Food Control 31 (2013) 224–229

Contents lists available at SciVerse ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

# Prediction of pork marbling scores using pattern analysis techniques

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ARTICLE INFO

*Article history:*
Received 17 April 2012
Received in revised form
17 September 2012
Accepted 25 September 2012

*Keywords:*
Pork
Marbling
Wide line detector
Multiple linear regression
Grey-level co-occurrence matrix

ABSTRACT

Marbling is an important technical quality attribute of pork. Its assessment usually corresponds to a subjective score being given by trained panelists based on the marbling standards charts. The purpose of this study was to investigate objective determination of pork marbling using pattern analysis techniques. A line pattern recognition technique called the wide line detector (WLD) and a texture extraction technique based on an improved grey-level co-occurrence matrix (GLCM) were employed and compared. Fifty three fresh pork loin chops from the longissimus dorsi (LD) muscle were collected and their marbling scores were assessed in a plant. Red-Green-Blue (RGB) images of these chops were acquired using a digital camera. The loin eye area was selected as the region of interest (ROI) of the pork images. Marbling was extracted from the ROI by either GLCM or WLD. Proportion of marbling (**PM**) obtained from WLD or image texture measurement from GLCM (**GI**) was formulated as indices of the marbling score. Linear regressions based on the **PM** and **GI** were carried out at the red, green, and blue channels as well as the combined RGB channels. The results of WLD and GLCM based models showed the effectiveness of pattern analysis techniques for pork marbling assessment. The comparison indicated that the WLD based models had stronger predictive ability for pork marbling score determination than GLCM. The green channel was demonstrated to have the best explanatory for pork marbling assessment no matter which pattern analysis technique used. High correlation coefficients of calibration and validation ($Rc = 0.94$, $Rv = 0.94$) of the WLD based linear model at the green channel strongly indicated the great potential of pattern analysis techniques especially the line pattern recognition methods for the accurate and real-time evaluation of pork marbling.



## 1. Introduction

Marbling is a visual attribute of meat that affects the acceptability and palatability of pork in market and is defined as the amount and spatial distribution of the visible fat within the longissimus dorsi (LD) muscle. In the pork industry, the evaluation of marbling mainly relies on subjective comparison with pork marbling standards or pictures such as those from National Pork Producers Council (NPPC) (NPB, 2002) and is carried out by an experienced employee. The NPPC marbling standards are pictures of pork samples containing low to high intramuscular fat content with standardized numerical marbling scores from 1.0 (devoid) to 10.0 (abundant). The visual assessment however leads to inconsistencies in pork quality of different companies, increases the labor cost, has low repeatability, and is easily influenced by environment. Therefore, more efficient and objective evaluation method for pork marbling determination would be useful for the pork industry.

In the past decade, research works related to marbling assessment of either beef or pork using machine vision approaches have been reported (Faucitano, Huff, Teuscher, Gariepy, & Wegner, 2005; Gerrard, Gao, & Tan, 1996; Liu, Ngadi, Prasher, & Gariépy, 2012; Qiao, Ngadi, Wang, Gariepy, & Prasher, 2007; Shiranita, Hayashi, Otsubo, Miyajima, & Takiyama, 2000; Tan, 2004; Toraichi et al., 2002; Yang, Albrecht, Ender, Zhao, & Wegner, 2006; Yoshikawa et al., 2000). In comparison with beef, evaluation of marbling in pork is more challenging not only due to the much more variable color of pork but also due to the paler color of the lean part and the attenuated contrast between lean and fat (Sun, 2008, p. 126). In order to enhance the color contrast between pork marbling and lean, a chemical pre-treatment was used in Faucitano et al. (2005) so that computer image analysis (CIA) was able to be conducted on the digital color pictures (i.e. Red-Green-Blue images) of the pre-processed pork samples. A group of CIA marbling variables was calculated and some of them (such as proportion of marbling fleck area (%), the number of marbling flecks/cm$^2$, the number of

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http://dx.doi.org/10.1016/j.foodcont.2012.09.034

marbling flecks, total length of marbling flecks (cm), and total marbling fleck area ($cm^2$)) were significantly correlated with intramuscular fat (IMF) content. Hyperspectral imaging technology was first introduced in Qiao et al. (2007) to evaluate pork quality and marbling scores. In this work, a texture pattern analysis technique called Grey-Level Co-occurrence Matrix (GLCM) was applied to assess pork marbling levels at the wavelength of 661 nm where a significant contrast image was obtained. The angular second moment (ASM) was exploited as the texture index of marblings. Results showed that the sorted marbling score based on the ASM value was about 1.0 higher than the subjective marbling scores. In addition, ASM differentiated samples in the range of marbling scores less than 5.0 but could not segregate the samples with scores of 5.0 and 10.0. Liu et al. (2012) regarded pork marbling as a line pattern and applied a line pattern recognition technique called the wide line detector (WLD) (Liu, Zhang, & You, 2007) for the marbling extraction. The proportion of marbling (**PM**) was obtained using the WLD on digital color pictures of NPPC standards and formulated as indices of marbling scores by multiple linear regression models. Experimental results demonstrated that the established multiple linear models successfully differentiated the marbling levels of NPPC standards over the entire range. Although leave-one-out cross-validation was used to assess the generalization of the predictive models in practice, model validation on an independent sample set with the reference data from fresh pork samples was absent in this work.

The overall objective of this work was to investigate the applications of different pattern analysis techniques for pork marbling evaluation. The specific objectives were to collect digital RGB images of fresh pork loin samples; to extract different image features, i.e. line pattern and image texture, using the WLD and the improved GLCM, respectively; to establish prediction model based on extracted image features; and to compare the performance of the WLD- and the GLCM-based models for prediction of pork marbling scores.

## 2. Materials and methods

### 2.1. Samples and image acquisition

Fresh boneless pork loins ($n = 53$) were obtained from a commercial packing plant in Quebec, Canada. A 2 cm thick chop was sliced from the mid portion of the Longissimus muscle and was exposed to air for a minimum of 15 min at 10 °C to allow blooming of the lean color. Marbling scores of the chop were assessed subjectively by two trained employees of the plant using the NPPC marbling standards (NPB, 2002) and the average value was used as the marbling score of the chop.

Following the subjective assessment of marbling, the RGB digital images of the chops were obtained using a NIKON D5000 digital camera with a predefined condition under a standardized environment. The spatial resolution of the camera was 300 dpi (dots-per-inch) × 300 dpi. Both surfaces of each chop were imaged for subsequent analysis.

### 2.2. Image preprocessing

The main task of image preprocessing was to select the region of interest (ROI), i.e. the loin eye area in this study. The loin eye area of each image was automatically selected by applying the image segmentation method presented in Liu et al. (2012). However, reflection points which were produced by the residual water on the chop surface were found in ROI and could affect the analysis results. In order to control the error caused by reflection points and keep the research as a single-factor study, the reflection points were removed from the ROI manually. The final ROI used in this study is the loin eye area without reflection points. All operations of image processing and data analysis in this study were performed using MATLAB 7.3.0 (The MathWorks, Inc., Mass., USA).

### 2.3. Feature extraction

After image prepossessing, image features were extracted from three channels (red, green, and blue) of RGB images for pattern analysis and measurement. In this study, two different feature extraction methods, i.e. the wide line detector (WLD) (Liu et al., 2012) and the gray-level co-occurrence matrix (GLCM) (Qiao et al., 2007), were employed to detect line patterns and image texture, respectively.

#### 2.3.1. Wide line detector

The WLD segmented marblings from ROI in each channel of the RGB image by detecting lines as

$$L(x_0,y_0;r,t) = \begin{cases} g - m(x_0,y_0;r,t), & \text{if } m(x_0,y_0) < g \\ 0, & \text{otherwise} \end{cases}, \tag{1}$$

$$m(x_0,y_0;r,t) = \sum_{x_0-r\le x\le x_0+r}^{y_0-r\le y\le y_0+r} s(x,y,x_0,y_0;r,t), \tag{2}$$

$$s(x,y,x_0,y_0;r,t) = \begin{cases} n(x,y,x_0,y_0;r), & \text{if } I_c(x_0,y_0) - I_c(x,y) \le t \\ 0, & \text{if } I_c(x_0,y_0) - I_c(x,y) > t \end{cases}, \tag{3}$$

$$n(x,y,x_0,y_0;r) = \begin{cases} 1/\pi r^2, & \text{if } (x-x_0)^2 + (y-y_0)^2 \le r^2 \\ 0, & \text{otherwise} \end{cases}, \tag{4}$$

where $(x_0,y_0)$ is the center of the circular neighborhood, $(x,y)$ is any other point within the neighborhood, $I_c(x,y)$ is the intensity of the point $(x,y)$ in the channel c, $r$ is the radius of circular mask, $t$ is the intensity contrast threshold. $s$ is the normalized weighting comparison based on the measure of similarity between the center point and any other point in the circular neighborhood, and $m$ is the mass of the neighborhood center $(x_0,y_0)$. $g$ is the geometric threshold and was set to 0.5 in this study. The output of the WLD was the isotropic line response $L$ with the range of 0–0.5. A global threshold ($l$) was used for image post-processing to remove objects with lower $L$. Therefore, three parameters involved in the WLD based feature extraction, i.e. the radius of circular mask ($r$) which determines the maximum width of marblings can be detected, the intensity contrast threshold ($t$) which defines the minimum visibility of marblings can be detected, and the global threshold ($l$) which controls the noise level in the detected marblings.

The proportion of marblings (**PM**) was used as image feature index to measure marbling scores, which was defined as

$$\text{PM} = \frac{\text{area(marblings)}}{\text{area(ROI)}}, \tag{5}$$

where area(marbling) is the total number of pixels of detected marbling, and area(ROI) is the total number of pixels of the corresponding ROI. The principle behind the calculation of **PM** is comparable to human vision scaling marbling with respect to the lean background.

#### 2.3.2. Improved GLCM

The image texture indices of pork samples were derived from the grey-level co-occurrence matrix (GLCM) which was created