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On-line system based on hyperspectral information to estimate acidity, moisture and peroxides in olive oil samples

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ABSTRACT

The analysis of the quality of virgin olive oil involves the determination of a series of properties, such as chemical indexes and organoleptic characteristics. In addition, the determination of these properties in real-time could be useful in order to improve the olive oil extraction process since the process parameters could be regulated with the real-time moisture information.

In this paper, the feasibility of using a non-invasive hyperspectral device, in order to determine on-line three parameters of the olive oil (free acidity, peroxide index and moisture) is studied. In order to study the correlation between these parameters and the information obtained by the hyperspectral sensor (absorption level), three different methods were applied: genetic algorithms (GA), least absolute shrinkage and selection operator (LASSO), and successive projection algorithm (SPA). From the experimental results, reduced values in cross validation were obtained and the optimal wavelengths were pointed out.

1. Introduction

In general, the quality of a product is determined by the set of characteristics that allow it to be classified as equal, better or worse than those of similar nature. For olive oil, the parameters that determine its quality are influenced by the olive fruit (origin, variety, maturity and agronomic conditions, mainly) and the elaboration process variables (thermomixer temperature, centrifugal decanter differential velocity and others) (Cano et al., 2011).

Currently, the official analysis of the physicochemical and organoleptic quality parameters of olive oil are performed according to the methods established in the European norm CE 1989/03 (CE, 2003). The procedures are manual, work-intensive methods and not eligible for their on-line implementation in order to adjust the elaboration parameters automatically.

In recent years, there have been several advances related to non-invasive techniques for automatic food quality analysis (Baiano et al., 2012; Huang et al., 2012; Jamshidi et al., 2012; Suphamitmongkol et al., 2013) including olive oil (Ruiz Altisent et al., 2010; Sinelli et al., 2010). They have been focused in the infrared spectral range and have achieved good results. For instance, in El-Abassy et al. (2009) a Raman spectroscopy in the spectral window 945–1600 cm^{-1}, which includes carotenoid bands, was found to be a useful fingerprint region, being statistically significant for the prediction of the free fatty acids. Also, in Armenta et al. (2007), one FT-NIR (Fourier Transform Near Infrared) spectrophotometer device was employed for the determination of acidity and peroxides index in edible olive, sunflower seed and maize oils (Inarejos García et al., 2013; Mailer, 2004; Marquez, 2003). Moreover, in Jimenez et al. (2008) one hyperspectral device working in the spectral range between 1100 and 2300 nm, the AOTF-NIR (Acousto-Optic Tunable Filter Near Infrared) spectrophotometer, was used for real-time prediction of the moisture and fat content in olive pomace using two-phase olive oil processing. To our knowledge, there are no contributions dealing with the selection of the best wavelengths for the evaluation of olive oil quality parameters from images captured by an imaging spectrograph.

In this context, and using the images acquired by an hyperspectral device, the goal of this work was to select the optimal wavelengths which are better correlated with the olive oil parameters: free acidity, peroxide index and moisture. With this information, the computation time of the regression algorithms and the hardware costs for building new hyperspectral sensors could be significantly reduced. To this end, three methods were studied in order to select the optimal wavelengths: genetic algorithm (GA) (Eiben and Smith, 2003), least absolute shrinkage and selection operator (LASSO) (Zou and Hastie, 2005) and successive projection algorithm (SPA) (Arajo et al., 2001). To our knowledge, these methods were selected for our experimentation because they are widely used in the literature and they have achieved good results with

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spectral data inputs (Andersen and Bro, 2010; Arajo et al., 2001). However, in the last years other variable selection algorithms and variations (Monteiro and Kosugi, 2007; Latorre Carmona et al., 2012) have arisen that could be used in future work. The correlation between the selected wavelengths and the values of the parameters obtained by means of analysis performed in a laboratory were evaluated with multi-linear regression (MLR) (Aiken et al., 2003).

This article is structured as follows. Section 2 describes the olive oil samples used for the experiments, the analytical methods employed in order to reach the reference parameters, the experimental set-up built for acquiring images and the mathematical algorithms used for selecting wavelengths. Then, Section 3 shows the results and its comments. Finally, Section 4 presents our conclusions.

2. Materials and methods

The procedure followed in this paper has been the selection and preparation of the olive oil samples, the measurement of these samples by a hyperspectral sensor, their analysis in a certified laboratory, and the study of the resulting data.

2.1. Olive oil samples

A total of 133 olive oil samples of around 30 cl per sample were provided by the olive oil laboratory CM Europa S.L. (www.cmeuropa.com). This number included different types of olive oil -virgin, extra virgin, lampante- from the campaigns of 2012–2013 and 2013–2014. A database with acidity, peroxides levels, moisture and other chemical analysis applied to the samples were given too.

Of these samples, 56 of them included peroxides index values, 69 of them with moisture values and 133 samples with free-acidity analysis. Maximum, minimum and average values are shown in Table 1.

2.2. Analytical methods

The analytical methods were carried out by CM Europa. Thus, the acidity index is determined by acid-base titration of the free fatty acids with potassium hydroxide of the olive oil sample dissolved in ethanol. In turn, the peroxides index is determined dissolving the sample in a mixture of acetic acid and chloroform, later in a potassium iodide solution and titrating the freed iodine. The moisture content is determined relating the weight of the sample before and after a drying process held in a drying oven.

2.3. Experimental setup

The hyperspectral camera device used was composed of a Xeva-1.7-320 digital camera with a thermo-electrically cooled InGaAs detector head, an ImSpector N17E spectrograph and a 8 mm lens (ImSpector, 2003). The integration time was set in 1 ms. It behaves like a lineal camera capturing one line of the sample composed of 320 pixels over 256 different wavelengths. Its spectral range captured is between 900 nm and 1700 nm, with a resolution of 4 nm. The result is an image with 320 columns and 256 rows, equal to 81,920 pixels codified by 14 bits of resolution. The device captures up to 120 frames per second which can be transmitted to a PC through its CameraLink interface.

An automatic sampler was built with the hyperspectral camera device, a 100 W halogen lamp, a conveyor controlled by a LXM32M speed shifter and an infrared sensor used to detect the presence of objects. The setup is shown in Fig. 1. The images were captured using the external trigger of the camera connected to the infrared sensor. In measuring time the belt was stopped.

The software employed to control the LXM32M speed shifter was SoMove Lite V.1.4.4.0. On the other hand, Matlab 7.11.0 (R2013a) was used for the development of the software for the capture and analysis of the hyperspectral images.

2.4. Data analysis

The hyperspectral images were first preprocessed to obtain the spectra of the samples and also to reduce the noise introduced by the lighting system and other sources. Then, component selection algorithms were employed based on the following prefilters.

Table 1
Reference parameters from laboratory.

	Number of samples	Maximum	Minimum	Average ± SD
Acidity %	133	1.99	0.12	0.48 ± 0.45
Peroxides index meq. O_2	56	6.70	3.90	5.31 ± 0.83
Moisture %	69	0.43	0.07	0.15 ± 0.07

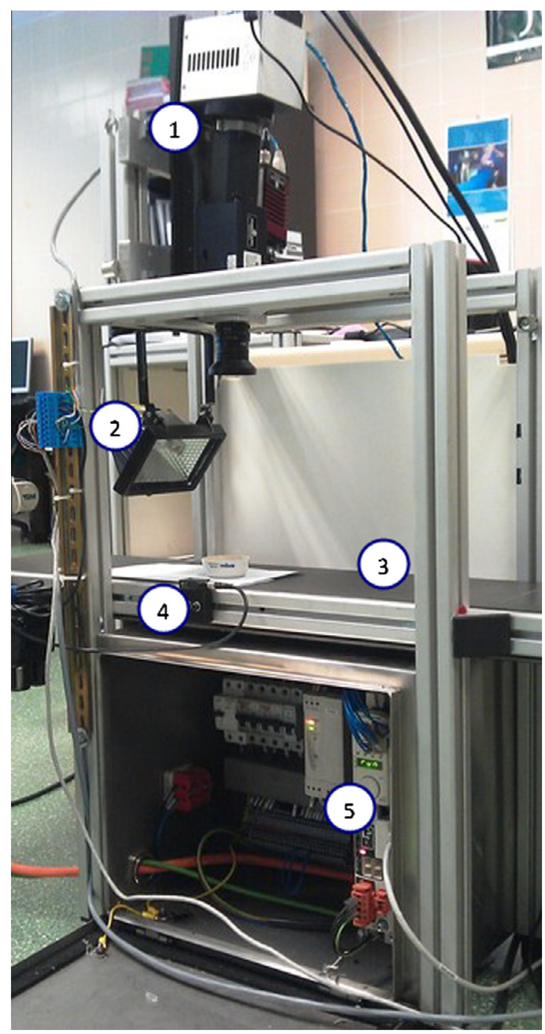

Fig. 1. Vision system configured. In the figure, label 1 indicates the InGaAs hyperspectral camera, label 2 the illumination system used, label 3 the conveyor belt, label 4 the infrared sensor and label 5 indicates the variable speed drive.