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The use of visible and near infrared spectroscopy for evaluating passion fruit postharvest quality

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A B S T R A C T

Visible and short-wave near infrared spectroscopy (Vis/SWNIRS) was investigated using a non-destructive method for evaluating passion fruit quality. In this study, interactance and transmission measurements were performed and their competences were compared. Prediction models of soluble solids content (SSC), titratable acidity (TA), ascorbic acid content (ASC), ethanol concentration (EtOH), peel firmness (PF) and pulp percentage (PP) were developed based on multivariate methods of partial least square regression (PLSR) analysis. The PLS models from interactance measurements provided better prediction results than the transmission technique. The best model was obtained from interactance SSC calibration with a correlation coefficient between measured and predicted values (*R*) of 0.923. Furthermore, the PLS models generated from interactance and transmission spectra also provided satisfactorily prediction results for EtOH, PF and PP. However, all calibrations failed to predict ASC by providing low correlations and high root mean square errors of prediction (RMSEP).

1. Introduction

Purple passion fruit (*Passiflora edulis* Sims.) is cultivated throughout the tropical and subtropical regions, i.e., Australia, Brazil and the State of Hawaii. Due to its delicious flavor and attractive, fruity aroma, passion fruit demand in terms of fresh produce and processed products has escalated rapidly (Janzantti et al., 2012). It is among the top class of horticultural commodities, and the purple fruit has a high nutritional value (Bora and Narain, 1997). Generally, passion fruit consistently accumulates soluble solids (fructose, glucose, and sucrose) and organic acids (citrate, malate, and ascorbate) until its abscission. The combination of those aforementioned compounds directly contributes to the fruit's unique taste and aroma (Pocasangre-Enamorado et al., 1995; Shiomi et al., 1996; Bora and Narain, 1997). Therefore, it is important to determine the fruit's physico-chemical quality prior to distribution and processing. In the food processing sector, namely passion fruit juice and jam production, large amount of fruit are needed to be monitored in order to sustain product quality in terms of nutritional traits and flavor.

In conventional quality analysis of postharvest quality, interested samples have to be destructed and homogenized. Complex procedures and hazardous chemicals are needed. This is considered to be time and cost consuming method, requiring materials and manual work (Kawano, 1998; Gómez et al., 2006; Nicolaï et al., 2007). Since the 1990s, nondestructive techniques, such as near infrared spectroscopy and image processing, have been implemented to predict internal fruit quality and fruit grade (Nakano, 1997; Kawano, 1998; Sugiyama, 1999). These non invasive techniques are time and labor reducing alternatives.

Near infrared spectroscopy (NIRS) provides a rapid and accurate method for measurement of different constituents in several fresh commodities (Blanco and Villarroya, 2002; Slaughter et al., 2003; Nicolaï et al., 2007) and processed products (Shao and He, 2007). The interest in NIRS lies in its advantages over alternative instrumental techniques that can record spectra for solid and liquid samples. Near infrared radiation can be absorbed by fundamental vibrations of O–H, C–H and N–H molecular bonds in compounds (Osborne et al., 1993; Nicolaï et al., 2007). The recorded spectrum contains both physical and chemical information of the radiated samples such as hardness, firmness, internal disorders, soluble solids content and total acids (McGlone et al., 2002; Nicolaï et al., 2006; Sun et al., 2010). This non-invasive technique has been

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previously used to predict soluble solids content in apple (Liu et al., 2007; Bobelyn et al., 2010), mango (Saranwong et al., 2004), apricot (Chen et al., 2006), prune (Slaughter et al., 2003) and jujube (Wang et al., 2011a), and total acidity in Satsuma mandarin (Gómez et al., 2006) and Fuji apple (Liu and Ying, 2005) with reliable accuracy by using different modes of measurement depending on the fruit and its characteristics. However, in the case of passion fruit, previous research has reported unsatisfactory results of NIRS application for soluble solids content prediction, and the failure of titratable acidity evaluation (Oliveira et al., 2014). They suggested that the technique was not appropriate to assess internal quality of the thickly peeled passion fruit since the penetration of long-wave NIR (LWNIR) radiation into fruit tissue was limited (Lammertyn et al., 2000; Oliveira et al., 2014). In addition, not only does the peel thickness obstruct NIRS ability, but also the non-uniformity of internal passion fruit pulp as well as macrostructures, such as hard black seeds (Nicolaï et al., 2007). The aforementioned challenges have not been studied by visible and short-wave near infrared spectroscopy (Vis/SWNIRS) on purple intact passion fruit. Also, the evaluation of interesting chemical attributes and physical quality needs to be conducted nondestructively.

Therefore, this work aims to study the feasibility of Vis/SWNIRS on postharvest physico-chemical quality evaluation, namely, soluble solids content (SSC), titratable acidity (TA), ascorbic acid content (ASC), ethanol concentration (EtOH), peel firmness (PF) and pulp percentage (PP) in purple passion fruit. Furthermore, the competence comparison between interactance and transmission modes of spectroscopic measurements was also studied.

2. Material and methods

2.1. Raw materials

Purple passion fruit for this study were obtained from a greenhouse in Murakami city, Niigata Prefecture, Japan. In order to get fully mature samples, each fruit was harvested at a specific number of days after flowering (DAF). Then, biological defects were taken out prior to transportation to the experimental unit. One hundred and twelve fruits were used to study the feasibility of Vis/SWNIRS by means of interactance and transmission. Eighty intact passion fruits were first collected in late July, 2012 as a calibration set. Another 32 fruits were collected in late August in the same year as an external validation set. Each fruit sample was numbered, and its total weight was recorded. Two marks were labeled onto the fruit's calyx, making up an angle of 90° (Fig. 1). Morphological characteristics (height, diameter and peel thickness) were measured by digital caliper (SK-caliper, SK Niigata Seiki Co., Ltd., Japan). Diameter and peel thickness were obtained by averaging 2 measured positions. Subsequently, all fruits were first allowed to equilibrate to 25.0 ± 0.8 °C in a temperature-controlled chamber prior to NIRS analysis.

2.2. Nondestructive apparatuses and methods

Fig. 2 shows a diagram of Vis/SWNIRS configurative panels of interactance and transmission measurements. The light source (MHAA-100W, Moritex Co., Ltd., Japan) for interactance measurement was delivered by a portable fiber bundle equipped with a detector. For transmission measurements, both visible and near infrared light regions (HR-k2150N, Hiroshi industry Co., Ltd., Japan) were derived from two 12-V/100-W tungsten halogen lamps (MCR 12–150 M). All interactance and transmission light intensity spectra were obtained from 310 to 1100 nm with a wavelength increment (interval wavelength) of 3.3 nm using a spectrophotometer (Handy Lambda II, Spectra Co., Ltd., Japan). Within the radiated chamber, the light source and fiber optic detector probe were placed at a 180° angle for transmission measurements (against each other) and 0° for the interactance procedure (same side). In order to get rid of the characteristics of the light source itself, a white ceramic plate with a thickness of 1.5 mm (for interactance) or 10.0 mm (for transmission) was used as a standard reference. The fruit sample was stationed on a fruit holder loop (polyethylene terephthalate: PET, thickness of 12 mm) with vertical stem-calyx axis. Spectral measurements were performed and averaged from two equatorial positions at angles of 0° and 90° for both interactance and transmission measurements by using Wave Viewer software (Spectra Co., Ltd., Japan) and Microsoft Excel®, respectively.

2.3. Data acquisition

In this study, spectral data were obtained by averaging 10 spectra for interactance and 4 spectra for transmission measurements. All NIR spectra were explained in terms of the logarithm of reciprocal absorbance (log(1/R)). Subsequently, spectral data were pretreated by a simple smoothing technique using 7 pointed-second derivatives (D_2log(1/R)) described by Savitzky and Golay (1964). A multivariate method: partial least square regression (PLSR) analysis of JMP v.10.0 software (SAS Institute Inc., Cary, NC, USA) was used to develop the calibration model from the threshold spectra with measured chemical (SSC, TA, ASC and EtOH) and physical (PF and PP) values. Statistically, the PLS regression technique helps to simplify the relationship between X-data (spectral data) and Y-data (chemical and physical data) by ensuring all latent variables are ordered according to their relevance for predicting Y (Wold et al., 2001; Nicolaï et al., 2007). Furthermore, in PLS modeling, the variable importance in projection (VIP) score, a weighted sum of squares of the PLSR-weights, is a statistic that summarizes the contribution a variable makes to the model. The score projects the importance of each variable (wavelength) used in calibration development (Wold, 1994). Multivariate analysis of JMP software indicates that variable with VIP score greater than 0.8 is important to the PLS model. On the other hand, if a variable has a small

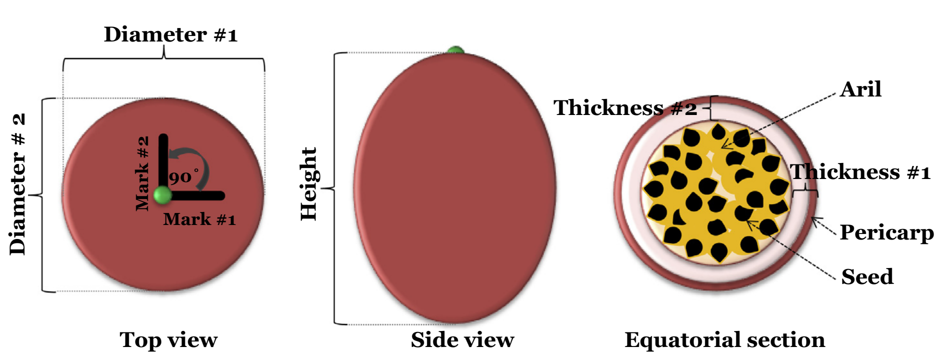

Fig. 1. Top view, side view and equatorial section diagrams of morphological measurement for intact passion fruit.