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Research Note

Quantitative determination of flesh mealiness in peach [*Prunus persica* L. (Batch.)] through paper absorption of free juice

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ABSTRACT

A simple and rapid method was developed for quantitative determination of juiciness in peach flesh based on the absorption of free juice with ordinary absorbent paper after a flesh sample is squeezed by two metallic rolling cylinders. Juiciness data were compared with trained panel determinations on three peach cultivars kept at 4 °C and 90% RH for 7, 14 and 21 d plus a ripening period at 20 °C and 65% RH until the flesh reached 19.6 ± 9.2 N. There was a high correlation between panel judgment and paper absorption (r^2 = 0.75 in 'Elegant Lady', 0.77 in 'O'Henry' and 0.93 in 'Ross'). A sub-sample of the juiciest and the mealiest fruit also were sorted after 14 and 21 d in cold storage. 'Ross', a non-melting peach cultivar, did not develop flesh mealiness during any evaluation period. During storage, there was a reduction in juiciness reaching 15% less after 21 d. Mealy fruit were exclusively observed with melting cultivars exposed to cold storage. The proposed method for determining juice content is easily executed and shows a high association with human perception of juiciness and mealiness in peach.

1. Introduction

Chilling injury (CI) is a physiological disorder that affects stonefruit kept for long periods under cold storage. CI symptoms are expressed during ripening, usually when fruit reach consumers. The phenotypic expression of this disorder is flesh mealiness (FM), a dry flesh with grainy sand-like texture, and flesh browning. Peach susceptibility to CI varies according to genetic background (Crisosto et al., 1999), maturity (Von Mollendorff, 1987), and orchard factors (Crisosto et al., 1997).

Flesh mealiness is a consequence of an enzymatic imbalance, where wall proteins play an important role. Among these, polygalacturonase (PG) and pectinesterase (PE) are active during FM development (Ben Arie and Sonego, 1980; Von Mollendorff and De Villiers, 1988). When stonefruit are exposed to 4–8 °C, PG activity is reduced, but this temperature does not significantly affect PE activity (Ben Arie and Sonego, 1980), producing an uneven balance of PG and PE, affecting cell wall pectin degradation and forming a gel-like texture. Quantitative methods for mealiness assessment, by weighing the supernatant after centrifuging homogenized fruit tissue have been described by Lill and Van der Mespel (1988) and Von Mollendorff et al. (1992). After disruption, collected tissue is centrifuged and the liquid phase is separated and expressed as % (mass/mass) of total tissue. These methods have practical steps that are quite difficult to execute, for example the excessive strength needed for extruding firm nectarines, or the inadequate separation of liquid and solid phases in mealy fruit (Crisosto and Labavitch, 2002). More recently, Crisosto and Labavitch (2002) developed a pressing apparatus, where flesh is exposed one to six times to high forces (from 222 to 890 N) for 1–10 min before the extracted tissue is carried through similar steps for separating the liquid phase (Lill and Van der Mespel, 1988). Even if this is a precise method, it has some limitations: it is a time-consuming procedure, and it is not adequate for non-melting peaches (even if this type of flesh is not affected by FM).

Some 106 genes have been reported to change relative expression levels in mealy fruit when compared with juicy fruit, and the abundance of most of the transcripts (93%) has been shown to decrease in mealy peaches (González-Agüero et al., 2008). This molecular approach to peach FM demands a solid definition of the mealy phenotype, and a reliable, accurate, easy and rapid method for determining FM. Our research describes a simple method for quantitative juiciness determination in peach flesh and the correlation between FM defined by a trained sensory panel and the paper absorption method (PAM).

2. Materials and methods

Melting fleshed ('O'Henry', and 'Elegant Lady') and non-melting fleshed ('Ross') peach cultivars [*Prunus persica* L. (Batch.)] were har-

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Table 1
Characterization of the fruit harvest maturity stage of peach cultivars

	'Elegant Lady'	'O'Henry'	'Ross'
Flesh firmness (N)	48.0 ± 9.5	51.1 ± 10.3	40.2 ± 8.8
Fruit mass (g)	164.1 ± 15.9	241.9 ± 21.0	212.6 ± 25.1
Total soluble solids (%)	12.6 ± 2.5	12.2 ± 2.8	9.4 ± 3.4
Titratable acidity (%)	1.2 ± 0.2	1.3 ± 0.2	0.7 ± 0.1

Data correspond to the mean of 20 fruits ± standard error.

vested by sorting fruit with green-yellow background color. The harvest maturity stage was characterized in a sample of 20 fruit, by measuring titratable acidity, flesh firmness, fruit mass, and total soluble solids (Infante et al., in press) (Table 1).

Juiciness sensory analysis was carried out using a trained panel organized as a focus group, formed by five assessors, highly competent in stonefruit evaluation and trained specifically to evaluate juiciness and FM. The 12 h training period was carried out during the same harvest season. Six sessions for discussing and criteria standardizing were performed. The evaluation guideline used was a continuous scale ranging from 0 to 15, marked with two anchors (0 = extremely juiceless and 15 = extremely juicy).

The same fruit used for panel evaluation were submitted to PAM for quantitative juiciness determination. Flesh was sampled just below the epidermis, perpendicular to the cheek surface, using a metal punch producing a cylinder of flesh 5 mm in diameter and 15 mm long. The flesh cylinder deprived of epidermis, was weighed and wrapped with two sheets (5 cm × 25 cm) of absorbent paper previously tared individually. Subsequently, the flesh cylinder wrapped with both sheets was passed between two metallic rollers operated by a manual crank 0.5 mm apart. By the effect of the pressure exercised by the rollers (110 ± 20 N), the flesh cylinder was squeezed and the juice released. The crushed flesh and a little juice remained in the sheet of paper in contact with the flesh cylinder. Juice exclusively remained in the sheet of paper that covered the one against the flesh, which was weighed separately. The proportion of juice in relation to the total flesh (mass/mass) was calculated and expressed as %.

Comparisons of the PAM/trained panel, and Lill and Van der Mespel method (1988)/trained panel were performed. Forty 'O'Henry' fruit were stored in a cold chamber (4 °C and 90% RH) for 21 d and then transferred to a ripening chamber (20 °C and 65% RH) for 3 d, until reaching 19.6 ± 9.2 N flesh firmness. After the ripening phase, fruit were submitted to sensory and instrumental analysis. Both correlations were fitted to a logistic model (InfoStat, 2004).

For quantitative juiciness determination using PAM, fuit of each cultivar were divided into four groups of 25 fruit each for 'Elegant lady' and 'O'Henry' and 8 for 'Ross'. The first group was transferred to the ripening chamber and kept for 6–7 d until the flesh firmness reached 19.6 ± 9.2 N. The second, third and fourth groups were stored (4 °C and 90% RH) for 7, 14 and 21 d, respectively plus 3–4 d in the ripening chamber until flesh firmness reached 19.6 ± 9.2 N. The panel evaluated all the fruit of each group, trying a thin slice from each one. PAM/trained panel correlations were fitted to a logistic model considering data from the groups submitted to cold storage together (InfoStat, 2004).

To determine quantitative juiciness over storage time, in each group of fruit, assessors defined five fruit that were classified as the juiciest and five that were mealy. The three to four samples that showed coincidence among assessors formed a sub-sample for each condition. Afterwards, these sub-samples (juicy and mealy) were submitted to ANOVA at 14 and 21 d of cold storage plus 3 d in ripening. Significant differences between means were determined by the *t*-test $P < 0.05$ (InfoStat, 2004).

3. Results and discussion

The Lill and Van der Mespel method (1988) showed an adequate determination coefficient ($r^2 = 0.64$) when compared with the sensory panel, $y = 61.17(1 + 2.19^{-0.34x})^{-1}$. The PAM showed an even higher determination coefficient ($r^2 = 0.74$) $y = 59.38(1 + 1.67^{-0.25x})^{-1}$. Flesh cylinder weight used in both methods varied between 1.21 and 1.54 g, with an accuracy of 0.01 g. The time required to manipulate a flesh sample following PAM was less than 10% the time required for a Lill and Van der Mespel (1988) determination. These encouraging results demonstrate the utility of using PAM for measuring FM in peach.

FM was not observed in those fruit not submitted to 4 °C, which is an expected result since mealiness occurs after fruit are exposed to low temperatures (Ben-Arie and Sonego, 1980). The non-melting fleshed 'Ross' did not show FM, agreeing with other authors (Brovelli et al., 1998) who indicated that clingstone peaches do not develop FM during cold storage, although they could be susceptible to other manifestation of CI such as loss of flavor and flesh browning (Crisosto et al., 1999).

It should be emphasized that there was a high correlation observed between PAM and juiciness determined by the panel in all three cultivars tested ($r^2 = 0.75$ in 'Elegant Lady', 0.77 in 'O'Henry' and 0.93 in 'Ross'). These confirmed that PAM is a reliable method and shows a high association with what assessors perceived as juiciness in peach. The melting fleshed cultivars showed maximum juiciness scores near 93%, while 'Ross' showed 82.3%. This difference could not be ascribable to dehydration, because this difference was already obvious in fruit not submitted to cold storage; it could be better explained by a higher cohesion force with which water is bound in this kind of flesh. Fruit of non-melting genotypes showed a higher capacity for calcium binding in the water-insoluble pectin fraction compared with fruit of the melting genotypes (Manganaris et al., 2006). Brummell et al. (2004) reported that with increasing length of cold storage and increasing development of mealiness, the extractability of chelator-soluble polyuronides declined.

The threshold for FM is the middle of sensory scale (7.5), which corresponds to 38.4 and 39.8% PAM scores for 'Elegant lady' and 'O'Henry', respectively (Fig. 1). In 'Ross' fruit, theoretically this threshold (39.5%) is also close to the same PAM values, but no sample below this threshold was observed (Fig. 1), confirming previous results (Brovelli et al., 1998).

Juicy fruit, of the three cultivars, showed juiciness reduction over storage time, reaching near 15% after 21 d at 4 °C plus 3 d at 20 °C (Fig. 2). The difference between the initial and the final juiciness levels could be mainly ascribed to fruit dehydration. This is a physical phenomenon that mainly depends on chamber relative humidity and fruit maturity (Lutz and Hardenburg, 1968). On the other hand, FM is a more complex physiological disorder governed by multiples genes induced when tissues are exposed to low temperatures (Peace et al., 2005; González-Agüero et al., 2008), and it is not necessarily associated with less water content.

The degree of mealiness in melting fleshed cultivars increased substantially with increasing length of cold storage (Brummell et al., 2004) as was also observed in our experiment. In 'Elegant lady' fruit, 20% of the fruit were mealy after 7 d of cold storage, 24% after 14 and 52% after 21 d, in 'O'Henry', no mealy fruit were observed after 7 d, 32% after 14 and 36% after 21 d. In all the cases the mealy fruit had PAM values statistically different from the juicy ones (Fig. 2).

The PAM for juiciness determination is an easy-to-use method and showed a high association with human perception of juiciness and mealiness in peach. Further, it uses only small amounts of flesh, allowing the use of the same fruit for more than one determination (sensory evaluation, instrumental quality, functional genomics,

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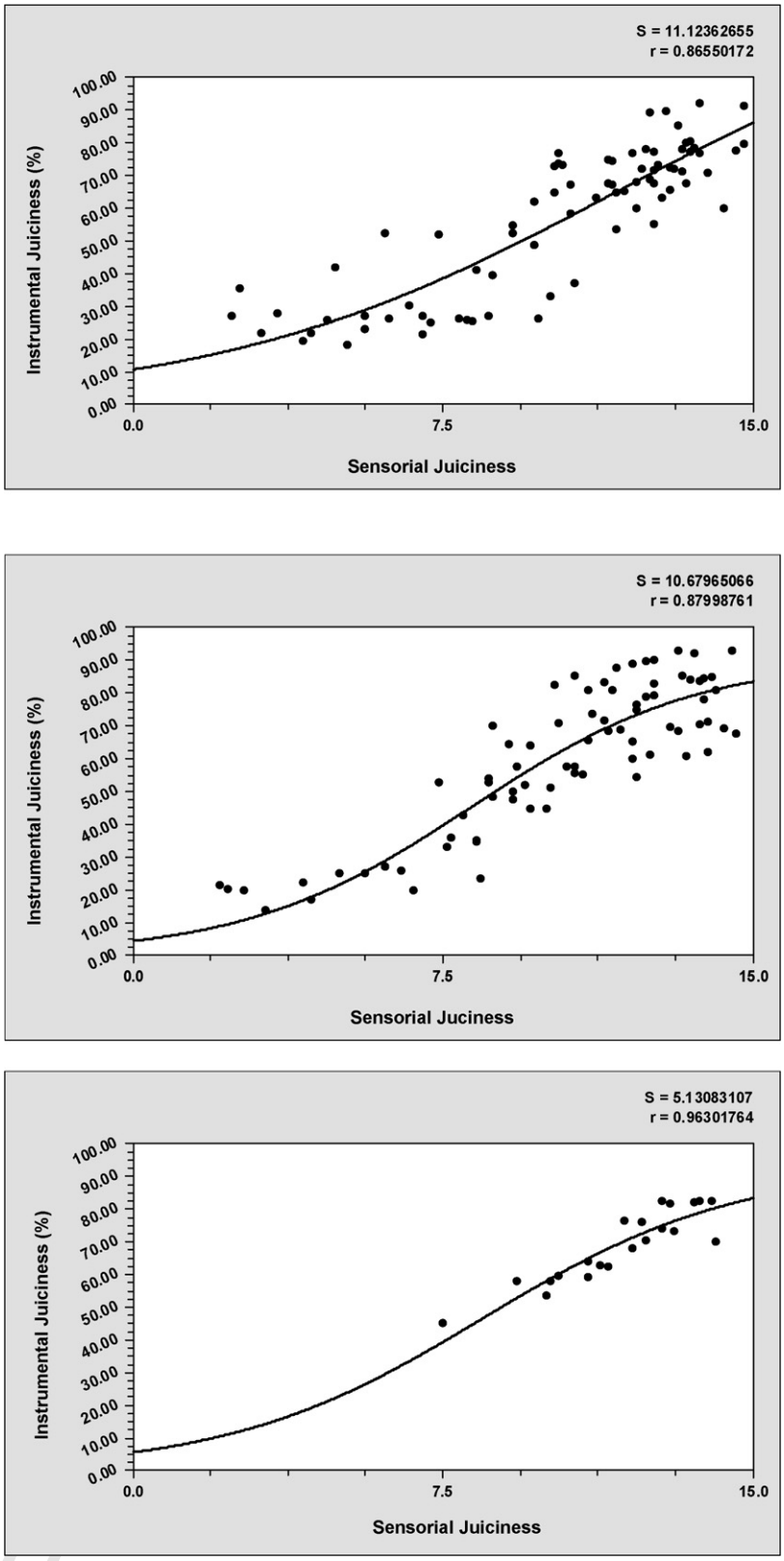

Fig. 1. Correlation PAM/trained panel on 'Elegant Lady' ($y = 121.08(1 + 11.25^{-0.22x})^{-1}$) (upper); 'O'Henry' ($y = 90.56(1 + 19.49^{-0.36x})^{-1}$) (middle); 'Ross' ($y = 93.39(1 + 15.57^{-0.32x})^{-1}$) (lower) peaches kept for 7, 14 and 21 d at 4 °C plus a period at 20 °C until the flesh reached 19.61.

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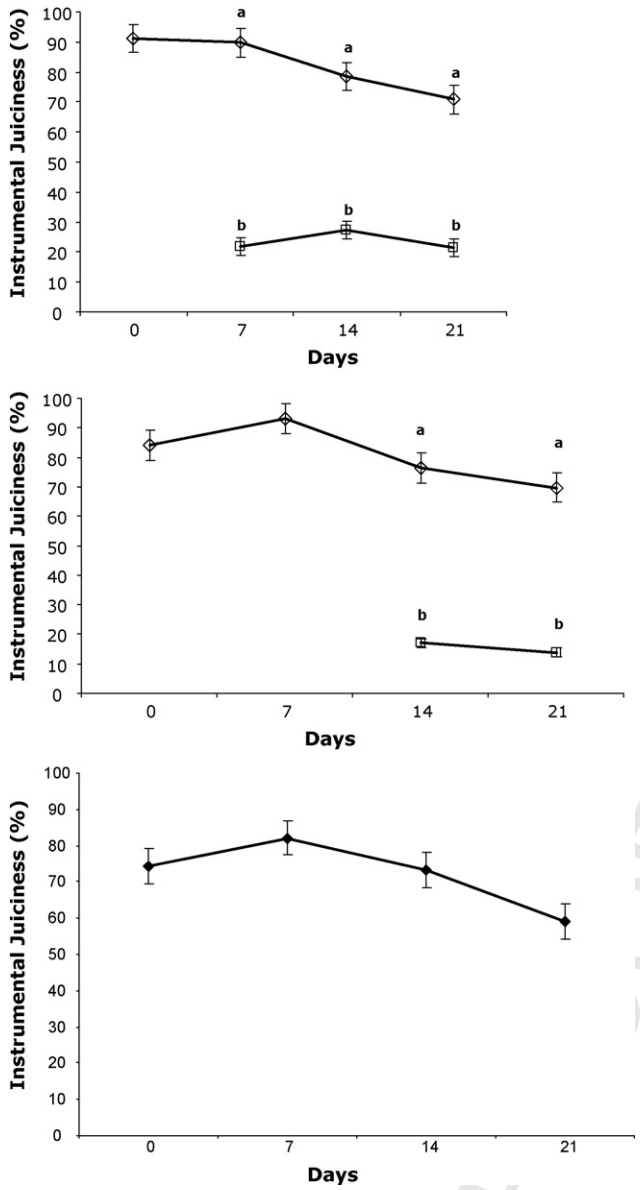

Fig. 2. Quantitative juiciness determination over storage time determined by PAM of juicy and mealy fruits kept at 4 °C for 0, 7, 14 and 21 d plus a period at 20 °C until the flesh reached 19.6 N. 'Elegant Lady' (a); 'O'Henry' (b); 'Ross' (c) peaches. Bars = standard error.

etc.), reducing the effect of high data variability within a sample, less than 3.5% S.D. (data not published), which is a common problem in stonefruit postharvest studies.

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