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Testing of a simplified LED based vis/NIR system for rapid ripeness evaluation of white grape (*Vitis vinifera* L.) for *Franciacorta* wine

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ABSTRACT

The aim of this work was to test a simplified optical prototype for a rapid estimation of the ripening parameters of white grape for *Franciacorta* wine directly in field.

Spectral acquisition based on reflectance at four wavelengths (630, 690, 750 and 850 nm) was proposed. The integration of a simple processing algorithm in the microcontroller software would allow to visualize real time values of spectral reflectance.

Non-destructive analyses were carried out on 95 grape bunches for a total of 475 berries. Samplings were performed weekly during the last ripening stages. Optical measurements were carried out both using the simplified system and a portable commercial vis/NIR spectrophotometer, as reference instrument for performance comparison. Chemometric analyses were performed in order to extract the maximum useful information from optical data. Principal component analysis (PCA) was performed for a preliminary evaluation of the data. Correlations between the optical data matrix and ripening parameters (total soluble solids content, SSC; titratable acidity, TA) were carried out using partial least square (PLS) regression for spectra and using multiple linear regression (MLR) for data from the simplified device. Classification analysis were also performed with the aim of discriminate ripe and unripe samples. PCA, MLR and classification analyses show the effectiveness of the simplified system in separating samples among different sampling dates and in discriminating ripe from unripe samples. Finally, simple equations for SSC and TA prediction were calculated.

1. Introduction

Establishing ripeness at harvest is a crucial issue since fruit quality are closely related to it. Grape ripeness monitoring in the orchard may provide valuable data to control quality of wine.

Ripening is a complex process, biochemical changes occur at skin and pulp level. To monitor these changes, routinely measurements of ripening parameters, essential for fruit and vegetables (e.g. soluble solids content, acidity, phenols, anthocyanins, firmness, etc.) are needed.

The search for non-destructive methods which could explore a larger sample and give a rapid and comprehensive overview of ripening would be helpful.

NIRs analyses are based on the use of spectral information arising from the interaction between food matrix and light for the simultaneous detection of all parameters necessary to monitor ripening. The light reflected from the product contains information about constituents in the inner layers and at the surface of the sample.

In literature, the feasibility of NIRs spectroscopy to measure quality attributes of fruit and vegetables has been shown for many products [1]. Arana et al. [2] studied NIR spectroscopy (800–1500 nm) in order to determine soluble solids content and to identify different varieties and origins of Chardonnay grapes. Gonzàlez-Caballero et al. [3] tested the ability of NIR spectroscopy to characterise the behavior of white and red grapes during on-vine ripening. Thereafter, Kemps et al. [4] evaluated the concentration of extractable anthocyanins, polyphenols, sugars and the density of 4 red grape varieties using vis/NIR spectrophotometer. Among the optical techniques, hyperspectral imaging was used in recent years to assess grape quality. The applicability of hyperspectral imaging (400–1000 nm) was tested on table grape by Piazzolla et al. [5] to classify fruits harvested at different times, and by Baiano et al. [6] for the prediction of physico-chemical and sensory attributes. Moreover, Nogales-Bueno et al. [7] studied the correlation between hyperspectral images (900–1700 nm) of wine grape during ripening and sugar concentration,

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titratable acidity, grape skin total phenolic concentration and pH obtaining good results.

Research and innovations have enabled NIRs devices to further decrease their physical size while increase dimensions of collected data. Therefore, new NIRs instrumentation tends to be more compact and portable [8,9].

For this reason, in order to support the small-scale producers, simplified, easy to use, low-cost systems for real-time assessment of fruit ripeness in field are desirable.

To reach this goal, recently, considerable effort has been directed towards developing and evaluating different procedures for an objective identification of variables which contain useful information and the elimination of variables containing mostly noise [10]. Liu et al. [11] proposed three effective wavelength selection methods combined with vis/NIR spectroscopy in order to determine the soluble solids content of beer. The authors already tested different variables selection approaches in previous studies in order to identity effective wavelengths to monitor quality decay in fresh-cut lamb's lettuce [12], to estimate ripening parameters on wine grapes [13] and blueberries [14], in a view of simplified optical systems.

Few examples of simplified non-destructive commercial system are already available on the market, based on absorbance differences between specific wavelengths to monitor ripening evolution of apples and kiwifruits [15] or on fluorescence to follow changes during grape ripening [16].

The aim of this work was to design and test a LED based simplified optical device operating at only four wavelengths in the vis/NIR region for a rapid estimation of ripening parameters of white grape for *Franciacorta* wine directly in field.

2. Materials and methods

2.1. Sampling

The experimental plan monitored the grape ripening in the *Franciacorta* wines (DOCG, controlled and guaranteed denomination of origin) viticultural area (Adro, Brescia, northern Italy) during the last period of ripening just before harvest. The experimentation was carried out on white grape (*Vitis vinifera* L.) *Chardonnay* cultivar, one of the most important varieties in Italy. A total of 95 bunches of white grapes were collected in 2013 at five sampling dates (August 7th, 14th, 19th, 28th and September 4th). For every date, non-destructive analyses were carried out on each sample using both a LED based simplified system operating at four vis/NIR wavelengths and a portable commercial vis/NIR spectrophotometer. Destructive chemical analyses were also performed.

For each bunch the optical acquisition was carried out on five individual berries for a total of 475 berries. For each berry two acquisitions were performed in the equatorial region and then averaged (950 optical measurements with each instrument).

Moreover, average data on bunches were also calculated and used for the chemometric analysis.

2.2. The simplified system

Light emitting diodes (LED) technology was chosen as light source in order to design a prototype of a simplified optical device [8]. Wavelengths used for the development of the simplified optical system are: 630 and 690, near chlorophyll absorption peak; 750, close to the third overtone of OH stretching [17,18]; 850, close to the third combination overtone of sugar OH stretching at 840 nm [19].

Fig. 1 shows a diagram of the instrument, with the relationships between its functional units. In particular the figure shows: (1) the control and processing unit; (2) the input/output unit; (3) the analog-to-digital and the digital-to-analog converters; (4) the LEDs and optical filters modules; (5) the photodiodes; (6) the eight-arm optical fiber; and (7) the battery.

2.2.1. The control/processing unit

The control/processing unit is the main board of the device, equipped with a PICTM microcontroller (Programmable Integrated Controller, PIC18F series, Microchip Corporation, USA) (1 in Fig. 1). When turned on, the microcontroller automatically runs a preloaded firmware and manages the inputs entered by the user. Based on these, it verifies the state of the system, sends signals to the other units, decides and coordinates all the following operations.

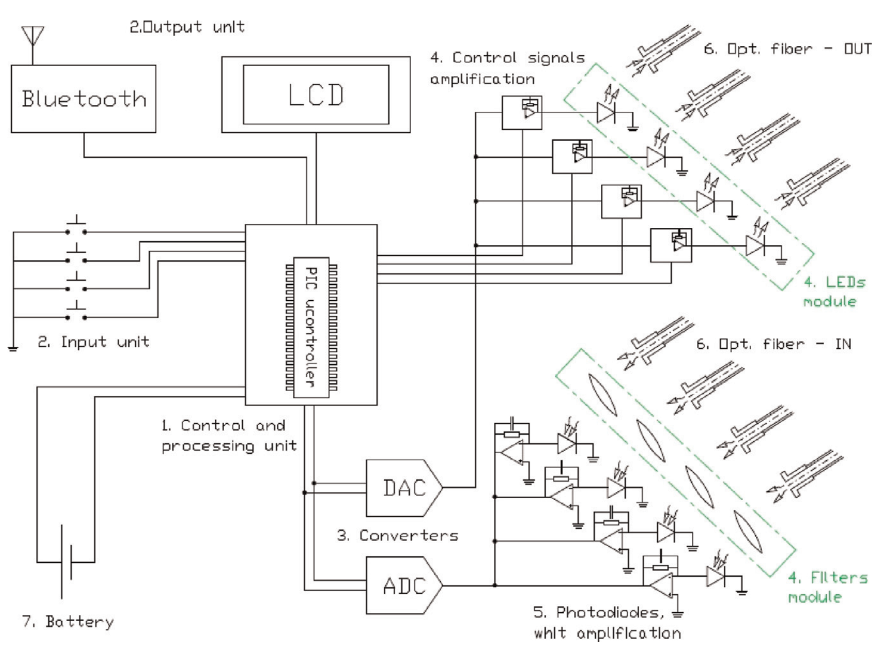

Fig. 1. Block scheme of the main components of the simplified LED based system.