

Improvement of dry-cured Iberian ham sensory characteristics through the use of a concentrate high in oleic acid for pig feeding

Á. Jurado¹†, C. García¹, M.L. Timón² and A.I. Carrapiso²

¹*Tecnología de Alimentos, Facultad de Veterinaria, Universidad de Extremadura, Av Universidad s/n, E-10071 Cáceres, Spain*

²*Tecnología de Alimentos, Escuela de Ingenierías Agrarias, Universidad de Extremadura, Crta Cáceres s/n E-06071 Badajoz, Spain*

The aim of this study was to investigate the sensory characteristics of dry-cured hams from confined Iberian pigs fed on a high oleic (HO) concentrate (HO-Pienso hams), and to study how different the characteristics of these hams are from those of Iberian hams from the best grade (Montanera hams, from extensively reared pigs). Nearly half of the fatty acids studied were similar in HO-Pienso and Montanera hams. No differences were found for 18:1, but some major fatty acids of subcutaneous fat of Iberian hams were different between the HO-Pienso and the Montanera hams (C16:0, C18:0, C18:2). The descriptive test revealed that 15 of the 23 sensory characteristics were not significantly different between both groups of hams. No sensory differences appeared for fat appearance or lean texture characteristics, but lean appearance, oiliness, saltiness and the most intensively perceived characteristics of odour and flavour were significantly different. These differences in the sensory traits between Montanera and Pienso hams were not as marked as found in previous studies. Therefore, the use of a concentrate high in oleic acid enables simulation, at least in part, of the sensory characteristics, especially texture.

Keywords: dry-cured meat; Iberian ham; oleic acid concentrate; rearing system; sensory analysis

Introduction

Iberian ham is a meat product characterised by a high sensorial quality. Several factors, which can be grouped into raw

meat properties and to processing technology, influence sensory attributes. One of the most important factors related to raw meat properties is rearing system,

†Corresponding author: ajuradog@unex.es; Tel.: +34 927257122; Fax: +34 927257110

which strongly affects the fatty acid profile of the tissues (Flores *et al.*, 1988; Cava *et al.*, 1997; Ruiz *et al.*, 1998) and determines the sensory characteristics of hams (Cava *et al.*, 2000; Carrapiso, Bonilla and García, 2003; Carrapiso *et al.*, 2007). Several commercial categories have been specified depending on rearing system (Real Decreto 1469/2007): “Montanera” and “Pienso” system. The Montanera system yields Iberian hams with the highest quality and prices on the market and are made from Iberian pigs reared outdoors and fed on acorns and grass during the finishing period (the two months prior to slaughter). The Pienso system produces the lowest quality and priced hams, which are obtained from pigs reared in confinement and fed a concentrate diet.

The formulation and composition of the concentrates used to feed the pigs is relevant because it affects not only fat composition (Wood *et al.*, 2004), but also the sensory characteristics of the resulting dry-cured hams (Pastorelli *et al.*, 2003). In recent years, some reformulated concentrates have been used to feed Pienso Iberian pigs. Among them, concentrates with high oleic acid concentration try to simulate the composition of the diet of Iberian pigs reared outdoors. In this way, it was found that Iberian dry-cured loins from animals fed on a concentrate high in oleic acid (HO-Pienso) had no sensory differences from outdoor-reared pigs fed on acorns and pasture (Muriel *et al.*, 2003). Another study only found differences in saltiness and marbling shape between Iberian dry-cured loins from Montanera pigs and pigs fed on a HO-Pienso supplemented with tocopherol acetate (Ventanas, Ventanas and Ruiz, 2007). Although some information relating to the differences between HO-Pienso and Montanera hams has been published (Ventanas *et al.*, 2007), there is no information on the sensory

profile of dry-cured hams from Iberian pigs fed with these concentrates, and it is not known if this results in Iberian hams with similar sensory characteristics to those of Montanera hams.

The objective of this study was to determine if the sensory characteristics of Iberian hams obtained from pigs fed in confinement with a concentrate high in oleic acid are similar to those of Iberian hams obtained from pigs fed in the Montanera system. The association between the sensory differences and subcutaneous fatty acid composition was also examined.

Materials and Methods

Samples

Forty dry-cured Iberian hams representing two pig groups with different feeding regimes during the finishing period (the last 8 weeks prior to slaughter) were used. One group (n = 20) represented pigs fed in a traditional extensive system based on acorns and pasture (Montanera). The other group was from pigs fed in confinement with a concentrate high in oleic acid (HO-Pienso). For details on chemical composition of concentrate diet, see Muriel *et al.* (2002). Hams were subjected to the dry-curing process, which lasted for 722 days (Jurado *et al.*, 2007).

Subcutaneous fatty acid analysis

Samples were taken from the subcutaneous fat of raw hams and were vacuum-packaged and kept at -80 °C. Lipids were extracted with chloroform:methanol (Bligh and Dyer, 1959). The neutral fraction was isolated using NH₂-aminopropyl minicolumns (Kaluzny *et al.*, 1985) and the fatty acid composition was determined by gas chromatography of the fatty acid methyl esters synthesized by using sodium methoxide and sulfuric acid/methanol, as described by Cava *et al.* (1997). Fatty acid

methyl esters were analysed using a HP 5890 II chromatograph (Hewlett-Packard) equipped with a cold on-column injector, a flame ionisation detector and a 30 m × 0.53 mm capillary column coated with FFAP-TPA stationary phase (1 µm thickness). Conditions were as follows: oven temperature 220 °C isothermal for 30 min, injector and detector temperature 230 °C, and flow rate of the carrier gas (N) 2.6 mL/min.

Intramuscular fat concentration

Lipids were extracted from muscle samples using chloroform:methanol (Bligh and Dyer, 1959). The solvent (chloroform) was removed using a rotary vacuum evaporator, and residual chloroform by evaporation under a stream of N. Intramuscular fat (IMF) was calculated by weighing the residue.

Sensory analysis

The samples were assessed by a trained panel of 18 members using a sensory descriptive test (García *et al.*, 1996). Twenty-three traits related to sensory characteristics of Iberian hams were evaluated using an unstructured scale (10 cm) with the extremes being classified as 'very low' and 'very high'. The traits were related to appearance of fat and lean, texture of fat and lean, odour, taste, and flavour. The results were assessed and summarised using sensory evaluation software (FIZZ, version 1.01; Biosystemes, France).

Three extremely thin slices from the back of each ham were obtained by using a knife and were immediately presented on a glass plate to the assessors. All sessions were performed at 20 to 22 °C in a 6 booth sensory panel room equipped with white fluorescent lighting. The full panel participated in each session, the panellist order being randomised. Three hams were successively evaluated in each session. The sample order was randomised.

Data analysis

The statistical analyses were performed on the mean responses of the panel for each sensory trait (Meilgaard, Civille and Carr, 1999). Student's *t* test was used to compare the means of the two groups. Pearson correlation and factor analysis (using principal components analysis as the method for factor extraction) were used to evaluate the interrelationships among variables (Hair *et al.*, 1998). Statistical analyses were performed using the SPSS (2001) statistical package.

Results and Discussion

The subcutaneous fatty acid analysis showed significant differences between the HO-Pienso and the Montanera hams for only five fatty acids (C14:0, C16:0, C18:0, C18:2, C18:3; Table 1). Previous studies have shown that most fatty acids were significantly different ($P < 0.05$) between conventional Pienso and Montanera hams (Cava *et al.*, 2000; Carrapiso *et al.*, 2002, 2003). Therefore, feeding on HO-concentrates provides hams with a fatty acid composition more similar to that of the Montanera hams (the high grade of Iberian hams) than conventional concentrates. This fact is in accordance with previous studies which reported that the composition of the concentrate has a major influence on the fatty acid composition of meat (Wood *et al.*, 2004; Mitchothai *et al.*, 2007) and meat products (Gandemer, 2002).

The IMF was not different between the HO-Pienso and the Montanera hams (Table 1). This agrees with previous reports that rearing system does not have a marked effect on IMF for Iberian dry-cured ham or loin (Cava *et al.*, 2000; Ventanas *et al.*, 2007; Carrapiso and García, 2005) nor for raw pig meat, although there is a tendency for local breeds to have a higher

Table 1. Fatty acid composition (g/kg total fatty acid) of neutral lipids from subcutaneous fat and the intramuscular fat (IMF) concentration (mean \pm s.d.) of dry-cured Iberian hams from pigs representing two production systems

	Production system ¹		Significance
	Montanera	HO-Pienso	
Fatty acid (g/kg total fatty acids)			
C12:0	1.8 \pm 2.3	0.7 \pm 1.2	
C14:0	5.2 \pm 3.3	0.83 \pm 0.21	**
C16:0	175.7 \pm 8.2	187.6 \pm 9.9	***
C16:1	20.9 \pm 2.9	21.4 \pm 3.8	
C17:0	3.6 \pm 0.6	3.9 \pm 0.6	
C17:1	3.7 \pm 0.9	4.1 \pm 0.8	
C18:0	103.9 \pm 9.7	114.2 \pm 10.6	**
C18:1	556.0 \pm 15.8	552.3 \pm 13.3	
C18:2	98.7 \pm 11.3	79.4 \pm 9.6	***
C18:3	6.7 \pm 1.1	4.3 \pm 0.9	***
C20:0	2.9 \pm 0.4	2.9 \pm 0.4	
C20:1	20.4 \pm 3.2	20.9 \pm 3.3	
Total SFA ²	293.7 \pm 14.9	317.7 \pm 17.3	***
Total MUFA ³	600.9 \pm 16.0	598.7 \pm 16.1	
Total PUFA ⁴	105.4 \pm 11.8	83.6 \pm 9.8	***
Intramuscular fat (g/kg dry sample)	124.1 \pm 46.4	134.3 \pm 41.7	

¹ Montanera = traditional outdoor system, HO-Pienso = fed in concentrates, with high oleic acid concentration, during indoor finishing period.

² Saturated fatty acids.

³ Monounsaturated fatty acids.

⁴ Polyunsaturated fatty acids.

IMF concentration when they are reared outdoors than when they are reared indoors (Pugliese *et al.*, 2004).

With regard to the sensory characteristics, 15 of the 23 traits evaluated did not differ significantly between the HO-Pienso and the Montanera groups (Table 2). No significant differences were found for fat appearance, texture (except for oiliness), taste (except for saltiness) or minor flavour traits. Previous studies on conventional Pienso and Montanera Iberian hams revealed only small differences for fat appearance, taste and minor flavour traits (Cava *et al.*, 2000; Carrapiso *et al.*, 2003), whereas the textural characteristics of fat and lean were markedly different (Cava *et al.*, 2000; Carrapiso *et al.*, 2003). The similarity in lean texture and fat hardness between the groups in

the present study (Table 2) confirms the great importance of diet composition, and also the major influence of the fatty acid composition on some dry-cured ham sensory characteristics. Previous studies have shown a strong influence of fatty acid composition on texture characteristics of meat (Wood *et al.*, 2004; Gandemer, 2002) and also of Iberian ham (Carrapiso *et al.*, 2003).

The present results indicate that feeding on HO-concentrate results in Pienso hams that are similar to the much more expensive Montanera hams. The reduction in the sensory differences between HO-Pienso and Montanera products associated with feeding the HO-concentrate is in accordance with results from a similar study performed on dry-cured Iberian loin (Muriel *et al.*, 2003; Ventanas *et al.*, 2007).

Table 2. Results (mean ± s.d.) from a sensory evaluation of dry-cured Iberian hams from pigs representing two production systems

Attribute	Production system ¹		Significance
	Montanera	HO-Pienso	
Fat appearance			
Yellowness	2.3 ± 0.65	2.1 ± 0.48	
Pinkness	3.3 ± 0.67	3.2 ± 0.96	
Lean appearance			
Redness	5.6 ± 0.60	6.0 ± 0.66	*
Brightness	5.5 ± 0.90	4.8 ± 0.98	*
Marbling	5.5 ± 0.96	5.5 ± 0.86	
Odour			
Intensity	5.3 ± 0.68	4.8 ± 0.55	**
Montanera-ham typical odour	4.2 ± 0.71	3.8 ± 0.67	
Fat texture			
Hardness	2.9 ± 0.40	3.0 ± 0.42	
Oiliness	5.8 ± 0.50	5.3 ± 0.74	*
Lean texture			
Hardness	3.2 ± 0.42	3.0 ± 0.56	
Dryness	2.4 ± 0.50	2.6 ± 0.53	
Fibrousness	3.9 ± 0.49	3.7 ± 0.39	
Juiciness	5.9 ± 0.69	5.6 ± 0.64	
Taste			
Saltiness	3.7 ± 0.46	3.3 ± 0.32	**
Sweetness	2.4 ± 0.50	2.3 ± 0.45	
Bitterness	1.1 ± 0.33	1.2 ± 0.27	
Flavour			
Intensity	5.7 ± 0.37	5.3 ± 0.41	**
Persistence	5.4 ± 0.43	4.9 ± 0.45	***
Cured	4.5 ± 0.60	4.1 ± 0.68	*
Rancid	1.4 ± 0.29	1.4 ± 0.42	
Other flavour descriptors			
Toasted	2.5 ± 0.36	2.3 ± 0.45	
Mouldy	1.0 ± 0.42	1.3 ± 0.51	
Pungent	1.0 ± 0.23	1.1 ± 0.34	

¹ See footnote to Table 1.

Despite the similarity between the groups in fatty acid composition, important sensory differences still remained with respect to appearance, odour and some texture and flavour traits. According to the principal component analysis

(PCA), the variability in the sensory data was strongly related to the differences between HO-Pienso and Montanera hams (Figure 1). This variability provided a clear grouping of hams; most HO-Pienso hams appeared to the left of the PC1

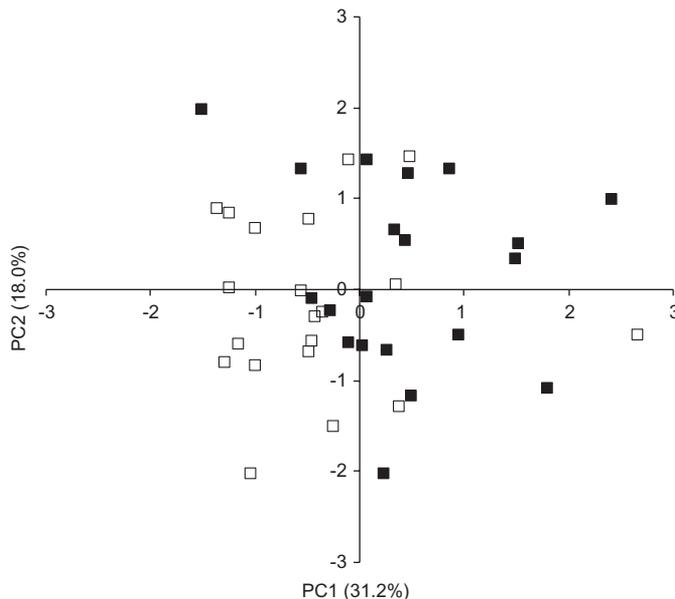


Figure 1. Projection of the individual hams onto the space defined by the first two principal components (PC1 and PC2): ■ Montanera hams, □ HO-Pienso hams.

axis and Montanera hams to the right. In fact, 8 of the 23 sensory characteristics evaluated were significantly different ($P < 0.05$) between the HO-Pienso and the Montanera hams, including lean redness and brightness, odour intensity, fat oiliness, saltiness and the most intensively perceived flavour traits (intensity, persistence and cured; Table 2). Most of these variables had high weights in PC1 (all except redness and saltiness) and were therefore strongly related (Figure 2).

With regard to appearance, lean redness and brightness were significantly different (Table 2). Lean of HO-Pienso hams was redder than that of Montanera hams, which agrees with results for dry-cured loins obtained from the same pigs (Muriel *et al.*, 2003). However, previous studies on Iberian ham did not reveal a clear and unequivocal difference in lean redness between Pienso and Montanera

hams (Cava *et al.*, 2000; Carrapiso *et al.*, 2003), which indicates that other factors determine ham redness to a larger extent.

Brightness was also significantly affected (Table 2); scores for the Montanera hams being higher than for the HO-Pienso. Similar differences in brightness between conventional Pienso and Montanera ham have already been reported (Cava *et al.*, 2000; Carrapiso *et al.*, 2003), and, therefore, the use of the HO-concentrate did not eliminate differences for this characteristic. A strong relationship between brightness and fatty acid composition of Iberian ham has been reported (Carrapiso *et al.*, 2003). However, in the present study a weak relationship was found between brightness and fatty acid composition; only linoleic acid (C18:2) and linolenic acid (C18:3) showed a significant although

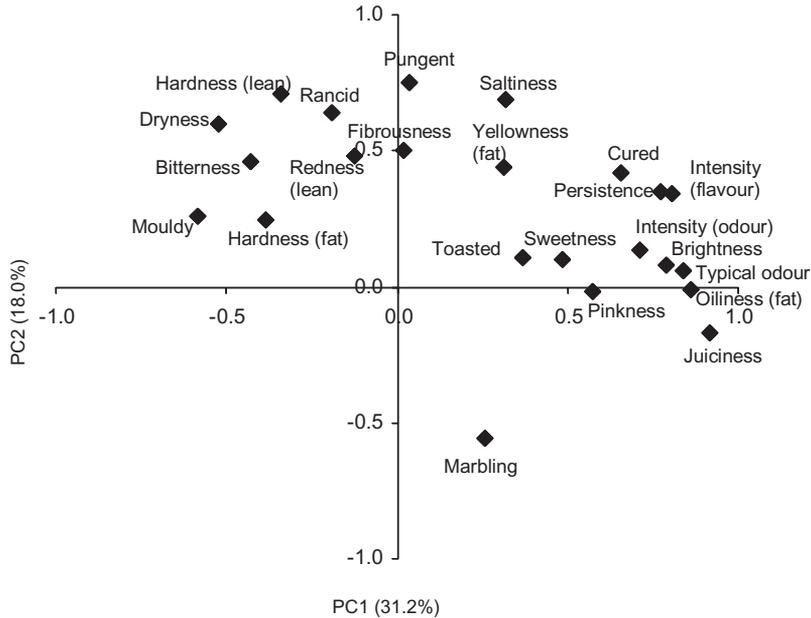


Figure 2. Projection of the sensory variables onto the space defined by the first two principal components (PC1 and PC2).

slight correlation (0.35, $P = 0.048$ and 0.38, $P = 0.031$, respectively). Therefore, the main fatty acids of subcutaneous fat were not useful predictors of brightness or oiliness in these hams, in contrast to the proposal by Carrapiso *et al.* (2003).

Brightness was significantly correlated with other lipid-related characteristics, mainly fat oiliness (0.81, $P < 0.001$). Brightness was also correlated with odour and flavour, the strongest relationships were with Montanera-ham typical odour (0.68, $P < 0.001$) and cured flavour (0.56, $P < 0.001$).

The scores for odour intensity were higher for Montanera hams than for HO-Pienso (Table 2). Previous studies on Iberian ham have yielded clear differences in odour intensity and also in the Montanera-ham typical odour between Montanera and conventional Pienso hams (Cava *et al.*, 2000).

Differences also appeared for fat oiliness (Table 2), which is in agreement with previous studies on Iberian ham (Carrapiso *et al.*, 2003). The strong correlations between fat oiliness and fatty acid composition reported by Carrapiso *et al.* (2003) were not found, and neither stearic or oleic acids were correlated with oiliness. Therefore, the HO-concentrate greatly reduced the difference in subcutaneous fatty acid composition of Iberian hams (Table 1), and probably other compounds or minor fatty acids were responsible for the observed differences in oiliness variability (Table 2).

With regard to taste characteristics, only saltiness was significantly affected ($P < 0.01$) by the rearing system, being more intense in Montanera hams (Table 2). Up to now, no clear effect of rearing system on taste characteristics of Iberian ham has been reported. Although salti-

ness can be related to NaCl and free amino-acids (Careri *et al.*, 1993), no differences in the NaCl concentration were observed between the HO-Pienso and the Montanera hams (Jurado *et al.*, 2007). Differences in free amino acids were limited, but significant for glutamic acid (Jurado *et al.*, 2007), and therefore differences in saltiness may be related to taste-active compounds such as this free amino acid or to peptides or organic acids, which can influence saltiness perception.

The most intensely perceived flavour descriptors (intensity, persistence and cured flavour) were significantly different ($P < 0.05$) between the HO-Pienso and the Montanera hams (Table 2), as was previously found (Cava *et al.*, 2000; Carrapiso *et al.*, 2002). Scores for the Montanera hams were higher than for the Pienso hams. In a previous study performed on dry-cured loins obtained from the same pigs as in this study, no differences for the flavour characteristics were found (Muriel *et al.*, 2003), probably because paprika masked the flavour differences in those products.

In conclusion, differences in the sensory traits between the Montanera and the HO-Pienso hams were not as marked as in previous studies that used traditional concentrates for Pienso pigs (Cava *et al.*, 2000; Carrapiso *et al.*, 2002, 2003). In consequence, the high oleic acid content concentrate improved the sensory quality of hams from indoor-reared pigs.

Acknowledgements

We thank Ana Isabel Galaz for her technical assistance and the panellists for their participation in the sensory analysis. Ángela Jurado thanks the Junta de Extremadura for its support.

References

- Bligh, E.G. and Dyer, W.J. 1959. A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology* **37**: 911–917.
- Careri, M., Mangia, A., Barbieri, G., Bolzoni, L., Virgili, R. and Parolari, G. 1993. Sensory property relationships to chemical data of Italian type dry-cured ham. *Journal of Food Science* **58**: 968–972.
- Carrapiso, A.I., Bonilla, F. and García, C. 2003. Effect of crossbreeding and rearing system on sensory characteristics of Iberian ham. *Meat Science* **65**: 623–629.
- Carrapiso, A.I. and García, C. 2005. Instrumental colour of Iberian ham subcutaneous fat and lean (biceps femoris): influence of crossbreeding and rearing system. *Meat Science* **71**: 284–290.
- Carrapiso, A.I., Jurado, A., Martín, L. and García, G. 2007. The duration of the outdoor rearing period of pigs influences Iberian ham characteristics. *Irish Journal of Agricultural and Food Research* **46**: 105–115.
- Carrapiso, A.I., Jurado, A., Timón, M.L. and García, C. 2002. Odor-active compounds of Iberian hams with different aroma characteristics. *Journal of Agricultural and Food Chemistry* **50**: 6453–6458.
- Cava, R., Ruiz, J., López-Bote, C., Martín, L., García, C., Ventanas, J. and Antequera, T. 1997. Influence of finishing diet on fatty acid profiles of intramuscular lipids, tryglicerides and phospholipids in muscle of Iberian pig. *Meat Science* **45**: 263–270.
- Cava, R., Ventanas, J., Ruiz, J., Andrés, A.I. and Antequera, T. 2000. Sensory characteristics of Iberian ham: influence of rearing system and muscle location. *Food Science and Technology International* **6**: 235–242.
- Flores, L.J., Birón, C., Izquierdo, L. and Nieto, P. 1988. Characterization of green hams from Iberian pigs by fast analysis of subcutaneous fat. *Meat Science* **23**: 253–262.
- Gandemer, G. 2002. Lipids in muscle and adipose tissues, changes during processing and sensory properties of meat products. *Meat Science* **62**: 309–321.
- García, C., Ventanas, J., Antequera, T., Ruiz, J., Cava, R. and Álvarez, P. 1996. Measuring sensorial quality of Iberian ham by Rasch model. *Journal of Food Quality* **19**: 397–412.
- Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C. 1998. "Multivariate data analysis". Fifth Edition. Prentice Hall, New Jersey, pages 87–138.
- Jurado, A., García, C., Timón, M.L. and Carrapiso, A.I. 2007. Effect of ripening time and rearing systems on amino acid-related flavour compounds of Iberian ham. *Meat Science* **75**: 585–594.
- Kaluzny, M.A., Duncan, L.A., Merrit, M.V. and Epps, D.E. 1985. Rapid separation of lipid classes in high yield and purity using bonded phase columns. *Journal of Lipid Research* **26**: 135–140.

- Meilgaard, M., Civille, G.V. and Carr, T. 1999. "Sensory evaluation techniques". Third Edition. CRC Press, Boca Raton, Florida, USA, 326 pages.
- Mitchaothai, J., Yuangklang, C., Wittayakun, S., Vasupen, K., Wongsutthavas, S., Srenanul, P., Hovenier, R., Everts, H. and Beynen, A.C. 2007. Effect of dietary fat type on meat quality and fatty acid composition of various tissues in growing-finishing swine. *Meat Science* **76**: 95–101.
- Muriel, E., Ruiz, J., Petró, M.J., Andrés, A.I. and Antequera, T. 2003. Influencia de la alimentación sobre parámetros físico-químicos y sensoriales del lomo curado de cerdo Ibérico. *Eurocarne* **121**: 75–90.
- Muriel, E., Ruiz, J., Ventanas, J. and Antequera, T. 2002. Free-range rearing increases (n-3) polyunsaturated fatty acids of neutral and polar lipids in swine muscles. *Food Chemistry* **78**: 219–225.
- Pastorelli, G., Magni, S., Rossi, R., Pagliarini, E., Baldini, P., Dirinck, P., Van Opstaele, F. and Corino, C. 2003. Influence of dietary fat, on fatty acid composition and sensory properties of dry-cured Parma ham. *Meat Science* **65**: 571–580.
- Pugliese, C., Calagna, G., Chiofalo, V., Moretti, V.M., Margiotta, S., Franci, O. and Gandini, G. 2004. Comparison of the performances of Nero Siciliano pigs reared indoors and outdoors: 2. Joints composition, meat and fat traits. *Meat Science* **68**: 523–528.
- Real Decreto 1469/2007 de 2 de noviembre por el que se aprueba la norma de calidad para la carne, el jamón, la paleta y la caña de lomo ibéricos. *Boletín Oficial del Estado*, 264, de 3 de noviembre de 2007, 45087–45104.
- Ruiz, J., Cava, R., Antequera, T., Martín, L., Ventanas, J. and López-Bote, C. 1998. Prediction of the feeding background of Iberian pigs using the fatty acid profile of subcutaneous, muscle and hepatic fat. *Meat Science* **49**: 155–163.
- SPSS. 2001. SPSS for Windows, Release 11.0, SPSS Inc., Chicago, USA.
- Ventanas, S., Ventanas, J. and Ruiz, J. 2007. Sensory characteristics of Iberian dry-cured loins: Influence of crossbreeding and rearing system. *Meat Science* **75**: 211–219.
- Ventanas, S., Ventanas, J., Tovar, J., García, C. and Estévez, M. 2007. Extensive feeding versus oleic acid and tocopherol enriched mixed diets for the production of Iberian dry-cured hams: Effect on chemical composition, oxidative status and sensory traits. *Meat Science* **77**: 246–256.
- Wood, J.D., Richardson, R.I., Nute, G.R., Fisher, A.V., Campo, M.M., Kasapidou, E., Sheard, P.R. and Enser, M. 2004. Effects of fatty acids on meat quality: a review. *Meat Science* **66**: 21–32.

Received 13 February 2008