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Relationship between sensory and NIR spectroscopy in consumer preference of table grape (cv Italia)

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ABSTRACT

A combination of near infrared spectroscopy (NIR) instrumental measurements and sensory analysis was investigated to predict solids soluble content (SSC, assessed as Brix) and to classify preference in table grape cv Italia. SSC was monitored in each berry of whole bunches in order to evaluate intra-bunch distribution and variability. NIR spectra were recorded in the spectral region 12,000–4000 cm^{-1} (833–2500 nm) using a set of 682 berries. The Partial Least Square (PLS) model based on cross-validation provided acceptable value for the main statistical parameters (coefficient of determination of cross-validation, r^2: 0.85; standard error of cross-validation, SECV: 1.08; residual predictive deviation, RPD: 2.6) and was confirmed by external validation performed with 115 independent berries (coefficient of determination of prediction, r_p^2: 0.82; standard error of prediction, SEP: 0.83). For consumer testing, the selected PLS model was used to predict the Brix value in 400 berries and Discriminant Analysis (DA) was then carried out to classify berries in terms of preference by relating NIR data to consumer judgment. The three defined preference clusters of berries were fully classified obtaining 100% membership. In cross-validation the value decreased especially for class 1 (78.5%) and 3 (75%) whereas class 2 obtained comparable values (98.7%). According to our results, NIR technology appears to be a promising technique for predicting SSC and obtaining information with regard to consumer preference in 'Italia' table grape for application of efficient and low cost on-line instruments in the fruit industry.

1. Introduction

Consumer concern and expectations about food quality has been constantly increasing. Therefore it becomes necessary for the food industry to have analytical methods for assessing the composition and quality of food and beverages. Measurement of quality characteristics are routinely performed by chemical, physical and sensory methods, which are not always well suited for industrial routine control. For this reason, the industry is demanding fast, non-destructive, accurate, and on-line/at-line instrumental techniques that are able to screen samples in a short time and to capture variations in the chemical and sensory properties both on processed and raw material. This is especially crucial for short-term marketed products such as fruit and vegetables.

The table grape production spearheads export of Italian fruit, contributing along with Chile about 45% of world exports. The Italian average production is about 14 million tons of grapes, 70% of which is produced in Apulia, then in Sicily, Abruzzo, Basilicata and Lazio. For many decades the table grape cultivar 'Italia' has been the favorite for growers accounting for 41% of the total production.

The ripeness level of table grapes is a matter of importance for producers and dealers, being a key quality index for consumer acceptance. Some chemical and physical methods are available to determine the reducing sugars, solids soluble content (SSC), pH, total acidity (TA), whereas sensory methods are used to evaluate preference; however they are time consuming and/or destructive. Lately, research has been aimed at the application of spectroscopic analysis to fruit and vegetables with the main purpose of obtaining rapid, on-line and non-destructive methods that preferably allow prediction of sensory properties and consumer acceptance directly from measurements, thus allowing the food industry to rapidly respond to the demands of producers, consumers and the market.

Spectroscopy in the near infrared region (NIR) is part of the electromagnetic spectrum which spans the wavelength range between 833 and 2500 nm (12,000–4000 cm^{-1}). This region is related to

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vibration and combination overtones of the fundamental O—H, C—H and N—H bonds, which are the primary structural components of organic molecules. In particular, NIR spectroscopy is a rapid and nondestructive technique which has the potential to be used in on/at-line monitoring systems (Roberts et al., 2004; Liao et al., 2012; Xu et al., 2012).

In the last decade, Vis/NIR spectroscopy has often been used in the food industry being suitable for screening methods during product development, in quality control and prediction of sensory characteristics of foods (González-Martín et al., 2011; Guy et al., 2011; Lyndgaard et al., 2012;), fruits (McGlone and Kawano, 1998; Cen et al., 2006; Subedi and Walsh, 2009, Nagle et al., 2010; Xu et al., 2012) and beverages (Pedro and Ferreira, 2007; Ribeiro et al., 2011).

Several researchers have addressed the potentiality of NIR spectroscopy in wine grape ripening control by measuring solids soluble content, reducing sugars, pH and acidity (Osborne et al., 1993; Gishen and Dambergs, 1998; Jarén et al., 2001; Dambergs et al., 2003; Herrera et al., 2003; Chauchard et al., 2004; Arana et al., 2005; Larraín et al., 2008; Fernández-Novales et al., 2009a).

Application of Vis/NIR or NIR methods to grape classification/discrimination (Cozzolino et al., 2003; Herrera et al., 2003; Arana et al., 2005; Dambergs et al., 2006; Fernández-Novales et al., 2009b), in quality control (González-Caballero et al., 2010), to define geographic origin of wine (Liu et al., 2006, 2008), to predict grape and wine components (Dambergs et al., 2003; Cozzolino et al., 2004; Ferrer-Gallego et al., 2011) and to study relationship between wine and wine grape sensory characteristic and instrumental measurements (Cozzolino et al., 2006a; Le Moigne et al., 2008) have also been reported.

Little is known about the possibility of relating chemical, physical and sensory characteristics to instrumental measurements in table grapes. Studies on the effect of texture on consumer preference are present in the literature (Rolle et al., 2012). Examples of prediction of SSC, pH and TA in cultivars of red and white table grape by means of hyperspectral imaging have been reported by Baiano et al. (2012). However the proposed PLS model failed to predict consumer preference through reflectance values inferred from pixels of specific area of the berry.

The solids soluble content being directly related to ripeness is one of the grape properties most likely to match consumer perceptions of internal quality and preference (Baldwin et al., 1998). Studies run by Nelson et al. (1973) in Thompson Seedless table grapes stated that the Brix/acid ratio is an important index to predict flavor preference (R^2: 0.878). Morever, Jayasena and Cameron (2008) reported different correlation for Crimson Seedless table grapes overall liking in relation to acidity (R^2: 0.79), Brix (R^2: 058), Brix/acidity (R^2: 0.85), sweetness (R^2: 0.98) and sourness (R^2: 0.96). However, studies in Red Globe table grapes demonstrated that degree of liking was significantly related to titratable acidity for SSC lower than or equal to 16.0%, whereas for grapes with a SSC higher than 16.0%, the acidity level did not affect acceptance (Crisosto and Crisosto, 2002). In a recent study (Baiano et al., 2012), correlation between chemical, physical and sensory parameters, such as TA/sourness, pH/sourness, SSC-sweetness, SSC/overall liking, TA/overall liking, pH/overall liking and SSC–TA ratio/overall liking, measured in different table grape varieties obtained acceptable values only for SSC/overall liking (R: 0.754).

The aim of the present work was firstly, to study the relationship between SSC (measured as Brix) and NIR data by Partial Least Square Regression (PLS), secondly, to find optimal model to predict the SSC in table grapes, and finally, to study the ability of instrumental NIR measurements to classify table grapes according to consumer preference by means of Discriminant Analysis (DA). The research was focused on the acquisition of information aimed to predict the sensory preference of table grapes by means of on/in-line instruments.

2. Materials and methods

2.1. Grape sampling

Fifty bunches of table grape cv Italia (Bicane × Moscato d'Amburgo) were collected at different ripenesses at their arrival in several markets located in Cesena (FC, Italy) during the 2011 harvest. After transport to the laboratory, samples were analyzed immediately or after storage at 4 °C for up to 2 days. Before testing, samples were taken out from cool storage and maintained at room temperature (21–22 °C).

2.2. Spectral acquisition

Diffuse reflectance spectra for the berry samples were collected with a Fourier Transform instrument (FT-NIR, MATRIX-F, Bruker, Ettlingen, Germany) equipped with optic fiber gun over the range 12,000–4000 cm^{-1} (resolution 8 cm^{-1}, background: 32 scans, sample: 32 scans). Two replicate different measurements were performed on each side of intact grape berries through contact between the external gun of the NIR device and the epicarp of the fruit at room temperature and averaged using the software supplied by the manufacturer for analysis control and data statistical pretreated for absorbance (log 1/R) transformation (OPUS v. 5.5 Bruker Optics, Milan, Italy). A total of 1197 table grape berries were analyzed as follows: 682 for calibration and cross calibration, 115 for external validation and 400 for the consumer preference test.

2.3. Measurement of sugar content

The solids soluble content (SSC) of berries was measured by means of a portable digital refractometer (PAL–1, ATAGO, Tokyo, Japan). Data were expressed in Brix, representing grams of dry matter contained into 100 g of solution (%). Despite Brix not being included in the International System of Units (SI), this parameter is officially included into the CODEX standard for table grapes (CODEX STAN 255-2007) and recognized by the International Organisation of Vine and Wine (OIV) as reference value for the minimum maturity requirements for table grapes (Resolution VITI 1-2008).

2.4. Consumer test

Assessors were recruited among employers and students at the Department of Food Science of the University of Bologna (Cesena, Italy). A preliminary consumer test was performed to evaluate effects of intra-bunch sugar content (measured as SSC) variability on consumer preference. With this aim, 20 consumers (aged between 22 and 56 years, 60% female, 40% male) were presented with berries belonging to the same bunch of grape and requested to classify the preference of single berries through a four point scale (1–4). At the time of tasting, half berry was used to determine Brix value.

One hundred consumers (57% female and 43% male, aged between 21 and 67 years) participated in the classification test. Each was presented with four berries and requested to give a score according to preference on a 1–9 points structured scale (from "I dislike very much" to "I like very much") in conformity to Lawless and Heymann (1998). The berries were presented according to a randomized complete block design.