Abstract

Enhancements of the productive processes in the food industry, as any other industry, are a key factor to keep the competitiveness and increase profits. In order to achieve this objective it is needed to use new methods that improve the quality and efficiency of these processes. Moreover, nowadays there is a farther distance between the place of production of the current foods and the place where they are eaten. This requires quality systems that can inspect the 100% of the food samples in a cheap and non-destructive way. Hyperspectral and 3D techniques are proposed in this thesis as a solution.

A review of the current state of art has been done for the different techniques to obtain three dimensions´ information as well as their uses in the food industry. Structured light (SL), stereo vision and time of flight (TOF) have been chosen as the best suitable. A comparison between SL and TOF for the in-line measurement of three animal foods and three vegetable foods has been done. The conclusion of this study is that both techniques are suitable to use having a mean R^2CV of 0.85 for TOF and 0.95 for SL for the volume estimation of the samples. SL techniques have been studied deeper solving the segmentation problem of detecting roots on potatoes. This is a difficult problem to solve using classic computer vision techniques due to the similar colors between the roots and the potatoes. This problem was solved doing an Adaboot model that classifies the 3D points of the cloud into roots or surface points using a 3D features vector for each point. The results achieved values of 94% in accuracy. Another problem solved was the assessment of grape cluster yield components based on 3D descriptors using stereo vision. Compactness is especially difficult to assess due its subjectivity. Currently, this quality component is evaluated by a group of experts following the method described in OIV volume 204. A semi-automatic method was developed to solve this problem using new 3D descriptors and a SVM model. A prediction value of R^2=0.8 was achieved for hundred bunches of ten different varieties.

With regard of hyperspectral techniques, a new methodology has been developed in order to get results from hyperspectral images. This methodology has been applied for solving three different problems. These problems were freshness assessment of different foods, understanding freshness as the level of degradation of the aliments since its initial quality. Currently, freshness assessment is done by a combination of destructive physic-chemical analyses. Freshness evaluation was performed using hyperspectral images in the range of SW-NIR to the following food: sliced chicken breast, cooked ham, cooked turkey and smoked salmon. The starting point was the basic use of the developed methodology to cooked ham and cooked turkey where a cross-validation results of R2 0.93 and 0.9 respectively were achieved. Time and spectra acquired were correlated using two PLS-DA models. The following practical case was conducted in chicken breasts freshness estimation, where the basic methodology was extended making a selection of the most important wavelengths using the

algorithm IPLSDA. They were reduced from 54 to 13 variables which made an improvement in the cross validation results from 0.77 to 0.85. It was also studied the possible influence of the film in the freshness estimation using hyperspectral analyses. It was found that the film only attenuates the intensity signal of the spectrum but it does not affect in the results. In the last case, it was determined when the smoked salmon was expired by hyperspectral imaging. This case was focused on the spatial segmentation phase where the spectra of lean tissue and fat tissue were obtained separately. This hyperspectral image is transformed into a 2D image in RGB using a calculated model of the hyperspectral system. Once transformed to 2D images, image segmentation was performed using a color based segmentation algorithm. A result of $R^2CV = 0.83$ was obtained with the proposed spatial segmentation. In this study, the requirement of a good spatial segmentation in the cases where samples are not homogeneous (like the salmon) was proven.

The main contribution of this thesis is the methodology developed for combining 3D and hyperspectral techniques for the food industry. The most important advantages using this new procedure are that the 3D techniques provide a high spatial resolution while the hyperspectral techniques offer a very good spectral resolution. In this work it is explained two of the many possibilities of using the developed methodology developed. In the first one, the fermentation process of flour mass was analyzed using 3D techniques. This 3D information was used to discriminate between supposedly equal flour (equals for the analysis performed in the industry) that behaved differently during fermentation. It was possible to predict this behavior from the hyperspectral information applying the methodology developed. The knowledge of this behavior is of great interest because it can be used to save money by grouping samples with similar fermentation times or selecting the best raw materials. The second case where the combination of techniques was researched and tested was based on taking advantage of the high spatial resolution obtained from the 3D techniques. Specifically, it was used in the segmentation stage when hyperspectral images of gilt-head were processed. The goal of segmentation based on the three-dimensional information was to obtain spectral information just from the fish eyes. Spectral information acquired from this area improved the estimation of freshness. It was obtained a cross-validation result of 0.844, correlating only the eyes spectra with time using a PLSDA model.

The development of these techniques may have a major impact on the food industry in the near future, as it represents a clear technological innovation in comparison with conducting destructive physical and chemical analyses on a subset of samples. These techniques allow the quality control and security of all the samples in a non-destructive way, thereby improving the quality, speed, safety, reliability and cost of numerous processes in the food industry.