LWT - Food Science and Technology 60 (2015) 649–655

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Combination of spectra and texture data of hyperspectral imaging for differentiating between free-range and broiler chicken meats

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ARTICLE INFO

Article history:
Received 8 August 2014
Received in revised form
1 October 2014
Accepted 5 October 2014
Available online 19 October 2014

Keywords:
Non-destructive
Hyperspectral imaging
Chicken meat
GLGCM
Support vector machine

ABSTRACT

This study investigated the potential of visible and near infrared (Vis/NIR) hyperspectral imaging (HSI) to differentiate between free-range and broiler chicken meats. 120 hyperspectral images of chicken fillets were acquired and then calibrated for reflectance. Spectral data were extracted from the region of interest (ROI), followed by multiple scatter correction (MSC) to reduce the noise. Successive projection algorithm (SPA) was used to select optimal wavelengths from the full spectra. On the other hand, principal component analysis (PCA) was applied to select optimum characteristic images, and the first two principal component (PC) images were selected because PC1 and PC2 explained over 95% of variances of all spectra. Then, gray-level gradient co-occurrence matrix (GLGCM) was implemented on PC1 and PC2 images to extract 30 textural variables in total. Based on data fusion, classification models were established, in which the radial basis function-support vector machine (RBF-SVM) model gave the best results with high correct classification rate (CCR) of 93.33% for the prediction samples, demonstrating that combining spectra with texture data were effective for differentiating between free-range and broiler chicken meats.

1. Introduction

Quality control is very important, therefore techniques used in the agri-food industry such as drying (Delgado & Sun, 2002; Sun, 1999; Sun & Byrne, 1998; Sun & Woods, 1997), cooling (Wang & Sun, 2001), freezing (Delgado, Zheng, & Sun, 2009) and edible coating (Xu, Chen, & Sun, 2001) can be used to enhance food product quality. In the meat industry, discrimination or classification is one of the critical quality control stages. However, in the meat industry, quality classification and control is mainly performed based on traditional methods, which are tedious, laborious and costly (Cen, Lu, Ariana, & Mendoza, 2014; Kamruzzaman, ElMasry, Sun, & Allen, 2011; Wei, Liu, Qiu, Shao, & He, 2014). Accordingly, the modern meat industry seeks rapid, accurate, and non-destructive methods for fast evaluation of meat and meat products.

Hyperspectral imaging (HSI) is an emerging, non-destructive, and reliable technique, which integrates the merits of computer vision (Costa et al., 2011; Jackman, Sun, Du, & Allen, 2008; Sun, 2004; Valous, Mendoza, Sun, & Allen, 2009) and spectroscopy (Wu & Sun, 2013; Xiong, Sun, Zeng, & Xie, 2014). Hyperspectral images, also called "hypercube", are saved in a three-dimensional (x, y, λ) form, where (x, y) represents spatial information and λ represents spectral information in the images (ElMasry, Barbin, Sun, & Allen, 2012; Xiong, Xie, Sun, Zeng, & Liu, 2014). If these spatial and spectral information are properly analyzed, not only physical/chemical characteristics of tested objects but also their spatial distributions can be determined (Naganathan et al., 2008; Wu et al., 2012; Wu et al., 2013; Xiong, Sun, Dai, Han, Zeng, & Wang, 2014; Zhu, Zhang, Shao, He, & Ngadi, 2014). Therefore, there is a great interest to work on HSI systems for quality classification of meat and meat products (ElMasry, Iqbal, Sun & Allen, 2011; ElMasry, Sun, & Allen, 2011; ElMasry, Sun, & Allen, 2012; Kamruzzaman et al., 2011; Kamruzzaman, ElMasry, Sun, & Allen, 2012). Recently, HSI has been successfully applied in quality classification of contaminated chicken carcasses (Chao, Yang, Chen, Kim, & Chan, 2007; Chao, Yang, Kim, & Chan, 2008; Park, Lawrence, Windham, & Smith, 2006), grading and classification of pork (Barbin, Elmasry, Sun, & Allen, 2012; Jun et al., 2007; Pu, Sun,

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http://dx.doi.org/10.1016/j.lwt.2014.10.021
0023-6438/

Ma, Liu, & Cheng, 2014), discrimination of lamb muscles (Kamruzzaman et al., 2011), and differentiation between fresh and frozen-thawed fish (Sone, Olsen, Sivertsen, Eilertsen, & Heia, 2012; Zhu, Zhang, He, Liu, & Sun, 2013). However, most of these studies only utilized spectral data for modeling without incorporating information on spatial data, which is also important for predicting quality characteristics of meat and meat products (Kotwal & Chaudhuri, 2013). In order to fully explore the spatial and spectral advantages of HSI, several authors (Huang, Zhao, Chen, & Zhang, 2013; Liu, Pu, Sun, Wang, & Zeng, 2014; Pu et al., 2014; Zhu et al., 2013) have investigated the feasibility of data fusion to improve the performance of hyperspectral prediction models. For example, spectral and image variables were extracted from hyperspectral images and were then integrated by feature level fusion for rapid prediction of pH in salted meat (Liu, Pu, et al., 2014), and the result showed that the partial least squares regression (PLSR) model based on data fusion was better than that based on spectral or image variables alone. In terms of quality classification, Zhu et al. (2013) combined spectra and texture data to differentiate between fresh and frozen-thawed fish. The least squares-support vector machine (LS-SVM) classification model established based on data fusion yielded the best prediction results with the highest average correct classification rate (CCR) of 97.22%. These studies demonstrated that HSI combined with data fusion would be more useful for non-destructive analysis and predictions.

Chicken meat is an important meat product in people's daily life as it can provide abundant protein, fat and trace elements. The quality of chicken meat can be influenced by factors like breed, sex, slaughter weight, feed types and level of feeds, age, and pre-slaughter stress (Feng & Sun, 2013a). According to the feed types and level of feeds, chicken meat can be sorted into free-range and broiler chicken meats. Free-range chicken refers to those chicken carcasses that are raised in the woodland or orchard, and its breeding period is usually long (about 6 months). Oppositely, broiler chicken, also called commercial chicken, is raised in captivity and its breeding period is relatively short (about 3 months) in order to satisfy the large consumption of the market (Niu et al., 2002). Compared with broiler chicken, free-range chicken has desirable properties such as suitability to surroundings, high disease resistance, good reproductive capacity. In addition, free-range chicken meats are more delicious, nutritious, and thus more popular with consumers (Niu et al., 2002). As free-range chicken meats are more valuable for the consumer than broiler chicken meats, rapid and accurate discrimination of free-range and broiler chicken meats is of significance for pricing, authentication and categorization of chicken meats. Recently, many studies have been carried out in determining quality characteristics of chicken meat by HSI (Feng et al., 2013; Feng & Sun, 2013b; Kandpal, Lee, Kim, Mo, & Cho, 2013; Lin & Quansheng, 2013), however most of these studies only utilized spectral data without incorporating

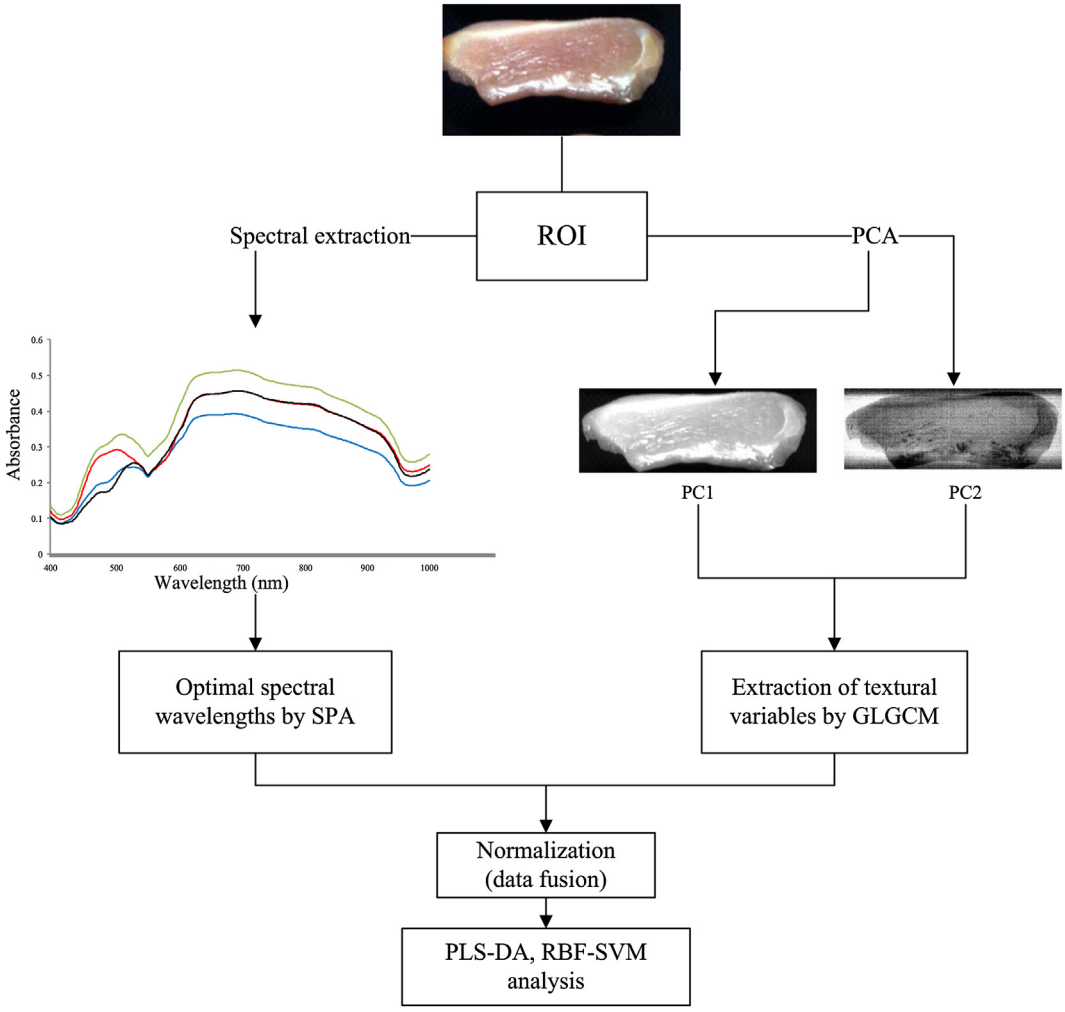

Fig. 1. Flowchart of main steps in data fusion analysis for differentiation between free-range and broiler chicken meats.