Short communication

Development of a dry matter maturity index for olive
(Olea europaea)

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Abstract  A method for calculating dry matter percentage of olive (Olea europaea) was developed as a potential means of assisting growers to determine optimal harvest time. The method was based on the microwave dry matter test commonly used in the avocado industry. Dry matter percentage was correlated with fruit oil content. Although the relationship was not a strong one, it was a better indicator of oil content than the commonly used colour index. This dry matter test may have potential for use in cool climate olive production.

Keywords  dry matter accumulation; oil content

INTRODUCTION

Olive oils from New Zealand are routinely evaluated as extra virgin (Reed et al. 2001), the highest standard defined by the International Olive Oil Council (I.O.O.C.). Therefore, the industry has the potential to produce high quality olive oil. However, the New Zealand olive industry is not likely to compete on price with the mass-produced oils of the Mediterranean region, and producing oils with consistently high quality is an important factor in the marketing of New Zealand olive oil.

There have been several investigations into potential methods for determining harvest date for olives (Olea europaea L.) without the need for laborious oil extraction and analysis. No simple parameter that gives reliable and accurate results has been determined. Proposed methods have included fruit size, texture, colour, water content, natural fruit drop, and fruit force removal. Presently, colour is the most widely used determinant of harvest time, but there are conflicting reports of the relationship between colour and optimal harvest time (Maestro-Duran 1990; Garcia et al. 1995; Rahmani et al. 1997).

Avocado fruits attain similar oil concentrations to olives: between 30 and 70% of fruit dry weight (Mazliak 1970). Lee et al. (1983) reported a strong correlation between avocado dry matter percentage (% DM) and oil content. Dry matter percentage can be obtained relatively easily (compared with oil extractions), making it an ideal maturity standard for oil-accumulating fruits. Microwaves have been used to obtain % DM for avocado fruit (Swarts 1978), corn (Beewar et al. 1977), kiwifruit (Ragozza & Colelli 1990), and other food products (Lee & Latham 1976). The avocado industry has refined the protocol to a simple process, and by monitoring % DM, growers can determine appropriate harvest dates (Lee 1982). A dry matter test such as the one used in the avocado industry, however, has never been reported as a possible indicator of olive maturity.

The objective of this study was to develop a simple and reliable test that could be used by growers to estimate an appropriate harvest date for olives. Specifically, we attempted to: (1) develop a dry matter test for olive based on the avocado dry matter test; and (2) examine the relationship between % DM and oil accumulation in olive fruits. The cultivars used in this study are five of the most commonly planted cultivars in the South Island of New Zealand.
MATERIALS AND METHODS

Olives were obtained from three groves in Blenheim, New Zealand (41.5°S, 173.9°E). Five cultivars (‘Barnea’, ‘Frantoio’, ‘Koroneiki’, ‘Leccino’, and ‘Manzanillo’) were evaluated, but not all cultivars were available at each grove. Sampling began on 14 April 2002, and was conducted approximately every 14 days until 2 July 2002. One bulk sample, consisting of c. 500 g of olives, was harvested between 0800 and 1200 h from the north-facing side of 10 random trees of each cultivar, within each grove. Samples were sealed in plastic bags and packed on ice until fruit were analysed on the following day.

Three subsamples of 20 fruit were taken from each bulk sample, and fruit colour, fresh weight (FW), and dry weight (DW) were determined. Fruit colour was assessed using the colour index prepared by the I.O.O.C. Individual fruit were visually scored from 0 to 7 based on skin and flesh colour, and an overall mean colour index was calculated. FW and DW were obtained from three subsamples of 20 fruit each and % DM was calculated. See Results section for complete details of the procedure.

For oil extraction, c. 50 g of olives were placed in a plastic container, sealed, and stored at –20°C. Frozen samples were lyophilised and ground in a Retsch Ultra Centrifugal Mill (Type ZM1) using a 5 mm sieve. Approximately 2 g of dried olive was placed in a Whatman cellulose extraction thimble in a Tecator Soxtec System (HT 1043 extraction unit). Thimbles were lowered into c. 40 ml of solvent X4 (50–60% v/v N-hexane, 40–50% v/v other isomers, 0.1% v/v benzene, and 86 ppm anti static additive) and refluxed for 1 h. The thimbles were rinsed with the solvent for 50 min, and then evaporated for 10 min. The soxhlett cups containing the extracted oil were removed and placed in a drying oven for 30 min. The cups were cooled to room temperature, and the weight of extracted oil was obtained. Oil content was calculated on a FW and DW basis. ANOVA and regression analyses were conducted using SAS (http://www.SAS.com).

RESULTS

Patterns of oil accumulation over the period of the study varied among cultivars and groves (Fig. 1). Oil content of fruit from ‘Frantoio’ and ‘Manzanillo’ trees tended to increase over the course of the study, whereas oil content of fruit from ‘Leccino’ trees tended to decrease over the same period. ‘Frantoio’ fruit had the highest oil content (40–50% DW), whereas ‘Leccino’ had the lowest oil content (30–37% DW) overall.

A method was developed to determine % DM of olives using a microwave oven to dehydrate the fruit, based on the avocado industry microwave dry matter test (Swarts 1978). Olive fruit are morphologically different from avocado fruit, so the procedure had to be modified. Three main modifications made to the procedure were fruit preparation, containment of fruit, and microwave duration.

A high power setting (using a 650 W microwave oven) resulted in burning of the samples, so a low power setting (defrost or equivalent) was used. For the avocado test the flesh is separated from the seed, and cut into eighths. However, olive fruit flesh is difficult to separate from the seed. Furthermore,

<table>
<thead>
<tr>
<th>Y variable</th>
<th>Cultivar</th>
<th>Regression equation</th>
<th>P value</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil content (% DW)</td>
<td>Barnea</td>
<td>$-0.016 + 0.888$ (% DW)</td>
<td>0.0898</td>
<td>0.2054</td>
</tr>
<tr>
<td></td>
<td>Frantoio</td>
<td>$-0.118 + 1.016$ (% DW)</td>
<td>0.0273</td>
<td>0.5667</td>
</tr>
<tr>
<td></td>
<td>Koroneiki</td>
<td>$-0.228 + 1.376$ (% DW)</td>
<td>0.0010</td>
<td>0.7593</td>
</tr>
<tr>
<td></td>
<td>Leccino</td>
<td>$-0.033 + 0.666$ (% DW)</td>
<td>0.1897</td>
<td>0.2043</td>
</tr>
<tr>
<td></td>
<td>Manzanillo</td>
<td>$0.251 + 0.270$ (% DW)</td>
<td>0.0185</td>
<td>0.6313</td>
</tr>
<tr>
<td>Oil content (% FW)</td>
<td>Barnea</td>
<td>$-0.028 + 0.443$ (% DW)</td>
<td>0.0797</td>
<td>0.2175</td>
</tr>
<tr>
<td></td>
<td>Frantoio</td>
<td>$-0.201 + 0.798$ (% DW)</td>
<td>0.0017</td>
<td>0.5443</td>
</tr>
<tr>
<td></td>
<td>Koroneiki</td>
<td>$-0.233 + 0.921$ (% DW)</td>
<td>0.0002</td>
<td>0.8355</td>
</tr>
<tr>
<td></td>
<td>Leccino</td>
<td>$-0.119 + 0.553$ (% DW)</td>
<td>0.0569</td>
<td>0.3820</td>
</tr>
<tr>
<td></td>
<td>Manzanillo</td>
<td>$-0.060 + 0.575$ (% DW)</td>
<td>0.0007</td>
<td>0.8731</td>
</tr>
</tbody>
</table>
Fig. 1  Oil content (on a fresh weight and dry weight (DW) basis) of fruit harvested from three sites (●, Grove 1; ▲, Grove 2; ◆, Grove 3) in Blenheim, New Zealand (41.5°S, 173.9°E) approximately every 14 days between April and June. Symbols represent an individual sample (consisting of c. 50 g DW fruit) from a bulk harvest from 10 trees.
cutting whole olives was difficult and increased potential losses of dry matter. Experiments conducted to compare dry matter percentages of whole versus cut olives indicated no statistical difference ($P \leq 0.05$) between the two methods (data not shown). Therefore, whole olives were used.

As the olive fruit matured, microwaving resulted in the splitting of the flesh, with subsequent losses of dry matter from the individual samples in the microwave. To contain each sample, fruit were placed in a paper envelope (12.5 $\times$ 9 cm). Approximately 30 small (<1 mm) holes were made in the upward facing side of the envelope to allow for evaporation. The envelopes were placed on glass petri dishes to collect any oil that may leak from the envelope during drying.

Olive fruit (all cultivars) took 45–60 min to reach a constant DW. It was determined that one period

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**Fig. 2** Relationship between oil content (on a fresh weight and dry weight basis) and percentage dry matter of fruit harvested from three sites in Blenheim, New Zealand (41.5°S, 173.9°E) approximately every 14 days between April and June.
of 50 min on a low power setting, followed by further periods of 5 min, until the samples had reached a constant weight, was optimal. The entire procedure takes c. 70 min to complete.

Application of the % DM test as an indicator of olive fruit maturity is dependent on a good relationship between oil content and % DM. When data for all cultivars was pooled, there was a significant linear relationship between % DM and oil content as a percentage of DW (P = 0.0158) or FW (P = 0.0001). However, the relationship between these two variables was weak (R² = 0.0997 and 0.3956 for oil content expressed on a DW and FW basis, respectively).

The relationship between oil content and % DM was different for all cultivars (Fig. 2, Table 2). When expressing oil content on a FW basis as a function of % DM, the relationship between oil content and
% DM was significant in all cultivars except ‘Barnea’, and when expressing oil percentage on a DW basis as a function of % DM, the relationship between oil content and % DM was significant in all cultivars except ‘Barnea’ and ‘Leccino’ (Table 1). Of the five cultivars tested, the relationship between oil content and % DM was strongest in ‘Koroneiki’ ($R^2 = 0.7593$ and 0.8353 for oil content expressed on a DW and FW basis, respectively).

When regressions were conducted for individual groves, significant relationships existed in only one of two groves for the cultivars ‘Manzanillo’, ‘Frantoio’, and ‘Koroneiki’, and there were no significant relationships within individual groves for the cultivars ‘Barnea’ and ‘Leccino’ (data not shown). However, this may be because of the small number of samples collected within a single grove for each cultivar.

Regressions of oil content (% DW) on the I.O.O.C. colour index values were significant for the cultivars ‘Barnea’, ‘Frantoio’, and ‘Koroneiki’, and the relationship was significant for all cultivars except ‘Leccino’ ($R^2 = 0.7593$ and 0.8353 for oil content expressed on a DW and FW basis, respectively).

When regressions were conducted for individual groves, significant relationships existed in only one of two groves for the cultivars ‘Manzanillo’, ‘Frantoio’, and ‘Koroneiki’, and there were no significant relationships within individual groves for the cultivars ‘Barnea’ and ‘Leccino’ (data not shown). However, this may be because of the small number of samples collected within a single grove for each cultivar.

Regressions of oil content (% DW) on the I.O.O.C. colour index values were significant for the cultivars ‘Barnea’, ‘Frantoio’, and ‘Koroneiki’, and the relationship was significant for all cultivars except ‘Leccino’ when oil content was expressed on a FW basis (Fig. 3, Table 2). However, in most instances the relationship between oil content and colour was weaker than that between oil content and % DM (Table 2).

**DISCUSSION**

Fruit size of all cultivars at all locations was smaller (data not shown) than that reported for other regions (Lavee & Wodner 1991; Del Rio & Caballero 1994; Pandolfi et al. 1994; Pannelli et al. 1994). ‘Frantoio’ gave consistently high oil yields at all three sites, similar to those recorded in Mediterranean regions (Del Rio & Caballero 1994; Pannelli et al. 1994), whereas oil yields of some other cultivars examined varied among sites (Fig. 1). Oil yields of ‘Barnea’ fruit were lower (maximum of 19% FW) than the range (23–28% FW) reported in Australia (Lavee & Wodner 1991; Lavee & Blanks 2001). Other cultivars, such as ‘Koroneiki’ and ‘Leccino’, had very different oil contents at different sites.

In cool climate growing regions, such as New Zealand, an accurate determination of optimal oil accumulation is needed to allow growers to harvest before early frosts without sacrificing quality due to harvest of immature fruits.

Several investigators have shown very different patterns between coloration and oil content among different olive cultivars (Lavee 1986; Tombesi et al. 1994). In our study, maximum oil content of most cultivars reached a maximum level before maximum colour development. Furthermore, very few of the cultivars in each of the sites reached a colour index score of five, the recommended harvesting time. Colour of ‘Frantoio’ fruit did not change dramatically over the course of the ripening period (data not shown), suggesting that colour is not a good indicator of fruit maturity for this cultivar. There was a strong relationship between fruit % DM and oil content in ‘Frantoio’ fruit (Fig. 2, Table 1). Therefore, the % DM test may be a more suitable indicator of fruit maturity for ‘Frantoio’. Because % DM was correlated with oil content for all cultivars except ‘Barnea’, the % DM test may be more useful to growers in determining the earliest possible harvesting date, thereby minimising the danger of crop losses as a result of frost. Frosts often occur early in the autumn, which forces growers to

### Table 2

Regression equations and parameters for oil content expressed on a dry weight (% DW) or fresh weight (% FW) basis as related to fruit colour index (CI). Fruit were collected from three sites in Blenheim, New Zealand (41.5°S, 173.9°E) approximately every 14 days between April and June.

<table>
<thead>
<tr>
<th>Y variable</th>
<th>Cultivar</th>
<th>Regression equation</th>
<th>$P$ value</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil content (% DW)</td>
<td>Barnea</td>
<td>0.278 + 0.023 (CI)</td>
<td>0.0345</td>
<td>0.3002</td>
</tr>
<tr>
<td></td>
<td>Frantoio</td>
<td>0.265 + 0.065 (CI)</td>
<td>0.0163</td>
<td>0.3689</td>
</tr>
<tr>
<td></td>
<td>Koroneiki</td>
<td>0.207 + 0.066 (CI)</td>
<td>0.0071</td>
<td>0.6172</td>
</tr>
<tr>
<td></td>
<td>Leccino</td>
<td>0.222 + 0.017 (CI)</td>
<td>0.4938</td>
<td>0.0604</td>
</tr>
<tr>
<td></td>
<td>Manzanillo</td>
<td>0.318 + 0.017 (CI)</td>
<td>0.1493</td>
<td>0.2727</td>
</tr>
<tr>
<td>Oil content (% FW)</td>
<td>Barnea</td>
<td>0.113 + 0.013 (CI)</td>
<td>0.0086</td>
<td>0.4231</td>
</tr>
<tr>
<td></td>
<td>Frantoio</td>
<td>0.117 + 0.040 (CI)</td>
<td>0.0119</td>
<td>0.3964</td>
</tr>
<tr>
<td></td>
<td>Koroneiki</td>
<td>0.064 + 0.041 (CI)</td>
<td>0.0090</td>
<td>0.5951</td>
</tr>
<tr>
<td></td>
<td>Leccino</td>
<td>0.102 + 0.012 (CI)</td>
<td>0.4392</td>
<td>0.0765</td>
</tr>
<tr>
<td></td>
<td>Manzanillo</td>
<td>0.104 + 0.016 (CI)</td>
<td>0.0180</td>
<td>0.5740</td>
</tr>
</tbody>
</table>
harvest olives before full colour development, the standard maturity indicator used in the industry.

Dry matter percentage has been used to determine the maturity of other crops (Lee et al. 1983; Ragozza & Colelli 1990), but has not been investigated as a potential maturity indicator of olives. The slopes of the cultivar regression lines for oil content and % DM appear to fall into two groups, with ‘Frantoio’ and ‘Koroneiki’ having higher slopes than the other three cultivars (Table 2). If a % DM standard were to be established, it may be possible to group cultivars, based on maximum oil content and the relationship between oil content and % DM. This would allow for easier sampling protocols for growers.

Other factors such as crop load (Barone et al. 1994), shading (Tombesi et al. 1999), water availability (Alegre et al. 1999), frosts and drying winds (Hartmann 1949), rainfall (Lavee & Wodner 1991), cultivar, cultural practices, and season and orchard location (Hofman & Jobin-Décor 1999) can affect the rate of development of olive fruit, causing optimum harvest date to vary from year to year. The most economical time to harvest is when oil content is at a maximum level, but maintaining high oil quality is also an important consideration for New Zealand growers. The proposed method requires further testing over a range of cultivars, and environments, but it may prove to be a valuable and simple test for olive growers in cool climate areas.

ACKNOWLEDGMENTS

We thank Chris Frampton and Bruce McKenzie for their assistance with the statistical analysis, Stuart Larsen for his help with the data collection, and the various olive growers (Creekside Olive Estate and Vineyard, Marlborough Olives, and Ponder Estate) who donated fruit and time to this project. This project was funded in part by a grant from the New Zealand Olive Association.

REFERENCES


