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Artificial vision and chemometrics analyses of olive stones for varietal identification of five French cultivars

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ABSTRACT

Visual and metric examinations of the agricultural products like olive stones to determine the varietal origin requires specialists who cannot always conclude with certainty because of the large number of varieties identified. This study aims to overcome the traditional observations of the olive stone by replacing it with an artificial vision and chemometric treatment. The potential of this approach is shown by applying it to the varietal identification of olive stones from five main French cultivars. Two hundred and six variables are extracted from two stone pictures (front and profile). A Principal Component Analysis (PCA) allows projection of the five stone groups corresponding to the five cultivars. Partial least square-discriminant analysis (PLS-DA) regression predicts the varietal origin of the stones. The best model considers all the data of front and profile pictures and gives 100% of correct classification. The methodology can be proposed as an alternative method for the recognition of olive fruits from five main French cultivars and can be extended to the varietal identification of stone fruits.

1. Introduction

The Mediterranean basin possesses a very rich patrimony of olive trees, with more than two thousands cultivars (Breton et al., 2009) among which approximately two hundred are mainly represented in France (Moutier et al., 2004). French cultivars are divided according to the importance of their culture surface in main, secondary, and local or old cultivars. Seven French cultivars have been characterized by means of descriptors harmonized at the international level (Word Catalog of Olive Varieties, 2000). Moutier et al. (2004) recently mentioned thirteen main French cultivars presenting some economical importance for the production of table olives or olive oils. Nowadays, the accurate varietal identification becomes a necessity in national and international trading to assure fair trades. The exchanges of plant material indeed involve some regulation concerning the nature of the cultivars. Moreover, many countries such as France, introduce the cultivar name as an element of quality of olive products. This is the case, for example, in the European system of quality labeling such as Protected Designation of Origin (PDO) or Protection of Geographical Indications (PGI). Due to the abundance of different cultivars, their correct identification is very difficult when we do not possess any information on the material under study. Numerous approaches for cultivar identification have been proposed in the literature. They have involved the biomolecular analysis of leaves or oil (Busconi et al., 2003), the chemical analysis of the various constituents of oil (triacylglycerol, fatty acids, sterols, volatile compounds) (Ollivier et al., 2003; Luna et al., 2006) and the spectral analysis (NIR, MIR, NMR, Raman) of leaves, olives or oils (Aouidi et al., 2012; Galtier et al., 2007; Dupuy et al., 2010; Korifi et al., 2011). The obtained results are mostly handled by chemometric methods. These various techniques are complementary and give satisfactory results in numerous cases. However, there are not always easy to implement for example in the identification of main cultivars in an old orchard. They reach their limits when attempting to determine the variety of the table olives that have undergone a preserving processing. In such conditions, the older identification method which is based on the description of twenty-seven morphological parameters of the tree, the leaf, the fruit and the stone, remains accurate in comparison with more advanced methods (Word Catalog of Olive Varieties, 2000). It is well established that the olive stones possess some features which can be exploited for identifying the cultivars. These features are only weakly influenced by the intervention of the man (Terral et al., 2004). However only a small number of specialists are trained to conduct such studies, and they cannot always conclude with certainty. So the use of expert system for stone cultivar identification would be very practical.

Artificial vision may be a possible and attractive approach for discrimination of olive varieties. This approach is based on the

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acquisition of numerical images with a camera connected to a computer. Imaging systems are easily adaptable to many environments, may give real-time analyses and are inexpensive. Artificial vision has been already applied for quality control in the food industry (Brosnan and Sun, 2004; Du and Sun, 2006; Dowlati et al., 2012). Chtioui et al. (1999) have applied the rough set theory as a classification tool for the quality assessment of edible beans. Kiliç et al. (2007) have developed a machine vision system devoted to the quality inspection of beans based on size and color quantification. Ghazanfari et al. (1996) have classified pistachios into four quality groups. They extracted some physical features of nuts from the numerical images, and obtained about 96% of correct identifications.

Several works have dealt with the identifications of seeds and grains. Chtioui et al. (1998) have developed an automated system devoted to the discrimination of four seed species (red fescue, perennial rye grass, rumex and wild oat). Artificial vision has also been applied to the recognition of durum wheat and soft wheat. With this goal, Utku (2000) obtained about 80% of correct identifications. Majumdar and Jayas (2000) have used a morphology–texture–color model for cereal discrimination. They attempted to discriminate wheat, barley and oats. They obtained 99.7% and 99.8% accuracy respectively on the independent and the training data sets. Color morphological, size and textural features are the most frequently parameters used to classify grains (Du and Sun, 2006). Maturity index (MI) of olive fruits has been determined by the combination of machine vision system, capable of performing a color-based raw prediction of MI, with an artificial neural network based algorithm to refine it (Furferi et al., 2010). Artificial vision method, based on the use of visible images, allows a fast, automatic and objective prediction of olive maturity index. Moreover, the method was applied to the automatic estimation of size and weight of olive fruits (Guzmán et al., 2013a). Maturity index was assessed on-line by image analysis obtained by visible machine vision (Guzmán et al., 2013b). Machine vision has been used to sort table olives of *Manzanilla* variety into four grades of quality depending on colorimetric differences and morphological features of the defects in the surface of olives (Diaz et al., 2004; Riquelme et al., 2008). Diaz et al. (2004) had compared three algorithms, Mahalanobis algorithm, partial least squares-discriminant analysis (PLS-DA) and neural network, for classifying the olives. Neural network is the best algorithm in discriminating the forth classes with an accuracy of over 90%. The application of three consecutive discriminant analyses resulted in the correct classification of 97% and 75% of olives during calibration and validation, respectively (Riquelme et al., 2008). Guzmán et al. (2013c) have developed an on-line estimation of olive quality according to the presence of defects based on an infrared vision system. To our knowledge, there is no study on the identification of olive varieties by computer vision of olive stones.

The aim of this work was to evaluate the potential of the artificial vision for determining the varietal origin of olive fruits from five main French cultivars (*Aglandau*, *Bouteillan*, *Lucques*, *Picholine*, *Tanche*). This determination was carried out from the numerical images of the stones of fresh olives and chemometric treatment.

2. Materials and methods

2.1. Olive samples

Samples of fresh olives ($n = 650$) were provided from the 'Centre Technique de l'Olivier' (CTO), Aix-en-Provence, France. Samples were obtained from crop 2009–2010. The sampling was constituted by *Aglandau* ($n = 240$), *Bouteillan* ($n = 95$), *Lucques* ($n = 55$), *Picholine* ($n = 150$) and *Tanche* ($n = 110$).

2.2. Stone preparation

Before acquiring images of the stones, it was necessary to process the fresh olives to obtain stones. The olives were first soaked in boiling water during 10 min. The pulps were removed and the stones brushed. The stones were then soaked in 40 ml hydrogen peroxide (30%, VWR International, France) during one day. They were then abundantly rinsed and dried at ambient temperature. Once dry, the stones were ready for image acquisition.

2.3. Stone description

A methodology for the description of olive stone has been published in the Word Catalog of Olive Varieties (2000). In this catalog, the stones are first characterized by their shapes using a standardized vocabulary: *elliptical*, *lengthened*, *ovoid–elliptical*, *ovoid*, *spherical*. The profile of a stone is defined as the position of maximum asymmetry along the longitudinal axis of the stone relative to an observer. Face is obtained by rotating 90° along the longitudinal axis to place the most convex towards the observer. The base of the stone corresponds to the peduncle side; the apex is situated at the other end. The mucro is a more or less pointed summit. The position of maximum transversal width (MTW) and the fibrovascular furrow (NFF) are defined in Fig. 1.

2.4. Image acquisition

Images were acquired by means of a high-resolution color camera (Baumer TXD13C). A lens was fitted on the camera in order to adjust the magnification (Fujinon 1:1.4/25 mm HF25HA-18). The lighting was assured by four 36W neon lamps, placed at each side of the camera. All the images were digitized by Visilog v6.7 imaging software from Noesis (Gif sur Yvette, France). Each stone was placed in face and profile positions in front of the camera. The distance between the camera and the working surface was 15 cm. The size of the vision field of the camera was 2.8 cm × 3.75 cm. Each numerical image was formed of 1040 rows and 1392 columns. The spatial resolution is equal to 0.026 mm. Image acquired with the above machine vision system (represented as known, by three channels R, G and B) were stored for further.

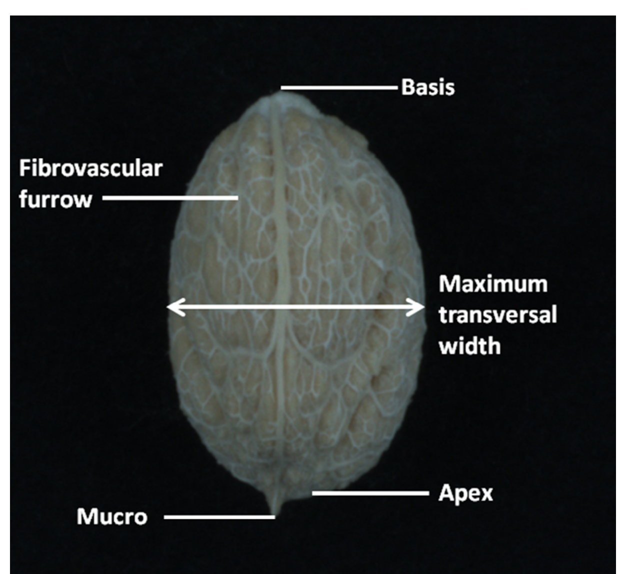

Fig. 1. Morphological parameters of olive stone.