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Prediction of texture and colour of dry-cured ham by visible and near infrared spectroscopy using a fiber optic probe

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Abstract

The potential of visible and near infrared spectroscopy to predict texture and colour of dry-cured ham samples was investigated. Sensory evaluation was performed on 117 boned and cross-sectioned dry-cured ham samples. Slices of approximate thickness 4 cm were cut, vacuum-packaged and kept under frozen storage until spectral analysis. Then, *Biceps femoris* muscle from the thawed slices was taken and scanned (400–2200 nm) using a fiber optic probe. The exploratory analysis using principal component analysis shows that there are two ham groups according to the appearance or not of defects. Then, a K nearest neighbours was used to classify dry-cured hams into defective or no defective classes. The overall accuracy of the classification as a function of pastiness was 88.5%; meanwhile, according to colour was 79.7%. Partial least squares regression was used to formulate prediction equations for pastiness and colour. The correlation coefficients of calibration and cross-validation were 0.97 and 0.86 for optimal equation predicting pastiness, and 0.82 and 0.69 for optimal equation predicting colour. The standard error of cross-validation for predicting pastiness and colour is between 1 and 2 times the standard deviation of the reference method (the error involved in the sensory evaluation by the experts). The magnitude of this error demonstrates the good precision of the methods for predicting pastiness and colour. Furthermore, the samples were classified into defective or no defective classes, with a correct classification of 94.2% according to pasty texture evaluation and 75.7% as regard to colour evaluation.

Keywords: Dry-cured ham; Pastiness; Colour; Visible and near infrared spectroscopy

1. Introduction

The development of screening methods for fast classification of meat quality is demanded by the industry. Near infrared spectroscopy (NIRS) has shown to be a rapid and effective tool for meat quality assessment (Monin, 1998). It is an easy to use, non-destructive, accurate and robust technique which allows determination of several parameters simultaneously. NIRS has been successfully used for determining food components much as fat, moisture and protein content in the last two decades (Brøndum et al., 2000; Hildrum, Ellekjær, & Isaksson, 1995a; Wählby & Skjöldebrand, 2001; Williams & Norris, 1987). Its use has until recently been restricted to off-line measurements, but on-line NIR instruments have frequently been used in the last few years (Isaksson, Nilsen, Tøgersen, Hammond, & Hildrum, 1996; Schwarze, 1996; Tøgersen, Isaksson, Nilsen, Bakker, & Hildrum, 1999). Moreover, NIRS is used in other and more complex applications much as the evaluation of sensory characteristics of meat. This is because instrumental techniques like Warner

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Bratzler shear force, Hunter colour measurement and sensory evaluation – the usual techniques for meat quality assessment – are destructive, time consuming and unsuitable for on-line application. Thus, the prediction of beef sensory attributes such as tenderness using NIRS has been extensively reviewed (Byrne, Downey, Troy, & Buckley, 1998; Hildrum, Nilsen, Mielnik, & Næs, 1994; Liu et al., 2003; Liu, Venel, Mullen, Downey, & Troy, 2001; Park, Chen, Hruschka, Shackelford, & Koohmaraie, 1998; Rødbotten, Mevik, & Hildrum, 2001). Prediction of pork quality using models based on NIRS has been reported less extensively. However, there are some contributions on the usefulness of NIR to predict pork quality attributes (Geesink et al., 2003); drip-loss, and water-holding capacity in fresh pork (Brøndum et al., 2000; Forrest et al., 2000) and to determine the RN^- phenotype in pigs, based on the fact that this character is associated with production of inadequate meat for cured and cooked ham (Josell, Borggaard, & Andersen, 2001; Josell, Martinsson, Borggaard, Andersen, & Tornberg, 2000).

Considering the lack of information on the use of NIRS to predict sensory quality of cured product from pigs, the objective of this study was to investigate the feasibility of visible and NIR spectroscopy for the classification of dry-cured hams as a function of their texture and colour evaluation. Furthermore, in order to facilitate the use of NIRS for process quality control in the meat industry, an NIR instrument fitted with a fiber optic probe was used. This assembly is supposed to be appropriate to obtain spectra directly from the muscle without any sample pre-treatment.

2. Materials and methods

2.1. Samples

Hams were obtained from a total of 117 pigs that were slaughtered in five pig killings distributed along one year. They were provided by five suppliers that used different crosses including Duroc, Landrace and Large White. The duration of the post-mortem period was 3–5 days and then hams were subjected to the traditional process for producing Spanish dry-cured ham that involves treatment of the raw ham with curing salts ($NaNO_2$ and KNO_3), followed by standing, salt-coated, at 2–3 °C for about 0.8 day/kg green ham. Subsequently, the ham is allowed to mature at 4–18 °C at a relative humidity (RH) of 70–80% for 6 months, followed by 25–30 °C at 80% RH for 4 months and finally at 12–15 °C at 80% RH for 3 months.

2.2. Sensory evaluation

The sensory evaluation of the product, at the end of the curing process, was aimed at detecting the incidence of pastiness and colour defects. One hundred and seventeen dry-cured hams were boned and cross-sectioned about 5 cm below the hip bone. Two expert judges from the ham manufacturing industry (specialized expert judges, as defined by ISO 8586-2:1994 (1995) that is, technicians specialized both in the curing process and detection of anomalous sensory properties in dry-cured ham) assessed the sensory properties of dry-cured ham on cross-sectioned surfaces. Thus, experts evaluated pastiness and colour. Pastiness is a textural defect which involves a lack of elasticity on pressing gently on the zone concerned, abnormal softness, an oily touch in the zone concerned and intense adhesiveness in some cases (Parolari, Virgili, & Schivazappa, 1994). It occurs mainly in *Biceps femoris* muscle, and hams with this textural defect also possess other unwanted properties such as a somewhat bitter, piquant flavour and a lack of aroma of cured ham. As regards colour evaluation, the zone exposed after a slice is cut must exhibit the typical red colour of the cured product (Arnau, 1998). A defective colour, similar to raw meat, is rejected by consumers because it is associated with unripeness. Both pastiness and colour were scored on a scale from 1 to 10; values lower than or equal to seven were attributed to the presence of defects and higher than seven to absence of defects. The final score was the average value of the score by both expert judges.

Once sensory evaluation was performed, slices of approximate thickness 4 cm were cut, vacuum-packaged and kept under frozen storage until spectral analysis.

2.3. Visible and near infrared spectroscopic analysis

Dry-cured ham slices were thawed overnight in a refrigerator at 4 °C and, then left for an hour at ambient temperature before being scanned. Then the skin and subcutaneous fat were removed and the *B. femoris* muscle was taken from the slice for analysis.

Samples were scanned using a remote reflectance fiber optic probe (NR-6539-A) connected to a Foss-NIRSystems 6500 spectrophotometer equipped with an auto-gain detector (Fig. 1(a)). *B. femoris* muscle was cut into two slices which were put together in order to cover the whole analysis window surface of 5×5 cm (Fig. 1(b)). Spectra were collected every 2 nm from 400 to 2200 nm by using WinISI II software version 1.50 (Infrasoft International, Port Matilda, PA, USA). A reference spectrum was recorded before analysis of each sample. The spectra were recorded at two positions of the muscle slice. Thus, two reflectance spectra per sample were obtained between 400 and 2200 nm, at 2 nm intervals, and stored as log $1/R$. The average spectrum of each sample was used for data analysis.