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Application of near infrared spectroscopy for grading and classification of chicken meat

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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). 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. Results suggest that NIR spectroscopy can become useful tool for quality assessment of chicken meat.**

1. INTRODUCTION

Poultry meat is considered an important component in healthy diets and has reached high levels of consumption worldwide, demanding strict quality assessment (1). 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 (2, 3). 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' (4). 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.

Recently, near-infrared (NIR) spectroscopy has emerged as an efficient and advanced tool to provide information about physical and chemical properties of complex organic matrices (1, 5). Prediction of physical and colour characteristics of intact chicken breast were investigated using the visible and near-infrared (NIR) (350 to 1400 nm). 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 to 0.76 (6). These results are encouraging, nevertheless should be improved in order to be confidently utilized by the meat industry for practical applications.

The main objective of the present study was to investigate the potential of using NIR spectroscopy technique as a fast and robust method to classify chicken breasts according to quality characteristics.

2. MATERIALS AND METHODS

2.1. Sample preparation

Slaughtered poultry breast fillets (n_{total} = 158 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 10s. NIR spectra were then acquired for minced meat samples. Near-infrared spectra were collected and analyzed according to the procedures described below (sections 2.4 and 2.5).

2.2. Analytical measurements

Chicken quality attributes were measured at 48h post-mortem. After a 30 minute 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 (7). In addition, chroma $((a^{*2} + b^{*2})^{1/2})$ was also calculated. Water holding capacity was performed according to Hamm (8), based on meat water loss when pressure is applied on the muscle.

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 *et al.*, (9) and Droval *et al.* (10), 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 400–2,498 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. PCA

PCA was applied to the spectral information obtained from the samples as a preliminary step to investigate main attributes affecting the spectral data. All steps described for spectral analysis were carried out in multivariate analysis software (Unscrambler version 9.7, CAMO, Trondheim, Norway).

3. RESULTS AND DISCUSSION

3.1. Quality characteristics of chicken breasts

Table 1 summarizes the variations in colour (L^*, a^*, b^*, chroma), pH, water-holding capacity of tested chicken breast.

Table 1. Experimental results for quality attributes of the tested chicken samples

Quality attribute	Min	Max	Mean±SD
L^*	43.53	67.53	57.27 ± 6.46
a^*	-1.38	7.60	1.33 ± 1.32
b^*	-2.64	14.66	4.48 ± 4.79
Chroma	0.09	14.73	5.33 ± 4.25
pH	5.62	6.43	5.95 ± 0.16
WHC (%)	57.90	77.44	66.07 ± 4.39

The quality feature results suggested the presence of a wide range of variation in these attributes, including different quality grades among samples, with extreme values for instrumental measurements. It has been previously reported a wide range of values for L^* in chicken samples influenced by several factors. All the results are in accordance with previous studies (4,6).

Based on colour reflectance, ultimate pH and water-holding capacity results, and with the aid of thresholds outlined, experimental chicken samples were conventionally classified into PSE (24 samples), normal (38 samples) and DFD (7 samples). It was also observed the occurrence of samples that had high values for *L**, with pH values higher than 5.8 (89 samples). These samples were classified as pale chicken muscle, according to Smith and Northcutt (4). This pre-classification was a crucial step for spectral data analysis and for comparison between the conventional and spectroscopic methods. Since this correlation between quality attributes is not mandatory, predicting the quality attributes individually could aid the identification and classification of samples where these attributes are not correlated. In this sense, it would be beneficial to verify whether these quality attributes could be predicted simultaneously by spectral information acquired from samples.

3.2. Spectral characteristics of chicken samples

Spectral data were analyzed by PCA carried out with a full (leave-one out) cross-validation to search for linear combinations of variables which best explain the data without taking into account any external information.

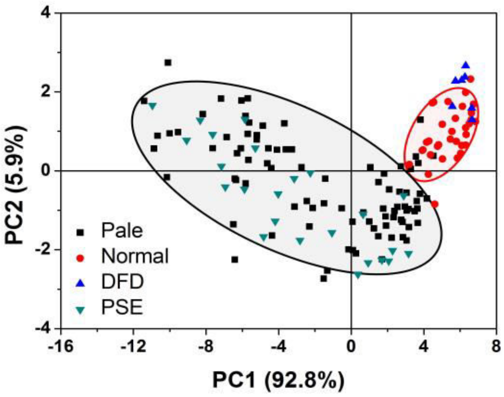

Figure 1. Score plot of the first two principal components for spectral data of chicken samples.

The first three principal components were responsible for 99.3% of the total variance among the examined samples. The scores plot of the first two principal components shown in Figure 1 indicated that chicken classes had different spectral patterns and can be distinguished into separate classes. Two distinct clusters can be observed, meaning that the profiles of objects in the same cluster are very similar and the profiles of objects in different clusters are distinct. It was observed that these principal components are related mainly to the colour reflectance (*L**) values of the samples.

The clusters are represented by the normal and dark chicken samples in the positive region of PC1 and PC2, with pale samples scattered in a wider area. Pale samples with normal pH values were mixed with PSE samples, indicating that pH values did not influence the scores in the first two PCs. This observation confirms the benefit of predicting individual quality features of chicken samples for accurate classification. Also, DFD samples are positioned in the edge of the cluster of normal samples, opposite to the location of the cluster of pale samples, confirming the difference between these quality grades. The region around the edge between normal and pale samples clusters are somewhat overlapped, with some pale samples mixed in the normal samples cluster.

Figure 2 shows the average reflectance spectra of the normal, dark and pale chicken samples.

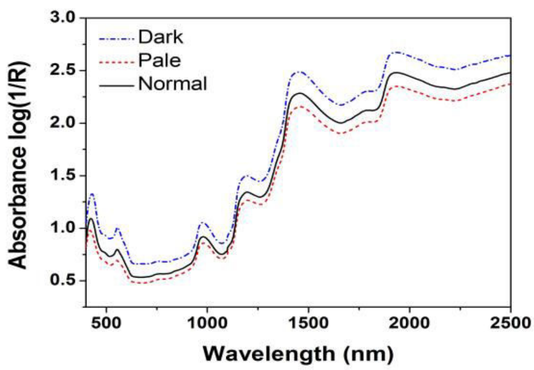

Figure 2. Average spectra for dark, normal and pale chicken samples.

Although the spectral information extracted has a similar spectral pattern, it shows different absorbance values for each chicken quality grade. It was observed that normal chicken samples had higher absorbance values (lower reflectance) than pale samples, while dark samples had highest absorbance values throughout the spectral range.

The difference observed in the visible range of the electromagnetic spectrum could be attributed to the difference in colour between the samples, as the dark samples present lower reflectance values. The difference in reflectance among chicken grades could be ascribed to sample composition in the NIR electromagnetic range.

A few broad local absorption maxima are noticeable around 980, 1,190, 1,460 and 1,950 nm; absorption at these wavelengths correspond to O-H, C-H, N-H stretch first and second overtones and combination bands that could be attributed to water absorption and protein changes (1,5). In depth scrutiny of absorbance related to each chemical vibration bond could also help in better understanding of how each quality parameter affects spectral fingerprints of chicken samples.

4. CONCLUSION

The results emphasized that the visible and NIR spectral information has the potential to classify chicken samples according to paleness without any background of physicochemical information. Distinctive spectral difference among chicken grades could be explained in various wavelengths in visible and NIR range of the spectra. These identified wavelengths are related to water and other chemical components of the samples.

This study revealed the potential of NIR spectroscopy for fast assessment of chicken quality features. The technique can be implemented as a key component of computer-integrated manufacturing in the poultry industry, offering a number of potential advantages, including the creation of product data in a real time for documentation, traceability, and labelling.

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