Food Chemistry 168 (2015) 554–560

Contents lists available at ScienceDirect

Food Chemistry

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

Analytical Methods

Prediction of chicken quality attributes by near infrared spectroscopy

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ARTICLE INFO

Article history:
Received 14 November 2013
Received in revised form 14 June 2014
Accepted 21 July 2014
Available online 30 July 2014

Keywords:
Pale poultry muscle
PSE
Partial least squares regression
NIR
Classification

ABSTRACT

In the present study, near-infrared (NIR) reflectance was tested as a potential technique to predict quality attributes of chicken breast (*Pectoralis major*). Spectra in the wavelengths between 400 and 2500 nm were analysed using principal component analysis (PCA) and quality attributes were predicted using partial least-squares regression (PLSR). PCA performed on NIR dataset revealed the influence of muscle reflectance (L^*) influencing the spectra. PCA was not successful to completely discriminate between pale, soft and exudative (PSE) and pale-only muscles. High-quality PLSR were obtained for L^* and pH models predicted individually (R^2_{CV} of 0.91 and 0.81, and SECV of 1.99 and 0.07, respectively). Water-holding capacity was the most challenging attribute to determine (R^2_{CV} of 0.70 and SECV of 2.40%). Sample mincing and different spectra pre-treatments were not necessary to maximise the predictive performance of models. Results suggest that NIR spectroscopy can become useful tool for quality assessment of chicken meat.

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1. Introduction

Poultry meat is considered an important component in healthy diets and has reached high levels of consumption worldwide (Alexandrakis, Downey, & Scannell, 2012). Therefore, there is a growing demand for poultry quality assessment and control. Quality of chicken meat is associated to physical and chemical traits usually assessed in the breast (*pectoralis major*) muscle. PSE (pale, soft and exudative) condition has been previously reported in poultry, with biochemical factors affecting the colour, pH and water-holding capacity of poultry meat. Several investigations have described chicken breast meat that appears lighter than normal with lower ultimate pH and water-holding capacity, leading to adoption of the PSE term for this particular poultry muscle defect (Smith & Northcutt, 2009; van Laack, Liu, Smith, & Loveday, 2000; Wilhelm, Maganhini, Hernandez-Blazquez, Ida, & Shimokomaki, 2010; Zhang & Barbut, 2005). Breast meat with low ultimate pH is linked to lower tenderness scores than meat with high ultimate pH (Droval et al., 2012).

In reality, the primary feature used to differentiate broiler muscle for the PSE defect is pale colour. However, colour alone is not a useful indicator of PSE in broiler breast meat, since broiler chickens may not exhibit a true PSE condition, leading to the proposition of the term 'pale poultry muscle syndrome' (Smith & Northcutt, 2009). In this sense, determining each of these physical and chemical attributes independently may be advantageous in order to proper classify chicken meat according to quality features.

Traditional analytical methods are usually destructive, requiring lengthy sample preparation procedures and therefore not applicable to the highly increasing fast paced industrial meat sector. Recently, novel techniques have been investigated for fast, reliable and reagent-less meat quality assessment. Near-infrared (NIR) spectroscopy has emerged as an efficient and advanced tool to provide information about physical and chemical properties of complex organic matrices, being applied as a process analytical technology (PAT) for continuous monitoring and control of process and product quality in the food processing industry (Alexandrakis et al., 2012; Osborne, Fearn, & Hindle, 1993).

The dominant information present in NIR spectra arises from vibrations from overtone and combination bonds in molecular groupings such as O–H, N–H, C–H and S–H, which are typically very broad, making it a complex task to identify detailed structure and to assign individual features from specific chemical components (Alexandrakis et al., 2012; Park, Chen, Hruschka, Shackelford, & Koohmaraie, 2001).

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http://dx.doi.org/10.1016/j.foodchem.2014.07.101
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Meat processing industry could benefit from a system that can predict variations in single attributes or even classify samples according to quality features. Near infrared reflectance (NIR) spectroscopy in the wavelength range between 1100 and 1830 nm was evaluated as at-line technique to predict fatty acids in chicken breast directly at the slaughterhouse. However, results obtained were not satisfactory (De Marchi, Riovanto, Penasa, & Cassandro, 2012). Prediction of physical and colour characteristics of intact chicken breast were investigated using the visible and near-infrared (NIR) (350–1400 nm). Partial least squares regressions were performed to correlate spectral data with analytical values of (pH); lightness (L^*), redness (a^*), and yellowness (b^*); thawing and cooking losses and shear force after freezing. It has been reported that models with only average prediction ability were obtained for pH, L^*, and thawing and cooking losses, with correlation coefficients (r_{cv}) varying in the range of 0.69–0.76 (De Marchi et al., 2011).

These results are encouraging, nevertheless should be improved in order to be confidently utilised by the meat industry for practical applications. The near-infrared spectral region (800–2500 nm) consists of overtones and combination bands of the molecular absorptions found in this range. Therefore, the near-infrared range could be advantageous by rendering a more detailed discrimination compared to spectral information in the visible range. Selecting a few essential wavelengths related to the chemical information is particularly useful in spectral analysis. This procedure drastically reduces the amount of data to be analysed and therefore is a significant step for further application on multispectral systems (Barbin, ElMasry, Sun, & Allen, 2012).

The main objective of the present study was to investigate the potential of using NIR spectroscopy technique as a fast and robust method to predict chicken quality attributes and classify chicken breasts accordingly. Specific objectives were to (1) establish the most adequate procedure of sample preparation for chicken meat analysis in NIR spectroscopy, (2) to study whether spectral pre-processing methods can improve robustness of the prediction models for this particular application, (3) to investigate the influence of samples from different qualities in the spectral dataset acquired, (4) to build robust PLS-R calibration models to quantitatively relate spectral information and quality attributes, (5) to identify the most significant wavelengths linked to the physicochemical attributes and testing the accuracy of prediction models using only selected wavelengths to predict chicken quality features.

2. Materials and methods

2.1. Sample preparation

Slaughtered poultry breast fillets were acquired from a local processing plant in two batches ($n_{\text{total}} = 158$ samples) and transported under refrigeration to the Laboratory of Food Science at UEL, Londrina-PR, Brazil, for further analysis, within 5 h after slaughter (Ding, Xu, & Chan, 1999). Samples were selected by an experienced grader in order to encompass as large variation in quality features as possible. Breast meat cuts (middle part of *pectoralis major* muscle) were carefully trimmed with a surgical scalpel to fit into a sample cell (ring cup). After acquiring NIR spectra for the samples, samples were minced using a kitchen chopper for 10 s. NIR spectra were then acquired for minced meat samples. Near-infrared spectra were collected and analysed according to the procedures described below (Sections 2.4 and 2.5).

2.2. Analytical measurements

Chicken quality attributes were measured at 48 h post-mortem, since it is within this time that most of the biochemical changes in meat take place (Brad Kim, Warner, & Rosenvold, 2014; Lawrie & Ledward, 2006). After a 30 min blooming period, ultimate pH values were measured on chicken breasts post-mortem using a Testo 205 (Testo AG, Lenzkirch, Germany); 2 measurements were taken for each sample and averaged before statistical analysis. Colour determination was obtained as the average of 4 consecutive measurements at random locations of breast samples using a Minolta colorimeter (CR 400, D65 illuminant and 10° observer, Konica-Minolta Sensing Inc., Osaka, Japan) after calibration with a standard ceramic tile. Colour was expressed in terms of values for lightness (L^*), redness (a^*), and yellowness (b^*) using the Comission Internationale de l'Eclairage (CIE) colour system (CIE, 1978; Honikel, 1998). In addition, chroma ($(a^{*2} + b^{*2})^{1/2}$) was also calculated, as it has been shown that chromaticity can change due to differences in quality (Norman, Berg, Heymann, & Lorenzen, 2003).

Water holding capacity was performed according to Hamm (1960), based on meat water loss when pressure is applied on the muscle. Meat cubes weighing 2 g were laid between two filter paper circles placed on acrylic plates, on which a 10 kg weight was put for 5 min, with the samples then removed from the filter papers, and weighted. Water loss was calculated as the difference between initial and final weight. Results were expressed as the percentage of drip loss relative to initial sample weight. Shear force was assessed on 5 cores (1 cm cross section) of each sample using a texture analyser (model TA-XT2i, Instron, Massachusetts, USA) with a Warner–Bratzler shear force blade (Honikel, 1998).

2.3. Sample classification

Based on colour reflectance, ultimate pH and water holding capacity, the samples were pre-classified into three different quality grades, namely PSE ($L^* > 53$, pH < 5.8), DFD ($L^* < 46$, pH > 6.1), and normal ($46 < L^* < 53$, pH > 5.8). Values are based on information adapted from Barbut, Zhang, and Marcone (2005) and Droval et al. (2012), indicating that samples within these ranges represent the 3 categories.

2.4. Near-infrared spectroscopy

Spectral data were collected in reflectance mode and recorded as absorbance ($\log 1/R$) using a XDS Near-Infrared model XM 1100 series – Rapid Content Analyser (Foss NIRSystems, Denmark) over the wavelength range 400–2498 at 2-nm intervals. Between samples, the sample cell analytical surface was washed with ethanol (70% v/v), rinsed with distilled water and dried using soft paper tissue. Spectra were acquired from fresh samples and minced samples in order to establish the most adequate procedure for sample preparation.

2.5. Spectral statistical analysis

2.5.1. Spectra pre-processing methods

In NIR measurements, sample physical characteristics and inconsistence in instrument response may be responsible for perturbations in spectra (baseline, shifts, slope changes, etc), generating spectral variations that are not related to the studied responses and affecting the reliability of multivariate calibration models. Since wavelength dependency of light scatter is different from that of chemically based light absorption, scattering effects can be attenuated by some mathematical treatments such as derivation, Multiplicative Scatter Correction (MSC) and Standard Normal Variate (SNV) (Fearn, Riccioli, Garrido-Varo, & Guerrero-Ginel, 2009; Isaksson & Næs, 1988). Both first and second derivatives have been used for removing baseline shifts and separating superposed peaks, but the second derivatives have been a more common choice in recent studies, probably because they have inverse peaks at the

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