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Use of a Portable vis Nir Device to Predict Table Olives Quality

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There is a growing interest today in high-quality and sustainable production especially in the agro-food sector where the use of automated, precise and non-destructive monitoring analytical systems is spreading more and more. In table olives consumption colour and texture are very important quality attributes deriving from ripening, size of the cell wall, middle lamella and fibrous tissues that can be compromised by bruising during harvest operations or postharvest handling. Mechanical damage also accelerates physiological processes, which lead to senescence, spoilage and loss of nutritional value. Nocellara del Belice cultivar is one of the most important table olive varieties in Italy both for the production and the marketed quantities, with an average annual production of 25,000 t. The aim of this study was to evaluate the feasibility of applying vis NIR spectroscopy as a non-destructive technique on Nocellara del Belice table olives to predict colour and firmness during harvest and post-harvest operations. The spectral acquisitions were performed using a portable vis NIR device (600 - 1000 nm). A regression model was considered to evaluate the prediction capacity of vis NIR starting from the observed values of a validation data set. The system gave excellent performance in predicting table olives colour (R^2 = 0.96 for “hue”), while the results showed a very low vis NIR ability to predict Nocellara del Belice table olives firmness (R^2 = 0.18) which make this device unsuitable for the purpose. The possibility of applying vis NIR spectroscopy in field before harvest or for selection in post-harvest operations is very encouraging for colour prediction and seems to be not adequate for firmness or damage evaluation.

1. Introduction

The Italian agro-food sector has got a strong vocation towards quality; focusing on quality requires the activation of functions aimed at the exactly define and evaluate the quality attributes of the product (Wang et al., 2015).

In recent years, many researchers developed non-destructive techniques and instrumentations to increase the number of fruits to be monitored and the analyses that can be repeated on the sample fruits during ripening and storage (Costa et al., 2009). Vis NIR technique has been increasingly studied and applied on many agro-food products including olives (Salguero-Chaparro et al., 2013).

Several studies demonstrated vis NIR feasibility for the prediction of oil content, moisture and fatty acid composition in olives for oil production (Cayuela et al., 2009; Cayuela et al., 2010; Armenta et al., 2010; Leòn-Moreno 2012). In Kavdir et al. (2009), oil content, pulp firmness and colour of two Turkish olive varieties were predicted using Fourier transform near infrared (FT-NIR) spectroscopy. Vis-NIR spectroscopy was also applied to evaluate the effect of some parameters such as focal distance and integration time on the spectral repeatability for the analysis of intact olive fruits on a conveyor belt (Salguero-Chaparro et al., 2012; Salguero-Chaparro et al., 2013); on-line versus off-line NIRS for the determination of fat content, free acidity and moisture of intact olives was also studied in Salguero-Chaparro et al. (2014). In Jiménez-Jiménez et al. (2012) the damage on Manzanilla olives was analyzed by developing mathematical models able to predict this parameter through the use of the NIR device.

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The aim of this study is to evaluate the feasibility of applying vis NIR spectroscopy as a non-destructive technique on Nocellara del Belice table olives, to predict colour and firmness during harvest and post-harvest operations, being this cultivar one of the most important table olive varieties in Italy.

2. Materials and Methods

2.1 Fruit materials

The tests were carried out in October 2017 on Nocellara del Belice table olives. Table olives are the major fermented edible vegetable of the Mediterranean basin. Sicily (south Italy) is one of the most important area of production in southern Europe (Poiana et al. 2006). Among the autochthonous Sicilian cultivars, Nocellara del Belice is that quantitatively most represented. Its main characteristics are reported in Table 1. Fruit and pit mass were measured by an electronic balance to an accuracy of 0.01 g (ORMA, BC4000S - Italy). Fruit and pit diameter and the mesocarp thickness were measured by a digital micrometer caliper to an accuracy of 0.01 mm.

Table 1: Olive fruit Cv. Nocellara del Belice characteristics

Character	Value[a]
Fruit longitudinal diameter [mm]	21.96 ± 0.59
Pit longitudinal diameter [mm]	12.90 ± 0.49
Mesocarp thickness [mm]	9.06 ± 0.94
Fruit mass [g]	8.47 ± 0.61
Pit mass [g]	0.96 ± 0.17
Mesocarp mass [g]	7.51 ± 0.54

[a] Numeric values are means ± standard error of thirty replicates

2.2 Portable vis NIR device

The spectral measurements were performed using a vis NIR system (model NCS001, Sacmi, Imola, Italy) that was operated in the wavelength range 600 - 1000 nm in transmittance mode. The system consisted of five elements: a lighting system, a power pack for lighting, a spectrophotometer, a PC for the user interface, which is responsible for data display and management parameters, and a fan to control the temperature. A control keyboard and a monitor complete the system. The measurements were acquired using a dedicated software (NCS software package, Sacmi, Imola, Italy). The system was based on the projection of an intense light beam with a near-infrared frequency band through the body of the product. The resultant light was collimated into a single narrow beam and analysed to determine the parameters of interest. Two acquisitions were performed for each fruit along the equator region on opposite sides. A 100 mm^2 Teflon® disk was used as the optical reference standard for the system, since it has low reflectance and its light-scattering characteristics were similar to those of the samples.

2.3 Quality attributes

Mechanical tests to evaluate olive fruit texture were performed compressing the olives by using a mechanical dynamometer (Imada DPS 5R - USA) connected to an electronic stand (IMADA MX2-500N - L) and a PC for data download. Each olive was longitudinally sectioned, removing half of the pulp through a blade and placed on a steel plate. Fruit compression was obtained by means of a cylindrical steel plate of 16 mm in diameter, whose surface was disposed orthogonally with respect to the minor axis of the olive. The test speed was set at 0.125 mm s^{-1} and was kept constant during the tests (Catania et al., 2015). The compression force was recorded continuously along the entire olive pulp. (Catania et al., 2014).
Colour was measured on four points of olive surface by means of a colourimeter (Chroma Meter CR-400C, Minolta, Osaka, Japan). Colour readings were recorded in the format of CIE XYZ colour space (also known as CIE 1931 colour space). It was then converted into Lab colour space (CIE L*a*b*) which is an absolute colour space. Chroma (calculated as $\sqrt{a^2 + b^2}$) and hue (calculated as arc tan [b*/a*]) were derived from Lab colour space.

2.4 Spectroscopic measurements

Vis NIR calibration was performed on quality measurements of olives carried out following the spectral measurements. These measurements were firmness and colour (chroma and hue). One hundred olives were manually and random harvested for the purpose. Then, in the laboratory spectral acquisition were performed on 50 intact olives and on 50 artificially damaged olives subjected to impact by dropping them from a fixed height of 1.9 m. The damaged olives were stored for 48 hours at room temperature and relative humidity (25-27 ° C; 65-68% R.H.) before spectral acquisition to let the damage appear.

2.5 Statistical analysis

A second step smoothing on the raw data was performed before the validation on the parameters. It was defined second step smoothing to eliminate the outliers after calibration. We substituted the outliers with median value as it was considered more appropriate for this research. The correction was separately made on intact and damaged olives. The ratio between the standard error of the transformed data set (SEC) and the standard error of the raw data (SD_raw) was calculated in order to evaluate the transformation gain applied to the raw data. When the value of the ratio is smaller than 1, there is a gain in terms of data variability.
After calibration, the performance of vis NIR device was quantified using standard error of calibration (SEC), standard error of prediction (SEP), correlation between predicted and observed value in validation set of the parameters (r^2), root mean squared of standard error of cross validation (SECV) and coefficient of determination for validation R^2. A good model should have a low SEC and SEP. A large difference indicates that too many latent variables influence prediction. R^2 and r^2 must be instead high.
Regression models were considered (Magwaza et al., 2012) to evaluate the prediction capacity of vis NIR starting from the observed values of the validation set. R^2 was defined as SSR/SST with SSR deviance explained by regression and SST the total deviance of observed values of the calibration set. The root mean standard error of cross-validation (RMSECV) was calculated as:

$$\mathrm{RMSECV} = \sqrt{\frac{1}{\mathrm{I_c}-1}\sum_{\mathrm{i}=1}^{\mathrm{I_c}}(\hat{y}_\mathrm{i} - \mathrm{y_i})^2} \quad (1)$$

$$\mathrm{SEP} = \sqrt{\frac{1}{\mathrm{I_p}-1}\sum_{\mathrm{i}=1}^{\mathrm{I_p}}(\hat{y}_\mathrm{i} - \bar{\mathrm{y}})^2} \quad (2)$$

$$\mathrm{SEC} = \sqrt{\frac{1}{\mathrm{I_c}-1}\sum_{\mathrm{i}=1}^{\mathrm{I_c}}(\hat{y}_\mathrm{i} - \bar{\mathrm{y}})^2} \quad (3)$$

where $\mathrm{I_c}$ is the number of observations in the calibration set, $\hat{y}_\mathrm{i}$ and $\mathrm{y_i}$ are respectively predicted and observed values and $\bar{\mathrm{y}}$ in (2) and (3) respectively represent the mean value in the validation and in the calibration set.

3. Results and discussion

3.1 Olive fruit NIR spectrum

Spectral data plots for absorbance are shown in Figure 1; the wavelength range is 300-1140 nm with an increase in absorbance between 700-900 nm.

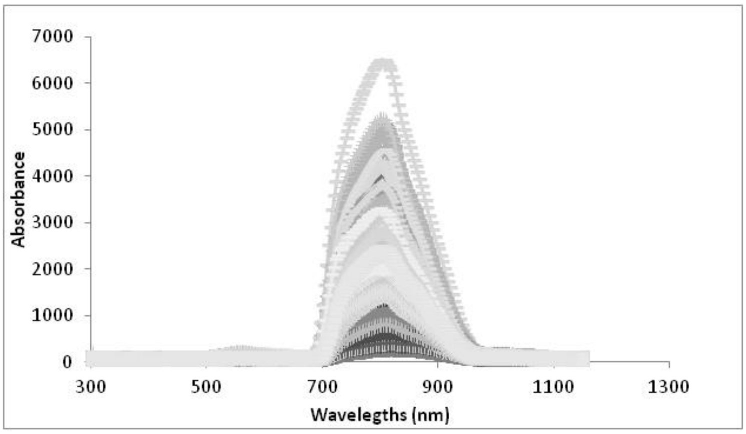

Figure 1: Spectra for Nocellara del Belice table olives (n = 100) acquired by NCS001 vis NIR system (Sacmi, Italy)

Cayuela et al. (2010), studying intact olives samples of Picual and Arbequina varieties, found that an increase in absorbance in the wavelengths 600-650 nm is due to the presence of anthocyanins, which determine the red colour, as well as the green and the yellow appear in 550-625 nm. The wavelength range between 780 and 2500 nm for reflectance, and between 800 and 1725 nm for transmittance were analyzed to find optimal intervals to obtain the best correlations between physical parameters and spectroscopic measurements in Turkish olives (Kavdir et al., 2009). Other studies suggest that the region between 700 and 950 nm of the near infrared can be useful to distinguish damaged olives according to the different levels of absorbed energy (Jimènez-Jimènez et al., 2012). Although in literature many studies report the creation of calibration models with a pretreatment of the spectra for a correct use of NIR, this allows to obtain useful and significant results (Fernández-Cabañas et al., 2008).

Table 2 shows the descriptive statistics of the parameters calculated on the raw data (firmness, chroma and hue) and on the transformed data (firmness_01, chroma_01 and hue_01).

Table 2. Descriptive statistics in pre-calibration and transformed data sets (calibration set)

Variable	Number of samples (fruit)	Mean	SEC	Min	Max
Firmness	100	32.81	14.87	6.6	72.5
Chroma	100	38.63	7.24	20.82	48.33
Hue	100	2.61	1.52	0	11.06
Firmness 01	100	32.42	14.51	6.6	72.5
Chroma 01	100	38.92	7.31	20.82	48.33
Hue 01	100	2.40	0.82	0	4.93

Table 3 shows the ratio between SEC in the raw and transformed data in order to evaluate the gain of the transformation in the standard error of the parameters. The data show that correcting raw data results in a standard error reduction for hue while the standard errors for firmness and chroma do not change. The correction was made for chroma and hue parameters of intact olives while for the damaged ones it was necessary to correct the abnormal values of the hue parameter.

Table 3. Descriptive statistics in raw data

SEC	Firmness	Chroma	Hue
SEC_R	14.87	7.24	1.52
SEC_T	14.51	7.31	0.82
SEC_R vs SEC_T	0.98	1.01	0.54

The quality indicators of prediction (Table 4) show a poor predictive ability of the vis NIR device for firmness parameter (R^2 = 0.18) in front of an average correlation between predicted and measured values. This result can be considered a limit of the vis NIR device application for firmness prediction in table olives. Conversely, a good prediction was obtained for chroma (R^2 = 0.73) where SEC and RMSECV are very similar. Similar results were obtained by Kavdir et al. (2009) with R^2 = 0.83 and 0.88 in reflectance and between 0.85 and 0.92 in transmittance for two varieties of olives for oil production. Hue shows a high R^2 value (equal to 0.96) and low values for RMSECV, SEC and SEP. However, by comparing the indicators to the respective mean value of the parameter, given their different units of measurement, hue shows the highest SEC and SEP values (Table 5). This result is probably related to the overestimation of the parameter, especially for values above the average.

Table 4. Quality indicators of prediction for each parameter

Parameter	N	R^2	r^2	RMSECV	BIAS	SEC	SEP
Firmness	100	0.18	0.43	12.15	-3.23	9.37	12.10
Chroma	100	0.73	0.86	6.29	4.34	7.08	8.78
Hue	100	0.96	0.98	0.43	0.30	1.51	1.51

Table 5. Quality indicators of prediction on the mean value of each parameter

Parameter	RMSECV/mean	BIAS/mean	SEC/mean	SEP/mean
Firmness	0.37	-0.10	0.29	0.37
Chroma	0.16	0.11	0.18	0.23
Hue	0.16	0.11	0.58	0.58

Figures 2, 3 and 4 show predicted values and the Interval of Confidence at 95% of probability for the three parameters. A very large interval was observed for firmness and this causes us not to consider valid the values predicted by vis NIR to evaluate this parameter on Nocellara del Belice table olives. Figure 2 shows that the Confidence Intervals are wider moving away from the mean value. The amplitude of the prediction interval for hue and chroma parameters (Figures 3 and 4) is smaller than firmness and therefore they are subject to a lower predictive error.

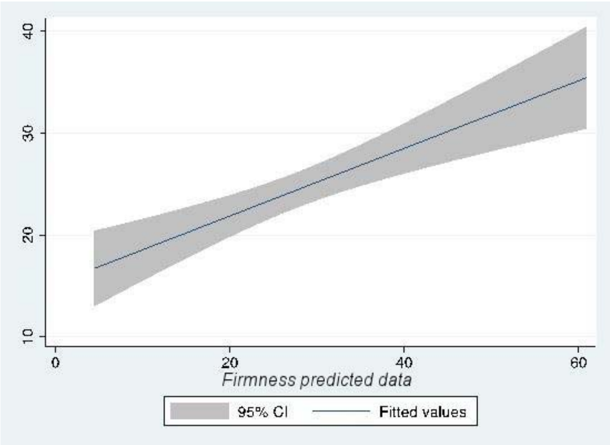

Figure 2: Predicted vis NIR versus measured values and Confidence Interval for firmness parameter

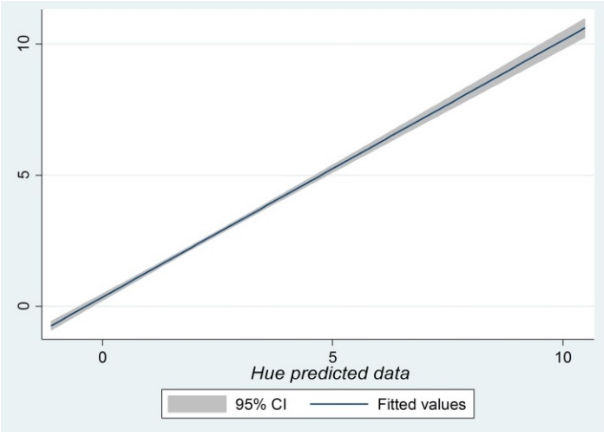

Figure 3: Predicted vis NIR versus measured values and Confidence Interval for hue parameter

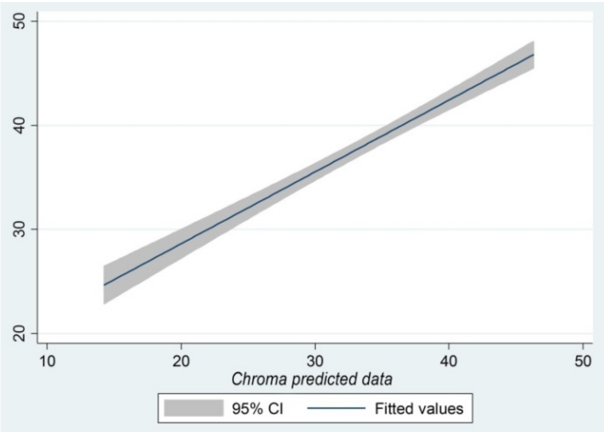

Figure 4: Predicted vis NIR versus measured values and Confidence Interval for chroma parameter

4. Conclusions

The prediction capabilities of a portable vis NIR device operating in the wavelength range 600-1000 nm were tested on Nocellara del Belice table olives to evaluate some olive characteristics in rapid and non-destructive way during harvest operations or postharvest handling.
The system gave excellent results to predict table olives colour (R^2 = 0.96 for hue), while a low feasibility in predicting Nocellara del Belice table olives firmness was observed (R^2 = 0.18) making this device unsuitable for the purpose also with reference to the evaluation of the damage suffered by the fruits during harvest and post-harvest operations. The results can be considered encouraging for the application of vis NIR spectroscopy in the field during pre-harvest operations as well as for the selection of the fruits in post-harvest procedures.

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