Spectral signatures: A way to identify species and conditions of vegetables

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ABSTRACT

This work shows the results obtained by the application of suitable techniques for the acquisition and processing of spectral absorbance data of several vegetable species, allowing its identification –assignment of each spectral signature to one specific plant- which in turn allows the control of origin of products (foodstuffs or not) and their characteristics. Spectral measurements of absorbance were performed on samples of two sugarcane varieties and four citrus types (orange, lemon, tangerine and grapefruit) taken periodically from a controlled crop, using a spectrophotometer FOSS-NIR 6500 in the range of 400-2500 nm by 2 nm. The measured samples were about 240 in the case of sugarcane and 160 in the case of citrus. A Principal Component Analysis was applied to the data by means of STATA 9 software and the results were interpreted in that PCA context. This procedure allowed us not only to clearly identify which variety of sugarcane corresponds to each spectral absorbance function, but also to determine which wavelength or wavebands have significant relevance for that identification. Similarly, this technique allows us to identify and classify the spectral functions coming from different types of citrus. The main conclusion is that the proposed technique is capable to precisely identifying the species each sample comes from; besides, this technique would allow us to determine the nutritional or health condition of them at the moment of the analysis, as could be seen from the obtained results.

1. INTRODUCTION

When the optical radiation reaches the surface of any of the numerous components of the environment is subject to one or more of the following processes: it can be reflected, transmitted or absorbed, according to energy conservation laws. The characteristics and intensity of this behaviour depend on the material and surface quality the radiation impinging on. The particular combination of elements making up the material staff, their proportions, quantity, size and form will determine the characteristics of the interaction, setting which aspects of the incident radiation will be modify and in what extent.

The energy of the electromagnetic wave is related to its wavelength in such a way that the smaller the wavelength, the more energy a given wave contains. When this energy reaches the surface of a body it is either reflected from, absorbed by or transmitted by it. The degree and intensity of each process being determined by the wavelength and the physical and chemical properties of that body (Scotford and Miller 2005).

The spectral reflectance in plants is influenced, besides the absorption of their elements, by the structure of the surface and the cells in the leaves (Zwiggelaar 1998). Leaf optical properties are a function of leaf components and structure, water content and the concentration of biochemicals (Asner 1998). According to numerous research works and

scientists, spectral reflectance in the visible and near infrared region (400-2500 nm) is a powerful and fruitful tool to evaluate properties and situations of plants and crops. Consequently, most agricultural studies use measurements in the visible (400-700 nm) and near infrared (700-2500 nm) region of the spectrum. Many studies performed in the last few decades sustain that optical properties in this region can potentially detect physiological and biological functions of plants and crops, offering potential for applications in agriculture (Scotford and Miller 2005). Some researchers proposed a set of wavelength in which the reflectance values are capable to offer much valuable information about the status and functionality of the plant (Gausman and Allen 1973). Particularly, they pointed out to 550 nm (green reflectance peak), 650 nm (chlorophyll absorption band), 850 nm (on infrared reflectance plateau), 1450 nm (water absorption band), 1650 nm (reflectance peak following water absorption band at 1450 nm), 1950 nm (water absorption band), and 2200 nm (reflectance peak following water absorption band at 1950 nm). All of these suggest that if the body under consideration is a plant and we can measure carefully the characteristics of one or more of these processes, from that data we could infer useful information about conditions and functionality of the plant. To start with this proposal, we try to discriminate and recognize different plant species by means of the analysis of their reflectance or absorbance functions.

Among the characteristics of the interaction determined by the matter structure, we are particularly concerned in reflection and absorption. Those, expressed by means of spectral reflectance or absorbance functions of materials, especially of vegetables and named here as "spectral signatures", allows us to obtain information about constitution and condition of the material analysed: measuring the spectral signature with enough precision will allow, under specific conditions and by means of an adequate treatment of data, identifying not only the specie to which the signature corresponds to, but also its phenology and nutritional condition as well as the presence or absence of diseases, affections and scarcities of the plant from which the sample comes from.

2. MATERIALS AND METHODS

In order to compare and identify the specie a leaf belongs to, several samples of leaves of different plants are collected and their spectral reflectance and/or absorbance (spectral signatures) were measured. The species considered in this study were 2 varieties of sugarcane (labelled 742 and 384) and 4 types of citrus: tangerine, grapefruit, orange and lemon.

In the case of sugarcane, about 240 samples were measured, half of each variety, including two forms to prepare the samples to be measured: finely minced and coarse chopped. In the case of citrus, the samples measured were about 160, both sides of leaves (front and back) being measured. Samples subsets were collected every fortnight during four months and measured within the following 24 hours.

Spectral signatures were measured between 400 nm and 2500 nm, at 2 nm intervals, by means of a NIR System 6500 scanning monochromator (Foss NIR Systems, Silver Spring, MD, USA). The spectral data obtained were processed and analysed statistically with STATA 9.0, applying Principal Component Analysis to suitable grouped subsets of data.

3. RESULTS

Some results from the measurements in the case of sugarcane are shown in Figure 1, which displays spectral signatures, plotted between 400 nm and 820 nm, for the two varieties analyzed.

Visual inspection of the figure indicates that is fairly hard to discriminate if one particular sample belongs to one or another of the varieties considered.

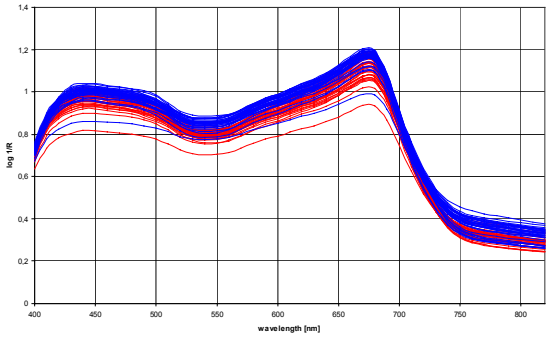

Figure 1. Spectral signatures for sugarcane samples (— 384; — 742).

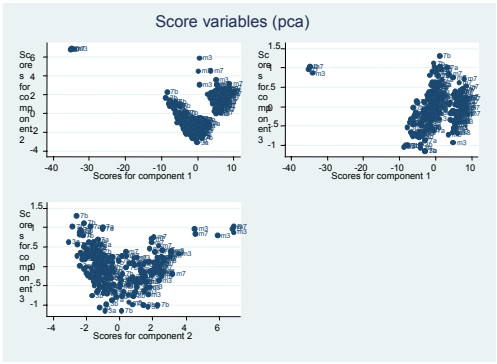

Figure 2. Scores for two sugarcane samples.

Doing this requires the spectral signatures to be analyzed statistically. To perform that analysis we applied a PCA initially to the complete set of data. Figure 2 shows PCA scores for the three main components, corresponding to 121 measurements of "384" and 122 of "742", considered between 400 nm and 820 nm (as in the case of Figure 1).

From Fig. 2, we can't decide which group represents each variety. In the upper left graph there can be seen three clouds but the only clearly differentiated from the rest is the small one on the upper left corner, which represent the scores for the measurements of a white reference disc included in the measurements.

In the representation, different types of treated samples are included together: minced and chopped leaves, front and back sides. The last are grouped in the central cloud, whilst the minced ones are gathered in the upper right cloud. The situation doesn't change substantially if we analyze just data corresponding to minced samples, as shown in Figure 3.

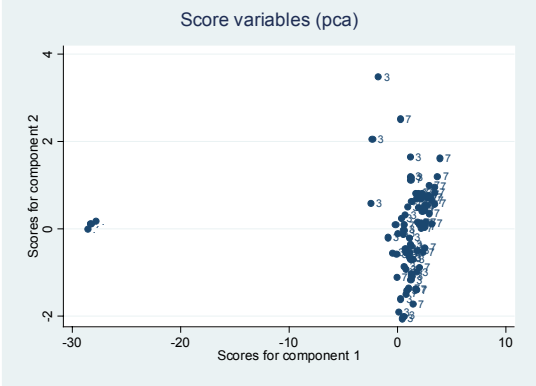

Figure 3. Scores for two sugarcane minced samples.

If we work now on the same type of sample (minced) but considering 79 measurements in different spectral range (in this case 400-500 plus 700-820 nm instead of 400-820 nm), the results from the PCA are rather different. Those are showed in Fig. 4. This tells us that is very important the conditioning (characteristics, spec-tral range, quantity) of the samples to be treated.

Figure 5 displays the PCA scores for data of minced samples considered between 400 and 1200 nm. The set comprises 21 spectral signatures, 10 of each variety plus one additional that correspond to variety "742", which is easily identified closest to the Component 1 axis.

Analogous procedure was applied to the comparison of 4 citrus, considered between 800 and 1100 nm. Figure 6 shows scores for all citrus samples without any special preparation. Despite that, is possible to separate samples of orange and tangerin (N and M) from lemon and grapefruit (L and P). When we applied the method to leaves of lemon (L) and orange (N) in the same condition, the identification of each type is very evident, as shows Figure 7.

4. CONCLUSION

The results obtained in this work show that a careful selection and suitable preparation of samples together with a precise collection of spectral signature data and the application of an adequate statistical analysis like Principal Component Analysis conform a powerful and reliable technique to recognize and classify plants, allowing us to identify the origin of a

given vegetable sample. That technique could be considerably improved by developing of a database of standardized spectral signatures of the main crops in each stage and status. This could be the basis for higher level of plants and crops analysis, allowing us the prediction, diagnostic and solution of different health and phenologic affections of plants.

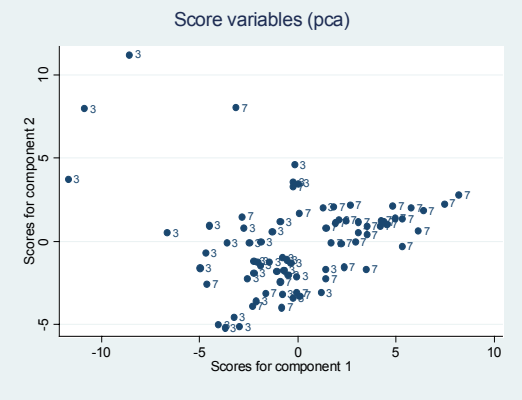

Figure 4. Scores for minced samples. Different spectral range.

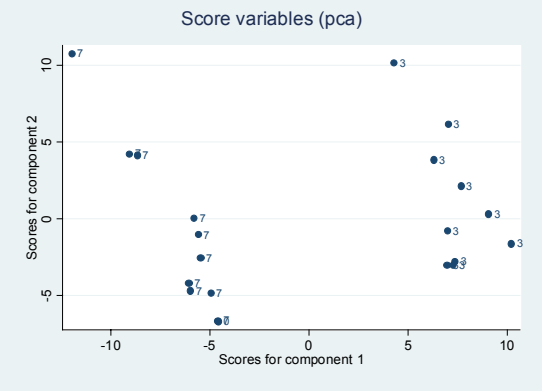

Figure 5. Scores for minced samples. Spectral range: 400 to 1200 nm.

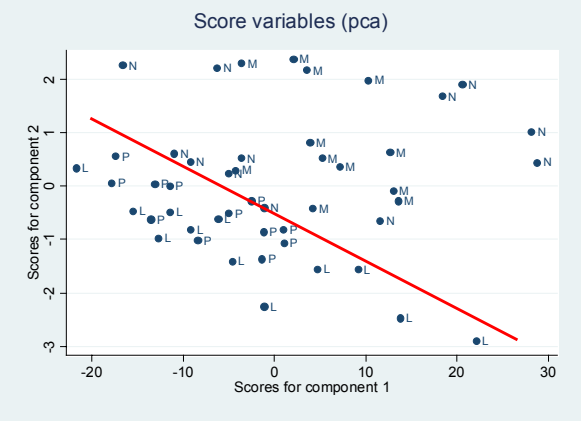

Figure 6. Scores for 4 citrus samples.

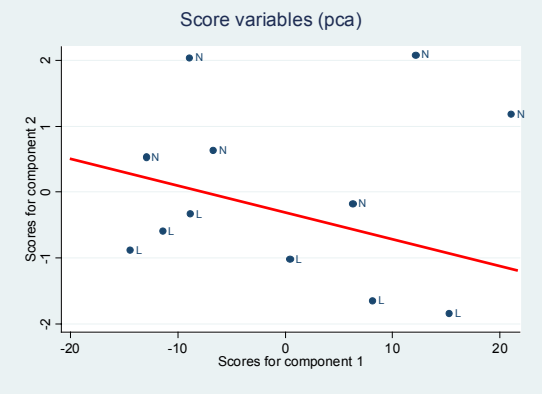

Figure 7. Scores for 2 citrus. Samples in the same condition.

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