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Empirical reduction of rind effect on rind and flesh absorbance for evaluation of durian maturity using near infrared spectroscopy

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A B S T R A C T

Durian possesses a thick-spiky rind that limits light penetration into the flesh and makes models based on rind and flesh absorbance measurements ineffective for prediction of flesh dry matter content (DMC). An empirical technique to adjust the rind and flesh absorbance to be closer to that of the flesh by reducing the effect of rind absorbance was developed. The difference in absorbance obtained by subtracting the flesh absorbance from that of the rind and flesh absorbance at each wavelength was partially related with the dry matter content of the flesh depending on wavelength. A regression equation partial least squares regression model (PLSR) for each wavelength was developed to relate the difference spectra with the DMC. The dry matter content was used to compute the difference absorbance at each wavelength which was subtracted from the rind and flesh absorbance to create the adjusted rind and flesh absorbance. The PLSR models were compared based on the flesh, rind and flesh and adjusted rind and flesh absorbance for prediction of the DMC. The adjusted rind and flesh model performed better than the original rind and flesh model. The results showed the advantage of the empirical technique in reducing the effect of rind absorbance on that of the rind and flesh absorbance.

1. Introduction

Thailand is regarded as the leader in the cultivation of durian (*Durio zibethinus* Murray) among the countries in the Association of Southeast Asian Nations (ASEAN) and one of the top countries that export durian to the international market (Maninang et al., 2011). Durian fruit is characterized by its spiky and thick rind (i.e. 4 to 6 mm thick) and comprises several fused carpels. The number of the carpels may vary from three to seven. In each carpel, the locule contains one to seven large seeds covered with the edible flesh connected to each other along the length of the fruit (Fig. 1a). Mature durian will ripen properly with a pleasant flavor and taste, while fruit harvested at the immature stages do not ripen properly and result in a poor tasting fruit, and overripe fruit perish rapidly (Hardenburg et al., 1986).

Several criteria are used to determine durian fruit maturity, including the number of days from full bloom, the disposition and elasticity of the spines, the color of the spine tip, the strength of the fruit stalk, the intensity of the released odor, the percentage of dry matter of fruit flesh and the sound of the fruit generated by tapping (Pascua and Cantila, 1992; Siriphanich, 2011). However, these criteria may not be implemented successfully due to the large volume of durian exported given their limitations in terms of accuracy and speed. In addition, some techniques are destructive and require harvester skill and experience. Therefore, the development of a rapid and non-destructive technique for sensing the degree of maturation would be very useful for the exporting industry.

The dry matter content (DMC) of durian flesh is a useful and potential maturity indicator (Yantarasri et al., 2000), and the Thai Agricultural Commodity and Food Standard (TACFS 3-2003) is widely accepted as an important standard of Thai durian maturity (National Bureau of Agricultural Commodity and Food Standard, 2003). However the only reliable method to determine dry matter is disadvantageously destructive resulting from drying slices of durian flesh.

Near infrared (NIR) spectroscopy can be employed as a non-destructive technique for both qualitative analysis (He et al., 2007; Liu et al., 2011; Shen et al., 2012) and quantitative analysis (Liu and Ying, 2007; Shao et al., 2009) of DMC and has been investigated for vegetables and fruits, such as onion (Jantra et al., 2017), kiwifruit (McGlone et al., 2002; Osborne et al., 1998; Jordan et al., 2000), mango fruit cv. (Guthrie and Walsh, 1997), avocado (Clark et al., 2003; Schmilovitch et al., 2001; Wedding et al., 2011), apple (Moons et al., 2000; Renfu et al., 2000; McGlone et al., 2003) and cucumber Kavdir et al., 2007). Non-destructive assessment of intact durian maturity is problematic, however, since durian has a very thick rind, spiky skin and non-uniform

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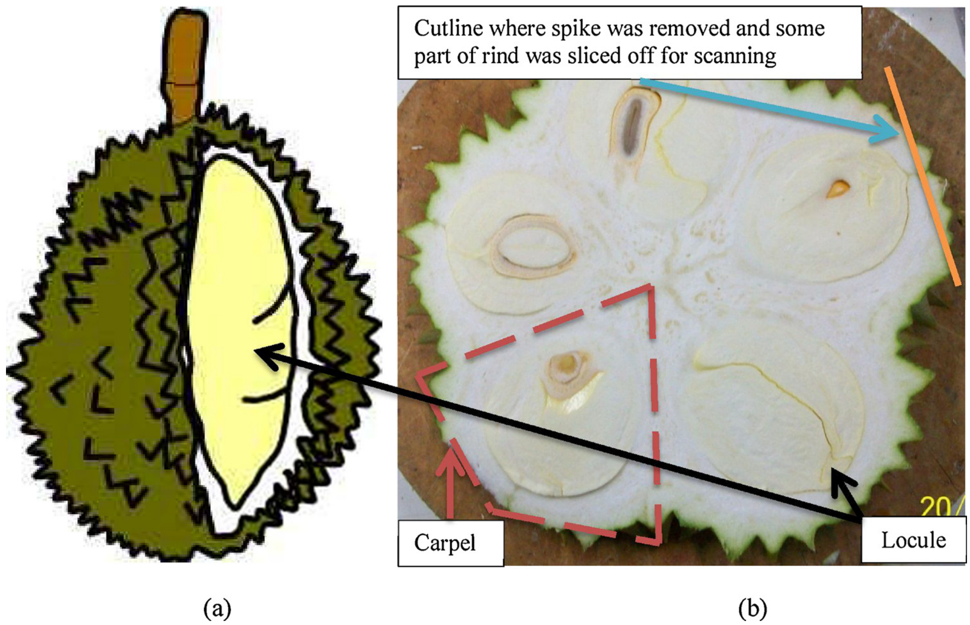

Fig. 1. (a) Whole durian with rind at one carpel removed showing a locule containing three seeds covered with edible flesh and (b) a cross section of a half-cut durian sample showing spiky and thick rind and the location where the spike was removed and some part of the rind was sliced off for scan location.

shape. Such features limit the light penetration into the flesh to obtain useful absorbance, although Somton et al. (2015) obtained reflectance data for the stem and rind of the whole durian fruit by minimally removing some peel to provide a flat area for scanning. The results showed that a combination of both stem and rind reflectance data at selected wavelengths yielded the highest accuracy of maturity classification.

The objective of the current study was to attempt to empirically reduce the effect of rind absorbance on rind and flesh absorbance of the fruit in the development of the predictive model of the flesh DMC.

2. Materials and methods

2.1. Durian samples

Samples of fresh 'Monthong' durians were harvested at intervals to cover immature and mature stages of durians from an orchard in Chumphon province in Southern Thailand. Flowers were tracked to follow the fruit growth by tagging flowers from the selected trees at full bloom. Approximately 30 trees were chosen to provide the targeted number of durian samples which were harvested at 108, 115 and 122 days after anthesis (DAA). The harvested samples from the three intervals provided variation in maturity from immature to mature. At each harvest date, about 20 fruit samples were harvested and transferred to the air-conditioned laboratory on the same day of harvest. All durian samples were stored at 25 °C overnight for acclimatization prior to conducting subsequent measurements on the following day.

2.2. Spectral measurement

2.2.1. Measurement of rind and flesh absorbance

Near infrared diffuse reflectance was acquired using a spectrometer (MPA FT-NIR, Bruker Optics, Ettlingen, Germany) in the range 4000–12500 cm^{-1} at 32 cm^{-1} resolution. An average based on 32 scans was derived to represent the spectrum of each sample. Since the main characteristic of durian is a thick-spiky rind, the penetration of the NIR illumination would be confined to the thick rind. Therefore, we attempted to enable the NIR light to pass through the rind and reach the flesh inside the fruit so as to obtain flesh absorbance for the rind and flesh absorbance with minimal destruction of fruit. The location of scan was chosen at the middle part of carpel where the rind is thinnest (Fig. 1b)). This required removal of the spike and slicing off part of the rind of the most fertile locule of each fruit (about 2–3 mm thick) leaving the rind with 2–3 mm thick to present a flat area of around 9 cm^2, which was then placed face down against the top window of the spectrometer for spectral acquisition of the rind and flesh from the fruit (Fig. 2). A fertile locule was defined as one that was fully filled along the length of the fruit and which could be observed from the carpel. Similarly, the second most fertile locule was also scanned for the same

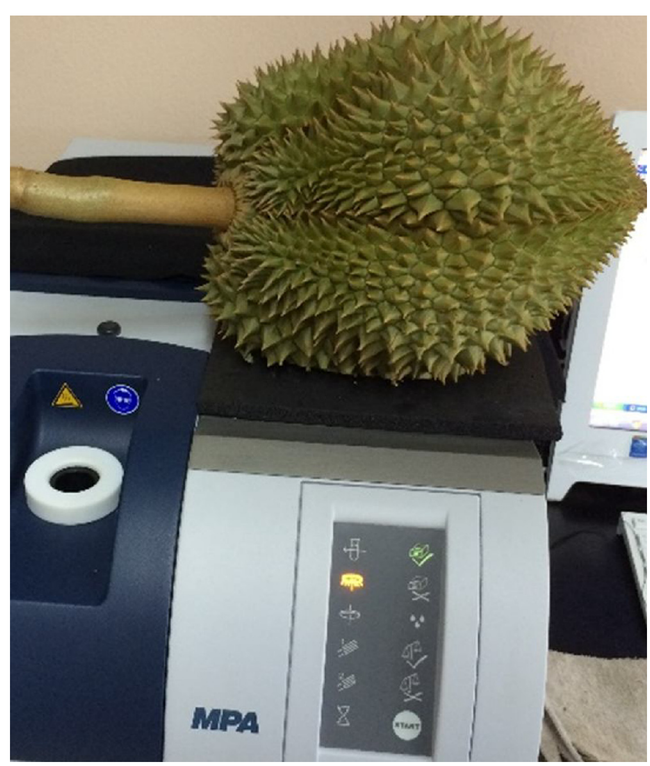

Fig. 2. Durian fruit being scanned with the flat area on the rind face down after removing the spike and part of the rind.