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Maturity sorting index of dragon fruit: *Hylocereus polyrhizus*

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ABSTRACT

The purpose of this research was to investigate maturity prediction of red flesh dragon fruit based on non-destructive measures. Specific weight, sphericity, color value *L*, *a*, *b* and light reflectance spectrum were linearly combined by partial least squares regression (PLSR) analysis. The PLSR models could predict days after fruit set, weight ratio and total soluble solids relatively well with standard deviation divided by standard error of prediction (RPD) of 2.86, 2.45 and 2.38, respectively. Date after fruit set, total soluble solids, total acid, ratio of total soluble solids and total acidity and weight ratio were transformed into a principal component 1 (PC1) by the principal component analysis and used to represent a single maturity index. The PLSR model with non-destructive parameters resulted in an improved performance in the prediction of the maturity index (PC1) with a RPD increase to 3.49. The model could be further simplified but retained a comparable accuracy by the application of a log (R680/R550) in place of the light reflectance spectrum.

1. Introduction

Dragon fruit (*Hylocereus*) or pitaya in Latin America (Nerd and Mizrahi, 1997) is of a member of the cactus family and known to be rich in nutritional value, high in economical value and medicinal uses. Pitaya exists in different variations of color known as white, magenta, red and yellow (Grimaldo-Juarez et al., 2007). The red flesh variety is in particular richer in betalains which meet the increasing trade interest for antioxidant products and natural food colorants (Le Bellec et al., 2006). However the proper stage of maturity at harvest is the most important determinant of storage life and final fruit quality.

The majority of researches have been carried out in attempts to monitor tropical fruit maturity and related properties. A common destructive method for measurement of the maturity and growth of fruit is to analyze its soluble solids and acidity. Subhadrabandhu and Ketsa (2001) suggested that the soluble solids content of durian is parallel to aril firmness with respect to maturity development. The decrease in firmness coincides with an increase in water-soluble pectin. More mature durian aril has greater water-soluble pectin which increases faster than that of less mature durian aril (Ketsa and Daengkanit, 1999). Acidity is extensively studied as a parameter in the description of growth of guava (Mercado-Silva et al., 1998) and mango (Saranwong et al., 2004).

Slope of the force–deformation curve is another measure that has been used to determine fruit maturity. For example, Jarimopas and Kittawee (2007) subjected mango to slow compression as a means of determination of the relationship between firmness and maturity. They found that the slope remained constant from immaturity to maturity but decreased as the fruit became overmature. Alternatively, maturity of a fruit can be evaluated from the force response of the fruit at constant deformation compression. Takao and Ohmori (1994) successfully developed a hardness immaturity tester (HIT) based on experiments with kiwi fruit. With the dragon fruit, Hoa et al. (2006) and Nerd et al. (1999) used a penetrometer to measure the firmness of fruit.

As for non-destructive method, there have been reports on physical, mechanical, light and physiological properties of the fruit. For example, Kato (1997) showed the relationship between the density and the maturity of Japanese watermelon. The threshold of pleasantly sweet watermelon without cavities had a density equal or greater than 0.934. Specific weight is also a physical and physiological property that is recognized by horticulturists and post harvest technologists. It has been investigated by researchers to determine the maturity of mango (Jarimopas and Kittawee, 2007), mangosteen (Sornsrivichai et al., 1999) as well as dragon fruit (Wanitchang and Jarimopas, 2008).

The dynamic frequency response of pear dropped onto a flat plate was investigated and found to be able to predict pear firmness (Wang et al., 2007). Wang et al. (2006) reported use of acoustic impulse response to monitor firmness change of mandarin during storage.

Light reflectance properties of fruit were also investigated as a sorting parameter of fruit maturity. Sound and green oranges of Shamuti variety differed in the light spectrum between 600 and

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Nomenclature

L	lightness axis in Hunter L, a, b color scale
a	redness–greenness coordinate in Hunter L, a, b color scale
b	yellowness–blueness coordinate in Hunter L, a, b color scale
DAFS	number of days after fruit set
X	major axis of dragon fruit (mm)
Y	minor axis of dragon fruit (mm)
SPH	sphericity (%)
W	sample weight (g)
V	sample volume (ml)
SW	specific weight (g/ml)
F	flesh weight (g)
WR	weight ratio (%)
FRF	fruit firmness (N/mm)
TA	total acidity (%)
FLF	flesh firmness (N/mm)
TSS	total soluble solids (°Brix)
MMI	multivariate maturity index
PLSR	partial least squares regression
R_C^2	coefficient of determination of calibration
R_P^2	coefficient of determination of prediction
SECV	standard error of cross validation
SEC	standard error of calibration
SEP	standard error of prediction
RPD	ratio between the standard error of prediction and the sample standard deviation for the prediction set
PC1	principal component 1
Bias	average difference between predicted and measured values

660 nm by 70% of reflectance. This reflectance difference was subsequently employed in the design of a device to segregate green oranges from good oranges (Peleg, 1985). With mangosteen, Jarimopas et al. (2008) measured the color of sound and defective fruit in terms of their tristimulus values. The corresponding chromaticity coordinates of a mangosteen were showed to be dependent on the maturity stage. Sweetness of mango naturally relates to its maturity. Jha et al. (2005) applied the multiple linear regressions to develop models for total soluble solids as indicators of sweetness of intact mangoes based on visible spectrum ranging from 440 to 480 nm. A high correlation between the predicted and the calibrated values of total soluble solids was established. Hoa et al. (2006) and Nerd et al. (1999) applied the hue angle system to evaluate skin and flesh color of dragon fruit.

Some essential physiological properties such as specific weight, total soluble solids content and acidity are commonly appreciated by consumers. However, no specific studies of mechanical, light and physiological properties of the Thai dragon fruit are known to exist. Therefore, the purpose of this research was to investigate those properties and to analyze their use as maturity indices in relation to non-destructive parameters as predictors. This could be used to ensure the commercial quality sorting of the dragon fruit.

2. Materials and methods

Dragon fruits of the red (*Hylocereus polyrhizus*) variety (red peel and red–purple pulp) were selected randomly from a commercial orchard in Chonburee province, Thailand. The fruit samples were tagged after fruit set and hand-harvested between the 23rd and 40th day after fruit set (DAFS) in June, 2007. The samples were harvested daily between the 23rd and 30th day and later that every two days until day forty, to follow the growth the rate, which was rapid at the early stages of the DAFS. Twenty individual fruits were selected for each harvesting day. The experiments were done immediately after the arrival of the samples in the laboratory conditioned at 25 °C and an average relative humidity of 67%.

2.1. Determination of light property

The each fruit sample was measured for light reflectance by spectrometer (Hunter L, a, b Color Flex model CFLX-45-2: D 65/10°, Reston, USA) at the equator of the sample. Four positions, 90 degree apart, along the fruit equator were exposed to the aperture for the measurement of each fruit. Twenty samples were duplicated. The Hunter L, a, b color scale was used to indicate the fruit color. The L value (lightness) is scaled between 0 (black) and 100 (white). The a value is from $-a$ (greenness) to +a (redness) whereas the b value changes from $-b$ (blueness) to $+b$ (yellowness). The fruit color value L, a, b and the reflectance of the visible spectrum (400–700 nm) were recorded. The average value of four measurements was used for further analyses.

2.2. Determination of physical characteristics

Major (X) and minor (Y) axes of the fruit sample were measured and the percentage sphericity (SPH) was calculated from SPH = $(Y \times 100)/X$. Weight (W) of each sample was measured by electronic balance (Mettler Toledo PB 3002-S, Switzerland). Volume (V) of each above sample was measured by water displacement based on the platform scale technique as described by Mohsenin (1986). The specific weight (SW) was derived from SW = W/V. Each individual fruit was peeled and its flesh (F) was weighed and recorded. The weight ratio (WR) of F and W was expressed as the percent of recovery or the usable part from WR = $(F \times 100)/W$ (Chuachoochat and Babprasert, 1999).

2.3. Determination of mechanical property

The mechanical property in terms of firmness was measured at two opposite locations on the equator of each fruit. Each sample was axially cut in half. Each bisection with cut surface downward was slowly compressed on the peel surface with an 8 mm cylinder probe mounted on a Universal Testing Machine (Lloyd EZ 20, Segensworth East Fareham, Hampshire, UK) to a deformation of 10 mm at a loading rate of 30 mm/min (ASAE Standards, 1998). The average diameter of fruit was 82.5 mm. The fruit firmness (FRF) as defined by the slope of the force–deformation graph at 30% of the peak force was analyzed. The second fruit half was subsequently peeled and its flesh firmness (FLF) was assessed analogously. Next, the FRF and FLF readings were then averaged for further analyses. The measurements were duplicated twenty times.

2.4. Determination of physiological properties

Flesh of each half was cut perpendicular to the fruit axis to obtain apportion of 10 mm thickness of the equator area. The flesh portion was crushed to get juice for the measurement of total soluble solids (TSS) using a hand digital refractometer (ATAGO PAL-1, Japan). The excess juice was filtered through cotton sheets. Clear juice was titrated with 0.1 N NaOH to an end point of 8.2 pH (measured with pH meter Mettler Toledo GmbH MP 120, Switzer-