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Ripeness estimation of grape berries and seeds by image analysis

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ABSTRACT

Digital imaging has become a powerful tool for the characterization and quality control of foodstuff. Because of the need to automate processes, faster tools are needed and Computer Vision is a good alternative to chemical analysis of many products in quality control. Appearance of grape seeds and grape berries change during the ripeness. These changes are closely related to the chemical composition, especially phenolics, which are very important compounds due to their implications on the intensity and stability of red wine colour. In this study, a complete characterization of grape seeds and grape berries by digital image analysis is described. The size of grapes and the veraison has been determined by image analysis and it has been also established an objective Browning Index of seeds. Morphological differences between varieties were studied by applying discriminant analysis models which allowed us to classify the grape seeds with high accuracy.

1. Introduction

1.1. Colorimetry and food stuff

Colour and appearance are closely related to sensory properties and chemical composition of food. Normally, colour is measured by tristimulus colorimetry. The colour stimulus is composed of three different sensations, giving to colour three-dimensional nature. These attributes are:

- Lightness: This feature makes a colour lighter or darker. It is a relative measure of the reflected light against the absorbed. Value 0 is assigned to black and value 100 is assigned to white.
- Chroma: It determines for each hue, the colour difference from the grey having the same lightness. It can take positive values from zero.
- Hue: It is the main attribute. It is a qualitative property which allows classifying colours as red, yellow, etc. It is related to differences in absorbance of radiant energy at different wavelengths. Hue is specified as an angle.

These attributes are often expressed as L^*, C^*_{ab} and h_{ab}, respectively, according to the CIELAB colour space.

It can be used different kinds of instruments, such as colorimeters, spectrophotometers and spectroradiometers. Nevertheless, these instruments require homogenizating the sample to achieve uniform colour, which becomes tedious and complicated task to measure colour of heterogeneous stuff or small objects, such as grape berries and grape seeds. In these cases, it is very advantageous the use of digital images for this purpose. Digital image analysis appears as successful complement since it can be determined not only colour but also other characteristics such as shape, texture and homogeneity (Savakar and Anami, 2009; Zheng and Sun, 2008b).

1.2. Imaging hardware and colour spaces

Computer Vision is a subfield of Artificial Intelligence. The aim of Computer Vision is 'teach' a computer for understanding a scene or the characteristics of an image. In this way, we can identify the seeds and grapes in these images, and then, morphological and colorimetric characteristics can be extracted from each one. Computer Vision is a powerful tool for testing quality in alimentary industry (Brosnan and Sun, 2004).

A Computer Vision system includes: an illumination system, a charge-coupled device (CCD), a frame grabber which converts the analogue image from the camera into a digitized one, and a computer with the suitable software for image processing and interpretation of results (Wang and Sun, 2002). Illumination system has high importance, not only because of the need to identify objects in the image, but because the colour calculation process needs a light standardization (CIE, 2007). Once the illumination is controlled, a digital camera receives images onto a CCD. It has

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capacitors which are stimulated by visible radiation and it is registered in gradations of three basic colours: red, green and blue (RGB). This is consistent with the theory that every colour can be reproduced by the combination of three primary colours.

The RGB colour space is an additive colour model that uses transmitted light to display colours. It is used for television and other devices screens, so this model is device-dependent (its appearance depends on the display) (Yam and Papadakis, 2004). The $L^*a^*b^*$ model is an international standard for colour measurement developed by the *Commission Internationale de l'Eclairage* (CIE) in 1976. Here, L^* has the same meaning that the L^* described previously. a^* (from green to red) and b^* (from blue to yellow) are Cartesian coordinates of Polar coordinates C^*_{ab} and h_{ab} previously described. This colour space is device-independent, providing consistent colour regardless of the input or output device such as digital camera, scanner, monitor and printer. CIELAB values are frequently used in food research (González-Miret et al., 2007).

Due to RGB colour space is not continuous each channel can take only integer values between 0 and 255. In order to calculate the colorimetric coordinated recommended by *Commission Internacionale de l'Eclairage* (CIE), it is necessary to transform from RGB to CIELAB colour spaces. This transformation requires calibration and it depends on illumination when images are taken (León et al., 2006).

One of the most important steps in image analysis is segmentation. Segmentation refers to the process of partitioning a digital image into multiple segments (sets of pixels). The goal of segmentation is to simplify and/or change the representation of an image into something more meaningful and easier to analyze (Zheng and Sun, 2008a).

1.3. Advantages of using image analysis for grapes and grape seeds characterization

The size of the grapes is measured in routine analysis during ripening. The diameter is normally measured with a calliper, which measures the size in only one direction and the mean of several grapes is given, making this a tedious task. In addition, the berry could be accidentally tightened during measurement and it induces error. For this purpose, the use of Feret diameter has been proposed (González Marcos et al., 2006). Feret diameter is the maximum length of chord for a counterclockwise angle with the *x* axis, defined between 0° and 180° (Fig. 1). Due to grape berries are not completely spherical, for each berry, the mean of all Feret diameters for all possible angles have been considered. This way, the size will be given as an average of all possible Feret diameters of all the grapes analyzed.

During the grapes ripening there is a loss of chlorophyll and the formation of the final dyes. This process starts at the veraison, the onset of ripening, when the colour of the grape berries change, being the transition from berry growth to berry ripening. In red grapes, the colour changes from green to purple, even almost black. The veraison is normally expressed as a percentage determined by visual inspection. It is possible to establish an objective veraison index by image analysis.

There are more appearance-related characteristics of the seeds and grapes associated to maturity, such as the browning of the seeds (Ristic and Iland, 2005). All these parameters can be estimated of an objective and automated manner by image analysis.

2. Material and methods

2.1. Sampling

The vineyards sampled are included under the "Condado de Huelva" Designation of Origin, in southwestern Spain, harvested in 2009 and 2010. Two red varieties (*Tempranillo* and *Syrah*) and one autochthonous white variety (*Zalema*) cultivated in two kinds of soil (*Sand* and *Clay*) were used. Samples were taken twice a week from early July until harvest (which occurred approximately at end of August depending on variety). Sampling was carried out taking a pair of berries from alternate grapevines and from both sides up to reach 2 kg of berries, ensuring this way the representativeness of the sample. Once in lab, one hundred berries were randomly taken and cleaned for acquiring the images. Seeds of these berries were removed and dried at room temperature for two hours before acquiring the image.

2.2. Apparatus

The DigiEye® imaging system based upon the calibrated digital camera was used (Luo et al., 2001). It includes an illumination box specially designed by VeriVide Ltd. (Leicester, UK) to illuminate the samples consistently and a digital camera connected to a computer (Fig. 2).

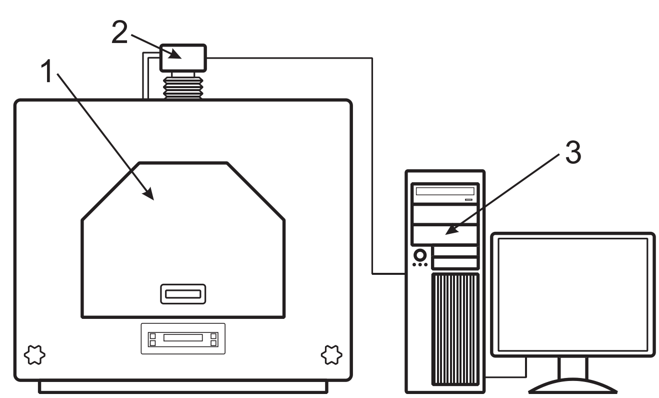

Fig. 2. The DigiEye® System: (1) illumination box; (2) digital camera; (3) computer.

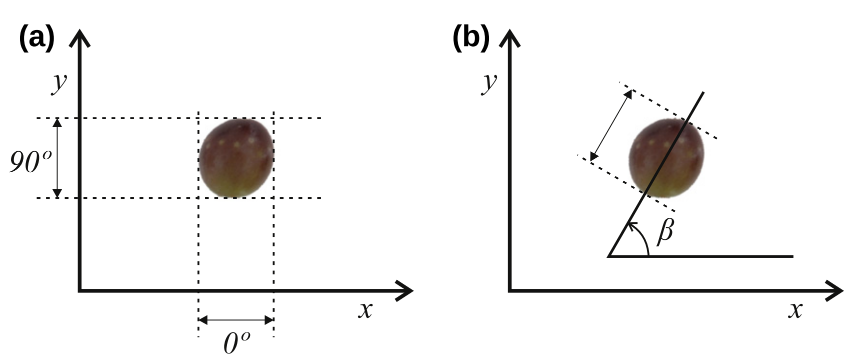

Fig. 1. (a) Feret diameters at 0° and 90°. (b) Feret diameter at an angle β.