Available online at www.sciencedirect.com
ScienceDirect
Food Chemistry 101 (2007) 107–112
Food Chemistry
www.elsevier.com/locate/foodchem

Fatty acid compositions of selected varieties of Spanish dry ham related to their nutritional implications

Manuela Fernández [a,*], Juan Antonio Ordóñez [b], Isabel Cambero [b], Carlos Santos [a], Carmen Pin [c], Lorenzo de la Hoz [a]

[a] Departamento de Nutrición, Bromatología y Tecnología de los Alimentos, Facultad de Veterinaria, Universidad Complutense de Madrid, Avda. Puerta de Hierro s/n, 28040 Madrid, Spain

[b] Instituto de Ciencia y Tecnología de la Carne, Universidad Complutense de Madrid, Avda. Puerta de Hierro s/n, 28040 Madrid, Spain

[c] Institute of Food Research (BBSRC), Norwich Research Park, Colney, Norwich NR4 7UA, United Kingdom

Received 17 January 2005; received in revised form 3 January 2006; accepted 3 January 2006

Abstract

Five varieties of Spanish dry cured ham were studied to assess their nutritional value in relation to fatty acids. Ten hams of the Traditional Speciality Guaranteed (TSG) "Jamón Serrano", and the Protected Designations of Origin (PDO) "Jamón de Teruel", "Dehesa de Extremadura", "Jamón de Huelva" and "Guijuelo", were analysed. Iberian hams ("Dehesa de Extremadura", "Jamón de Huelva" and "Guijuelo") were characterised by a lower proportion of saturated fatty acids (SFA) and a significantly higher percentage of monounsaturated fatty acids (MUFA) than white hams ("Jamón Serrano" and "Jamón de Teruel"). The Iberian varieties also showed a high proportion (approximately 50%) of C18:1 $n-9$, while "Jamón Serrano" showed the highest percentage of C18:2n−6. The PUFA/SFA (P/S) ratio of the five varieties was $\geqslant 0.19$, with the highest ratio corresponding to "Jamón Serrano" (0.3). The n−6/n−3 ratio was in the order of 13/1 in "Jamón Serrano" and "Jamón de Huelva", and ranged from 9.3/1 to 10.3/1 in the other varieties. The most favourable hypocholesterolemic/Hypercholesterolemic (h/H) ratio ($\geqslant$2.5) was found in the Iberian varieties. TSG "Serrano" was shown to supply the lowest percentage of the recommended daily intake of MUFA, the Iberian varieties showed the highest percentage of the daily intake of long-chain PUFA, and PDO "Dehesa de Extremadura" showed the highest percentage of the intake of C18:3n−3. The higher MUFA proportion and h/H ratio observed in the Iberian hams, together with their contribution to the recommended daily intake of fatty acids, would make these products more suitable for healthier diets, although consumption must be recommended in moderation.

Keywords: Spanish dry cured ham; Fatty acids; n−6; n−3; Hypocholesterolemic; Hypercholesterolemic

1. Introduction

Current human diet in Western countries is characterised, among other facts, by a high intake of fats, especially saturated and n−6 polyunsaturated fatty acids (PUFA) (Bengmark, 1998; Simopoulos, 2004). Saturated fatty acids are correlated with increased risk of cardiovascular disease while a high intake of monounsaturated and $n-3$ polyunsaturated fatty acids has been shown to have an inverse effect (Alexander, 1998; FAO, 1994; Kris-Etherton, 1999; Mattson & Grundy, 1985; Schaefer, 1997). On the other hand, a diet rich in $n-6$ polyunsaturated fatty acids is not considered as balanced. Clinical studies, in patients with cardiovascular disease, arthritis, asthma, cancer and mental illness, clearly indicate the need to balance the n−6/n−3 fatty acid intake for prevention, and during treatment, of chronic diseases (Simopoulos, 2004). There is strong scientific evidence for decreasing the n−6 and increasing the n−3 intake to improve health throughout the life cycle (Simopoulos & Cleland, 2003). For this reason, researchers are now emphasising the importance of

* Corresponding author. Tel.: +34 91 3943946; fax: +34 91 3943743.
E-mail address: manuela@vet.ucm.es (M. Fernández).

0308-8146/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2006.01.006

the $n-6/n-3$ PUFA ratio rather than the absolute content of each family of fatty acids in the diet (British Nutrition Foundation, 1992; Simonsen et al., 1998; Simopoulos, 2004). Today, in Western diets, the ratio of n-6/$n-3$ fatty acids ranges from approximately 15/1 to 16.7/1, instead of the optimal ratio recommendations, which vary from 1/1 to 4/1 (Simopoulos, 2004).

Fat from meat and meat products, such as dry cured ham, is not considered among the "healthy" fats, since it contains cholesterol and large amounts of saturated fatty acids and very low levels of $n-3$ PUFA (Rhee, 1992). However, the composition of meat fat depends on many factors, such as animal species, genetics and feeding and every product has to be considered separately. In this way, the increasing awareness of the need for diets to contain higher levels of "healthy" fats has focussed on the importance of the characterisation of fat from different meat products from a nutritional point of view.

Dry-cured hams are manufactured in many countries, but production is mainly located in the Mediterranean area (Álvarez de la Puente, 2003). There is a great variety of dry-cured hams in this area, some of the most important being Spanish Iberian and Serrano, Italian Parma and San Daniele, and French Bayonne hams. These varieties differ in the pig breed, type of feed, meat weight, type of cut and processing conditions (Martín-Bejarano, 2001; Ockerman, Basu, León Crespo, & Céspedes, 2002; Toldrá, 1998; Ventanas, Ruiz, & Córdoba, 2001).

The Spanish population consume approximately 4.5 kg of dry-cured ham per capita per year (Ministerio de Agricultura, 2004). Spanish hams are dry salted, air dried and aged during 7–24 months and they are not smoked (Martín-Bejarano, 2001; Ventanas et al., 2001). "Jamón" is produced throughout the entire country, but certain differences exist in production, depending on the zone and according to the production techniques. Basically, there are two distinct types of Spanish "jamón" related to the breed used: white and Iberian hams. In order to maintain quality and to avoid imitations, most of the Spanish production of ham is covered by different quality designations, according to the European Union systems for developing and protecting regional foods (European Commission, 1996, 1999).

Iberian ham production is today restricted to Southwestern Spain. These hams are produced from Iberian pigs (an indigenous, black footed, fine skeleton and long legged breed with a great adipogenic ability) and sometimes from Iberian pigs cross-bred with Duroc or Duroc-Jersey pigs (Ministerio de la Presidencia, 2001). There are three quality categories of hams, depending on feeding: "pienso" or "cebo" (the pigs are fed and fattened with commercial feed), "recebo" (the hogs are fed in the Mediterranean forest -"dehesa"- with acorns and pasture complemented with grains) and "montanera" or "bellota" (the hogs are exclusively fed and fattened in the "dehesa" with acorns and pasture). Iberian pigs are slaughtered at about 18 months and approximately at 160 kg weight (Ventanas et al., 2001). They give high quality products characterised by much infiltration of fat in meat, which provides a high degree of marbling, a firm texture and an intense, delicate and very special flavour. These hams are dried in ambient air during 18–24 months and are the most appreciated by consumers, especially the "bellota" (acorn) type. There are three Protected Designations of Origin (PDO) of Iberian hams: "Dehesa de Extremadura", "Jamón de Huelva" and-the main producer of Iberian hams- "Guijuelo", varying in the geographical area of production, which implies differences in the hog line, the leg size, the ripening time and conditions, etc. (Ministerio de Agricultura, 1986, 1990, 1995; Ministerio de la Presidencia, 2001, 2003). Fig. 1 shows the geographical areas where the different types of Iberian hams are manufactured.

White pigs have taken a great part of the Spanish ham market from the Iberian hogs during recents decades due to their precocity, higher yielding and better adaptation to intensive farming, although Iberian ham production is recovering at the present moment. White hams show certain fat infiltration, although much lower than that of Iberian hams. Ripening usually takes 7–12 months and it is normally carried out in drying rooms (Ockerman et al., 2002). An important part of the Spanish white ham production comes under the Traditional Speciality Guaranteed (TSG) "Jamón Serrano", a European Union standard that, since 2000, protects the processing method of this product (European Commission, 1999), although it does not make reference to a specific processing area or the origin of the raw material. However, there also exists a PDO of Spanish white ham, "Jamón de Teruel" (Ministerio de Agricultura, 1993), which is produced in the Northeast of Spain (Fig. 1) from white pigs fed with commercial feeding, by a minimum of 9 months of air-curing at more than 800 meters above sea level.

Fig. 1. Geographic areas of production of Spanish dry cured hams with protected designation of origin (PDO). ■ PDO "Jamón de Teruel"; ▩ PDO "Guijuelo"; ⊡ PDO "Dehesa de Extremadura"; ▧ PDO "Jamón de Huelva".

Taking into account the various origins and methods of production of Spanish hams, differences in composition must be expected, which are of interest, either from a technological or nutritional point of view. Although the genotype has a limited effect on the fatty acid composition of meat, this characteristic is strongly influenced by the diet, especially in the last stages prior to slaughter (Andrés et al., 2001; Cava et al., 1997; Tejeda, García, Muriel, & Antequera, 2002; Wood et al., 2003). The purpose of the present work was to study and compare the fatty acid composition of the five above mentioned varieties of Spanish ham, with special reference to their nutritional properties.

2. Materials and methods

Ten dry-cured hams of each of the above mentioned varieties (TSG "Jamón Serrano" and PDO "Jamón de Teruel", "Dehesa de Extremadura", "Jamón de Huelva" and "Guijuelo",) were purchased in different marketplaces. "Guijuelo", "Dehesa de Extremadura" and "Jamón de Huelva" hams belonged to the "bellota" category. All the hams analysed in this study corresponded to the left leg of the hog and were manufactured by different commercial brands. Ham samples were taken by cutting 1 cm slices parallel to the bone, containing sections of the muscles *Biceps femoris*, *Semi-tendinosus* and *Semi-membranosus*. Subcutaneous and intermuscular fat was removed. Samples were analysed in triplicate for dry matter, intramuscular lipid content and fatty acid composition of the intramuscular fat.

Dry matter was determined by drying the sample at 110 °C to constant weight.

Lipids were collected from the samples by cold extraction in chloroform and methanol in the presence of antioxidant BHT according to Hanson and Olley (1963) and quantified gravimetrically.

For the fatty acid analysis, methyl esters were prepared by acidic transesterification in the presence of sodium metal (0.1 N in methanol) and sulphuric acid (5% in anhydrous methanol (Sandler & Karo, 1992). The methyl esters were extracted with petroleum ether and analysed using a Perkin-Elmer 8420 gas chromatograph (Perkin-Elmer, Beaconsfield, UK) equipped with a flame ionization detector and a capillary column HP-Innowax (30 m × 0.32 mm i.d. and 0.25 μm). The chromatographic conditions were as follows: the initial column temperature was 170 °C, which was maintained for 2 min, then raised to 240 °C at 3.5 °C/min and finally held for 20 min; injector and detector temperature were 250 °C. Helium was used as carrier gas, at a flow rate of 2 ml/min. Fatty acid methyl esters were identified by comparison with commercial standards analysed under the same conditions, and quantified as percentage of total methyl esters.

A Kruskal-Wallis test, equivalent to one-way ANOVA, was carried out to test the hypothesis of equality on the five groups. When this hypothesis was rejected, a multiple mean comparisons Dunn's test was carried out. A further study of the differences between white and Iberian samples was performed by a non-parametric contrast on the ranks of the observations. Two models were compared: a model considering two groups of observations (white and Iberian samples) and a model consisting of the total average of the ranks of the 5 groups. The contrast was solved by calculating the Kruskal-Wallis statistics and approximating the associated p-value from the F-distribution. When the p-value was less than 0.05, the hypothesis of equality of the models was rejected, leading to conclusive differences between white and Iberian samples. Canonical discriminant analysis was carried out on the 50 independent samples.

3. Results and discussion

The water content of hams (Table 1) ranged from 41% to approximately 53%. Only TSG "Jamón Serrano", which exhibited the highest water content, showed significant differences in comparison with the other varieties. The lipid content of the muscle (g/100 g D.M.) ranged from 17.2% in TSG "Jamón Serrano" to 29.2% in PDO "Dehesa de Extremadura" (Table 1). Hams belonging to PDO "Jamón de Teruel" showed a similar intramuscular lipid content (ILC) to that observed in PDO Guijuelo (Table 1).

Table 1 also shows the fatty acid profile (means of the observations) of each variety of ham. As can be observed in the Table, Iberian hams ("Dehesa de Extremadura", "Jamón de Huelva" and "Guijuelo") were characterised by a significantly lower proportion of saturated fatty acids (SFA) and a significantly higher percentage of monounsaturated fatty acids (MUFA). The proportion of polyunsaturated fatty acids (PUFA) varied from 6.76% in PDO "Dehesa de Extremadura" to 12.2% in TSG "Jamón Serrano". PDO "Jamón de Teruel" and "Jamón de Huelva" showed similar values among them, while PDO "Guijuelo" showed intermediate values.

In relation to the individual fatty acids, Iberian hams showed a higher percentage of C18:1 $n-9$ and, in general, of C20:1 $n-9$, compared to white hams (Table 1). TSG "Jamón Serrano" showed a significantly higher proportion of C14:0, C:16:0, C20:3 $n-6$ and C22:5 $n-3$. TSG "Jamón Serrano" and PDO "Jamón de Huelva" showed the highest proportion of C22:4 $n-6$ and PDO "Jamón de Teruel", the highest levels of C22:6 $n-3$. According to the statistical analysis, no significant differences were found between the five types of hams for C16:1$n-7$, C18:1 $n-7$, C18:3$n-6$, C18:3$n-3$, C20:0, C20:4$n-6$ and C20:5$n-3$ (Table 1).

Among PUFA, the main $n-6$ fatty acid in all samples was C18:2$n-6$. TSG "Jamón Serrano" showed the highest values (10.2%). As a consequence, TSG "Jamón Serrano" showed the highest proportion of total $n-6$ fatty acids among all the types analysed. The major $n-3$ fatty acid was C18:3$n-3$, which did not show significant differences between hams. A significantly higher proportion of C22:5$n-3$ was found in TSG "Jamón Serrano", and thus,

Table 1
Water (%), intramuscular lipid content (ILC) (g/100 g D.M.) and fatty acid profile (% of total fatty acids) of the five varieties of Spanish dry-cured hams (means of the observations for each group)

	Serrano	Teruel	Dehesa	Huelva	Guijuelo	p-value
Water	52.8^{a}	43.2^{b}	41.0^{b}	44.2^{b}	44.3^{b}	<0.001
ILC	17.2^{c}	24.2^{b}	29.2^{a}	$20.7^{b,c}$	23.3^{b}	<0.001
Fatty acid						
C12:0	0.13^{a}	$0.11^{a,b}$	$0.06^{b,c}$	0.05^{c}	$0.06^{b,c}$	<0.001
C14:0	1.72^{a}	1.02^{b}	1.00^{b}	0.96^{b}	0.97^{b}	< 0.05
C16:0	26.1^{a}	$24.6^{a,b}$	$22.9^{b,c}$	22.4^{c}	21.9^{c}	<0.001
C16:1$n-7$	2.41	2.24	2.56	2.45	2.43	ns
C18:0	$12.5^{a,b}$	15.6^{a}	$10.8^{b,c}$	10.7^{c}	$12.0^{b,c}$	<0.001
C18:1$n-9$	40.6^{b}	42.5^{b}	50.5^{a}	48.9^{a}	50.1^{a}	<0.001
C18:1$n-7$	2.99	3.07	3.09	3.33	3.38	ns
C18:2$n-6$	10.2^{a}	7.14^{b}	5.43^{c}	7.18^{b}	$6.13^{b,c}$	<0.001
C18:2*cis*-9,-*trans*11	0.23^{a}	$0.15^{a,b}$	$0.13^{b,c}$	0.10^{c}	0.12^{c}	<0.001
C18:3$n-6$	0.07	0.05	0.04	0.05	0.04	ns
C18:3$n-3$	0.51	0.46	0.40	0.34	0.35	ns
C20:0	0.19	0.23	0.16	0.18	0.20	ns
C20:1$n-9$	0.85^{c}	0.93^{c}	$1.06^{b,c}$	1.15^{b}	1.48^{a}	<0.001
C20:3$n-6$	0.45^{a}	$0.36^{b,c}$	0.31^{c}	$0.37^{a,b}$	0.39^{b}	<0.05
C20:4$n-6$	0.28	0.18	0.17	0.40	0.19	ns
C20:5$n-3$	0.11	0.09	0.10	0.10	0.16	ns
C22:4$n-6$	0.11^{a}	0.06^{b}	0.04^{b}	0.11^{a}	0.08^{b}	<0.05
C22:5$n-3$	0.10^{a}	0.07^{b}	0.06^{b}	0.06^{b}	0.06^{b}	<0.05
C22:6$n-3$	0.10^{b}	0.15^{a}	0.08^{b}	0.09^{b}	0.09^{b}	<0.05
SFA	40.6^{a}	41.5^{a}	34.9^{b}	34.3^{b}	35.1^{b}	<0.001
MUFA	46.9^{b}	48.7^{b}	57.2^{a}	55.8^{a}	57.4^{a}	<0.001
PUFA	12.16^{a}	8.71^{b}	6.76^{c}	8.80^{b}	$7.61^{b,c}$	<0.001
PUFA/SFA	0.30^{a}	$0.21^{b,c}$	0.19^{c}	0.26^{b}	$0.22^{b,c}$	<0.001
$n-6$	11.11^{a}	7.79^{b}	5.99^{c}	8.11^{b}	$6.83^{b,c}$	<0.001
$n-3$	0.82^{a}	0.77^{b}	0.64^{c}	0.59^{c}	0.66^{c}	<0.005
$n-6/n-3$	13.55^{a}	10.12^{b}	9.36^{b}	13.75^{a}	10.35^{b}	<0.05
h/H	2.0^{b}	2.11^{b}	2.52^{a}	2.61^{a}	2.67^{a}	<0.001

[a,b,c] Values in a row with different letters are significantly different ($p < 0.05$) (Dunn's test); equal letters for groups mean no differences for that characteristic; ns = not significant.
h/H = hypocholesterolemic/Hypercholesterolemic ratio = [(sum of C18:1$n-9$, C18:1$n-7$, C18:2$n-6$, C18:3$n-6$, C18:3$n-3$, C20:3$n-6$,C20:4$n-6$, C20:5$n-3$, C22:4$n-6$, C22:5$n-3$ and C22:6$n-3$)/(sum of C14:0 and C16:0)].

a higher total $n-3$ percentage was also found in this type of ham.

To assess the nutritional properties of ham fat, the PUFA/SFA ratio (P/S), the PUFA $n-6/n-3$ ratio and the hypocholesterolemic/Hypercholesterolemic fatty acids ratio (h/H), were determined. In relation to P/S, a value above 0.4 is recommended for healthy foods and diets (UK Department of Health, 1994) although, as previously mentioned, the high proportion of PUFA in and on itself is not necessarily healthy if it is not balanced in relation to the $n-6/n-3$ ratio (Simopoulos & Cleland, 2003). The hams studied in the present work showed a P/S ratio of 0.19–0.30, TSG "Jamón Serrano" reaching the highest values.

The high MUFA percentage observed in the Iberian hams indicates their suitability for healthier diets, since MUFA (and PUFA) rich diets decrease cholesterol levels in blood and are related to a low incidence of cardiovascular diseases (Mattson & Grundy, 1985; FAO, 1994; Schaefer, 1997; Alexander, 1998; Kris-Etherton, 1999). García-Rebollo et al. (1998) found in clinical studies, in which Iberian ham was habitually included in the diet of elderly persons, a decrease in plasma total cholesterol, triglycerides and LDL cholesterol. These observations are in agreement with the h/H ratio observed in the samples (Santos-Silva, Bessa, & Santos-Silva, 2002, with some modifications). The percentage of fatty acids considered as hypocholesterolemic (C18:1$n-9$, C18:1$n-7$, C18:2 $n-6$, C18:3$n-6$, C18:3$n-3$, C20:3$n-6$, C20:4$n-6$, C20:5 $n-3$, C22:4$n-6$, C22:5$n-3$ and C22:6$n-3$) was significantly higher in the Iberian hams (>60%) than in the white ones (<55.5%), while the amount of hypercholesterolemic fatty acids (C14:0 and C16:0) showed the opposite behaviour (<24% in the Iberian hams vs. >25% in the white ones) (data not shown). As a result, the h/H ratio of the Iberian hams was significantly more favourable (>2.5) (Table 1).

The highest $n-6/n-3$ ratios (13.5–13.7/1) were found in TSG "Jamón Serrano" and PDO "Jamón de Huelva" (Table 1). Hams belonging to PDO "Guijuelo", PDO "Dehesa de Extremadura" and PDO "Jamón de Teruel" varities showed $n-6/n-3$ ratios of 9.3–10.3/1. Therefore, no typical pattern was found for either white or Iberian hams. The ratio obtained in the five varieties of hams is above the levels recommended by different authors and institutions, such as the British Nutrition Foundation (1992) ($n-6/n-3$ ratio = 6/1) or Simopoulos (2004) ($n-6/n-3$ ratio = 1 − 4/1), although the ratios found in PDO "Dehesa de Extremadura", "Jamón de Teruel" and "Guijuelo" would be considered within the range recommended by the Sociedad Española de Nutrición Comunitaria (Ros, 2001) ($n-6/n-3$ ratio = 6 − 10/1).

Canonical discriminant analysis (CDA) was carried out on the fatty acids listed in Table 1. The two first canonical variables were retained. The first canonical variable (C1) accounted for approximately 84% of the total variability, while the second canonical variable (C2) accounted for approximately 13%. C1 directly correlated (Pearson coefficient >0.6) with C18:2$n-6$, C14:0, C12:0, C22:5 $n-3$ and C22:4$n-6$, and was inversely associated with the percentage of C18:1$n-9$ (with a correlation coefficient <−0.6). C2 showed a high positive correlation with C16:0 and C18:0, and was inversely correlated with C20:1 $n-9$ and C18:1$n-9$. Fig. 2 shows the scores of the observations on the two first canonical variables and the distribution of the samples on the plane defined by C1 and C2. As can be seen, hams were clearly grouped in the plot. The C1 mainly distinguished between TSG "Jamón Serrano" and the other four varieties of hams, while the C2 was useful for differentiating among the other 4 groups of hams.

Table 2 shows the fatty acid daily intake recommended for the Spanish adult population (DRSP) (Martínez, 1998; Mataix, 2004). According to these authors, SFA should supply 8% of the recommended total energy daily intake (2,300 kcal or 9.62 MJ), MUFA 20%, C18:2$n-6$ 4%, C18:3$n-3$0.8% and long-chain PUFA 0.2% On the basis of these criteria, and considering the fatty acid composition of hams, the percentage of the DRSP supplied by 100 g of ham was calculated (Table 2). As can be seen in the Table, PDO "Jamón de Teruel" and "Dehesa de Extremadura" supply the highest percentage of the DRSP in terms of SFA. The percentage of the DRSP of MUFA supplied by 100 g of ham was 2–3-fold lower in TSG "Serrano" than in the other ham varieties analysed in the present study. The percentage of the PUFA DRSP covered by all the ham varieties was 5–8% for C18:2$n-6$, 2–3% in the case of C18:3$n-3$ and 15–21% for long-chain PUFA. PDO "Dehesa de Extremadura" was shown to supply the lowest percentage of the daily intake of C18:2$n-6$, and the highest intake of C18:3$n-3$. In general, the three Iberian varieties ("Dehesa de Extremadura", "Jamón de Huelva" and "Jamón de Teruel") cover the highest percentage of the intake of long-chain PUFA.

From the results obtained in the present work, it can be concluded that Iberian hams could be considered as healthier from a nutritional point of view in relation to their fatty acid profiles, and thus, they could be included regularly in the diet, although in moderation, since the fatty acid ratios are within the limit or above the nutritional recommendations and these products also contain a high amount of salt.

Table 2
Daily intake recommended for the Spanish adult population (DRSP)[A], estimation of the amount of fatty acids in 100 g of ham and percentage of the DRSP covered by the intake of 100 g of ham

	SFA[B]	MUFA	PUFA		
			C18:2$n-6$	C18:3$n-3$	Long PUFA
DRSP (g/day)	20.4	51.0	10.5	2.01	0.52
g Fatty acids/100 g ham					
Ham					
Serrano	2.97^c	3.46^c	0.75^a	0.037^c	0.08^b
Teruel	5.10^a	6.20^b	0.89^a	0.050^b	0.09^b
Dehesa	5.55^a	9.05^a	0.49^c	0.062^a	0.11^a
Huelva	3.69^b	5.91^b	0.74^a	0.035^c	0.11^a
Guijuelo	4.20^b	6.54^b	0.71^{a,b}	0.041^b	0.10^{a,b}
% DRSP covered by the intake of 100 g of ham					
Ham					
Serrano	14.6^c	6.78^c	7.17^a	1.84^c	15.4^b
Teruel	25.0^a	12.2^b	8.51^a	2.48^b	17.3^b
Dehesa	27.2^a	17.7^a	4.68^c	3.08^a	21.2^a
Huelva	18.1^b	11.6^b	7.07^a	1.74^c	21.2^a
Guijuelo	20.6^b	12.8^b	6.79^{a,b}	2.04^b	19.2^{a,b}

[a,b,c] Values in a column with different letters are significantly different ($p < 0.05$).
[A] Adapted from Mataix (2004) and Martínez (1998).
[B] SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

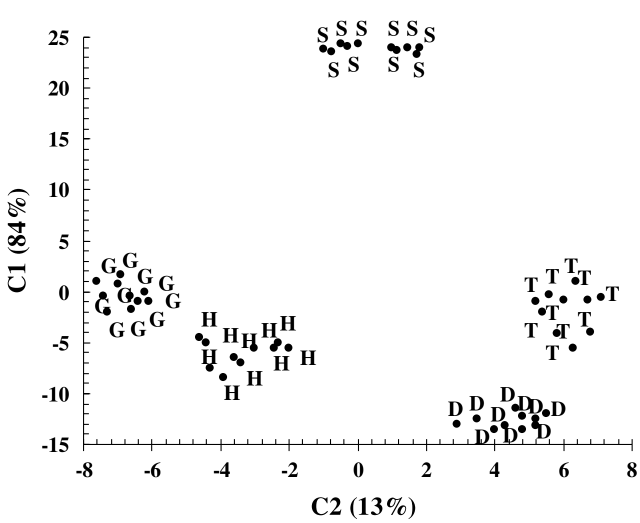

Fig. 2. Scores of the observations on the canonical variables (canonical discriminant analysis). D: PDO "Dehesa de Extremadura"; G: PDO "Guijuelo"; H: PDO "Jamón de Huelva"; S: TSG "Jamón Serrano"; T: PDO "Jamón de Teruel".

Acknowledgement

This work was funded by the Ministerio de Ciencia y Tecnología (Project AGL 2000-0050-P4-02, and AGL03-5803). C. Santos is the beneficiary of a predoctoral grant from the Universidad Complutense de Madrid.

References

Alexander, J. W. (1998). Immunonutrition: the role of $\omega-3$ fatty acids. *Nutrition, 14*, 627–633.

Álvarez de la Puente, J., (2003). International trade of cured ham: promotion and barriers. *II World Congress of Dry Cured Ham.* International Commerce Plenary Session conferences. Cáceres, Spain.

Andrés, A. I., Cava, R., Mayoral, A. I., Tejeda, J. F., Morcuende, D., & Ruiz, J. (2001). Oxidative stability and fatty acid composition of pig muscles as affected by rearing system, crossbreeding and metabolic type of muscle fibre. *Meat Science, 59*, 39–47.

Bengmark, S. (1998). Ecoimmunonutrition: a challenge for the third millennium. *Nutrition, 14*, 563–572.

British Nutrition Foundation (1992). *Unsaturated fatty acids: Nutritional and physiological significance. The Report of British Nutrition Foundation's Task Force*. London: Chapman & Hall.

Cava, R., Ruiz, J., López-Bote, C. J., Martín, L., García, C., Ventanas, J., et al. (1997). Influence of finishing diet on fatty acid profiles of intramuscular lipids, triglycerides and phospholipids in muscle of the Iberian pig. *Meat Science, 45*, 263–270.

European Commission. (1996). Commission Regulation (EC) No. 1107/96 of 12 June 1996 on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Council Regulation (EEC) No. 2081/92. *Official Journal of the European Communities*, *L148*, 1–15.

European Commission. (1999). Commission Regulation (EC) No. 2419/1999 of 12 November 1999 supplementing the Annex to Regulation (EC) No. 2301/97 on the entry of certain names in the Register of certificates of specific character provided for in Council Regulation (EEC) No. 2082/92 on certificates of specific character for agricultural products and foodstuffs. *Official Journal of the European Communities*, *L291*, 25–26.

FAO. (1994). *Fat and oils in human nutrition*. FAO Food and Nutrition, Rome, Paper No. 57.

García-Rebollo, A. J., Maciá, E., Ortiz, A., Morales, P. J., Martín, M., Fallola, A., et al. (1998). Effects of the consumption of meat product rich in monounsaturated fatty acids (the ham from the Iberian pig) on plasma lipids. *Nutrition Research, 18*, 743–750.

Hanson, S. W. F., & Olley, J. (1963). Application of the Bligh and Dyer method of lipid extraction to tissue homogenates. *Biochemical Journal, 89*, 101–102.

Kris-Etherton, P. M. (1999). AHA science advisory: monounsaturated fatty acids and risk of cardiovascular disease. *Journal of Nutrition, 129*, 2280–2284.

Martín-Bejarano, S. (2001). Elaboración del jamón curado de cerdo blanco. In S. Martín-Bejarano (Ed.). *Enciclopedia de la carne y de los productos cárnicos* (Vol. 2, pp. 1205–1219). Plasencia: Martín & Macías.

Martínez, J. A. (1998). Nutrición y recomendaciones dietéticas. In J. A. Martínez (Ed.), *Fundamentos teorico-prácticos de nutrición y dietética* (pp. 51–58). Madrid: McGraw-Hill-Interamericana de España.

Mataix, J. (2004). Requerimientos e ingestas recomendadas de ácidos grasos omega-3 y ácido oleico. In J. Mataix & A. Gil (Eds.), *Libro blanco de los omega-3* (pp. 135–151). Madrid: Editorial Médica Panamericana.

Mattson, F. H., & Grundy, S. M. (1985). Comparison of the effects of dietary saturated, monounsaturated and polyunsaturated fatty acids on plasma lipids and lipoproteins in man. *Journal of Lipid Research, 26*, 194–202.

Ministerio de Agricultura, Pesca y Alimentación. (1986). Orden de 10 de junio de 1986 por la que se aprueba el Reglamento de la Denominación de Origen "Guijuelo" y de su Consejo Regulador. *Boletín Oficial del Estado*, *141*, 21572.

Ministerio de Agricultura, Pesca y Alimentación. (1990). Orden de 2 de julio de 1990 por la que se ratifica el Reglamento de la denominación de Origen "Dehesa de Extremadura" y su Consejo Regulador. *Boletín Oficial del Estado 150*, 18901.

Ministerio de Agricultura, Pesca y Alimentación. (1993). Orden de 3 de noviembre de 1993 por la que se ratifica el Reglamento de la Denominación de Origen "Jamón de Teruel" y su Consejo Regulador. *Boletín Oficial del Estado 286*, 33977.

Ministerio de Agricultura, Pesca y Alimentación. (1995). Orden de 12 de julio de 1995 ratificando el Reglamento de la Denominación de Origen "Jamón de Huelva. *Boletín Oficial del Estado*, *170*, 21993–22002.

Ministerio de Agricultura, Pesca y Alimentación (2004). *La alimentación en España*. Madrid: Ministerio de Agricultura, Pesca y Alimentación.

Ministerio de la Presidencia. (2001). Real Decreto 1083/2001 de 5 de octubre por el que se aprueba la norma de calidad para el jamón ibérico, paleta ibérica y caña de lomo ibérico elaborados en España). *Boletín Oficial del Estado*, *247*, 37830–37833.

Ministerio de la Presidencia. (2003). Real Decreto 144/2003 de 7 de febrero, por el que se modifica el Real Decreto 1083/2001 de 5 de octubre por el que se aprueba la norma de calidad para el jamón ibérico, paleta ibérica y caña de lomo ibérico elaborados en España. *Boletín Oficial del Estado*, *34*, 5156–5157.

Ockerman, H. W., Basu, L., León Crespo, F., & Céspedes, J. (2002). *Comparison of European and American systems of production and consumption of dry-cured hams*. Des Moines: National Pork Board. American Meat Science Association, pp. 1–12.

Rhee, K. S. (1992). Fatty acids in meats and meat products. In C. K. Chow (Ed.), *Fatty acids in foods and their health implications* (pp. 65–93). New York: Marcel Dekker.

Ros, E. (2001). Guía para una alimentación cardiosaludable. Aporte de grasa. In: Sociedad Española de Nutrición Comunitaria, *Guías alimentarias para la población española. Recomendaciones para una dieta saludable* (pp. 413–421). Madrid: IM & C.

Sandler, S. R., & Karo, W. (1992). *Sourcebook of advanced organic laboratory preparations*. San Diego: Academic Press, p. 332.

Santos-Silva, J., Bessa, R. J. B., & Santos-Silva, F. (2002). Effect of genotype, feeding system and slaughter weight on the quality of light lambs. II Fatty acid composition of meat. *Livestock Production Science, 77*, 187–194.

Schaefer, E. J. (1997). Effects of dietary fatty acids on lipoproteins and cardiovascular disease risk. *American Journal of Clinical Nutrition, 65*(S), 1655–1656.

Simonsen, N., van't Veer, P., Strain, J. J., Martín-Moreno, J. M., Huttunen, J. K., Navajas, J. F. C., et al. (1998). Adipose tissue omega-3 and omega-6 fatty acid content and breast cancer in the EURAMIC study. (European Community Multicenter Study on Antioxidants, Myocardial Infarction, and Breast Cancer). *American Journal of Epidemiology, 147*, 342–352.

Simopoulos, A. P. (2004). Omega$-$6/omega$-$3 essential fatty acid ratio and chronic diseases. *Food Reviews International, 20*, 77–90.

Simopoulos, A.P., Cleland, L.G., (2003). *Omega-6/omega-3 essential fatty acid ratio. The scientific evidence*. Karger, World Review of Nutrition and Dietetics, Basel, Vol. 92.

Tejeda, J.F., García, C., Muriel, E., Antequera, T., (2002). Muscle lipid composition of Iberian pig meat as related to genetic line. *In: Proceedings of the fourty eighth international congress of meat science and technology*, Rome, Vol. 2, p. 734.

Toldrá, F. (1998). Proteolysis and lipolysis in flavour development of dry-cured meat products. *Meat Science, 49*(S), 101–110.

UK Department of Health, (1994). *Nutritional aspects of cardiovascular disease*. Report on Health and Social Subject No. 46. Her Majesty's Stationery Office, London.

Ventanas, J., Ruiz, J., & Córdoba, J. J. (2001). El jamón curado de cerdo ibérico: descripción del proceso tradicional de elaboración. In S. Martín-Bejarano (Ed.). *Enciclopedia de la carne y de los productos cárnicos* (Vol. 2, pp. 1221–1245). Plasencia: Martín & Macías.

Wood, J. D., Richardson, R. I., Nute, G. R., Fisher, A. V., Campo, M. M., Kasapidou, E., et al. (2003). Effects of fatty acids on meat quality: a review. *Meat Science, 66*, 21–32.