BIOSYSTEMS ENGINEERING 123 (2014) 12–18

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/issn/15375110

Research Paper

First steps to predicting pulp colour in whole melons using near-infrared reflectance spectroscopy

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ARTICLE INFO

Article history:
Received 5 February 2014
Received in revised form
16 April 2014
Accepted 28 April 2014
Published online 21 May 2014

Keywords:
Near-infrared spectroscopy
Melon
Internal colour
MPLS regression
Local algorithm

Near-infrared reflectance spectroscopy (NIRS) technology was used for the non-destructive measurement of melon-pulp colour (a^*, b^*, C^* and h^*), one of the main indicators of ripeness and quality. A total of 432 Cantaloupe and Galia melons were used in the construction of calibration models, testing various spectral signal pretreatments and both linear and non-linear regression algorithms. The coefficient of determination (r^2) and the standard error of cross-validation (SECV) obtained for parameters a^* (0.96, 2.16), b^* (0.85, 3.25), C^* (0.82, 3.76) and h^* (0.96, 3.64) in intact fruit confirmed the *a priori* viability of NIRS technology with modified partial least squares (MPLS) regression for measuring melon ripeness and quality. Moreover, the application of a local algorithm improved the ability of models to predict all the internal-colour quality parameters studied. These results suggest that NIRS technology is a promising tool for monitoring ripening in melons and thus for establishing the optimal harvesting time.

1. Introduction

Harvesting melons at their ideal stage is especially critical to their storage life and eating quality. Although sweetness is the key attribute affecting eating-quality, other properties such as aroma, flesh colour and texture—depending on the fruit concerned—are also indispensable indicators of overall quality (Vallone et al., 2013).

The quality of muskmelons (*Cucumis melo*) at harvest is traditionally estimated on the basis of a number of subjective external features, chief among which are background colour, net development, and stem abscission (Cantwell & Kasmire, 2002; Portela & Cantwell, 1998; Simandjuntak, Barrett, & Wrolstad, 1996).

Cantaloupes may be harvested when the fruit begins to separate from the stem, when the external colour beneath the netting begins to change from green to yellow-green (because the skin colour typically changes from grey to dull green when immature, becomes deep uniform green at maturity, and then light yellow at full ripeness), and when the net is well

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http://dx.doi.org/10.1016/j.biosystemseng.2014.04.010

developed with a waxy covering (Cantwell, 1996). To ensure excellent eating quality, it is critical to harvest melons at a sufficiently advanced stage when the sugars have already accumulated in the fruit, since postharvest changes in sugar concentration are small (Lester & Shellie, 1992; Pratt, Goeschl, & Martin, 1977). Similarly, although skin colour may change after harvest, pulp colour changes very little, so that harvesting at the appropriate stage of maturity is crucial to good internal visual quality (Cantwell, 1996).

Honeydew melons are harvested by maturity, which is very difficult to judge since the abscission zone, a valuable harvest criterion for Cantaloupes, does not form until the fruit is overripe (Pratt et al., 1977). Maturity classes are grouped predominantly by changes in 'ground colour' from greenish to cream with yellow accents. Cantwell (1996) noted that Honeydew melons may be considered mature but unripe when the external colour is white with a greenish aspect, the peel is slightly fuzzy, there is no aroma, when the melon splits when cut, and when the pulp is crisp. They may be classed as mature and ripening when the external colour is white with traces of green, the peel is not fuzzy but slightly waxy, the aroma changes from slight to noticeable, the melon splits when cut and the flesh is crisp. The characteristics of ripe Honeydews are as follows: ground colour is creamy white with yellow accents, peel is clearly waxy, the characteristic aroma is noticeable and the blossom-end yields slightly to pressure. Pratt et al. (1977) report that ripening in Honeydew melons is associated with increased respiration and ethylene production rates, aroma development and softening.

The Galia melon is a hybrid originating from a Cantaloupe-Honeydew cross, it is larger than a Cantaloupe, and with deep green flesh. Ripeness is measured not by softness at the stem but rather by colour and fragrance (Escribano & Lazaro, 2012).

Growers and consumers generally estimate melon quality in terms of aroma, softness to the touch and surface colour (Lester, 2006). However, while these are important for establishing product quality and optimal harvesting time, there are other key criteria which cannot be assessed externally, and require non-destructive methods in order to avoid damage to the fruit. Pulp colour is one such criterion, as Cantwell (1996) noted, autumn and winter grown Cantaloupe melons may be ripe on the inside but have a green peel colour. Cantwell and Portela (1998) highlighted the link between pulp colour and surface defects such as sunburned areas and large ground spots (poorly netted areas where melons touch the ground), reporting that average pulp chroma (orange colour) values were highest in good-quality pieces, intermediate in ground-spot pieces, and lowest in pieces from sunburned areas.

Growers and the industry would therefore clearly benefit from fast, precise and, above all, non-destructive techniques for predicting pulp colour. Near-infrared reflectance spectroscopy (NIRS) technology not only appears to potentially meet these requirements, but also offers a number of other advantages which could make it ideal for meeting current demands in terms of control and traceability: low cost per sample analysed; little or no need for sample preparation; the ability to analyse a wide range of products and parameters; a high degree of reproducibility and repeatability. NIRS can also be built into in-line processes, and – since no reagents are required – it produces no waste.

NIR spectroscopy has been used successfully to predict colour in animal products such as fresh breast muscle (Abeni & Bergoglio, 2001), deboned chicken breast (Liu, Lyon, Windham, Lyon, & Savage, 2004), and beef (Andrés et al., 2008; Cecchinato, De Marchi, Penasa, Albera, & Bittante, 2011; Prieto, Andrés, Giráldez, Mantecón, & Lavín, 2008; Prieto et al., 2009), as well as for external colour in mandarins and oranges (Sánchez, De la Haba, & Pérez-Marín, 2013; Sánchez, De la Haba, Serrano, & Pérez-Marín, 2012).

Although the prediction of internal colour is a key factor in establishing optimal harvesting time in melon, no published research appears yet to have addressed this criterion, since the majority of studies have focused on the determination of SSC (Flores et al., 2008; Guthrie, Liebenberg, & Walsh, 2006; Long & Walsh, 2006).

The overall aim of this study was to evaluate the ability of NIR technology to predict melon-pulp colour (a^*, b^*, C^* and h^*), a quality parameter strongly influencing consumer acceptance or rejection of the product.

2. Material and methods

2.1. Fruit samples

A total of 432 melons – 220 Cantaloupe (*Cucumis melo* L. var. reticulates Naud., Vulcano cultivar) and 212 Galia (*Cucumis melo* L. var. reticulates Naud., Siglo, Deneb, Esmeralda and Solarking cultivars) – were harvested in glasshouses belonging to the Provincial Fruit and Vegetable Harvesters' and Exporters' Association in Almeria, Spain.

On arrival at the laboratory, fruit was promptly placed in cold storage, at 5 °C and 95% relative humidity. Prior to each measurement, fruit samples were left in order to allow the near-surface temperature to stabilise at the laboratory temperature of 20 °C.

2.2. Reference data

Internal colour was analysed on the pulp surface using a Minolta Chroma Meter CR-400 (Minolta Co. Ltd., Osaka, Japan). Two readings were taken in the equatorial region of the fruit; readings were averaged for each sample. Colour was expressed as CIELAB (a^*, b^*, C^*, h^*) colour space, where a^* and b^* define red-greenness and blue-yellowness, respectively (CIE, 2004). Chroma (C^*) and hue angle (h^*) were calculated as $(a^{*2} + b^{*2})^{1/2}$ and $\tan^{-1}(b^*/a^*)$, respectively. Illuminant C and 2° standard observer measurements were made in all cases.

2.3. NIR Analysis

NIRS analysis was performed using a Perten DA-7000, Flexi-Mode diode array spectrometer (Perten Instruments North America, Inc., Springfield IL, USA), operating between 400 and 1700 nm with a 5 nm scanning interval. The main technical specifications of the instrument are reported in Table 1.

Fruits were scanned using the instrument in the standard upright position. Samples were irradiated from below by the light source. The distance of measurement between the sample and the instrument was 120 mm, with a large, circular