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An integrated approach for flavour quality evaluation in muskmelon (*Cucumis melo* L. *reticulatus* group) during ripening

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ABSTRACT

Numerous and diverse physiological changes occur during fruit ripening and maturity at harvest is one of the key factors influencing the flavour quality of fruits. The effect of ripening on chemical composition, physical parameters and sensory perception of three muskmelon (*Cucumis melo* L. *reticulatus* group) cultivars was evaluated. Significant correlations emerging from this extensive data set are discussed in the context of identifying potential targets for melon sensory quality improvement. A portable ultra-fast gas-chromatograph coupled with a surface acoustic wave sensor (UFGC–SAW) was also used to monitor aroma volatile concentrations during fruit ripening and evaluated for its ability to predict the sensory perception of melon flavour. UFGC–SAW analysis allowed the discrimination of melon maturity stage based on six measured peaks, whose abundance was positively correlated to maturity-specific sensory attributes. Our findings suggest that this technology shows promise for future applications in rapid flavour quality evaluation.

1. Introduction

Netted muskmelon (*Cucumis melo* L., *reticulatus* group), also commonly called cantaloupe, is an orange-fleshed, sweet and aromatic melon that is highly popular in the United States, representing a large share of the produce market. In 2010, the estimated net domestic use of muskmelon totaled over 2.6 billion pounds, and muskmelon ranked fourth in U.S. annual per capita consumption of fresh fruit after bananas, watermelons and apples (USDA-ERS, 2010). Consumer surveys assessing "overall preference" for several muskmelon cultivars highlighted that flavour, sweetness and texture were important factors in determining consumer liking of melons (Lester, 2006). While these attributes are dictated by the specific cultivar, or genetic makeup, of the muskmelon, maturity at harvest has also been shown to have a large impact on the sugar content (related to sweetness), volatile content (related to flavour and aroma) and texture of melon fruit (Beaulieu & Grimm, 2001; Beaulieu, Ingram, Lea, & Bett-Garber, 2004; Beaulieu & Lancaster, 2007; Pratt, 1971).

Harvesting firmer and early mature fruits is a commercial practice commonly adopted in order to maximise post-harvest life during handling, shipping and storage of climacteric fruits (Kader, 2008). However, this practice is detrimental for flavour quality because it does not allow full development of the fruit aroma profile (Beaulieu, 2006; Beaulieu et al., 2004; Wyllie, Leach, & Wang, 1996).

Typically, muskmelon fruit maturity in the field is determined by the extent of the development of an abscission layer (also called "slip" in the trade) between the vine and the fruit. In California, melons are generally harvested at ¾- to full-slip stage for local market distribution. However, genetic, environmental and agronomic factors often complicate maturity assessment by influencing fruit physiology and the development of this abscission zone, resulting in variable postharvest fruit quality. In addition, melons destined for long distance transport are typically harvested earlier, sometimes even before the clear development of an abscission zone.

Due to the interactions of many parameters (e.g., sugar content, aroma profile, colour, texture) in determining fruit sensory characteristics, measuring a single composition parameter such as sugar content is seldom sufficient to reflect an objective assessment of overall fruit flavour quality. From an applicative perspective, a comprehensive assessment of flavour quality is often unfeasible due to the requirement of expensive analytical instrumentation, highly trained personnel and time- and labour-consuming proce-

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dures. While the availability of rapid methods for the detection of external, visual quality has allowed the distribution of aesthetically superior fruit, the lack of rapid methods for flavour quality control may hinder the delivery of more flavourful fruit to consumers.

In our study we first evaluated the effect of ripening on sensory perception, chemical composition and physical measurements of melon fruit. Changes in chemical composition and physical properties during the ripening process were then correlated to sensory attributes in an attempt to predict flavour perception by chemical composition analysis. Finally, an ultra-fast gas-chromatograph was evaluated for its ability to monitor changes in melon volatile concentrations during ripening and to predict the sensory perception of flavour.

2. Materials and methods

2.1. Plant material and sample preparation

Muskmelons (*C. melo* L., *reticulatus* group) cv. Navigator, Mas Rico and Thunderbird, were grown in Davis, CA (38.55 N, 121.74 W), and provided by HM. Clause Seed Company (Modesto, CA, USA). Each of the three cultivars was planted on three different dates with approximately 2-week intervals during the spring of 2010 and grown on raised beds using standard commercial cultivation practices with drip irrigation. Each cultivar plot corresponding to one "planting date" was used to supply one of three iterations of fruit materials for sensory testing and physiochemical analysis.

Fruit were harvested at five different maturity stages, ranging from early mature to fully ripe, between July and September 2010. The maturity at harvest was assessed in the field by examining the presence or absence of the abscission zone formed around the peduncle, commonly called "slip". Early mature melons corresponded to fruits that had reached full size, but did not show a visible abscission zone around the peduncle (thereafter named "pre-slip" fruit). Fruits were classified as "full slip" when a fully developed abscission zone (as evidenced by the development of a crack around the peduncle) was visible at harvest time. Under our growing conditions, the abscission zone developed very quickly (within less than a day), making the standard ¼-, ½- and ¾-slip maturity assessment impractical. Therefore, "full-slip" melons were grouped in three classes, "slip A" (Sa), "slip B" (Sb) and "slip C" (Sc), based on increasing force needed to detach the fruit from the plant (force applied to detach the fruit: Sa > Sb > Sc). Six melons were chosen for each maturity stage based on the absence of external and internal defects, and size homogeneity. Fruits were rinsed with tap water in order to remove dirt and dust, cut longitudinally into four wedges, and a further classification of the "pre-slip" fruit was performed visually based on the degree of colour lightness of the flesh: "pre-slip light orange" (PL) and "pre-slip dark orange" (PD).

Seeds and cavity tissue were removed, and two opposite wedges per fruit were selected for physiochemical analysis and the other two opposite wedges were used for sensory analysis on the same day.

2.2. Environmental conditions

Average and maximum daily air temperature and total solar radiation data were retrieved from the web-site of California Information Management System (CIMIS; http://www.cimis.water.ca.gov) weather station, located 5 miles North-West (38.54 N, 121.78 W) of HM. Clause Seed Company fields. Total solar radiation was converted into photosynthetic active radiation (PAR) in 400–700 nm wavebands, according to Thimijan and Heins (1983), and expressed in $\mu mol\ m^{-2}\ s^{-1}$.

2.3. Sensory analysis

2.3.1. Panellist recruiting and training

Students and staff with various backgrounds in sensory testing were recruited from the UC Davis campus to participate in sensory panel training.

Nine panellists underwent six one-hour training sessions, over a period of 3 weeks. During the initial training sessions, panellists generated and agreed upon a list of sensory attributes presented in Table 1. The attributes were rated on a 10 cm unstructured scale, anchored at the ends with "none" and "strong", except for colour intensity, which ranged from "pale orange" to "strong orange", and unevenness of colour, which ranged from "even" to "uneven".

2.3.2. Sensory descriptive analysis

Melon balls (1.3 cm in diameter) carved from melons of the same cultivar and maturity stage were gently mixed in a mixing bowl, and a set of five balls was put into five 162-mL plastic cups with lids labelled with random three digit codes. The samples were served in complete randomised order, as established by the software program CSA, Compusense Five (Version 5.0, Compusense, Guelph, Ontario, Canada, 2008), in individual booths and under normal fluorescent white light, at ambient room temperature (20 °C). Water and unsalted crackers were used as rinsing agents between samples.

A modified quantitative descriptive analysis (QDA) (Stone, Sidel, Oliver, Woolsey, & Singleton, 1974) was used to evaluate the samples. Five samples per cultivar, representing all five maturity stages, were evaluated during each session and each cultivar evaluation was repeated three times (corresponding to the three different planting dates). Panellists evaluated the samples one by one, on a computer screen, according to the order presented in the software program. Appearance of the fruit was evaluated first based on the overall average colour intensity and unevenness of colour for the five melon balls. Panellists then smelled the sample, and evaluated the aroma attributes. Two sample balls were used for evaluation of the texture attributes. Panellists swallowed the samples after completing the evaluation. Flavours, tastes and flavour lasting sensation were evaluated on the remaining three sample balls.

2.4. Physical and chemical analysis

2.4.1. Physical measurements

Colour measurement was performed using a Minolta Colorimeter (CR-300, Minolta, Ramsey, NJ, USA). L^*, a^*, b^* values were recorded on six replicates per sample, from the side of $2 \times 2 \times 2$ cm flesh cubes obtained from the equatorial region of the fruit. Hue angle, h, was calculated as $h = \arctan(a^*/b^*)$.

Puncture and compression assessments were performed to evaluate fruit flesh firmness, using a TA.XT2 Texture Analyzer (Texture Technologies, Scarsdale, NY, USA). Puncture testing was performed with a 100 g force load on the side of a $2 \times 2 \times 2$ cm flesh cube obtained from the equatorial region of the fruit. A 5 mm diameter flat-head stainless steel cylindrical probe travelled at a rate of 1 mm s^{-1} for a total of 6 mm. The area under the curve from 0 to 6 mm was used as the puncture measurement. Compression testing using a 38 mm flat compression probe was performed with a 100 g force load on the side of a $2 \times 2 \times 2$ cm cube. Pretest speed was 10 mm s^{-1} with a test speed of 0.5 mm s^{-1}, followed by a post-test speed of 10 mm s^{-1}. The compression measurement determined from the graph was total force area ($N * s$). Six melon cubes were analysed for puncture and compression for each cultivar, maturity level, and planting date.