Available online at www.sciencedirect.com
SCIENCE DIRECT
Journal of Food Engineering 78 (2007) 22–26
JOURNAL OF FOOD ENGINEERING
www.elsevier.com/locate/jfoodeng

Modeling of color values for nondestructive evaluation of maturity of mango

S.N. Jha [a,*], Sangeeta Chopra [a], A.R.P. Kingsly [b]

[a] *Agriculture Structure and Process Engineering Division, Central Institute of Postharvest Engineering and Technology, PO PAU, Ludhiana 141 004, India*
[b] *Horticulture crop processing division, CIPHET, Abohar 152 116, Punjab, India*

Received 20 May 2005; accepted 24 August 2005
Available online 19 October 2005

Abstract

Mango, an important tropical fruit, is marketed throughout the world. Quality of ripened mango depends on its maturity at harvest, which is hitherto determined subjectively by experience. In the present investigation, the potential of a nondestructive method for predicting maturity using color values taken by a handheld colorimeter was explored. Maturity of mango was defined in term of maturity index (I_m), a ratio of total soluble solids (TSS) of mango under experiments and minimum level of TSS (8 °Brix) of matured mango, expressed in percentage. Hunter *L*, *a*, and *b* values of 315 freshly harvested mangoes ranging from immature to over matured were measured using HunterLab colorimeter. TSS of whole mango juice was measured by a handheld refractometer and maturity index was computed. The maturity index and *L*, *a*, and *b* values of 160 samples were fitted in different forms of models using multiple linear regression (MLR), partial least square and principal component regression. The model using MLR on variables *a*, *b* and the product *ab* was selected. The prediction performance of the model was tested with another set of 100 unripe samples. Precision of prediction was also verified by sensory evaluation of 55 ripe mangoes and was found that the fruits predicted to be mature could ripe with high-satisfied taste while the ones predicted to be immature or over mature were mostly rejected by the panels.

Keywords: Maturity index; Total soluble solids; Color values; Regression models; Nondestructive method

1. Introduction

Mango (*Mangifera indica* L.) is an important tropical fruit having heavy demand in world market. Taste, physical appearance and postharvest shelf life of fruit are dependent upon maturity level at harvest. When fruits are harvested before maturity they do not ripen uniformly and may present excessive shrinkage and low levels of sweetness. Even ethylene or acetylene treatment cannot induce complete ripening with proper aroma, flavour, and taste in immature fruits. On the other hand fruits harvested at late maturity stage, result in reduced shelf life with greater susceptibility to disease.

Maturity has been correlated with various physical characteristics like skin color, shape, size and shoulder growth. Attempts have been made to fix a maturity standard for mango based on specific gravity (Tandon, Kalra, & Singh, 1988) and firmness (Samson, 1980) but inconsistency in these parameters of mango varieties restricted its use as a criterion to predict maturity (Tandon & Kalra, 1983, 1986). Some chemical parameters like soluble solids content (TSS), titratable acidity, starch, phenolic compounds, carotenoids and dry matter content have also been used to determine maturity of mango (Jha, Kingsly, & Chopra, 2006). TSS above 8% and acidity about 1% are some indices for assessing mango maturity. Many workers have worked for maturity and quality indices of other fruits and vegetables too (Lee, 1981), but most of them are of chemical or physiological nature,

* Corresponding author. Tel.: + 91 161 2572039.
E-mail address: snjha_ciphet@yahoo.co.in (S.N. Jha).

0260-8774/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jfoodeng.2005.08.048

and their determination involves very laborious laboratory techniques.

Nowadays, nondestructive techniques for quality evaluation have gained in popularity (Iwamoto, Kawano, & Ozaki, 1995; Jha & Matsuoka, 2000, 2004). These techniques, particularly for fruits and vegetables, are quick and easy to use. Many physical characteristics of fruits and vegetables have been determined nondestructively (Kato, 1997; Lammertyn, Nicolai, Ooms, Smedt, & Baerdemaeker, 1998; Lesage & Destain, 1996; Nussinovitch, Ward, & Mey-tal, 1996). For mango some such efforts using near-infrared (NIR) spectroscopy (Guthrie & Walsh, 1997; Saranwong, Sornsrivichai, & Kawano, 2001, 2003a, 2003b, 2004; Walsh, Golic, & Greensill, 2004), visual spectral analysis (Jha, Chopra, & Kingsly, 2005; Schmilovitch, Mizarach, Hoffman, Egozi, & Fuchs, 2003), acoustic and ultrasound techniques (Mizrach, Flitsanov, Schmilovitch, & Fuchs, 1999; Mizrach, 2000; Polderdijk, Kho, Kruif, & Carmi, 2000; Shmulevich, Galili, & Howarth, 2003; Valente & Ferrandis, 2003) are also reported, but these instruments are costly and difficult to carry to the mango orchards. A hand held colorimeter is cheaper and easier to carry to the orchards. Medlicott, Semple, Thompson, Black bourne, and Thompson (1992) have reported a significant correlation between peel color score (visual assessment) and Hunter a/b ratio for mango, which gives an idea of maturity. A calibration equation related to maturity level based on some chemicals at harvest and color values must be developed for use with the portable colorimeter to replace the typical subjective method and reduce the problem of carrying the instruments to the field.

The objectives of this paper were thus to define a maturity index based on mango TSS, develop the calibration equation using color values and evaluate the calibration efficiency by examining the eating quality of fruits to explore the potential of prediction of the index nondestructively using a robust and portable colorimeter.

2. Materials and methods

2.1. Sampling of mango

Three mango (cv. *Dashehari*) orchards from different locations of the university farm were selected based on flowering amount, size of trees (for easy harvest) and location (easily approachable) for the study in spring 2003 to 2004. Fruiting of mango was continuously observed. Four mangoes from different directions of selected trees, situated at different location of the orchard, were randomly harvested at 48 h intervals from the 6th June in 2003 and the 27th May 2004 (when mango was not fully mature) to their final harvesting dates (when the majority of the mangoes was ripening on the tree) of respective years, and they were brought to laboratory and kept at 35 ± 1 °C and $65 \pm 1\%$ relative humidity (RH) to equilibrate with environment before experimentation. Altogether 315 samples were collected from the orchards for experiment.

2.2. Experimentation

The HunterLab color values of freshly harvested mangoes were obtained in terms of L, a, and b values using a HunterLab Mini Scan XE plus colorimeter (HAL, USA, model 45%-L). In the Hunter scale, 'L' measures lightness and varies from 100 for perfect white to zero for black, approximately as the eye would evaluate it. The chromaticity dimensions 'a' measures redness when positive, gray when zero, and greenness when negative, and 'b' measures yellowness when positive, gray when zero, and blueness when negative.

The colorimeter was calibrated with standard black and white calibrations tiles provided with the instrument and displayed values were matched with the values reported in the operating manuals. The setup of the colorimeter was changed to color scale and the nose cone was kept in complete contact with the mango surface to prevent leakage of light emitted by the colorimeter. The color values L, a, b were stored automatically in the instrument. The experiment was repeated at four places; located near the apex and the stem regions of each mango and average values were used for further calculation. Immediately after getting the color values, the mango was peeled (0.2 mm thick) and squeezed with a domestic juicer at room temperature (32.2 °C). Suspended particles were removed from the juice by filtering through the muslin cloth. The TSS value was measured from the juice with a handheld refractometer (ERMA, Japan). Average TSS value from duplicate measurements were used for the computation of maturity index ($I_{m,}$ %) as follows:

$$I_m = \frac{\mathrm{TSS}}{8} \times 100 \quad (1)$$

The I_m was correlated with L, a and b values to know maturity level of mango before harvest. If it falls below or above 100%, mangoes were considered to be under or over matured, respectively.

A random portion (55 total number) of daily harvest of known maturity was stored at 35 ± 1 °C temperature and $65 \pm 1\%$ RH for a week for ripening; and a sensory evaluation of ripe mangoes by a trained panel of the institute using a 9 point hedonic scale was conducted to verify the hypothesis that the mangoes having the computed maturity of about 100% are actually matured and ripened properly. Mature mangoes ripen properly and are liked more as compared to relatively immature and over matured ones, which do not ripe properly.

2.3. Data analysis

Acquired L, a, and b values were imported to MS-excel software from the instrument and then to the *Unscrambler* (CAMO AS, Trondheim, Norway, version 8.0.5), a statistical software package, for multivariate calibration. The I_m was calculated from TSS values for all 315 samples and they were split randomly into three sets (Table 1):