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Meat quality characteristics in different lines of Iberian pigs

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Abstract

Physico-chemical parameters involved in technological meat quality for dry cured processing of four different lines (Entrepelado, Lampiño, Retinto and Torbiscal) of Iberian pigs were studied in the *Masseter* (MS) and *Longissimus dorsi* (LD) muscles. The line of Iberian pig significantly affected intramuscular fat content of MS muscle, animals from the Torbiscal line showing lower values. Proportions of several fatty acids of total lipids and polar lipids from the MS muscle were also affected. However, fatty acid composition and total lipids, neutral lipids and polar lipids of LD muscle and neutral lipids of MS muscle were scarcely affected. Lipid oxidation was also unaffected by Iberian pig line, but instrumental colour parameters of MS muscle showed significant variations.

Keywords: Iberian pig lines; Meat quality; Intramuscular fat; Fatty acids; Colour

1. Introduction

Technological quality of fresh meat and sensory quality of meat products from Iberian pigs are mainly determined by the lipid fraction. In this sense, Ruiz, Ventanas, Cava, Andrés, and García (2000) linked juiciness of dry cured Iberian products to total intramuscular fat content, and Cava, Ruiz, Ventanas, and Antequera (1999) observed a marked influence of intramuscular fatty acid composition of fresh meat on the flavour of Iberian meat products.

The Iberian pig breed includes several different genetic lines leading to a heterogeneity in morphological and productive features. Several authors have described differences in growth parameters and body composition (Dobao, Poza, Rodrigáñez, & Silió, 1985; García-Casco, 1993). Parameters such as daily weight gain, ham, shoulder and loin weight, and carcass length and carcass yield also vary among Iberian lines (Rodríguez, Béjar, Rodrigáñez, & Silió, 1993) and have been linked to the genetic variability between lines (García-Casco & Silió, 1991; Silió, Rodríguez, Toro, & Rodrigáñez, 1994). However, there is little scientific information about differences between Iberian lines in the physico-chemical properties involved in meat quality and their importance in dry cured processing.

Tejeda, García, Muriel, and Antequera (2002) and Petrón (2002) found small differences in the intramuscular fat content and composition of the lipid fractions of fresh meat and dry cured ham from three lines of Iberian pigs (CENSYRA, Torbiscal and Entrepelado). However, some of the more common lines were not considered in these studies, and such features as the susceptibility to lipid oxidation or the colour were not evaluated. In studying different lines of Iberian pigs slaughtered at 90 kg live weight for fresh meat consumption, Estévez, Morcuende, and Cava (2003) found higher intramuscular fat content and lower linoleic acid contents (C18:2 ($n-6$)) in polar lipids from animals of the Lampiño line compared to those of the Retinto and Torbiscal lines. However, the usual slaughter weight of Iberian pigs for dry cured product processing is around 150 kg, which make the results of the latter study of limited value.

Most chemical analysis for assessing meat quality are destructive, and are therefore not suitable for routine quality control in the industry. For this reason, *Masseter* (MS) muscle has been used in several studies for evaluating meat quality (Cava et al., 1997) since this

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muscle is not commonly used for consumption. However, it has not been unequivocally demonstrated that this muscle is affected by different parameters in the same way as the most valuable muscles such as *Longissimus dorsi* (LD) or the muscles included in the ham.

The aim of the present study was to evaluate the technological quality of fresh meat for dry cured product processing of the four most important lines of Iberian pigs (Entrepelado, Lampiño, Retinto and Torbiscal) and to determine the feasibility of using the MS muscle as predictor of quality for the more valuable muscles.

2. Material and methods

2.1. Animals and sampling

This study was carried out with 28 pure Iberian pigs of the same age from four different lines (Entrepelado, Lampiño, Retinto and Torbiscal (seven animals from each line)). All animals commenced the fattening (60 days prior to slaughter) at an initial weight of 90 ± 5 kg. All animals were kept together on 30 ha land and were reared outdoors. The feed consisted of acorn and pasture, i.e., the traditional type of feed. All the animals were slaughtered at 150 ± 10 kg and 17 months of age by electrical stunning and exsanguination at a local slaughterhouse. Sampling was carried out within 1 h of slaughter. A portion of the LD muscle from the last lumbar to the first thoracic vertebra and the whole MS muscle of all the 28 animals were removed. Colour was measured 24 h after slaughter and then samples were stored at −80 °C until analysis.

2.2. Chemical analysis

Moisture content was determined following the AOAC method (1984).

For fat extraction, samples were ground using a commercial grinder. Intramuscular total lipids were extracted as described by Bligh and Dyer (1959). Polar and neutral lipids (PL and NL) from the intramuscular fat were separated using NH_2-aminopropyl minicolumns as described by Kaluzny, Duncan, Merrit, and Epps (1985). Briefly, 0.1 g of intramuscular fat dissolved in 1 ml of chloroform was added to the column, which was previously activated with 1 ml of chloroform. Neutral lipids (NL) were eluted with 3 ml of chloroform:isopropanol (2:1). Polar lipids (PL) were subsequently eluted with 3 ml of methanol. Fatty acid methyl esters (FAMEs) of intramuscular fat, muscle NL and PL and of the diets were prepared by acidic-*trans*-esterification in the presence of sulphuric acid (5% sulphuric acid in methanol) (Cava et al., 1997). FAMEs were analysed by gas chromatography using a Hewlett-Packard HP-5890A gas chromatograph, equipped with a flame ionisation detector (FID). Separation was carried out on a polyethylene glycol-TPA modified fused silica semicapillary column (30 m long, 0.53 mm i.d., 1 μm film thickness) maintained at 220 °C. Injector and detector temperatures were 230 °C. The carrier gas was nitrogen at a flow rate of 1.8 ml min^{-1}. Individual FAME peaks were identified by comparing their retention times with those of standards (Sigma, St Louis). All analyses were performed in duplicate.

The susceptibility of muscle homogenates to iron-induced lipid oxidation was determined as described by Kornbrust and Mavis (1980). To prepare homogenates, 1 g ground muscle was homogenized with 9 ml of 0.15 M KCl for 45 s. During homogenisation, the tubes were kept in ice. Protein content was measured in 1 ml of homogenate following the Lowry procedure (Lowry, Rosenberg, Farr, & Randall, 1951). One milliliter of muscle homogenate was incubated at 37 °C in 40 mM tris-maleate buffer (pH 7.4) with 1 mM $FeSO_4$ and 2 mM ascorbic acid in a total volume of 10 ml. At fixed intervals (0, 50, 100 and 200 min), aliquots were removed for measurement of TBARS by the method of Buege and Aust (1978). TBARS were expressed as nanomoles of malonaldehyde (MDA) per milligram protein.

Colour of the muscle surface was measured after 30 min blooming by means of a Minolta Colorimeter (CR-300, Aquatecnica S.A., Valencia, Spain) which recorded a^*, b^* and L^* values. Chroma and hue angle were obtained from a^* and b^* following equations described below (Comission Internationale de l'Eclariage., 1975):

$$\text{Chroma } (C) = ((a^*)^2 + (b^*)^2)^{1/2},$$

$$\text{Hue angle } (H^\circ) = \text{arctg } (b^*/a^*).$$

2.3. Statistical analysis

An individual pig was the experimental unit for analysis of all data. Response data were evaluated by means of a one way ANOVA, including the slaughter weight as a covariable, using the General Linear Model of SPSS (v.11.0). When a significant probability was detected ($P < 0.05$), comparisons between means were carried out using the Tukey's test. Pearson's correlation coefficients were also calculated using SPSS (v.11.0).

3. Results and discussion

Table 1 shows the moisture, protein and intramuscular fat (IMF) contents of the MS and LD muscles of the four lines. Anatomical location clearly affected muscle composition. This has been discussed elsewhere (Muriel, Antequera, & Ruiz, 2002a) and is mainly due to

Table 1
Moisture, intramuscular fat and protein contents (g kg^{-1} of fresh matter) of *Masseter* and *Longissimus dorsi* muscles of the different Iberian pig lines

Muscle	Iberian pig line				SEM[A]	P[B]	Cov[C] (S.W.)
	Entrepelado	Lampiño	Retinto	Torbiscal			
Masseter							
Moisture	711.22	715.20	703.43	726.10	3.377	ns	ns
Fat	43.97[a]	45.50[a]	44.59[a]	23.91[b]	2.606	*	ns
Protein	147.09	146.49	141.77	152.73	2.596	ns	ns
Longissimus dorsi							
Moisture	674.23	697.73	687.52	698.87	0.093	ns	ns
Fat	51.06	48.38	48.04	36.70	0.122	ns	ns
Protein	182.19	178.05	181.48	181.20	0.049	ns	ns

Means with different superscript within a row show statistical differences ($P < 0.05$) between lines.
[A] Standard error of the mean.
[B] Significance levels: ns, $P > 0.05$; *, $P < 0.05$; **, $P < 0.01$ and ***, $P < 0.001$.
[C] Cov., covariable; S.W., slaughter weight.

the different metabolisms of each muscle (Andrés et al., 2001). The line did not significantly influence the moisture, protein and IMF contents of the LD muscle, but significantly ($P < 0.05$) affected the fat content of the MS muscle, animals from the Torbiscal line showing lower values than the those of the other three lines (Entrepelado, Lampiño and Retinto). In fact, animals from the Torbiscal line also tended to have lower IMF contents in the LD muscle. Therefore, despite their different metabolisms, MS behave similarly to the more valuable and glycolityc LD muscle regarding IMF content.

The analysis of slaughter weight as a covariable showed no significant effect. Therefore, the lower IMF contents in both muscles in animals from the line Torbiscal are not due to lower slaughter weights. Benito

Table 2
Fatty acids (g kg^{-1} of total FAMES) of total lipids from *Masseter* muscles of the different Iberian pig lines

Fatty acid	Iberian pig lines				SEM[A]	P[B]
	Entrepelado	Lampiño	Retinto	Torbiscal		
C12:0	0.06	0.00	0.00	0.00	0.015	ns
C14:0	6.39	6.49	7.32	6.99	0.185	ns
C15:0	0.15[b]	0.27[b]	0.32[ab]	0.55[a]	0.039	**
C16:0	187.31	182.41	189.64	181.46	2.237	ns
C16:1 ($n-7$)	28.55	28.79	32.62	29.96	0.580	*
C17:0	3.07[b]	4.13[ab]	4.40[ab]	5.44[a]	0.265	*
C17:1 ($n-9$)	2.60	3.28	3.65	3.62	0.180	ns
C18:0	118.30	115.74	111.03	117.47	1.573	ns
C18:1 ($n-9$)	505.45[a]	496.15[a]	491.68[a]	449.93[b]	4.754	***
C18:2 ($n-6$)	99.26[b]	110.61[b]	106.18[b]	133.69[a]	3.408	**
C18:3 ($n-3$)	7.58	9.65	10.02	10.51	0.517	ns
C20:0	2.16	2.59	2.45	2.40	0.275	ns
C20:1 ($n-9$)	15.16	15.64	14.55	14.56	0.316	ns
C20:4 ($n-6$)	23.96[b]	24.24[b]	26.14[b]	43.43[a]	2.193	**
SFA	317.43	311.64	315.16	314.30	3.088	ns
MUFA	551.76[a]	543.87[a]	542.50[a]	498.08[b]	4.907	***
PUFA	130.81[b]	144.49[b]	142.33[b]	187.62[a]	5.546	**
$\sum n-6$	123.22[b]	134.84[b]	132.32[b]	177.11[a]	5.419	**
$\sum n-3$	7.58	9.65	10.02	10.51	0.517	ns
$n-6/n-3$	19.28	14.48	13.88	17.13	1.086	ns
UI	0.87[b]	0.89[ab]	0.89[ab]	0.97[a]	0.016	**
PI	22.41[b]	24.04[b]	24.43[b]	34.09[a]	1.194	**

Means with different superscript within a row show statistical differences ($P < 0.05$) between lines.
UI (unsaturation index) = (average number of double bonds per fatty acid residue).
PI (peroxidability index) = (% monoenoic × 0.025) + (% dienoic × 1) + (% trienoic × 2) + (% tetraenoic × 4) + (% pentaenoic × 6) + (% hexaenoic × 8).
[A] Standard error of the mean.
[B] Significance levels: ns, $P > 0.05$;*, $P < 0.05$; **, $P < 0.01$ and ***, $P < 0.001$.

et al. (1998) and Tejeda et al. (2002) observed similar trends in the IMF content of Torbiscal pigs. This difference is probably due to the better muscular conformation of the animals of the Torbiscal line. Fernández et al. (2003) have shown a negative correlation between IMF content and the weights of the hams and the loins. As a practical consequence, pigs from this line should be slaughtered at higher weights to achieve similar IMF levels. This is important since IMF content is the main factor determining the juiciness of dry cured meat products (Ruiz et al., 2000) which is one of the main factors affecting consumer acceptability of these products (Ruiz, García, Muriel, Andrés, & Ventanas, 2002).

Tables 2 and 3 show the fatty acid profiles of the intramuscular total lipids of MS and LD muscles from the four different lines. The analysis of slaughter weight as a covariable had no significant effect on fatty acid composition. IMF from the MS muscles showed a higher total polyunsaturated fatty acids (PUFA) content, unsaturation index (UI) and peroxidability index (PI) than that from the LD muscles. Such differences between muscles have been discussed elsewhere (Muriel, Ruiz, Ventanas, & Antequera, 2002b). Iberian pig line had different effect on the fatty acid composition of the total muscle lipids in the MS and LD muscles, the former being markedly affected whereas the LD was unaffected. MS muscle showed significant differences due to the line for pentadecanoic acid (C15:0), palmitoleic acid (C16:1 ($n-7$)), heptadecanoic acid (C17:0), oleic acid (C18:1 ($n-9$)), linoleic acid (C18:2 ($n-6$)) and arachidonic acid (C20:4 ($n-6$)), and consequently in the total monounsaturated fatty acids (MUFA) and PUFA, the total $n-6$ fatty acids, and the UI and PI. The more remarkable results were the considerably lower oleic acid and higher linoleic and arachidonic acid contents of the Torbiscal animals compared to the other three lines. This disagrees with Tejeda et al. (2002) who found no significant difference IMF contents in our study. In our study, the higher proportion of PUFA and lower of MUFA in the MS muscle of Torbiscal animals could be because of their lower IMF content. Variations in the IMF content are mainly due to changes in the triglyceride content as the phospholipid content is relatively constant; therefore, a higher IMF content would give a higher level of triglycerides, and so a relative decrease in the phospholipid content (Leseigneur-Meynier & Gandemer, 1991; Ruiz et al., 2000). Due to the higher PUFA content in the polar lipids of Iberian pig muscles (Andrés et al., 2001; Muriel et al., 2002a, 2002b), lower IMF levels will give rise to a greater proportion of PUFA and lower MUFA in the total muscle lipids. This relationship between IMF and

Table 3
Fatty acids (g kg^{-1} of total FAMES) of total lipids from the *Longissimus dorsi* muscles of the different Iberian pig lines

Fatty acid	Iberian pig lines				SEM[A]	P[B]
	Entrepelado	Lampiño	Retinto	Torbiscal		
C12:0	0.10	0.43	0.18	0.30	0.224	ns
C14:0	8.94	8.83	9.10	9.16	0.565	ns
C15:0	0.14	0.00	0.16	0.00	3.878	*
C16:0	203.56	206.49	202.25	207.52	0.859	ns
C16:1 ($n-7$)	40.01	39.74	43.39	40.52	0.866	ns
C17:0	3.03	1.78	3.07	2.25	1.629	ns
C17:1 ($n-9$)	2.33	1.94	2.92	2.19	1.156	ns
C18:0	123.75	119.48	114.30	117.30	4.315	ns
C18:1 ($n-9$)	515.20	516.72	517.30	511.93	4.675	ns
C18:2 ($n-6$)	72.19	76.03	75.47	79.62	6.378	ns
C18:3 ($n-3$)	4.93	4.24	5.41	4.13	5.438	ns
C20:0	2.88	2.19	2.96	1.69	2.364	*
C20:1 ($n-9$)	11.90	12.26	12.46	11.83	3.438	ns
C20:4 ($n-6$)	11.04	9.87	11.03	11.57	20.907	ns
SFA	342.40	339.21	332.02	338.22	24.953	ns
MUFA	569.44	570.66	576.07	566.47	4.607	ns
PUFA	88.16	90.14	91.91	95.31	3.461	ns
$\sum n-6$	83.23	85.90	86.50	91.18	4.444	ns
$\sum n-3$	5.47	4.24	5.41	4.13	0.113	ns
$n-6/n-3$	17.05	20.61	17.29	23.01	0.020	ns
UI	0.77	0.77	0.78	0.78	0.049	ns
PI	14.04	13.83	14.48	14.83	0.154	ns

Means with different superscript within a row show statistical differences ($P < 0.05$) between lines.

UI (unsaturation index) = (average number of double bonds per fatty acid residue).

PI (peroxidability index) = (% monoenoic × 0.025) + (% dienoic × 1) + (% trienoic × 2) + (% tetraenoic × 4) + (% pentaenoic × 6) + (% hexaenoic × 8).

[A] Standard error of the mean.

[B] Significance levels: ns, $P > 0.05$; *, $P < 0.05$; **, $P < 0.01$ and ***, $P < 0.001$.

Table 4
Fatty acids (g kg^{-1} of total FAMES) of neutral lipids from the *Masseter* muscles of different Iberian pig lines

Fatty acid	Iberian pig lines				SEM[A]	P[B]
	Entrepelado	Lampiño	Retinto	Torbiscal		
C12:0	0.41	0.52	0.45	0.44	0.021	ns
C14:0	7.30	5.37	7.32	8.61	0.487	ns
C15:0	0.29[b]	0.33[b]	0.37[ab]	0.48[a]	0.018	**
C16:0	180.83	191.77	182.41	191.97	2.974	ns
C16:1 ($n-7$)	34.39	41.66	37.54	38.97	1.231	ns
C17:0	3.11	3.68	3.56	3.51	0.251	ns
C17:1 ($n-9$)	2.60	2.85	3.03	2.82	0.100	ns
C18:0	107.25	103.76	106.27	105.54	4.024	ns
C18:1 ($n-9$)	515.86	509.31	507.27	478.04	5.678	ns
C18:2 ($n-6$)	100.59	102.56	102.73	119.88	3.041	ns
C18:3 ($n-3$)	8.78	9.02	9.26	9.36	0.416	ns
C20:0	3.77	2.69	2.95	2.69	0.202	ns
C20:1 ($n-9$)	17.22	14.76	16.54	14.82	0.371	*
C20:4 ($n-6$)	17.60	11.73	20.30	22.88	1.894	ns
SFA	302.95	308.11	303.32	313.23	3.630	ns
MUFA	570.08	568.57	564.38	534.65	5.779	ns
PUFA	126.97	123.31	132.30	152.13	4.968	ns
$\sum n-6$	118.19	114.29	123.04	142.77	4.688	ns
$\sum n-3$	8.78	9.02	9.26	9.36	0.416	ns
$n-6/n-3$	14.08	13.31	13.53	15.46	0.556	ns
UI	0.87	0.88	0.88	0.89	0.009	ns
PI	20.28	18.17	21.66	24.35	1.060	ns

Means with different superscript within a row show statistical differences ($P < 0.05$) between lines.
UI (unsaturation index) = (average number of double bonds per fatty acid residue).
PI (peroxidability index) = (% monoenoic × 0.025) + (% dienoic × 1) + (% trienoic × 2) + (% tetraenoic × 4) + (% pentaenoic × 6) + (% hexaenoic × 8).
[A] Standard error of the mean.
[B] Significance levels: ns, $P > 0.05$; *, $P < 0.05$; **, $P < 0.01$ and ***, $P < 0.001$.

Table 5
Fatty acids (g kg^{-1} of total FAMES) of neutral lipids from the *Longissimus dorsi* muscles of different Iberian pig lines

Fatty acid	Iberian pig lines				SEM[A]	P[B]
	Entrepelado	Lampiño	Retinto	Torbiscal		
C12:0	0.55	0.58	0.45	0.64	0.320	ns
C14:0	10.26	7.96	11.06	8.28	3.564	ns
C15:0	0.27	0.41	0.66	0.50	2.946	ns
C16:0	223.13	207.56	227.77	208.68	4.253	ns
C16:1 ($n-7$)	41.42	44.52	49.33	48.03	7.266	ns
C17:0	4.32	4.49	4.72	4.79	0.051	ns
C17:1 ($n-9$)	3.48	3.19	3.54	3.32	0.231	ns
C18:0	134.80	113.63	127.15	115.59	0.026	ns
C18:1 ($n-9$)	475.57	510.53	484.10	501.83	2.168	ns
C18:2 ($n-6$)	74.53	78.16	60.87	81.51	1.129	ns
C18:3 ($n-3$)	7.76	7.84	6.95	6.56	0.258	ns
C20:0	4.52	3.47	3.61	3.14	0.175	ns
C20:1 ($n-9$)	12.96	11.42	12.91	11.54	1.776	ns
C20:4 ($n-6$)	6.44	6.24	6.89	5.59	3.256	ns
SFA	377.85	338.10	375.42	341.62	2.328	ns
MUFA	533.43	569.66	549.87	564.72	0.363	ns
PUFA	88.72	92.24	74.71	93.66	0.204	ns
$\sum n-6$	80.96	84.40	67.76	87.11	0.248	ns
$\sum n-3$	7.76	7.84	6.95	6.56	0.715	ns
$n-6/n-3$	12.26	10.80	10.26	15.97	0.252	ns
UI	0.73	0.77	0.72	0.77	0.003	ns
PI	12.91	13.30	11.61	13.11	0.298	ns

Means with different superscript within a row show statistical differences ($P < 0.05$) between lines.
UI (unsaturation index) = (average number of double bonds per fatty acid residue).
PI (peroxidability index) = (% monoenoic × 0.025) + (% dienoic × 1) + (% trienoic × 2) + (% tetraenoic × 4) + (% pentaenoic × 6) + (% hexaenoic × 8).
[A] Standard error of the mean.
[B] Significance levels: ns, $P > 0.05$; *, $P < 0.05$; **, $P < 0.01$ and ***, $P < 0.001$.

MUFA and PUFA was confirmed by high and significant correlation coefficients between these variables ($R = 0.769$ and -0.737, respectively). In addition, Fernández et al. (2003) found a positive and significant correlation between the weight of premium cuts and linoleic acid content. Given that Torbiscal pigs show the best muscular conformation, results from our study indicates the same relationship between conformation and linoleic acid.

Although the same trend for these fatty acids (oleic, linoleic, arachidonic, total MUFA and total PUFA) was seen in the LD muscle, differences were small and not significant.

MS muscle fatty acid composition does not accurately reflect that of the more valuable muscles, such as the LD, although the trends were similar. This is probably due to the marked oxidative character of the MS muscle, which influences its fatty acid composition and polar lipid content (Andrés et al., 2001). Given that high oleic acid and low linoleic acid levels have been linked to better characteristics of Iberian pig meat products (Cava et al., 1999), animals from the Torbiscal line might give inferior quality products. A similar conclusion was reached by Estévez et al. (2003) but for fresh pork.

Tables 4 and 5 show the fatty acid composition of the neutral lipids from MS and LD muscles of the different lines. As with intramuscular total lipids, slaughter weight did not influence the fatty acid composition of the neutral lipids. In contrast to total muscle lipid fatty acid composition, the effect of line was small in both muscles. Tejeda et al. (2002) found lower proportions of linoleic acid in the muscle neutral lipids of muscles from the Torbiscal line. Although the lines are not exactly the same, we did not find such behaviour for the Torbiscal line. Furthermore, these animals showed the highest values for linoleic acid content in neutral lipids of both muscles.

Fatty acid composition of the polar lipids from MS and LD muscles of the different lines are shown in Tables 6 and 7. Slaughter weight did not influence the fatty acid composition of the polar lipids. As with the total muscle lipids, the fatty acid composition of the polar lipids from the MS muscle was more markedly affected than that of LD muscle. The line significantly affected

Table 6
Fatty acids (g kg^{-1} of total FAMES) of polar lipids from the *Masseter* muscles of different Iberian pig lines

Fatty acid	Iberian pig lines				SEM[A]	P[B]
	Entrepelado	Lampiño	Retinto	Torbiscal		
C12:0	0.61^{ab}	0.70^{ab}	0.91^{a}	0.53^{b}	0.045	**
C14:0	1.67^{ab}	1.63^{ab}	2.15^{a}	1.39^{b}	0.082	**
C15:0	0.88	1.05	0.91	0.66	0.052	ns
C16:0	105.56^{b}	109.83^{ab}	126.94^{a}	93.62^{b}	3.146	***
C16:1 ($n-7$)	8.41	7.82	8.50	7.48	0.211	ns
C17:0	3.57	3.61	3.50	4.42	0.155	ns
C17:1 ($n-9$)	4.08	5.36	4.30	5.70	0.804	ns
C18:0	214.36	208.50	198.41	222.82	3.685	ns
C18:1 ($n-9$)	117.32^{b}	115.09^{b}	143.04^{a}	107.93^{b}	3.587	***
C18:2 ($n-6$)	228.58	242.41	231.60	226.27	3.306	ns
C18:3 ($n-3$)	9.99^{ab}	9.58^{b}	12.97^{a}	9.52^{b}	0.453	**
C20:1 ($n-9$)	3.84	3.71	4.08	3.04	–	ns
C20:3 ($n-6$)	9.70	9.58	8.64	8.62	0.134	ns
C20:4 ($n-6$)	225.80^{ab}	217.26^{ab}	198.55^{b}	247.13^{a}	0.210	**
C20:5 ($n-3$)	16.32	15.62	16.12	18.08	5.168	ns
C22:4 ($n-6$)	2.50^{ab}	3.66^{a}	1.33^{b}	3.21^{a}	0.590	**
C22:5 ($n-3$)	39.19	32.03	30.92	31.81	0.256	ns
C22:6 ($n-3$)	7.62^{b}	12.38^{a}	7.13^{b}	7.78^{b}	1.534	***
SFA	326.66	325.30	332.82	323.43	0.573	ns
MUFA	133.64^{b}	131.99^{b}	159.92^{a}	124.15^{b}	2.329	***
PUFA	539.70^{a}	542.71^{a}	507.27^{b}	552.42^{a}	3.850	***
$\sum n-6$	466.58^{a}	472.92^{a}	440.12^{b}	485.22^{a}	4.351	***
$\sum n-3$	73.12	69.79	67.14	67.20	3.823	ns
$n-6/n-3$	6.56	6.82	6.62	7.36	0.171	ns
UI	1.89^{ab}	1.87^{ab}	1.77^{b}	1.93^{a}	0.018	**
PI	156.85^{ab}	153.84^{ab}	141.23^{b}	161.58^{a}	2.495	*

Means with different superscript within a row show statistical differences ($P < 0.05$) between lines.

UI (unsaturation index) = (average number of double bonds per fatty acid residue).

PI (peroxidability index) = (% monoenoic × 0.025) + (% dienoic × 1) + (% trienoic × 2) + (% tetraenoic × 4) + (% pentaenoic × 6) + (% hexaenoic × 8).

[A] Standard error of the mean.

[B] Significance levels: ns, $P > 0.05$; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Table 7
Fatty acids (g kg^{-1} of total FAMES) of polar lipids from the *Longissimus dorsi* muscles of different Iberian pig lines

Fatty acid	Iberian pig lines				SEM[A]	P[B]
	Entrepelado	Lampiño	Retinto	Torbiscal		
C12:0	1.20	1.30	1.32	0.70	0.093	ns
C14:0	2.49	2.73	2.58	2.29	0.122	ns
C15:0	0.99	1.01	1.20	1.13	0.049	ns
C16:0	147.22	166.02	152.68	149.65	2.705	ns
C16:1 ($n-7$)	11.67	10.21	11.03	11.57	0.296	ns
C17:0	2.22	2.82	3.61	3.84	0.247	ns
C17:1 ($n-9$)	8.43	7.08	4.17	2.81	0.982	ns
C18:0	122.05	92.07	101.62	105.19	5.282	ns
C18:1 ($n-9$)	173.48	198.77	171.14	182.05	4.293	ns
C18:2 ($n-6$)	285.65	295.65	305.30	290.13	3.523	ns
C18:3 ($n-3$)	8.39[b]	9.53[ab]	12.61[a]	11.02[ab]	0.568	*
C20:1 ($n-9$)	3.84	5.18	3.61	4.29	0.001	ns
C20:3 ($n-6$)	13.35	12.29	13.47	13.67	0.224	ns
C20:4 ($n-6$)	175.17	154.54	171.40	165.07	0.565	ns
C20:5 ($n-3$)	11.18	8.07	11.14	14.05	3.878	ns
C22:4 ($n-6$)	0.75	3.51	4.04	2.92	0.859	ns
C22:5 ($n-3$)	27.70	18.81	23.03	30.88	0.866	ns
C22:6 ($n-3$)	4.21	10.42	6.04	8.74	1.629	ns
SFA	276.17	265.94	263.02	262.81	1.156	ns
MUFA	197.41	221.24	189.96	200.71	4.315	ns
PUFA	526.42	512.82	547.03	536.48	4.675	ns
$\sum n-6$	474.92	465.98	494.20	471.78	6.378	ns
$\sum n-3$	51.49	46.84	52.83	64.70	5.438	ns
$n-6/n-3$	9.39	10.32	9.56	8.04	2.364	ns
UI	1.76	1.71	1.79	1.80	3.438	ns
PI	130.18	120.76	130.12	134.44	20.907	ns

Means with different superscript within a row show statistical differences ($P < 0.05$) between lines.

UI (unsaturation index) = (average number of double bonds per fatty acid residue).

PI (peroxidability index) = (% monoenoic × 0.025) + (% dienoic × 1) + (% trienoic × 2) + (% tetraenoic × 4) + (% pentaenoic × 6) + (% hexaenoic × 8).

[A] Standard error of the mean.

[B] Significance levels: ns, $P > 0.05$; *, $P < 0.05$; **, $P < 0.01$ and ***, $P < 0.001$.

palmitic acid (C16:0), oleic acid, linolenic acid (C18:3 ($n-3$)) and arachidonic acid, and also some minor fatty acids such as the long chain PUFA docosotetraenoic acid (C22:4 ($n-6$)) and docosohexaenoic acid (DHA) (C22:6 ($n-3$)) in the MS muscle. This led to a significant effect of line on total MUFA and PUFA and on UI and PI of the polar lipids in this muscle. Retinto animals showed higher amounts of oleic and linolenic acids and lower amounts of arachidonic and docosatetraenoic acids. Interestingly, although palmitic acid was more than three units higher in Retinto animals than in Torbiscal ones, their total saturated fatty acids (SFA) were less than one unit different.

Lipid oxidative phenomena in muscle based food products take place mainly in the phospholipid function (Pikul, Leszczynski, & Kummerow, 1984) due to their higher unsaturation and proximity to the prooxidant systems. The significantly higher PI of MS muscles from the Torbiscal animals could make them susceptible to lipid oxidation during processing. MS muscles from the Retinto line and LD muscles from the Lampiño line (although in the latter not to a significant degree) show lower PI. Lipid oxidative changes during the processing of Iberian pig meat lead to formation of a number of compounds, which contribute to their desirable flavour (Ruiz, Ventanas, Cava, Andrés, & García, 1999) and also to the development of rancidity (Cava et al., 1999). As a rule, meats of rancidity potential are preferred in the industry, and therefore, the use of Torbiscal animals could be a problem from a meat quality point of view.

Table 8 shows the levels of lipid oxidation (measured as nanomoles of malonaldehyde per milligram of protein) during incubation under in vitro conditions. The inclusion of slaughter weight as a covariable had no significant effect on lipid oxidation. As shown previously (Andrés et al., 2001; Muriel et al., 2002a, 2002b) muscles with a more oxidative metabolism, such as MS muscle, are more prone to lipid oxidation than glycolytic ones (LD muscle), probably due to their higher myoglobin and membrane phospholipid contents (Andrés et al., 2001).

Iberian pig line did not significantly affect oxidation levels in the MS muscle, and only affected the initial stages in the LD muscle. Therefore, it seems that dif-

Table 8
Iron-induced lipid oxidation during incubation (nanomoles malonaldehyde per milligram protein) in *Masseter* and *Longissimus dorsi* samples from different lines of Iberian pigs

	Iberian pig lines				SEM[A]	P^B
	Entrepelado	Lampiño	Retinto	Torbiscal		
Masseter						
Min 0	0.22	0.22	0.28	0.22	0.025	ns
Min 50	0.38	0.30	0.39	0.29	0.033	ns
Min100	1.80	2.51	1.73	2.65	0.280	ns
Min 200	4.42	4.48	4.57	4.41	0.305	ns
Longissimus dorsi						
Min 0	0.14^{a}	0.04^{b}	0.14^{a}	0.11^{ab}	0.270	*
Min 50	0.19^{ab}	0.29^{a}	0.26^{ab}	0.12^{b}	0.030	**
Min100	0.41	0.36	0.56	0.33	0.025	ns
Min 200	2.08	1.69	2.20	2.22	0.098	ns

Means with different superscript within a row shows statistical differences ($P < 0.05$) between lines.
[A] Standard error of the mean.
[B] Significance levels: ns, $P > 0.05$; *, $P < 0.05$; **, $P < 0.01$ and ***, $P < 0.001$.

ferences in fatty acid composition of the polar lipids in the MS muscle were not sufficient to affect the development of lipid oxidation in an in vitro test. Previous studies found similar behaviour in this type of test and in processed meats (Cava et al., 1999).

Table 9 shows the colour coordinates (L^*, a^* and b^*) and the calculated Chroma and hue angle values for MS and LD muscles of the different lines. As with the other studied variables, colour was not affected by the slaughter weight of the pigs. MS muscles showed lower values for lightness (L^*) and higher ones for redness (a^*) than LD muscles, which led to a more intense colour (higher chroma C^* values and lower hue angle $H°$ values). This is due to the higher amount of myoglobin in the more oxidative MS muscle (Andrés, Ruiz, Mayoral, Tejeda, & Cava, 2000). MS muscle did not show the same behaviour in colour parameters as the LD muscle. Therefore, colour measurements in the MS are not good for predicting the colour of the other more valuable muscles.

Iberian pig line did not significantly affect any of the colour coordinates in the MS muscle. However, redness and colour intensity were significantly influenced by line in the LD muscle, animals from the Entrepelado and Lampiño lines showing higher values for both variables, whereas Torbiscal ones exhibited a less intense colour. These differences are probably due to differences in muscle myoglobin contents. As discussed for the IMF content, Torbiscal animals are selected by considering production parameters which explains why, at the same age, animals from this line are less mature (Dobao et al., 1985), which explains their lower IMF and myglobin contents. Estévez et al. (2003) found no differences in haem pigment contents between Torbiscal and Lampiño animals, nor in any of the colour coordinates, but this was on 90 kg live weight animals, reared for fresh pork

Table 9
Cie L^*, a^* and b^*. Chroma (C^*) and hue ($H°$) values in *Masseter* and *Longissimus dorsi* samples from different lines of Iberian pigs

	Iberian pig lines				SEM[A]	P^B
	Entrepelado	Lampiño	Retinto	Torbiscal		
Masseter						
L^*	39.26	36.53	36.57	38.56	0.489	ns
a^*	23.64	23.61	22.73	24.15	0.233	ns
b^*	8.80	8.72	8.55	9.45	0.162	ns
C^*	25.24	25.19	24.30	25.97	0.247	ns
$H°$	20.39	20.28	20.67	21.42	0.321	ns
Longissimus dorsi						
L^*	48.36	44.25	47.66	47.39	0.682	ns
a^*	14.16^{a}	13.20^{a}	12.18^{ab}	10.21^{b}	0.356	**
b^*	8.35	6.69	7.55	6.41	0.294	ns
C^*	16.48^{a}	14.83^{ab}	14.37^{ab}	12.07^{b}	0.425	**
$H°$	30.22	26.43	31.68	32.00	0.726	ns

Means with different superscript within a row shows statistical differences ($P < 0.05$) between lines.
[A] Standard error of the mean.
[B] Significance levels: ns, $P > 0.05$; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

production. In the present study, pigs were slaughtered at 150 kg live weight and this difference in weight could explain the differences in colour coordinates found. Differences in colour due to the line could be important, since one of the features of Iberian meat products which influences their overall quality is an intense colour. Thus, considering the colour of the LD muscle, Torbiscal animals could display poorer characteristics for manufacturing dry cured Iberian meat products.

It can be concluded that Iberian pig line has little influence on the quality of raw meat but Torbiscal animals tend to show worse features for dry cured product production because of lower IMF contents, higher levels of polyunsaturated fatty acids, higher peroxidability indexes and a less intense red colour. MS muscle does not seem to be a good predictor for estimating the quality characteristics of more valuable muscles such as LD, due to their different behaviour regarding fatty acid composition and colour.

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