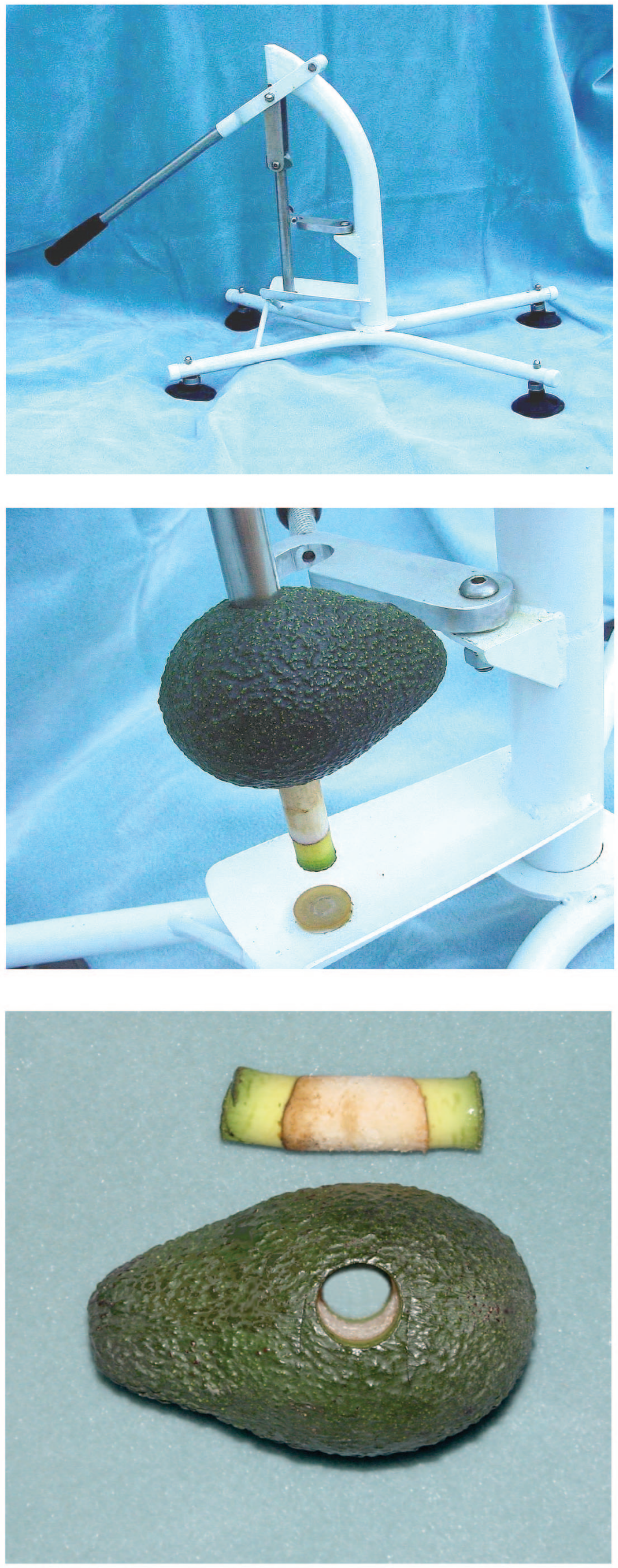

Figure 2. Picture of the Hofshi Coring Device.

Table 1. Mean dry matter value and standard error of the mean (SEM) for 20 fruit from three Far North orchards (September 2002) measured using the three different methods.

	Hofshi System (core)		Current NZ System (slice)		Old Californian system (grated)	
Orchard	Mean	SEM	Mean	SEM	Mean	SEM
1	25.6	0.60	26.2	0.67	26.4	0.65
2	30.6	0.69	30.6	0.64	30.3	0.57
3	31.8	0.75	31.2	0.69	31.7	0.49

to over 44%. This wide variability (a range of up to 20%) simply leads to an issue of pragmatism with regard to the time taken to carry out measurements, the cost of fruit, versus the level of accuracy required. In New Zealand a sample of 20 fruit is taken from the orchard, for official testing in California two sets of 5 fruit are used, while in Australia, they recommend sampling five fruit. Perhaps with the ability to process more samples using the corer we can obtain more reliable measures of dry matter.

Drying Technique

In general, California uses the microwave, New Zealand uses household dehydrators, and Australia recommends using either the microwave or oven to dry fruit samples. Each method has advantages and disadvantages. For example, while the microwave technique is very rapid (minutes), it requires careful attention so as to completely dry the sample without burning it. Conversely, using dehydrators or ovens requires less labour, but generally 12- 24 hours is required to dry the sample. The key underlying principle for this issue is not how you dry it, but simply that the tissue is dried to constant weight. When comparing three different techniques for drying fruit tissue (microwave, dehydrator (65°C), and convection oven (65°C)), no significant difference was found between the techniques (Phetsomphou, 2000). As long as the temperature is not too high (<65°C is generally recommended), the samples can remain in a dehydrator or oven for longer than the time required to reach a constant weight.

Future Developments

Aside from development of the "corer", where else might we go in the future? A technique which has been receiving a lot of interest in the last few years has been the use of NIR (Near InfraRed spectroscopy) for prediction of dry matter. This technique involves shining a bright light at a fruit and measuring the spectrum of light that returns. This technique is non-destructive and very rapid. By correlating the spectrum "seen" with measured dry matter, NIR units can be placed "in line" in the packhouse allowing fruit to be sorted into different dry matter categories. This method is currently being used for kiwifruit and other crops internationally. An initial examination of the ability of NIR to predict dry matter of avocados has developed a model that predicted dry matter with at least a 90% accuracy (Figure 5) (Clark et al., 2003).

Potentially, hand-held NIR "guns" could be used in the orchard to measure large numbers of fruit non-destructively and rapidly. Alternatively, this method could be used in the packhouse to grade fruit into dry matter categories which potentially may be sold to different clients on the basis of taste, or shipped to different markets (as fruit with differing dry matter levels are likely to have different storage potential). However, NIR machinery is expensive, requires continued calibration, and there are significant technical difficulties in transferring the systems out of the laboratory and into a fully commercial environment (temperature, water, dust, operation speed, reliability and operator skill).

Aside from the issues involved in simply measuring dry matter, an important area which requires greater understanding is that of the relationship between dry matter (oil content) and various taste attributes of avocados, and not just an "overall consumer acceptability". The sensory unit at HortResearch has developed taste descriptors of 'Hass' avocados, and these could be used in further work to better link maturity changes with sensory descriptors. This might help in examining regional effects in terms of dry matter levels and taste.

Although measurement of dry matter as a means of defining maturity of avocados has been around for several decades, significant advances in understanding can be made by defining the relationship between dry matter and 'quality'. Trends in the kiwifruit industry linking high dry matter and favourable sensory and storage attributes suggest that there is a need to better define the role of dry matter, not only in maturity, but as an indicator of avocado fruit quality. The Hofshi coring machine and NIR technology are but two examples of innovative new attempts to improve fruit maturity testing. Perhaps the next step is to understand more clearly how the dry matter levels or other factors might be used to better predict taste acceptability.

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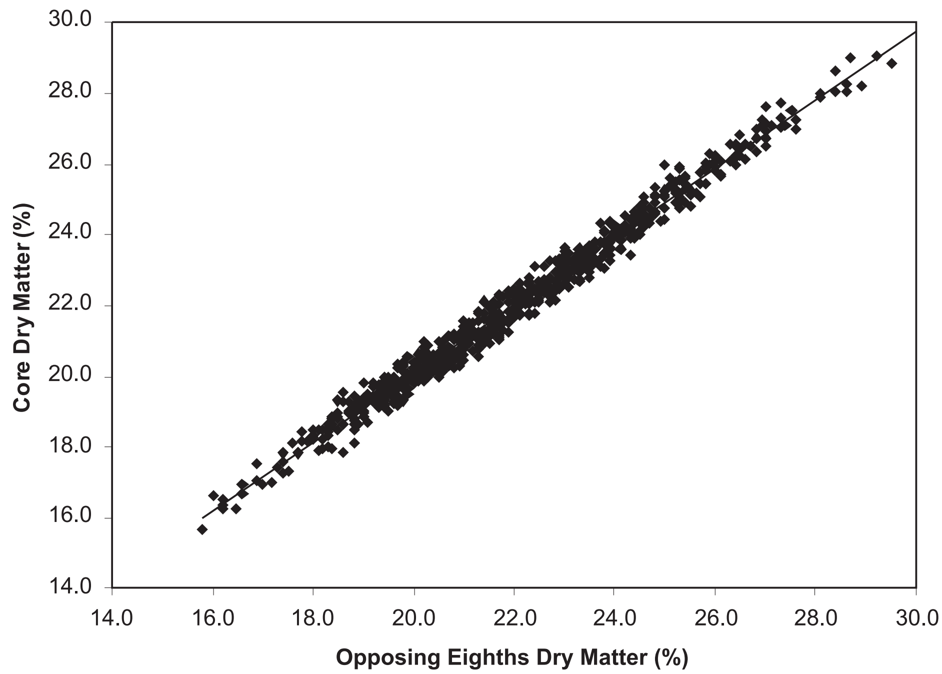

Core Dry Matter (%)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
Opposing Eighths Dry Matter (%)

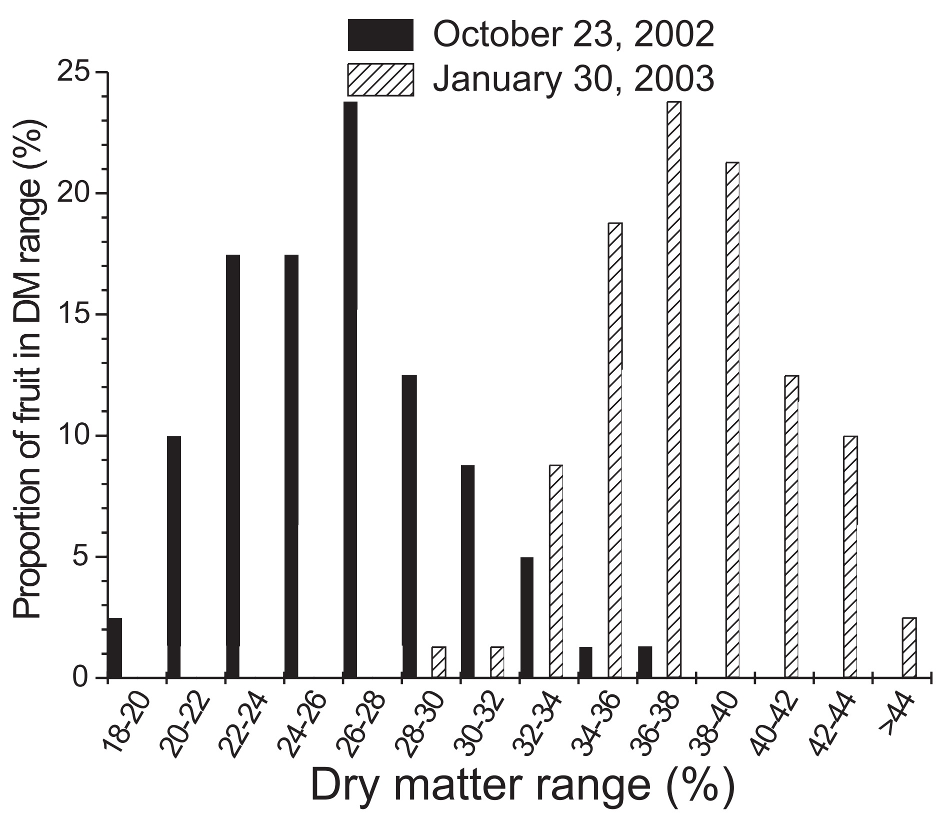
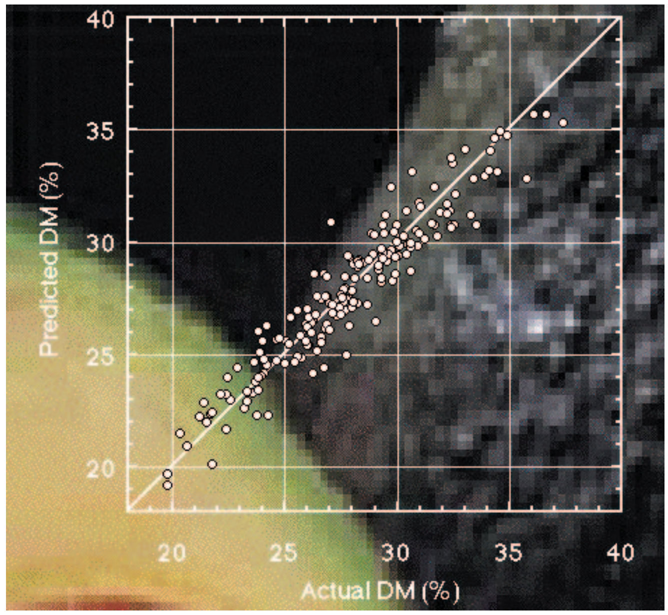

October 23, 2002
January 30, 2003
Proportion of fruit in DM range (%)
25
20
15
10
5
0
18-20
20-22
22-24
24-26
26-28
28-30
30-32
32-34
34-36
36-38
38-40
40-42
42-44
>44
Dry matter range (%)

Figure 3 (left). Relationship between core dry matter (%) and opposing eighths dry matter (%) of 'Hass' fruit sampled throughout California from 21/11/01 to 4/01/02 (N=722). Each point represents one fruit. Samples collected as part of the official maturity testing conducted by CDFA Avocado Inspection Service.

Figure 4 (left). Dry matter distribution of 80 individual fruit from one Katikati orchard harvested on two occasions (October 2002 and January 2003).

Figure 5 (right). Actual (measured) dry matter versus predicted dry matter value using NIR mode (n = 180). Model has an R2 of 90 %, and an error of measurement of 1.2 % DM.



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