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Differentiation of perirenal and omental fat quality of suckling lambs according to the rearing system from Fourier transforms mid-infrared spectra using partial least squares and artificial neural networks analysis

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ABSTRACT

Fourier transform mid-infrared (FT-IR) spectroscopy was evaluated as a tool to discriminate between carcasses of suckling lambs according to the rearing system. Fat samples (39 perirenal and 67 omental) were collected from carcasses of lambs from up to three sheep dairy farms, reared on either ewes milk (EM) or milk replacer (MR). Fatty acid composition of the samples from each fat deposit was first analyzed and, when discriminant-partial least squares regression (PLS) was applied, a perfect discrimination between rearing systems could be established. Additionally, FT-IR spectra of fat samples were obtained and discriminant-PLS and artificial neural network (ANN) based analysis were applied to data sets, the latter using principal component analysis (PCA) or support vector machines (SVM) as processing procedure. Perirenal fat samples were perfectly discriminated from their FT-IR spectra. However, analysis of omental fat showed misclassification rates of 9–13%, with the ANN approach showing a higher discrimination power.

1. Introduction

The production of suckling lambs to be slaughtered at about one month old, rendering carcasses of less than 7-kg-weight, is common in dairy sheep farms in Mediterranean countries because the meat is considered a valuable product due to its good eating quality (Vergara, Molina, & Gallego, 1999). In such farms, two different suckling lamb rearing systems can be followed. One consists of lambs being fed a milk replacer (MR) from the third day of life, while the other allows lambs to remain suckling with their dams (EM).

The effect of milk source on some suckling lamb meat quality traits has been investigated (Bas & Morand-Fehr, 2000; De la Fuente, Tejón, Rey, Thos, & López-Bote, 1998; Lanza et al., 2006; Napolitano, Cifuni, Pacelli, Riviezzi, & Girolami, 2002; Napolitano et al., 2006; Osorio, Zumalacárregui, Bermejo et al., 2007; Osorio, Zumalacárregui, Cabeza, Figueira, & Mateo, 2008; Osorio, Zumalacárregui, Figueira, & Mateo, 2007a; Osorio, Zumalacárregui, Figueira, & Mateo, 2007b; Santos-Silva, Bessa, & Santos-Silva, 2002; Vergara & Gallego, 1999; Vicenti, Colonna, Ragni, & Toteda, 2004). Apparently, milk source exerts a significant effect on fatty acid (FA) profile, volatile compounds, and colour and lipid oxidation stability. These studies agreed that meat from lambs fed with EM had higher saturated FA (SFA), lower monounsaturated FA (MUFA) contents and higher $n-3/n-6$ ratios than fat from lambs fed with MR. In addition, according to Osorio et al. (2008), meat from MR-fed suckling lambs, which had higher levels of vitamin E, was more stable to lipid oxidation compared to meat from EM-fed suckling lambs. Moreover, the type of rearing system had a significant effect on volatile compound profiles of the meat, leading to the suggestion that MR-meat might result in a different flavour from that expected from more traditional EM-fed suckling lamb meat. However, Napolitano et al. (2002) and Osorio et al. (2008) performed triangle tests and contradictory results were found. While in the former study the panel was able to distinguish between EM and MR meat samples, in the latter samples the rearing systems could not be discriminated.

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There seems to be a need to develop control methods for classifying suckling lamb carcasses according to the rearing system, since the regulation attached to several suckling lamb meat quality labels, such as "Lechazo de Castilla y León" Protected Geographical Indication (PGI) (Council Regulation 2081/92/EC), indicates that lambs must be reared exclusively on EM. Authentication of the type of feeding using analytical techniques will be a key issue in the certification of suckling lamb carcasses, with the rearing system being responsible for differences in price and quality.

Osorio et al. (2007a, 2007b) found that it is possible to classify suckling lamb carcasses according to the type of rearing system by means of FA analysis of different fat deposits. Furthermore, as a simpler, easier and more rapid alternative, infrared reflectance spectroscopy (NIRS) applied to perirenal fat samples has successfully been used for the discrimination of carcasses from suckling lambs reared with either EM or MR (Osorio, Zumalacárregui, Prieto et al., 2007).

FT-IR spectroscopy is a rapid and information rich technique for investigating the structure and composition of food components, allowing, in combination with chemometrics, the classification of foods without any chemical determination (Dupuy, Duponchel, Huvenne, Sombret, & Legrand, 1995). The introduction of the Attenuated Total Reflectance (ATR) technology extended the use of FT-IR in the food industry (Pedersen, Morel, Andersen, & Engelsen, 2003) where solid and semi-solid samples can be measured with high precision and reproducibility by use of the diamond ATR. The application of FT-IR to discriminate edible oils and fats has been proven to be successful in rapidly classifying these products (Dupuy et al., 1995; Vlachos et al., 2006; Yang, Irudayaraj, & Paradkar, 2005). According to Yang et al. (2005), FT-IR has more application for qualitative analysis than NIRS, because the 'fingerprints' of functional groups can be measured more narrowly and intensely in the MIR region (4000–400 cm^{-1}).

The aim of the present study was to investigate the potential of FT-IR spectroscopy for the discrimination of fat samples from carcasses of EM or MR reared suckling lambs. In addition, PLS multivariate regression and ANN models were applied to the spectral data and compared according to the rearing system.

2. Materials and methods

2.1. Animals and sampling

Lambs originated from the flocks of three farms (A, B and C) affiliated to the 'Asociación Nacional de Criadores de Ganado Ovino de Raza Churra', which is a Churra breeders association from the region of 'Castilla-León' (Spain). Lambs were reared either exclusively on EM or MR (from up to three days after birth to slaughter). Both EM and MR lambs were from all three farms. Four different commercial MR were used, two in farm A (MR_{A1} and MR_{A2}) and one in each of the remaining farms (MR_B and MR_C). The four MR were those most frequently used by regional breeders. According to the MR labels, the proximate composition of the MR was: moisture, 4–5%, crude protein, 23–24%, crude fat, 23–25%, ash, 6.6–8.6%, starch, 0–3%, crude fiber, 0–0.5%; and their ingredients: powdered milk and milk solids, vegetable fats and oils, products and byproducts from cereals, mineral supplements, i.e. iron and copper and Vitamins, i.e. E and A.

Two different samplings were carried. The first lasted two months (April and May, 2006) during which, among all the 30-to-35-days-old and 11-to-14-kg-live-weight suckling lambs reared in farms A and B on EM or MR (MR_{A1} for farm A and MR_B for farm B), thirty nine were randomly selected and slaughtered in an industrial slaughterhouse. The second sampling was carried out in the following month and 28 suckling lambs of the same characteristics described above, reared on EM or MR but in farms A (using MR_{A2} as the MR), B (using MR_B) and C (using MR_C) were selected and slaughtered. Approximately four hours after slaughter a perirenal (approximately 20 g) and an omental fat sample (approximately 20 g) were obtained from each of the first thirty nine carcasses. For the remaining 28 carcasses, only the omental fat sample was obtained. Table 1 shows the distribution of samples according to sampling, fat deposit, type of rearing, farm, and milk replacer.

In addition, one sample of each of the MR used in the farms and one of the bulk EM tanks of those farms were collected. Fat, EM and MR samples were packed individually in Ziploc freezing plastic bags (SC Johnson, Racine, WI, USA) and frozen and stored at −40 °C for up to three months prior to analysis.

2.2. Fatty acid composition

For the analysis of the FA composition of the fat deposits, lyophilized EM and MR samples (0.15 g each) were analyzed by gas chromatography as described by Osorio et al. (2007a).

2.3. Spectroscopic analysis, Fourier transform mid-infrared (FT-IR) spectroscopy

After thawing (overnight at 4 °C), fat samples were homogenized using an IKALabortechnik A10 blender (IKA, Staufen, Germany) and analyzed using FT-IR. The MB100 FT-IR spectrometer (Arid-Zone™, Quebec, Canada) was used to record the IR spectra. All spectra were recorded from 4000 to 750 cm^{-1} with a resolution of 4 cm^{-1}. IR spectra of fat samples were performed using an Attenuated Total Reflectance (ATR) device with a Durascope diamond crystal (SensIR Technologies, Norwalk, CT, USA). The fat samples were squeezed against the ATR diamond crystal. A total of 32 scans were collected for each spectrum and the average calculated and subtracted from the background spectrum using an empty ATR diamond crystal. Duplicate spectra of each sample were collected. Data acquisition and processing software was Win-Bomem Easy (Galactic Industries Corp., Salem, NH, USA).

2.4. Data analysis

In order to recognize fat samples belonging to a particular rearing system, in the first place, FA contents of each fat deposit (per-

Table 1
Distribution of fat samples according to the sampling, fat deposit, rearing system, farm and milk replacer.

Sampling	1				2					
Fat deposit	Perirenal and omental				Omental					
Rearing system	EM		MR		EM			MR		
Farm code	A	B	A	B	A	B	C	A	B	C
MR code	EM_A	EM_B	MR_{A1}	MR_B	EM_A	EM_B	EM_C	MR_{A2}	MR_B	MR_C
Number of samples	11	8	11	9	11	2	4	4	3	4

EM: ewe milk.
MR: milk replacer.