PS3.04 Analyzing the Semimembranosus muscle by MRI for clasifying fresh Iberian hams as a function of the diet 116.00

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Abstract— Magnetic Resonance Imaging (MRI) contrastive analysis were carried out in Iberian hams from pigs that have been fattened only with acorns and grass (AG) and those that have been fattened with high oleic acid concentrates (HO). Based on computer vision techniques, the implemented methods of image processing allowed for the automatic recognition of the Semimembranosus muscle as well as for computational texture feature detection in the muscle. The data collected was then checked against physical-chemical composition. Most computational texture characteristics proved to be statistically different between the AG and HO image sets. Two groups (G1 and G2) of texture features were derived. G1 was closely related to oleic acid (C18:1 n-9), defining Iberian ham of AG pigs. However, G2 showed positive correlation with elaidic (C18:1 n-7), linoleic (C18:3 n-6) and arachidonic (C20:4 n-6), which describe the HO ham. Thus MRI-based analyses enable computational distinction of Iberian hams according to the feeding background via the examination of the texture features.

Index Terms— Computer vision techniques, diet, Iberian ham, lipid composition, MRI

I. INTRODUCTION

Iberian ham from animals fed outdoors on acorns and grass reach the highest prices in the market because of its quality characteristics. However, these pigs may also be fattened with concentrates, which causes lower quality and less market acceptance [1,2]. Nowadays, MUFA enriched diets, through the inclusion of high oleic acid (C18:1 n-9) sunflower oil, are been used to feed Iberian pigs in order to imitate the FA profile of acorn-fed animals. The FA composition of subcutaneous and intramuscular fat of Biceps femoris and Semimembranosus muscles as well as some components of the unsaponiable fraction, neophytadiene and γ-tocopherol, may be regarded as useful means for the classification of different pig feeding diets [3]. Magnetic Resonance Imaging (MRI) constitutes a non-destructive and non-invasive technique. Different combinations of MRI and computer vision techniques have demonstrated being feasible for studying meat and meat products. Cernadas et al. [4], for example, employ MRI and computational texture features to classify Iberian loins as a function of cross-breeding and in terms of intramuscular fat content and certain sensory attributes [5]. The calculation of intramuscular fat levels of Iberian ham Biceps femoris and Semimembranosus muscles can also result from MRI applications [6]. The implementation of active contours in MRI can be used to explore the Biceps femoris and Semimembranosus muscles in Iberian hams. These techniques enabled the measurement of ham weight and moisture so that an optimal ripening time period may be determined for Iberian hams [7, 8]. The main goal of this research was to be able to discriminate fresh Iberian hams from pigs fattened with different diets (acorn and grass vs. high oleic acid concentrates) analyzing the Semimembranosus muscle by MRI-based active contours and computational texture features. The relationship between the MRI-based texture characteristics and the lipid composition was also examined.

II. MATERIALS AND METHODS

Experimental design This study was based on testing done with 30 Iberian pigs, divided into two groups according to the two feeding diets applied during the fattening period. The group of pigs labelled as AG (n=15) corresponds to those animals reared outdoors with free access to acorns and grass. The other group of pigs (HO) (n=15) also matched outdoors breeding criteria but mainly fed on oleic acid enriched concentrates. After the fattening period of 110 days, all the pigs were slaughtered. One ham was taken from each animal, and individual weights were recorded. MRI acquisition Magnetic resonance sequences enabled the exploration of Semimembranosus muscles in Iberian hams via computer vision techniques. MR images were stored on a database acquired at the ‘‘Infanta Cristina’’ University Hospital (Badajoz, Spain), using a MRI (Philips Gyroscan NT Intera 1.5 T) scanner. Computer-Aided MRI Analysis A software application containing three modules was used for the analysis (Figure 1). The initial module aimed to detect the Semimembranosus muscle by using Active Contours according to the method described by Antequera et al. [8] (Figure 1a).The second module consisted in the selection procedure for the Region of Interest (ROI) on each image; this selection drew up the maximum rectangular area on the muscle (Figure 1b). The third and last module included the analysis of the ROIs by applying the three most common methods in computational texture analysis: The first one, Grey Level Coocurrence Matrix (GLCM), was constructed with information of the complete ROI, and presents five features: Energy, Entropy, Haralicks Correlation, Inverse Difference Moment, and Inertia. Second, the so-called Neighbouring Grey Level Dependence Matrix (NGLDM) gathered information from square neighbourhoods inside the ROI, providing five features: Small Number Emphasis, SNE; Long Number Emphasis, LNE; Number Nonuniformity, NNU; Second Moment, SM; Entropy, ENT. Third, the Grey Level Run Length Matrix (GLRLM) only accounted for information about lineal segments of the ROI and it gave five features: Long Run Emphasis, LRE; Short Run Emphasis, SRE; Grey Level Nonuniforminty, GLNU; Run Length Nonuniformity, RLN; Run Percentage, RPC (Figure 1c). Physical-chemical analysis The entire Semimembranosus muscles of the hams were dissected. Lipids were extracted with chloroform:methanol (2:1, v/v) according to the method described in Pérez-Palacios et al. [9]. FA methyl esters (FAME) obtained from lipid tissues were assembled by transesterification in the presence of sodium metal (0.1 N) and sulphuric acid within methanol [10] (Sandler & Karo, 1992). FAME were analysed by gas chromatography and a flame ionization detector (FID). Statistical analysis The statistical application used was the one-way analysis of variance (ANOVA). Both the Pearson correlation and Principal Component Analysis (PCA) were applied to evaluate the relationships between the computational texture characteristics obtained and lipid composition. Analyses were done by using the SPSS package (v.15.0).

III. RESULTS AND DISCUSSION

Most computational texture characteristics of the three methods used for analyzing MRI showed significant differences between images from AG and HO Iberian hams (Table 1). The GLCM and NGLDM method applications led to statistical distinctions among all their characteristics. Values of Energy, Inertia, SN, LNE, SM, ENT and GLNE were higher in the AG hams than in the HO ones. With the GLRLM method, two of the five texture features showed statistical differences, being GLNU higher in AG hams than in the other group whereas the levels of RLNU were higher in the HO group of hams than in the AG group.

According to the significance of each computational texture feature, it seems that homogeneity plays a important role in MRI measurements in order to discriminate the diet source of Iberian pigs. The Pearson correlation coefficient and PCA (Figure 2) were run to measure the relationship between MRI computational texture characteristics and lipid composition in the two groups of Iberian hams. Two sets of computational texture characteristics were derived from their correlation coefficients with the physical-chemical components. The G1 group (Energy, Inertia, SNE, LNE, NNU, SM, GLNU and RLNU) positively correlated with oleic (C18:1 n-9) and eicosatrienoic (C20:3 n-3) acids. In turn, G1 results in a negative correlation coefficient with palmitoleic (C16:1), vaccenic (C18:1 n-7), linolenic (C18:3 n-6), eicosatrienoic (C20:3 n-6) and arachidonic (C20:4 n-6) acids. The G2 group (Entropy, HC, IDM, and ENT) significantly correlated with the same G1 fatty acids, but it does so in the opposite way. A PCA test was then conducted with the data from the MRI texture characteristics and the lipid composition of Semimembranosus hams.

Figure 2a illustrates with a similarity map the measured parameters, defined by two principal components (PC1 and PC2) accounting for 47% and 22%, respectively, of the total variance. Oleic (C18:3 n-3) and eicosatrienoic (C20:3 n-3) acids showed high negative values for PC1, and were found close to Energy, Inertia, SM, LNE, GLNU, NMU, SNE and RLNU. The positions agreed with the positive and significant correlation coefficients found between the variables ($p < 0.01$). On the opposite side, palmitoleic (C16:1), vaccenic (C18:1 n-7), linolenic (C18:3 n-6), eicosatrienoic (C20:3 n-6) and arachidonic (C20:4 n-6) acids, Entropy, HC, IDM and ENT all featured high negative values for PC1, a result that also matched the correlation findings among the variables ($p < 0.01$). By projecting the samples onto the areas where the main components were found (Fig. 2b). AG hams were located on the left, both at the upper and lower quadrants. These locations correspond to oleic (C18:1 n-9) and eicosatrienoic (C20:3 n-3) acids, and texture characteristics of Energy, Inertia, SNE, LNE, NNU, SM, GLNU and RLNU. In contrast, HO samples were found on the opposite side of the graph, at both upper and lower quadrants, defined by palmitic (C16:0), palmitoleic (C16:1), vaccenic (C18:1 n-7), linolenic (C18:3 n-6), eicosatrienoic (C20:3 n-6) and arachidonic (C20:4 n-6) acids, as well as by the texture features of Entropy, HC, IDM and ENT. Such results partly matched those in Pérez-Palacios et al. (2009), where the γ-tocopherol and linolenic acids (C18:3 n-3) define the AG ham area, while the arachidonic acid (C20:4 n-6) appears in the HO area.

IV. CONCLUSION

The feeding diet of the Iberian pig (either linked to acorn and grass or high oleic acid concentrates) can be figured out computationally by means of Semimembranosus-driven texture feature analysis. The group of texture features composed by Energy, Inertia, SNE, LNE, NNU, SM, GLNU and RLNU showed a markedly relationship with oleic (C18:1 n-9) and eicosatrienoic (C20:3 n-3) acids and define Iberian hams from pigs fattened with acorns and grass. However, Entropy, HC, IDM and ENT were the texture features associated to hams from pigs with high oleic acid concentrates.

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Figure 1. Processing modules within the computer-aided MRI analysis of Iberian hams: a) *Semimembranosus* muscle detection; b) region of interest selection; c) region of interest analysis by using three different methods of texture features.

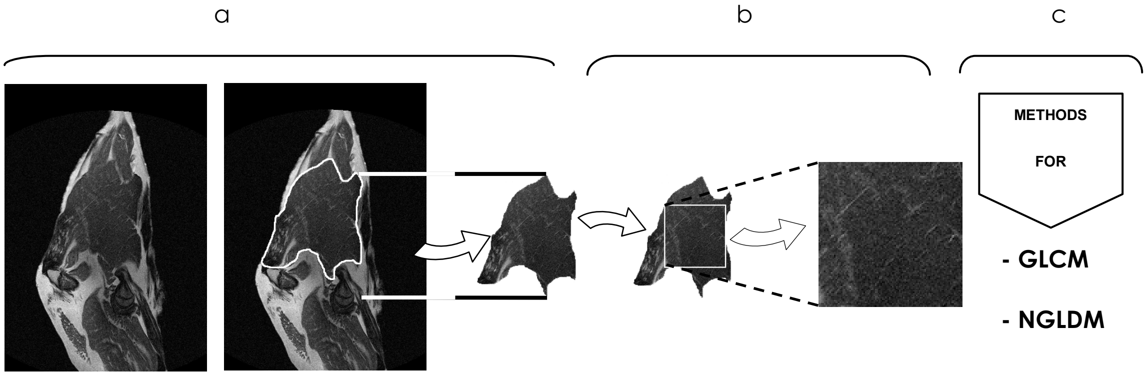
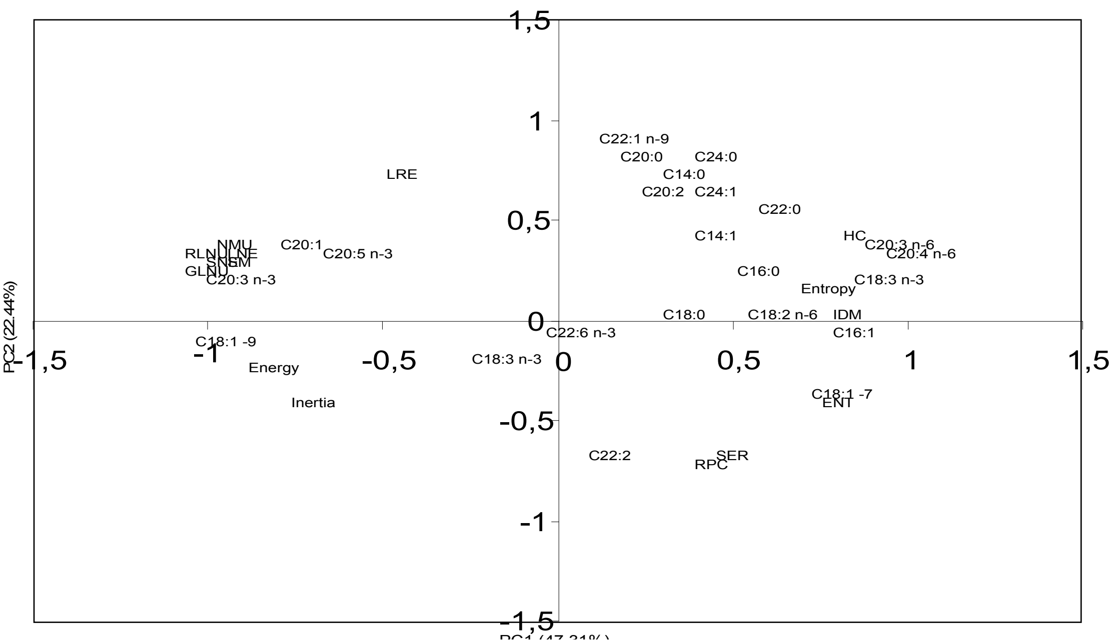


Figure 2. Principal component analysis: MRI-based texture characteristics and fatty acid composition: (a) variables plot, (b) score plot of Iberian pigs fattened with different diets. (AG: acorns and grass; HO: high oleic acid enriched concentrates).

a



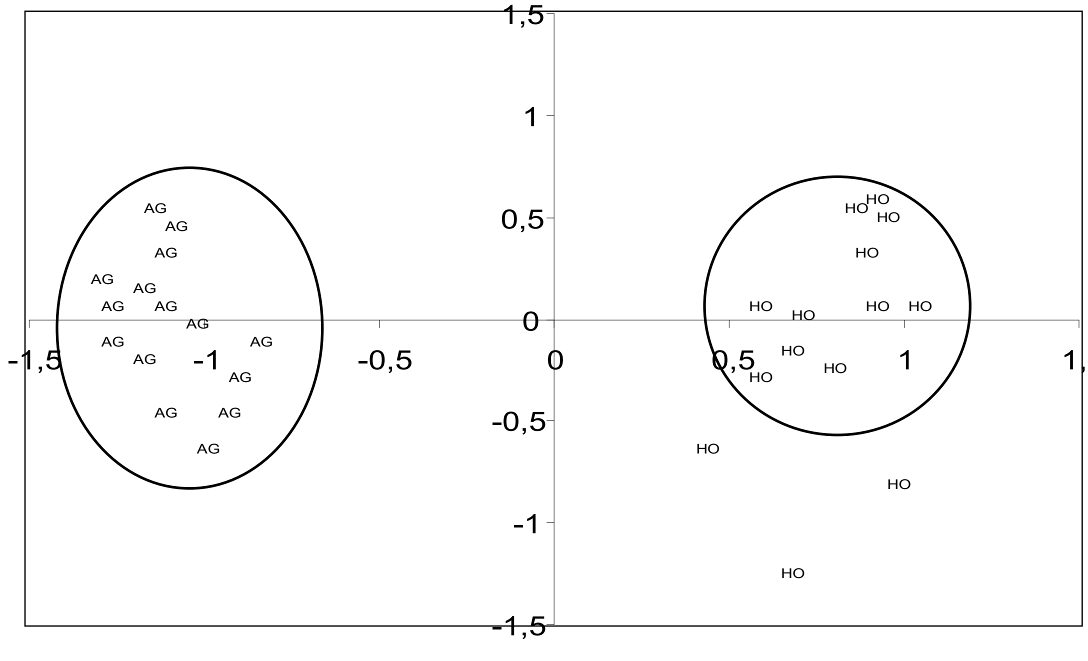


Table 1. Values of texture characteristics of MRI of hams from Iberian pigs attened with different diets: acorn and grass (AG) and high oleic acid enriched concentrate (HO).

		AG	**HO**	*p*
	Energy	$11.10^{-4} \pm 5.10^{-5}$	$10.10^{-4} \pm 4.10^{-5}$	0.008
	Entropy	$30.10^{5} \pm 3.10^{4}$	$31.10^{5} \pm 1.10^{4}$	0.006
GLCM	HC	$8.10^{-4} \pm 1.10^{-4}$	$11.10^{-4} \pm 1.10^{-4}$	0.002
	IDM	$63.10^{-3} \pm 3.10^{-3}$	$74.10^{-3} \pm 4.10^{-3}$	0.002
	Inertia	$47.10^{7} \pm 5.10^{7}$	$34.10^{7} \pm 4.10^{7}$	0.006
	SNE	$10.10^{6} \pm 1.106$	$6.10^{6} \pm 0.8.106$	0.003
	LNE	$26.10^{6} \pm 4.106$	$16.10^{6} \pm 2.106$	0.003
NGLDM	NNU	$11.10^{10} \pm 3.10^{10}$	$42.10^{10} \pm 1.10^{10}$	0.003
	SM	$35.10^{8} \pm 10.10^{8}$	$12.10^{8} \pm 2.10^{8}$	0.002
	ENT	$30.10^{6} \pm 6.10^{6}$	$17.10^{6} \pm 2.10^{6}$	0.002
	LRE	$11.10^{5} \pm 1.10^{4}$	$11.10^{5} \pm 3.10^{4}$	0.224
	SRE	0.97 ± 2.10^{-4}	0.97 ± 6.10^{-4}	0.172
GLRLM	GLNU	$43.10^{7} \pm 7.10^{7}$	$25.10^{7} \pm 2.10^{7}$	0.001
	RLNU	$12.10^{9} \pm 2.10^{9}$	$78.10^{8} \pm 9.10^{8}$	0.003
	RPC	0.96 ± 3.10^{-4}	0.96 ± 8.10^{-4}	0.197