Title A multispectral vision system to evaluate enzymatic browning in fresh-cut apple slices

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Abstract

The main objective of this study was to develop a vision system that is able to classify fresh-cut apple slices according to the development of enzymatic browning. The experiment was carried out on 'Granny Smith' apple slices stored at 7.5 °C for 9 days (n = 120). Twenty-four samples were analyzed per day: at zero time and after storage for 1, 3, 7 and 9 days, which corresponds to treatments t_0, t_1, t_3, t_7 and t_9 respectively. Multispectral images were acquired from the samples by employing a 3-CCD camera centered at the infrared (IR, 800 nm), red (R, 680 nm) and blue (B, 450 nm) wavelengths. Apple slices were evaluated visually according to a visual color scale of 1–5 (where 1 corresponds to *fresh samples without any browning* and 5 to *samples with severe discoloration*), to obtain a sensory evaluation index (I_{SE}) for each sample. Finally, for each sample and for each treatment, visible (VIS) relative reflectance spectra (360–740 nm) were obtained. In order to identify the most related wavelengths to enzymatic browning evolution, unsupervised pattern recognition analysis of VIS reflectance spectra was performed by principal components analysis (PCA) on the autoscaled data. Maximum loading values corresponding to the B and R areas were observed. Therefore, a classification procedure was applied to the relative histograms of the following monochromatic images (virtual images), which were computed pixel by pixel: (R − B)/(R + B), R − B and B/R. In all cases, a non-supervised classification procedure was able to generate three image-based *browning reference classes* (BRC): Cluster A (corresponding to the t_0 samples), Cluster B (t_1 and t_3 samples) and Cluster C (t_7 and t_9 samples). An internal and an external validation (n = 120) were carried out, and the best classifications were obtained with the (R − B)/(R + B) and B/R image histograms (internal validation: 99.2% of samples correctly classified for both virtual images; external validation: 84% with (R − B)/(R + B) and 81% with B/R). The camera classification was evaluated according to the colorimetric measurements, which were usually utilized to evaluate enzymatic browning development (CIE *L*a*b** color parameters and browning index, BI) and according to I_{SE}. For both validation phases *a**, *b**, BI and I_{SE} increased while *L** values decreased with image-based class number, thereby reflecting their browning state.