Melon Surface Color and Texture Analysis for Estimation of Soluble Solids Content and Firmness

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Purpose: The net rind pattern and color of melon surface are important for a high market value of melon fruits. The development of the net and color are closely related to the changes in shape, size, and maturing. Therefore, the net and color characteristics can be used indicators for assessment of melon quality. The goal of this study was to investigate the possibility of estimating melon soluble solids content (SSC) and firmness by analyzing the net and color characteristics of fruit surface.

Methods: The true color images of melon surface obtained at fruit equator were analyzed with 18 color features and 9 texture features. The partial least squares (PLS) method was used to estimate SSC and firmness in melons using their color and texture features.

Results: In sensing melon SSC, the coefficients of determination of validation (R_v^2) of the prediction models using the color and texture features were 0.84 (root mean square error of validation, RMSEV: 1.92 °Brix) and 0.96 (RMSEV: 0.60 °Brix), respectively. The R_v^2 values of the models for predicting melon firmness using the color and texture features were 0.64 (RMSEV: 4.62 N) and 0.79 (RMSEV: 2.99 N), respectively.

Conclusions: In general, the texture features were more useful for estimating melon internal quality than the color features. However, to strengthen the usefulness of the color and texture features of melon surface for estimation of melon quality, additional experiments with more fruit samples need to be conducted.

Keywords: Firmness, Fruit color feature, Fruit texture feature, Melon, Soluble solids content (SSC)

Introduction

Melon (Cucumis melo L.) is one of the most consumed crops with high marketability in the world. Internal quality of melon fruit is determined by complicated biochemical and developmental processes that result in changes in flavor, texture, and color (Li et al., 2006). Many researchers have studied assessment of melon fruit quality using various technologies: NIR spectroscopy, dielectric characteristics, multi-spectral imaging, and acoustic vibration. Guthrie et al. (2006) used near infrared spectroscopy for on-line assessment of soluble solids content of rockmelons. Nelson et al. (2006) studied the correlations between the dielectric properties of Honeydew melons and their soluble solids contents for nondestructive sensing of maturity. Sugiyama (2009) visualized sugar content of melons with spectral absorption images captured by a multi-spectral imaging system. Taniwaki et al. (2010) determined the ripeness of melons with their resonance frequency by an acoustic vibration. These technologies mainly measure physical and chemical attributes of internal flesh of fruits. Therefore, appearance features of fruits, which are also important factors to grade fruits, cannot be considered.

The rind of muskmelon fruits contains a network of suberized tissue, referred to as the ‘net’ (Keren-Keiserman et al., 2004). The net pattern is important for a high market value and therefore can be one of factors that determine melon quality. The net is a shallow, greenish, non-dried tissue that protrudes only slightly above the fruit surface in an immature stage. As it becomes mature, it changes to a dry, white material that extends above the fruit surface...
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Figure 1. Processing of fruit surface image: (a) color image, (b) binary image, and (c) net-rind-segmented image obtained by applying adaptive median filter to the binary image.

Materials and Methods

Melon samples
A total of 45 muskmelon (*Cucumis melo* L. var. *reticulates*) samples were obtained from a greenhouse in Naju, Korea during March through April in 2009. A set of fifteen melons was harvested on the 40th, 44th, and 52nd day after pollination, respectively. The melons were kept at room temperature (23°C) for 20h before measurements were started. The fruit weight and diameter were measured before taking images of fruit surfaces. The SSC and firmness were measured by a destructive method right after taking images of fruit surfaces.

Image acquisition system
A single charge coupled device (CCD) digital color camera (DFK-31BF03, Imaging Source, USA) with a zoom lens (F1.4 and focal lengths of 1-11 mm) was used to acquire melon surface images. A light chamber was illuminated uniformly with 12 circular fluorescent lamps. Each fruit sample was put in the light chamber manually. The surface images of a melon were acquired at evenly distributed 6 points on the fruit equator. The values of color and texture features that were obtained by analyzing the images were averaged and the mean values were used as the representatives of each sample. The acquired image was 1024 × 768 pixels that corresponded to the size of 4.5 × 3.5 cm on the surface of a melon.

Color feature analysis
The original color images captured by the CCD camera were transformed to the hue-saturation-intensity images which consisted of hue (H), saturation (S), and intensity (I) images. The true-color images were also divided into red (R), green (G), and blue (B) images. Otsu’s threshold method (Gonzalez and Woods, 2002) was applied to each R, G, B, H, S, I image to mask netted rind pixels of the melon surface images. After segmentation processing, adaptive median filter was applied to remove impulse noise that still existed in the segmented images (Fig. 1). Histograms of pixels in each image were plotted. The highest frequency in the histograms, the intensity value that showed the highest frequency, and the average intensity of pixels were calculated from each R, G, B, H, S, I image. Therefore, 18 color features were obtained from a true-color image. The mentioned image processing for color feature analysis was conducted using Matlab (Ver. 7.6, The MathWorks, USA) with the functions provided by Matlab Image Processing Toolbox (Ver. 6.1, The MathWorks, USA).

Texture feature analysis
The true-color images were transformed to the gray scale images. Through the Otsu’s threshold method and adaptive median filter used for color feature analysis, the gray scale images were processed to net-rind-segmented images. The ratio of the area of the net rind to the area of the