Journal of Food Engineering 109 (2012) 114–119

Contents lists available at SciVerse ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Determination of translucent content in mangosteen by means of near infrared transmittance

Anupun Terdwongworakul [a,*], Natrapee Nakawajana [a,b], Sontisuk Teerachaichayut [c], Athit Janhiran [d]

[a] Department of Agricultural Engineering, Faculty of Engineering at Kamphaengsaen, Kasetsart University, Kamphaengsaen, Nakhon Pathom, Thailand
[b] Postharvest Technology Innovation Center, Commission on Higher Education, Bangkok, Thailand
[c] Department of Food-Processing Engineering, Faculty of Agro-Industry, King Mongkut's Institute of Technology Ladkrabang, Ladkrabang, Bangkok 10520, Thailand
[d] Agricultural and Agro-Industrial Product Improvement Institute, Kasetsart University, Bankok 10520, Thailand

ARTICLE INFO

Article history:
Received 14 May 2011
Received in revised form 7 September 2011
Accepted 27 September 2011
Available online 4 October 2011

Keywords:
Mangosteen
Translucent content
Translucent area
Near infrared spectroscopy
Transmittance
Fruit orientation

ABSTRACT

Translucent flesh disorder is undesirable in mangosteen meant for export. However, mangosteens are judged as translucent when the translucent flesh is visible on the pulp surface regardless of the quantity of the internal translucent flesh which may result in some mangosteen assessed as normal having the same amount of translucent flesh content as a mangosteen judged as translucent. The critical amount of translucent flesh to be visible on the pulp surface needs to be determined for assessment purposes. A non-destructive technique to measure the translucent content is a practical tool as the first step towards the establishment of the critical value.

A non-destructive model was developed to estimate the translucent content in mangosteens using near infrared transmittance. The translucent area of the flesh section on the fruit surface was used to indicate the translucent content. The effects of the orientation of the fruit and also of the light source to the relative position of the detector as well as the effect of the measurement position of the fruit on the predictive performance were examined. The results showed that the best partial least squares model was achieved with spectra acquired from the fruit position which revealed the largest flesh segment (prediction correlation coefficient was 0.86 and root mean square error of prediction was 7.58%). The horizontal stem–calyx fruit axis and a 135° angle from the light source relative to the detector were the optimal fruit orientation and configuration for measurement.

1. Introduction

The quality of the mangosteen (*Garcinia mangostana* L.) fruit is determined by both external factors such as color, shape, size, skin blemishes, latex staining, and insect damage, as well as by internal factors such as translucency of the flesh, the presence of yellow gummy latex, and the hardening of the pericarp. These factors substantially influence consumer acceptance. Flesh translucency disorder is undesirable in mangosteens intended for export. A floating technique which applies the divergences in specific gravity is usually employed for the non-destructive detection of translucent flesh in mangosteen; however, the results are not reliable (Teerachaichayut et al., 2008).

For export purposes each individual mangosteen fruit has its pericarp half cut open to allow visual evaluation of the fruit for the appearance of translucency. In the absence of visible translucency, its pericarp is closed and the fruit is subsequently taped around the cut line, and frozen for export. Thus, the level of translucency of the flesh surface is taken as a measure of the quality of the fruit. However, the lack of translucency at the surface of the flesh segment does not signify the absence of translucency within the fruit. Hence, the evaluation of the translucent content in the fruit is a potential key to attain appropriate categorization of mangosteen fruit.

Near infrared (NIR) spectroscopy has been proven to be a very useful technique for non-destructive classification of diverse intact fruit (Walsh et al., 2004). An increasing number of researchers have concentrated on transmission spectra as NIR diffuse reflectance spectra are only able to acquire data approximately one centimeter into the intact sample (Huang et al., 2008). Many researchers have investigated the use of short wavelength near infrared (SW-NIR) spectroscopy based on the transmittance mode for an accurate evaluation of the internal quality of fruit (Kawano et al., 1993; Upchurch et al., 1997; Miyamoto et al., 1998; Krivoshiev et al., 2000; McGlone et al., 2003; Carlomagno et al., 2004; McGlone and Martinsen, 2004; Fan et al., 2009). To detect hidden internal disorders in intact fruit, NIR instruments which comprise a transmission mode are required for light to be able to sufficiently penetrate the fruit (Clark et al., 2003). Watercore disorder in apple

* Corresponding author. Tel.: +66 86 7751723; fax: +66 34 351896.
E-mail address: anupunterd@yahoo.com (A. Terdwongworakul).

0260-8774/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jfoodeng.2011.09.027

was quantified with high levels of accuracy with the application of light transmittance intensity in the range of 760–810 nm (Birth and Olsen, 1964). Transmission visible–NIR spectroscopy was implemented to classify the Chinese pear 'Yali' into pears of acceptable quality and those with brown cores with an accuracy of 95.4% (Han et al., 2006). Moreover, the detection of brown heart in pears was investigated by means of visible/NIR transmission spectra which attained an accuracy of 91.2% (Fu et al., 2007). Clark et al. (2003) revealed that the degree of browning in 'Braeburn' apples was a significant factor in the detection of brown heart by employment of transmission NIR spectroscopy.

Mangosteen fruit with translucency visible on the flesh surface (henceforth referred to as translucent mangosteen) may contain an identical amount of translucent content as that of fruit considered to be normal (that is, with no apparent translucency on the flesh surface). The minimum critical amount of internal translucency that allows emergence onto the flesh surface to appear visibly translucent is yet to be established. Classification based on such a critical amount could be more effective and would reduce the false negative error of classifying an internally translucent mangosteen as a normal mangosteen. This would require the use of a non-destructive technique which is able to predict the translucent content within mangosteen fruit. The objective of this investigation is therefore to develop a model which can predict the translucent content in mangosteen based on near infrared transmittance and to investigate the effects of fruit orientation and light source positions relative to the detector on the predictive levels of performance.

2. Materials and methods

A sample set of 135 mangosteen fruits was purchased from a wholesale market. Fruits of color and size suitable for export were selected. The sample fruits were transported in an air-conditioned truck to the laboratory and kept at 25 °C in an air conditioned laboratory overnight so as to attain temperature equilibrium prior to measurement.

2.1. Spectral acquisition

Each sample was subjected to near infrared absorbance with the application of a transmittance mode (PureSpect, HOS-200, Saika Technologinal Institute Foundation, Japan). Three configurations of a light source angle relative to the detector and fruit orientation were investigated. Fig. 1 depicts the three configurations, which are detailed as follows:

- L135FH: The light source was located at an angle of 135° to the detector head with the fruit stem–calyx axis both horizontal and perpendicular to the light beam.
- L135FV: The light source was located at an angle of 135° to the detector head with the fruit stem–calyx axis at an angle of 90° relative to the light irradiation direction.
- L90FH: The light source was located at an angle of 90° relative to the detector head with the fruit stem–calyx axis both horizontal and perpendicular to the light beam.

A 100 W tungsten halogen lamp served as the light source for the purpose of the experiments described herein. A Teflon sphere measured using the L135FH configuration was used as a reference for each set of ten fruit.

Each individual fruit was scanned in the range of 665–955 nm with a scan interval of 500 ms, integration time of 4 ms, and a spectra average count of four. To examine the effects of measurement positions on the model prediction accuracy, the scans were performed at eight positions located at intervals of 45° on the circumference of the equator of each sample. The first position was referenced at the external surface of the pericarp, where the internal segment was most expansive. The largest internal segment was identified by means of assessment of the external shape of the fruit. Visual inspection (Fig. 2) on the internal pericarp of cut-open mangosteens revealed that the largest segment of the flesh was normally translucent (Chaisrichonlathan and Noomhorm, 2011). In addition, the number of petals on the bottom of the mangosteen indicates the number of flesh segments within the fruit. Thus, the first position on the fruit was visually assigned by means of assessment of the eccentric shape and the petal direction on the fruit bottom (Fig. 3). The second position was located 45° counter clockwise from the first position when viewed from the stem. The subsequent positions were referenced in proximity to their previous positions in an analogous manner.

2.2. Assessments of translucent content

Subsequent to the NIR spectral acquisition, each sample pericarp was removed and the pulp segments were separated. Each individual segment was cut into four transverse sections along the stem–calyx axis with each section then cut into two halves. Photographs were taken with a digital camera (Fujifilm, FinePix FX10J, 1600 × 1200 pixel jpegs) from each side of the cut surfaces of the sections. The images of pulp obtained (as in the example shown in Fig. 4) were subjected to further analysis using the public domain software package Image J (Ver. 1.36, available at http://www.rsb.info.nih.gov/ij; developed by Wayne Rasband, National

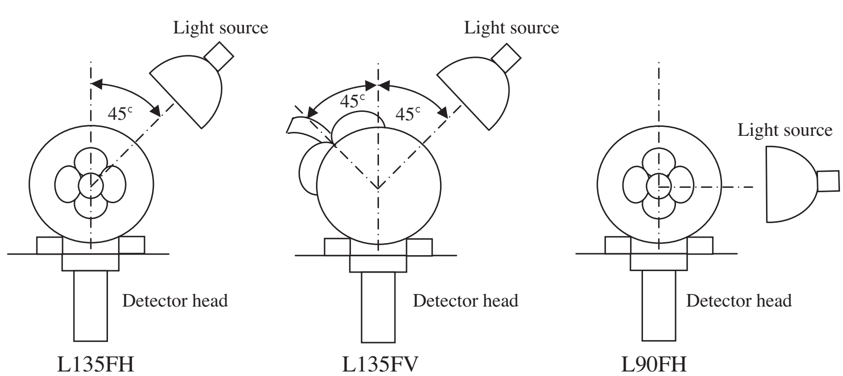

Fig. 1. Three configurations of spectral acquisition with variation in relative position of light source to detector and orientation of stem–calyx axis of the fruit. L135FH: Light source is 135° to the detector with fruit stem–calyx axis horizontal. L135FV: Light source is 135° to the detector with fruit stem–calyx axis at 90° to the light direction. L90FH: Light source is 90° to the detector with fruit stem–calyx axis horizontal.