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Rapid determination of cabbage quality using visible and near-infrared spectroscopy

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ABSTRACT

The feasibility of Vis-NIR spectroscopy was investigated for its ability to determine the quality of cabbage. This study aims to compare the prediction ability of interactance and reflectance measurements in determining the quality of cabbage (moisture, SSC and ascorbic acid contents). The wavelength ranges of 500–1100 nm were used in this experiment. Two types of data preprocessing were applied to enhance the calibration model based on partial least squares (PLS) regression with respect to the logarithms of reciprocal absorbance (log (1/*R*)), its first and second derivatives. The PLS regression models for moisture content yielded correlation coefficients (R^2) of 0.48–0.67 and root mean square error of prediction (RMSEP) of 2.34–2.83 g/kg for interactance, with R^2 of 0.58–0.74 and RMSEP of 2.50–3.25 g/kg for reflectance. The PLS statistics for SSC were R^2 of 0.59–0.66 and RMSEP of 0.20–0.22 °Brix for interactance and R^2 of 0.53–0.64 and RMSEP of 0.22–0.27 °Brix for reflectance, respectively. Statistics for ascorbic acid content were R^2 of 0.24–0.61 and RMSEP of 0.11–0.15 g/kg FW for interactance and R^2 of 0.35–0.38 and RMSEP of 0.13 g/kg FW for reflectance. Finally, it is possible to use the Vis/NIR spectroscopy as a rapid tool for evaluating the cabbage quality.

1. Introduction

Cabbage (*Brassica oleracea* L. var. *capitata*) is one of the major vegetables consumed in the world; where the initial purchase decision made by the consumers is usually based on external quality, which is highly related with freshness. Cabbage consists of about 900 g/kg water and is an excellent source of minerals and vitamins (Kramchote, Srilaong, Wasusri, Wongs-Aree, & Kanlayanarat, 2012). It has also been recognized as an important source of ascorbic acid (Vitamin C), containing about 0.57–0.83 g/kg FW (Singh et al., 2006). Total sugar content of cabbage varies depending on the cabbage cultivar; glucose (292–315 g/kg dry weight (DM)) is the most important sugar, followed by fructose (220–240 g/kg DM) and sucrose (62–74 g/kg DM) (Wennberg, Ekvall, Olsson, & Nyman, 2006). The freshness of cabbage is also related to sweetness and vitamin C content. Therefore, total sugars estimated or measured as soluble solids content (SSC) and vitamin C are important components that are of high concern to consumer perception of cabbage quality (Kramchote et al., 2012; Podsedek, Sosnowska, Redzynia, & Anders, 2006; Singh et al., 2006). A number of researchers have presented several methods for determining cabbage quality (Kramchote et al., 2012; Podsedek et al., 2006; Singh et al., 2006). However, most of these are based on destructive and time consuming methods or techniques. Therefore, development of an accurate, rapid, reliable and nondestructive method for quality determination of cabbage head at packinghouses will be beneficial for ensuring and guaranteeing good quality of cabbage available in the markets.

Near infrared spectroscopy (NIR) has been one of the most important techniques used in the analysis of agricultural products and foods in past several years (Nicolaï et al., 2007; Salguero-Chaparro, Palagos, Pena-Rodriguez & Roger, 2013). NIR spectroscopy consists of a light source (usually a tungsten halogen light bulb), sample presentation accessory, monochromator, detector, and optical components such as lenses, collimators, beam splitters, integrating spheres and optical fibers (Nicolaï et al., 2007). NIR

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radiation covers the range of the electromagnetic spectrum between 780 and 2500 nm associated with vibration and combination overtones of the fundamental O—H, C—H and N—H bonds, which are the primary structural components of organic molecules (Williams & Norris, 2002). It is a rapid and nondestructive analysis technique that has a potential for the measurement of quality attributes of fruits and vegetables (Camps & Christen, 2009; Nicolaï et al., 2007). NIR technique has gained wide acceptance in quality evaluation of agricultural products and its applications include qualitative determinations of fruits and vegetables (Cozzolino, Cynkar, Dambergs, Mercurio, & Smith, 2008; Kawano, Watanabe, & Iwamoto, 1992; Liu & Ying, 2005; Nicolaï et al., 2007; Saranwong, Sornsrivichai, & Kawano, 2004). However, there have only been a few studies of using NIR to determine the quality of vegetables, including onions (Birth, Dull, Renfroe & Kays, 1985), bell peppers (Ignat, Schmilovitch, Fefoldi, Steiner, & Alkalai-Tuvia, 2012; Penchaiya, Bobelyn, Verlinden, Nicolaï, & Saeys, 2009), carrot (Schulz, Drews, Quilitzsch & Kruger, 1998), Mushroom (Roy, Anantheswaran, Shenk, Westerhaus, & Beelman, 1993), tomatoes (Clément, Dorais, & Vernon, 2008), pickling cucumbers (Kavdir, Lu, Ariana, & Ngouajio, 2007) and *B. oleracea* species (broccoli, Brussels sprouts, cauliflower, white kohlrabi, white cabbage and red cabbage) (Szigedi, Lenart, Dernovics, Turza, & Fodor, 2012) have been studied. Former researches have concentrated mostly on different spectral measurements that were used to evaluate the internal properties of the fruit and vegetables (He, Zhang, Pereira, Gomez & Wang, 2005; Wang, Nakano, & Ohashi, 2011). Reflectance mode measures the light that is reflected or scattered from the surface and outer surface layers of a fruit. This method has been applied extensively for surface quality (Balasundaram, Burks, Bulanon, Schubert, & Lee, 2009) and internal fruit quality (Xing & Guyer, 2008). In contrast, the transmission mode can detect both external and internal properties of the sample. The transmission is more suitable to reflectance measurements for detecting the internal qualities of some fruits (Fu, Zhou, Ying, Lu, & Xu, 2007); however, interactance is a method that can be used to obtain information on the inside of fruit when transmission measurements are difficult to obtain (Kavdir et al., 2007; Wang, Nakano, Ohashi, Takizawa, & He, 2010).

However, until now only a few studies dealing with cabbage quality evaluation using NIR have been performed. In order to have better cabbage quality evaluation during storage and transport, an NIR technology would be suitable. The objectives of this study were a) to investigate the potential of visible and near infrared (Vis-NIR) spectroscopy to develop a rapid nondestructive method and b) to compare the prediction potential of interactance and reflectance measurements in evaluating the quality of cabbage including moisture content, SSC and ascorbic acid content.

2. Materials and methods

2.1. Plant material

A total of 135 fresh cabbage heads (*B. oleracea* L. var. *capitata*) with wrapper leaves were used for this experiment in order to evaluate and develop Vis/NIR models for moisture content, soluble solids content (SSC) and ascorbic acid content by means of interactance and reflection measurements. The cabbages were purchased from a wholesale market in Niigata prefecture. All were harvested from a commercial farm in Gunma prefecture, Japan. After that, the samples were transported to a laboratory at Niigata University and then stored at 23 ± 1 °C, 85 ± 2% relative humidity in a controlled room for a maximum of 8 days in order to increase the variability of moisture, sugar and vitamin C contents of the cabbage. Individual measurements were made by SW-NIR interactance and reflectance spectrometer at three equatorial points around the head and a top point of the head by manually rotating, as shown in Fig. 1. All measurements including spectral collection and quality analysis were carried out on the same day.

2.2. Spectral acquisition

Spectra were directly acquired, interactance and reflectance measurements were between 310 and 1100 nm with a wavelength increment of 3.3 nm (resolution of 0.3 nm) using a spectrophotometer (Handy Lamda II, Spectra Co., Ltd., Japan), which consisted of two 12 v/100-W tungsten/halogen lamps (MCR 12–150 M) that could be used in both the visible and the near-infrared regions (Fig. 1). The optical configuration for reflectance measurement consists of a box containing a light source. The angle between the incident light and the detector fiber was 45° (Fig. 1B). A spectral white panel (1.5 mm thickness) was used as a reference standard to eliminate the characteristics of the light source for both interactance and reflectance measurements (Fig. 1). Vis/NIR spectra were collected and transformed using Wave Viewers software (Spectra Co., Ltd., Japan).

Cabbage samples were equilibrated at room temperature for approximately 3 h before spectral acquisitions. The samples were placed in the middle of the holder. For each sample, visible-NIR measurements were carried out on 3 different marked locations along the equatorial circumference (~120°) and a marked location on the top side of cabbage heads (Fig. 1). Each marked location was scanned for 10 NIR spectrums, a total 40 spectrum/cabbage head, prior to calculating average spectra for each cabbage head. Additionally, for NIR spectral measurement, each marked location was subsequently determined for quality attributes (moisture content, SSC and ascorbic acid) by destructive methods and made up to an average value for each sample head.

2.3. Quality parameters measurement

The reference data were collected using the conventional destructive methods. The moisture content was measured using 10 g of freshly shredded cabbage samples from each scanned location of head that were placed in an aluminum cup to determine

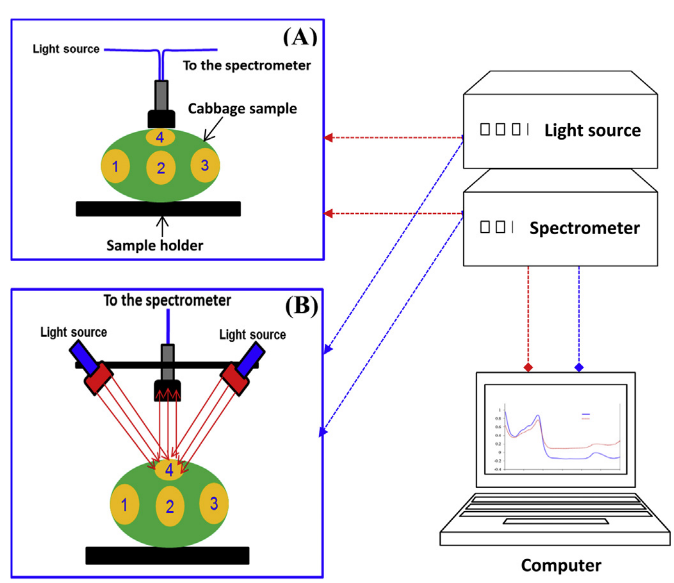

Fig. 1. Sample presentation for NIR spectral acquisition of cabbage head and schematic of interactance (A) and reflectance (B) measurements.