

Title Monitoring of fresh-cut spinach leaves through a multispectral vision system

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Citation Postharvest Biology and Technology, Volume 63, Issue 1, January 2012, Pages 74-84

Keywords RTU leafy spinach; Shelf life; Multispectral image; Image algorithm; Classification

Abstract

This paper reports the development of image processing methods for the detection of superficial changes related to quality deterioration in ready-to-use (RTU) leafy spinach during storage. The experiment was performed on spinach leaves stored at 4.5 °C for 21 days (Set 1) and at 10 °C for 9 days (Set 2). Regarding Set 1, 75 units were evaluated beginning at time zero and after 7, 14, and 21 days of storage (treatments $t_{1,0}$, $t_{1,1}$, $t_{1,2}$, and $t_{1,3}$, respectively). In the case of Set 2, 24 samples were measured at time zero and after 3, 6, and 9 days (treatments $t_{2,0}$, $t_{2,1}$, $t_{2,2}$, and $t_{2,3}$, respectively). Multispectral images were acquired using a 3-CCD camera centered at the infrared (IR), red (R), and blue (B) wavelengths. Opportune combinations of these bands were calculated using virtual images, and a non-supervised classification was performed. A large number of spinach leaves belonging to Set 2 showed injuries due to the effects of in-pack condensation; thus, an image algorithm was developed to separate these defective leaves before applying the classification. For Set 1, Set 2 and all the calculated virtual images, the classification procedure yielded two image-based deterioration reference classes (DRCs): Class A, including the majority of the samples belonging to $t_{1,0}$ and $t_{1,1}$ (Set 1) and to $t_{2,0}$ and $t_{2,1}$ (Set 2) treatments and Class B, which comprised mainly the samples belonging to $t_{1,2}$ and $t_{1,3}$ (Set 1) and to $t_{2,2}$ and $t_{2,3}$ (Set 2) treatments. An internal validation was performed, and the best classification was obtained with the virtual images based on R and B bands. For each sample, camera classification was evaluated according to reference measurements (visible (VIS) reflectance spectra and $CIE L^*a^*b^*$ coordinates); in all cases, VIS reflectance values corresponded well with storage days, and Classes A and B could be considered homogenous with regards to L^* and a^* values. Taken together, these results confirmed that a vision system based on R and B spectral ranges could constitute an easy and fast method to detect deteriorating RTU packed spinach leaves under different refrigeration conditions.