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Objective determination of pork marbling scores using the wide line detector

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ABSTRACT

Marbling is an important factor in evaluating pork quality and can be estimated by marbling scores based on the official marbling standards. The marbling score is normally assessed by experienced graders by comparing pork chops with the standardized chart system. In this paper, the potentials of automatic objective prediction of marbling scores were studied. The region of interest (ROI) of the marbling standards and the pork samples was automatically determined for marbling extraction. Marblings were regarded as kind of line patterns and thereby extracted by the wide line detector. Proportion of marblings (PM) was used for determinating the marbling score. The stepwise procedure was employed to select prediction models. A multiple linear regression equation was used as the initial model of the procedure and the PM of marbling standards at all three channels as potential variables. Three models were developed by the stepwise procedure with different first entry variable of the initial model. The multiple linear model obtained by the PM of marbling standards at all three RGB channels outperformed the two simple linear models respectively developed at the green and blue channels. The adjusted coefficient of determination (R^2) of the multiple linear model was 0.9992 and the root mean square error of leave-one-out cross-validation (RMSECV) was 0.0938. Forty pork loin samples were used to predict marbling scores. The prediction results of the three models showed that the prediction ability of the simple linear model developed at the blue channel was comparable with the multiple linear model.

1. Introduction

Marbling is the intermingling of fat with lean in the muscle and is regarded in some markets as an important attribute of the pork quality. Marbling in pork contributes to the juiciness and flavor of meat and may also have a positive effect on its tenderness (Jeremiah, 1998). The NPPC pork marbling standards of pork (NPB, 2002) depict seven grades from 1.0 (devoid) to 6.0 and 10.0 (abundant) which also represent an estimation of the intramuscular fat content of the loin eye muscle. In the pork meat industry, visual assessment of marbling scores is currently widely used. However, such subjective procedure is not easy and has poor repeatability in addition to the environmental factors that can also influence the grader.

Recently, some research works about objective marbling assessment has been reported for beef (Shiranita et al., 2000; Tan, 2004; Toraichi et al., 2002; Yoshikawa et al., 2000) and for pork (Faucitano et al., 2005; Qiao et al., 2007). Compared to beef, marbling in pork offers a lower color contrast against the lean meat, which makes its assessment more challenging. Faucitano et al. (2005) enhanced the color contrast of marbling in pork by a chemical pre-treatment and conducted the image analysis based on the preprocessed pork samples. They proposed several quantitative descriptions of marbling and focused their study on the relationship of marbling with intramuscular fat content and pork tenderness. Qiao et al. (2007), for the first time, formulated the marbling standards for objective assessment of marbling scores. Instead of detecting marbling in pork, they determined the marbling scores using image texture indices measured by angular second moment (ASM). In their work, a hyperspectral imaging system was built up to acquire the hyperspectral image data of pork samples. The image at wavelength of 661 nm was selected to estimate the marbling scores by calculating ASM of the selected region of interest. The results showed that the sorted results using ASM were between 3.0 and 5.0 for most pork samples, which were higher than that obtained subjectively with an error around 1.0. Furthermore, ASM differentiated the different marbling scores except the standard score of 10.0 which had the same ASM value as the score of 5.0. This strongly indicated that more work is needed to be done for the objective determination of pork marbling scores.

Marbling can indeed be regarded as kind of line patterns, i.e. lines with different widths. This suggests that marbling could be extracted by a line detection algorithm. Recently, Liu et al. (2007) proposed a wide line detector to completely extract a line. This line detector applied a nonlinear filter to extract a whole line, which made it insensitive to noise. Since no Gaussian kernel is used to detect lines, even narrow lines can be efficiently extracted as long as

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the intensity contrast between the narrow lines and the background is strong enough. Thus, the wide line detector can extract lines of different widths. This method has been successfully applied for palm line detection (Huang et al., 2008) and tongue crack extraction (Liu et al., 2008). Hence, it is of interest to apply the wide line detector to extract marbling in pork.

In this paper, we aimed to automatically determine pork marbling scores by modeling the pork marbling standards. The specific objectives were to extract marbling of pork marbling standards and pork samples using the wide line detector; to develop and validate linear models using the stepwise procedure based on the analysis of marbling standards; and further to estimate marbling scores of pork samples by the developed models and based on the results, to analyze the predictive abilities of the models.

2. Materials and methods

2.1. Samples and hyperspectral imaging system

Digital color images of marbling standards were obtained by scanning the NPPC official pork marbling standards with the resolution of 150 dpi (dot per inch) by Canon scanner, as shown in Fig. 1. The prediction models for pork marbling scores were developed based on the analysis of these digital marbling standard images.

The data used by Qiao et al. (2007) were employed in this study to investigate marbling score estimation. Forty fresh pork loin samples, ten of each of the RFN, PSE, PFN, and RSE quality group, were captured by a hyperspectral imaging system in a wavelength range of 400–1000 nm with a spectral resolution of 2.8 nm and a spot radius <9 μm. The details of the sample preparation and the hyperspectral imaging system can be found in Qiao et al. (2007). Sample image data at the visible wavelengths 720 nm, 580 nm, and 460 nm (RGB channels, respectively) were selected and used for all analysis. This was to ensure that the sample image data was comparable with the standard image data.

2.2. Image preprocessing

The purpose of image preprocessing was to segment the region of interest (ROI) from the peripheral and intermuscular fat as well as the connective tissue and surrounding muscles. Image preprocessing was conducted on marbling standards and hyperspectral images of pork samples to obtain the ROI for marbling detection. All operations in this section were performed using MATLAB 7.3.0 (The MathWorks, Inc., MA, USA).

The contour of marbling standards, referring to the outer boundary of meat, was obtained by using a thresholding technique and an edge detection algorithm. The thresholding technique (Jain, 1989) transforms a gray-level image (the green channel of marbling standards) to a binary image (i.e. black and white image). The grey-level of 200 was used as threshold (the range of gray-levels varies from 0 to 255). Pixels whose values are higher than the threshold are closed (set to 0), otherwise are open (set to 1). The obtained binary images of the marbling standards were used to extract the contour of marbling samples on these standards by employing the Sobel edge detector (Jain, 1989).

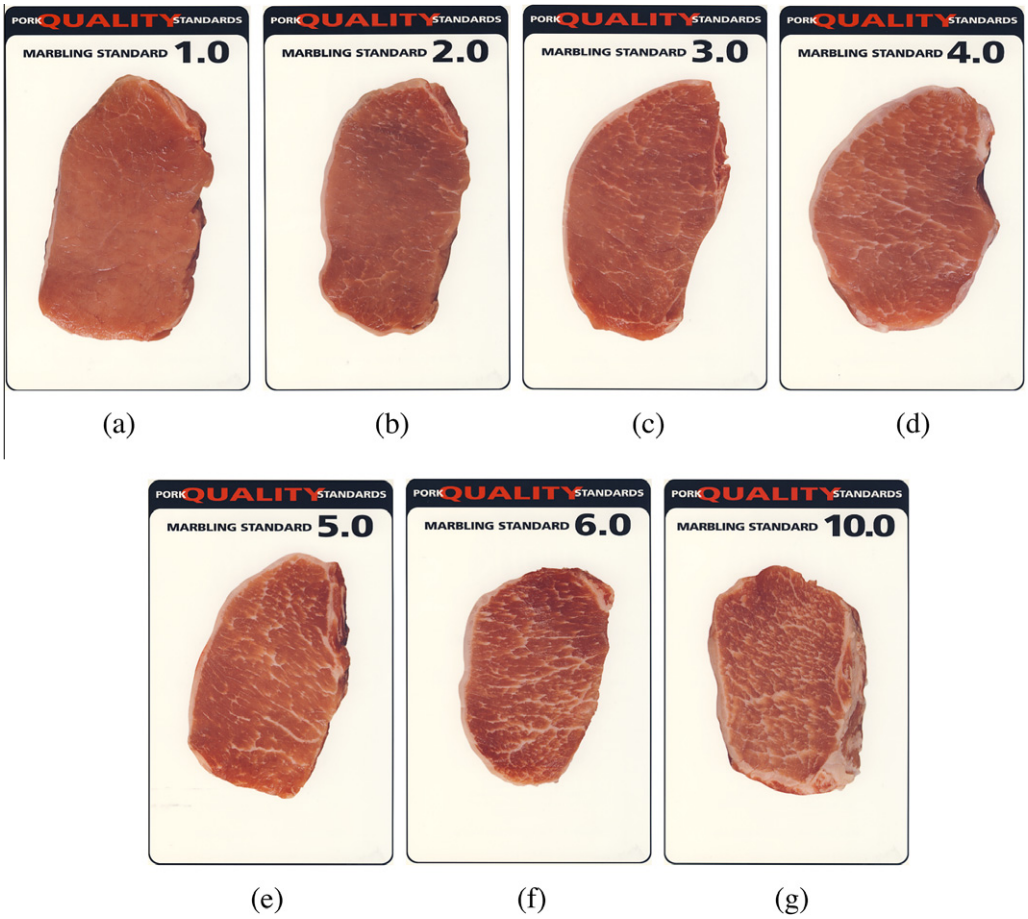

Fig. 1. Pork marbling standards.