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Simultaneous measurement of brown core and soluble solids content in pear by on-line visible and near infrared spectroscopy

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ABSTRACT

The feasibility of brown core and soluble solids content (SSC) simultaneously online by visible and near infrared (visible–NIR) transmittance spectroscopy. Visible–NIR spectra of brown core and sound pears were recorded at a moving speed of five samples per second. Different combinations of two wavelengths were searched by correlation analysis in the wavelength range of 600–904 nm to discriminate brown core and sound pears. Partial least squares (PLS) regression models calibrated with sound samples yielded better results then PLS models built with brown core pears and the combinations of brown core and sound ones. Then a novel strategy was proposed for simultaneous measuring brown core and SSC by on-line visible and NIR spectroscopy. The new samples, including 8 brown core pears and 32 sound ones, were applied to evaluate the performance of the classification and quantitative analysis models. The classification accuracy of brown core pears was 98.3%. The percentages of SSC predictive precision were 97.8% and 99% within deviations of ±0.5 and ±1%, respectively. The results suggested that classification using two wavelengths and quantitative analysis using PLS were suitable to measure brown core and SSC of pears simultaneously by on-line visible and NIR spectroscopy.

1. Introduction

Chinese pear 'Yali', a variety of the 'White pear system', is popular with consumers in China and abroad. It may develop browning disorders that poses quality constrains on export of produce when they are late harvested or the environment temperature changes rapidly from high to low during storage. The symptoms of the disorder include unsightly flesh browning around the core, and cavities in affected flesh where browning extends into the cortex (McCollum et al., 2013). Browning disorders make 'Yali' pear unmarketable but are impossible to detect with the human eye alone. Such disorders affect also other 'White' pears including 'Laiyangshili', 'Pingguoli' and 'Jingfengli' (Gamble et al., 2010; Han et al., 2005, 2006a). Consequently, a reliable, nondestructive method for detecting and segregating such fruit is required by the industry.

Visible and near infrared (visible–NIR) spectroscopy has shown potential to analyze material composition and to probe localized features rapidly and nondestructively, such as bruises of fruit (Zhang et al., 2013; Luo et al., 2012; Xing and Baerdemaeker, 2007; Xing et al., 2006, 2003; Jiménez-Jiménez et al., 2012). Visible–NIR spectroscopy is not only a suitable technique for detecting external defects, but also an appropriate method for measuring internal quality properties of fruit, such as soluble solids content (SSC), titrable acid (TA) and firmness (Paz et al., 2009; Nicolaï et al., 2008; Li et al., 2013; Sun et al., 2009; Travers et al., 2014; Xu et al., 2012). Typically a regression model between the spectra and corresponding concentrations is constructed using multivariate calibration (MC) methods. Partial least squares (PLS) regression, a typical MC method, is most widely used to develop the regression relation model for its characteristics of simple and effective. Visible–NIR spectroscopy also shows great potential for inspecting internal defects (McGlone et al., 2005; Clark et al., 2003). Han et al. (2006b) developed a discriminant analysis (DA) model with Mahalanobis distance (MD) for identifying brown core pears and sound ones in the wavelength range of 651–1282 nm, and the classification accuracy was 95.4%. Fu et al. (2007) reported that the transmission mode for detecting brown core pears is better than the reflectance mode with the classification accuracy of 91.2% in the wavelength range of 400–1028 nm. Brown core pears and sound ones may exist simultaneously when fruit are sorted in the sorting line. Reports on simultaneous detection of brown core and SSC of the Chinese 'Yali' pear were not found in the scientific literature. Therefore, a method for identifying brown core pears and quantifying SSC of pears simultaneously was proposed, and it was integrated on the same sorting line.

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Table 1
Soluble solid content of pears in the calibration and prediction set for three groups of brown core pears (B), sound ones (C), and their combination (A).

Group	Calibration set				Prediction set			
	Number	Range (%)	Mean (%)	SD (%)	Number	Range (%)	Mean (%)	SD (%)
Group A	95 + 55[a]	7.6–15.2	11.2	1.4	32 + 18[a]	8.2–15.1	11.2	1.4
Group B	55[a]	7.6–14.0	10.1	0.9	18[a]	8.2–11.8	10.1	0.8
Group C	95	9.9–15.2	12.2	1.0	32	10.6–15.1	12.2	1.0

SD, standard derivation.
[a] Represents black heart pear.

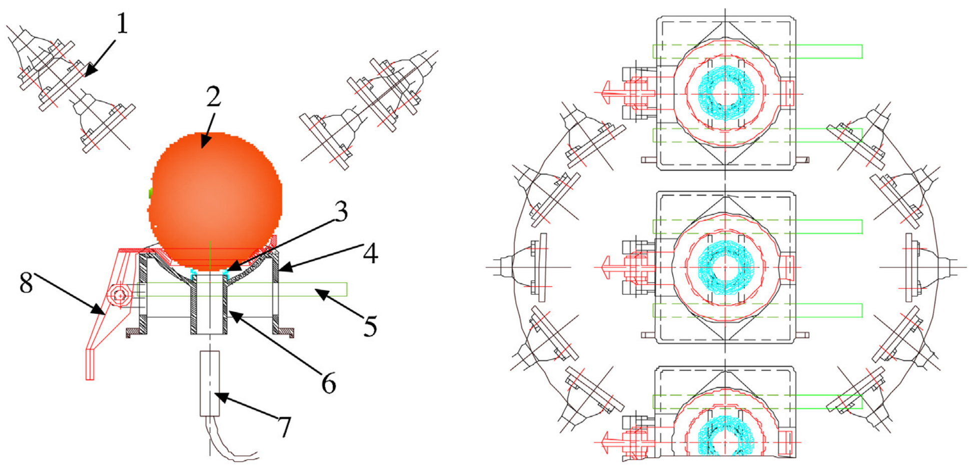

Fig. 1. Schematic diagram of detection mechanism in on line detection equipment (a) front view (b) top view 1 source, 2 sample, 3 barrier ring for light, 4 fruit cup, 5 driving lever, 6 light transmission hole, 7 collimating lens, 8 bounce claw.

2. Material and methods

2.1. Sample preparation

All fruit were supplied in February, 2015 by a fruit dealer in Hebei, China. They were cleaned and stored at 25 °C and 60% relative humidity for 24 h before collection of spectra. The samples with irregular and surface defects were removed before the experiment. Equator diameters of the samples were measured by vernier caliper and were in the range of 70–80 mm. A total of 200 samples, among which 73 brown core pears and 127 sound ones, were chosen for the experiment. The brown core pears were identified by cutting all pears and visually inspecting them. To study the influence of brown core pears on the performance of PLS models, the samples were divided into three groups of brown core pears, sound ones and their combination. For developing PLS models, the samples were divided into the calibration and prediction sets based on the Kennard-Stone method. The details of the calibration and prediction sets were shown in Table 1.

2.2. NIR Online system and spectra collection

The visible–NIR on-line system consisted of a transmission chain, light source, detector, sorting mechanism and fruit cup (Fig. 1). A commercial miniature fiber optic spectrometer (Mod. QE65 Pro, Ocean Optics, Inc., USA) was connected a collimating lens (Mod. 74-90-UV, Ocean Optics, Inc., USA) with an optical fiber (Mod. QP 1000-2-UV–VIS, Ocean Optics, Inc., USA). The core diameter of the optical fiber bundle was 1000 μm. The diameter and focal length of the lens were 5 and 10 mm, respectively. The collimating lens was installed under the light transmission hole of the fruit cup. The spectrometer was equipped with a Hamamatsu S7031-1006 detector in the wavelength range of 200–1100 nm. The combination of the spectrometer's low-noise detector and 16-bit

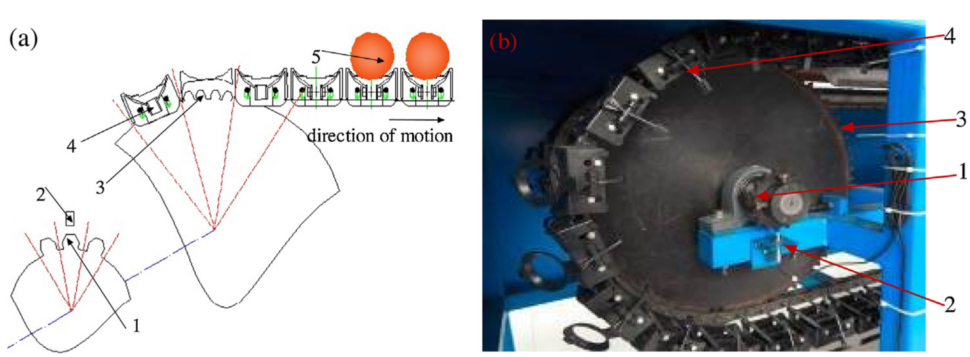

Fig. 2. Schematic diagram (a) and photo (b) of the hardware trigger mode 1 tooth of index plate, 2Hall sensor, 3 tooth of driving gear, 4 fruit cup, 5 fruit.