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NON DESTRUCTIVE SPECTRAL SENSORS FOR AUTHENTICATION OF THE FEEDING REGIME OF IBERIAN HAMS DURING THE SALTING PROCESS

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ABSTRACT

The authentication of the feeding regime followed by Iberian pigs during the stage prior to their slaughtering is critical and necessary for each of the stages of the production process of the ham. The high price of this product demands the study of non-destructive methods that can be applied by the industry and its members. This paper reports on the performance of a handheld micro-electro-mechanical system (MEMS)-based spectrometer (1600–2400 nm) for *in situ* and non-destructive authentication of the feeding regime ("*Acorn*" *vs.* "*Feed*") on meat (*Adductor* muscle) and skin-free fat of Iberian hams at two different stages of the processing – before and after salting. A total of 560 spectra (280 spectra before and 280 after salting) from 140 Iberian pigs hams raised under different feeding regimes (60 fed on "*Feed*" and 80 fed on "*Acorn*") were recorded on meat and fat tissue. Various mathematical and scatter correction treatments were tested and used to develop Partial Least Squares Discriminant Analysis (PLS2-DA) models for the authentication of the feeding regime for meat and fat tissue, before and after salting. PLS2-DA models developed for meat and fat tissue showed excellent results reaching values of 98.3–100% of correct classifications. The methodology presented here, based on discriminant analysis using a portable NIRS device provides the industry with a reliable, fast and affordable means of authenticating the feeding regime of Iberian hams throughout the critical salting process.

Key words: Iberian ham / NIRS

1 INTRODUCTION

Iberian dry-cured hams coming from pigs fed with natural resources from the "*dehesa*" (graze lands) are highly reputed at the national and international level not only because of their sensory characteristics but also because of their health claims (Cava *et al.,* 2000; Ventanas *et al.,* 2007) and their "organic" production; taking advantage of the natural resources of the graze lands ("*dehesas*") (Garrido and De Pedro, 2007). The quality of the feeding regime received by the animals and the production process performed are determinant for the sensory quality of the hams (Cava *et al*., 2000). Both the amount of fat as well as its composition will be responsible for characteristics such as salt content, loss of humidity, juiciness, aroma, *etc.*; knowing the characteristics of the product prior to its production process will play a key role.Many producers in the industry purchase fresh hams without having reliable actual information of the individual characteristics of each of them. Generally, the only information available is a global evaluation of the batch of animals based on the report from field inspectors and therefore, there are important differences among individuals (De Pedro and García Olmo, 1999). The research team of the Universidad de Cordoba (Andalusia, Spain) has carried out studies over a period of years that have shown the potential of the Near-infrared spectroscopy (NIRS) for the classification of Iberian pig cuts; using at-line and on-line equipment. (Zamora, 2013). The individual authentication of hams prior to the salting process would allow the producer to know, in a reliable way, the type of product about to be used and therefore design a curing process

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that would fit its characteristics. The aim of the current work is to evaluate the potential of a portable NIRS tool for the authentication of Iberian pig hams, both at the beginning and at the end of the salting process. This would provide the industry with the tools to control the quality of the raw material it receives and would allow producers to design a production process suitable for the characteristics of the product.

2 MATERIAL AND METHODS

A total of 140 Iberian pig hams were obtained in the 2011/2012 campaign at the ages of 12–15 months; 60 of them were fed on the so-called "*Feed*" and 80 on "*Acorn*" regimes, as described in Spanish legislation (BOE, 2007). Salting process was carried out at 4 °C and RH = 95%; the hams remained covered by salt during 15 days. Spectral measurements were taken on skin free fat and meat (*Adductor* muscle) before and after the Iberian ham salting process. These spectra were collected using a handheld MEMS (micro-electro-mechanical system)-based NIRS digital transform spectrometer (MEMS-NIRS) (Phazir1624, Polychromix Inc., Wilmington, MA, USA), working in reflectance mode in the spectral range 1600–2400 nm with a non-constant interval of around 8 nm (pixel resolution 8 nm, optical resolution 12 nm). Five spectra were taken for each sample and each spectrum was the mean of 10 scans. Sensor integration time was 600 ms. Sample temperature during measurements was 8–10 °C. Principal Component Analysis (PCA) was performed in order to decompose and compress the data matrix. After PCA, the centre of the spectral population was determined in order to detect outlier samples. The Mahalanobis distance (GH) was calculated between each sample and the centre; samples with a GH value greater than 3 were considered outliers (Shenk and Westerhaus, 1996). Discriminant models were constructed to classify the samples according to the feeding regime ("Acorn" or "Feed") for skin free fat and meat before and after the salting process, using partial least squares discriminant analysis (PLS2-DA) for supervised classification. More specifically, the PLS2 algorithm was applied, using the "discriminant equations" option in the WINISI II version 1.50 software package (ISI 2000). Different signal pre-treatments were evaluated for qualitative model development: no scatter correction (none) pre-treatment, Multiplicative Scatter Correction (MSC) and SNV followed by DT. Moreover, four derivative mathematical treatments were tested in the development of NIRS models (1,4,4,1; 1,5,5,1; 2,4,4,1 and 2,5,5,1), where the first number denotes the derivative order while the second number denotes the number of nanometers in the segment used to calculate the derivative. The third and four numbers denote the number of data points over which running average smoothing is conducted (ISI, 2000). The accuracy of the models obtained was evaluated using the percentage of correctly-classified samples, both for the global model and for each class. Arbitrary values of 1 and 2 were assigned for a two-class model. Thus, a cut-off limit of 1.5 was used as suggested by several authors (McElhinney *et al.*, 2000; Downey 1994).

3 RESULTS AND DISCUSSION

The best discrimination models constructed using the commercial handheld MEMS instrument and various scatter/derivative pre-treatments are shown in Table 1. The more precise and exact models at the beginning of the salting process were obtained using a mathematical pre-treatment 1,4,4,1 on Adductor muscle and a 2,4,4,1 on fat; both with no scatter correction and with a 100% global classification.

The results shown in Table 1 confirm the high po-

Table 1: *Results of the classification for authentication of hams coming from pigs "Acorn" or "Feed", prior and after the salting process*

		Original group of production stage			
		Beginning of salting		End of salting process	
Area	Classified group	*Acorn* (n = 80)	*Feed* (n = 60)	*Acorn* (n = 80)	*Feed* (n = 60)
Adductor muscle	*Acorn*	77 *	0	79 *	1
	Feed	0	60	0	59
	Properly classified percentage	100%	100%	100%	98.3%
Adipose tissue	*Acorn*	78 *	0	79 *	0
	Feed	0	60	0	58 *
	Properly classified percentage	100%	100%	100%	100%

* number of samples once spectral outliers have been removed

tential of the NIR technology for the individual control of Iberian pig products as shown in other studies performed on adipose tissue coming from meat cuts (Zamora *et al.,* 2012) or on muscle (De Pedro *et al.,* 2007), the latter being performed with a monochromator based equipment (Foss NIRSystems 6500).

The differences in the type of feeding regime were not affected by the salting process and it was possible to spectrally differentiate the two categories, through both the muscle as well as the fat. The PLS2-DA models developed for the end of the salting process also had the mathematical pre-treatment 2,4,4,1 with no scatter correction in both cases (muscle and fat).

As such, the model developed for the spectral authentication of the fat allowed us to identify 100% of the samples in its "*Acorn*" and "*Feed*" categories respectively. However, when the classifications were performed on the *Adductor* muscle, all the samples of the "*Acorn*" class were correctly included in their group and only one sample from the "*Feed*" class was classified as "*Acorn*" (Table 1). Given the high degree of discrimination of the spectral information and the fact that the spectrum of the wrongly classified sample was not anomalous, it is possible that this spectrum is a reflection of a muscular alteration or reaction suffered by the ham during the handling process at the beginning or at the end of the salting process. The high precision reached by the classification models suggests that the NIR spectral range (1600–2400 nm) contains information that will make it possible to precisely differentiate and define the animal's feeding regime, based both on the fat as well as the muscle in the hams, prior to and after the salting process.

4 CONCLUSIONS

The use of NIRS technology allows the control of the type of food given to animals, based on the ham's adipose tissue and muscle, allowing the differentiation to remain even after the salting process.

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