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The effect of gender and slaughter weight on loin and fat characteristics of pigs intended for Teruel dry-cured ham production

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Abstract

A total of 200 Duroc × (Landrace × Large White) pigs intended for Protected Designation of Origin Teruel dry-cured ham manufacture was used for the study. The objective was to investigate the effect of gender (barrows and gilts) and slaughter weight (SW; 120, 125, 130, 135 or 140 kg) on *Longissimus dorsi* (LD) muscle characteristics and the fatty acid (FA) profile of the subcutaneous fat. The LD from barrows had higher intramuscular fat (P<0.01), b* value (P<0.01), colour intensity (P<0.01 for c* and P<0.05 for Hº) and tenderness (P<0.05) than the LD from gilts. Fat from barrows had a higher saturated FA content (P<0.01) a lower polyunsaturated (P<0.001) and unsaturated FA content (P<0.01) than fat from gilts. On the other hand, intramuscular fat was increased (P<0.05) but moisture and L* (P<0.05), thawing (P<0.001) and cooking losses (P<0.01) decreased as SW increased. Polyunsaturated FA content decreased (P<0.001) and saturated FA proportion tended to increase (P<0.10) as the SW increased. It was concluded that barrows and gilts were adequate for both fresh meat and dry-cured ham production. An increase in SW from 120 to 140 kg impairs subcutaneous fat quality but improves some loin characteristics which are desirable for Teruel dry-cured pork production.

Additional key words: fat, gender, loin, slaughter weight, Teruel dry-cured ham.

Resumen

Efecto del sexo y del peso al sacrificio sobre las características del lomo y de la grasa de cerdos destinados a la producción de Jamón curado de Teruel

Un total de 200 cerdos Duroc × (Landrace × Large) destinados a la Denominación de Origen Protegida Jamón de Teruel fueron usados para el estudio. El objetivo fue estudiar el efecto del sexo (machos castrados y hembras) y el peso al sacrificio (120, 125, 130, 135 y 140 kg) sobre las características del músculo *Longissimus dorsi* (LD) y el perfil de ácidos grasos de la grasa subcutánea. El LD de los castrados presentó mayor contenido en grasa intramuscular (P<0,01), valor de b* (P<0,01), intensidad del color (P<0,01 para c* y P<0,05 para Hº) y terneza (P<0,05) que el LD de las hembras. La grasa de los castrados tuvo mayor porcentaje de ácidos grasos saturados (P<0,01) y menor de poliinsaturados (P<0,001) e insaturados (P<0,01) que la grasa de las hembras. El aumento del peso al sacrificio incrementó el contenido en grasa intramuscular (P<0,05), pero redujo la humedad y el valor L* (P<0,05) y las pérdidas por descongelación (P<0,001) y por cocinado (P<0,01) del lomo. Asimismo, el contenido en ácidos grasos poliinsaturados disminuyó (P<0,001) y la proporción de ácidos grasos saturados tendió a aumentar (P<0,10) a medida que el peso al sacrificio aumentaba. Concluimos que machos castrados y hembras son adecuados para carne fresca y para la elaboración de productos curados. El incremento del peso al sacrificio empeora la calidad de la grasa, pero mejora algunos aspectos de la carne que son deseables para la industria de carne curada de cerdo de Teruel.

Palabras clave adicionales: grasa, Jamón curado de Teruel, lomo, peso al sacrificio, sexo.

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Abbreviations used: a* (redness), b* (yellowness), BW (body weight), c* (chroma), FA (fatty acid), Hº (hue angle), IMF (intramuscular fat), L* (lightness), LD (*Longissimus dorsi*), MUFA (monounsaturated fatty acid), PC (principal components), PDO (Protected Designation of Origin), PUFA (polyunsaturated fatty acid), SE (standard error of the mean), SFA (saturated fatty acid), SW (slaughter weight), UFA (unsaturated fatty acid).

Introduction

Spain is the world leader in production of dry-cured hams and shoulders with a total production of 251,345 Mg in 2006 (Resano *et al*., 2007). Currently, there are five Protected Designations of Origin (PDO) of dry-cured ham in Spain; four of them are from Iberian pigs and the fifth, named "Teruel ham", is from heavy white pigs. Teruel ham was the first Spanish PDO to control and guarantee dry-cured ham manufacture. Since 1997 this type of ham has been included on the list from the European Community of special quality products. Teruel ham production has increased dramatically in recent decades from 2,000 pieces in 1985 to 600,000 in 2008 (Consejo Regulador PDO Jamón Teruel, 2009).

The BOA (1993) regulations for the Teruel ham PDO establishes that the pigs have to be crossbreed from Duroc sires mated with Landrace × Large White sows and have to have a body weight (BW) between 120 and 140 kg at slaughter. Further, a minimum level of fat thickness over the *Gluteus medius* muscle of 18 mm and a fresh ham weight (11.3 kg) are required to improve uniformity and quality of the end product. Recently, Latorre *et al*. (2008a) concluded that 130 kg was an adequate slaughter weight (SW) for these pigs from the point of optimizing Teruel ham production.

Besides hams, a considerable quantity of meat is obtained, yearly, from the carcasses of these animals. Previous studies have compared barrows and gilts and evaluated the influence of SW on the meat and fat quality of heavy pigs (Latorre *et al*., 2004; Lo Fiego *et al*., 2005). However, there is no information available for the specific case of pigs destined to be processed into Teruel ham. The aim of this research was to determine the characteristics of the *Longissimus dorsi* (LD) muscle and subcutaneous fat from barrows and gilts intended for Teruel dry-cured ham and to investigate the effect of SW on these characteristics.

Material and methods

Husbandry and slaughtering

All experimental procedures used in this study complied with Spanish guidelines for the care and use of animals in research (BOE, 2005). Pigs of 182 ± 3 days of age (107.0 ± 2.4 kg BW) with barrows and gilts in equal numbers were used for the study. All animals were the progeny of Duroc sires (Asociación Turolense de Industrias Agroalimentarias, Teruel, Spain) and Landrace × Large White dams (Hypor España G.P., Barcelona, Spain). Males were castrated at 5 ± 3 days of age. Pigs were housed in a natural-environment barn at 1.20 m^2 pig^{-1} and had free access to a pelleted barley-wheat-soybean meal diet and water throughout the study. The diet was formulated to meet, or exceed, the requirements of pigs of that age (NRC, 1998). The composition and the estimated (FEDNA, 2003) and determined nutrient value (AOAC, 2000) of the diet are shown in Table 1.

Once the pre-planned SW was achieved (average of 120, 125, 130, 135 and 140 kg BW or 189, 196, 203, 210 and 217 days of age, respectively), all pigs belonging to each SW group were starved for 7 h and transported, the same day, 130 km to a commercial abattoir plant (Jamones y Embutidos Alto Mijares, S.L., Teruel, Spain). At the abattoir, animals were rested for 10 h with access to water but not to feed. Pigs were electrically

Table 1. Composition, estimated and determined diet analyses (g kg^{-1} fed)

Ingredient	
Barley	551
Wheat	250
Soybean meal-47	142
Animal fat	29
Sodium chloride	4
Calcium carbonate	9
Dicalcium phosphate	10
Vitamin and mineral premix[1]	5
Calculated nutrient composition[2]	
Net energy (MJ kg^{-1})	9.89
Crude protein	152
Neutral detergent fibre	139
Ether extract	47
Lysine	6.9
Calcium	6.7
Total phosphorus	5.5
Sodium	1.7
Analyzed composition[3]	
Moisture	
Ash	48
Crude protein	149
Ether extract	50

[1] Supplied (mg kg^{-1} diet): retinol: 2.1; cholecalciferol: 0.03; DL-α-tocopherol: 7.37; menadione: 0.5; thiamin: 0.2; riboflavin: 2.5; pantothenic acid: 8; niacin: 15; choline: 350; pyridoxine: 0.2; cyanocobalamin: 0.015; Cu: 75; Fe: 80; Mn: 50; Zn: 110; Co: 0.1; Se: 0.2; I: 0.5. [2] According to FEDNA (2003). [3] According to AOAC (2000).

stunned (225 to 380 V 0.5 amps^{-1} for 5 to 6 s), exsanguinated, scalded, skinned, eviscerated using standard commercial procedures, and split down the midline. Carcasses were suspended in air and refrigerated at 2ºC (1 m s^{-1}; 90% relative humidity) for 2 h and were then processed using the simplified EC-reference method (Branscheid *et al*., 1990).

Experimental design

At the farm, 200 pigs were allotted to 20 pens (10 pigs pen^{-1} with five barrows and five gilts) on the basis of BW. After slaughter, 80 carcasses were randomly selected (4 carcasses pen^{-1} with two barrows and two gilts) to study the effect of gender (barrows and gilts) and SW (120, 125, 130, 135 and 140 kg BW) on loin quality and the fatty acid (FA) profile of the subcutaneous fat. Each of the ten treatments was replicated eight times and the experimental unit was the pig.

Longissimus dorsi traits

After processing, a sample of 500 ± 20 g of the LD was excised at the level of the last rib from each left loin of the carcass and stored in individual vacuum-packaged bags at -20ºC until subsequent analyses. The LD samples were thawed in the vacuum-packed bags for 24 h at 4ºC, removed from the packages, blotted dry for 20 min and weighed. Thawing losses were calculated by dividing the difference in weight between the fresh and thawed samples by the initial fresh weight. Afterwards, the LD colour was evaluated with a reflectance spectrophotometer (CM 2002 Minolta, Minolta Camera, Osaka, Japan) which had been previously calibrated with a pure white colour tile, using objective measurements (CIE, 1976). An average of three observations per sample were used to measure the lightness (L*) and two colour co-ordinates (redness, a*; yellowness, b*). Additionally, two measures of colour intensity were taken; chroma (c*) as $c^* = \sqrt{(a^{*2} + b^{*2})}$ and hue angle (Hº) as Hº = arctg (b*/a*) (Wyszcecki and Stiles, 1982).

The intramuscular fat (IMF), crude protein and moisture proportions of the LD samples were determined using a near infrared transmittance meat analyzer (Infratec® 1265, Tecator, Höganäs, Sweden). Firstly, the chops were trimmed free of intermuscular fat, minced and distributed in a cup ring equipped with a plastic bottom plate of 100 mm diameter and 15 mm deep and minced. The monochromator contained a 50 W tungsten lamp and a diffraction grating which created monochromatic light. Measured spectra were separated in the range 800 to 1,100 nm.

Cooking losses were determined by the method of Honikel (1998). Briefly, a LD slice was taken from each chop, weighed (200 ± 20 g), placed in a plastic bag and cooked to an internal temperature of 70ºC in a 75ºC water bath (Precisterm, J.P. Selecta S.A., Barcelona, Spain). Internal temperature during cooking was monitored with a handheld temperature probe (model HI9063, Hanna Instruments, Woonsocket, RI, USA). Cooked samples were cooled at 15ºC for 30 min, blotted dry and weighed. The difference between pre- and post-cooking weights was divided by the pre-cooked weight to calculate cooking losses. Samples were then cut parallel to the long axis of the muscle fibres into rectangular cross-section slices, 10-mm x 10-mm and 30 mm long. Slices (8 chop^{-1}) were cut perpendicular to fibre orientation, with a Warner-Bratzler device attached to an Instron Universal testing machine attached to a PC (Instron model 5543, Instron Ltd, Buckinghamshire, UK), and equipped with a 5-kg load cell and a crosshead speed of 150 mm min^{-1}.

Fatty acid profile of subcutaneous fat

Subcutaneous fat samples, including fat layers, skin and lean, were taken at tail insertion in the coxal region of the left side of each carcass and were stored in individual vacuum-packaged bags at -20ºC until analysis. The day before the analysis, samples were defrosted and skin and lean were removed. Briefly, a 200 mg sample of subcutaneous adipose tissue was homogenized and saponified and the FAs were extracted, methylated and analyzed with a gas chromatograph (Autosystem XL Agilent Technologies 6890N Net Work GC System, Perkin Elmer, Boston, USA) equipped with a flame ionization detector, a Hamilton injector, and a Omegawax 320 capillary column (30 m x 0.32 mm with a film thickness of 0.25 µm; Supelco, Bellefonte, PA) with 0.4 mL min^{-1} of He as the carrier gas. The temperature of the inlet detector was 260ºC and the initial oven temperature was 190ºC for 2 min, increasing to 205ºC at 5ºC min^{-1} for 3 min. From individual FA percentages, saturated FA (SFA), monounsaturated FA (MUFA), and polyunsaturated FA (PUFA) proportions were calculated. Total unsaturated FA (UFA) was calculated as UFA = MUFA + PUFA.

Statistical analyses

Data were analyzed as a completely randomized design with treatments arranged factorially using the GLM procedure of SAS (1990). The model included gender and SW as main effects, and their interaction. The REG procedure of SAS (1990) was used to analyze the response of each trait as SW increased. Means were computed and separated by a *t*-test, and $P<0.05$ was classified as a significant difference. A *P* value of between 0.05 and 0.10 was classified as a tendency. In addition, principal component (PC) analysis was performed using the Princomp procedure of SAS (1990) to evaluate the relationship among the traits studied.

Results

Longissimus dorsi traits

No significant interaction for gender × SW was observed for any loin quality trait studied. Therefore only main effects and the linear response to SW are presented (Table 2). The LD from barrows had a lower moisture (74.2 *vs* 74.6%; $P<0.05$) and a higher IMF (3.21 *vs* 2.53%; $P<0.01$) proportions than the LD from gilts. However, the protein percentage was similar ($P>0.10$). Loin from barrows was yellower (11.4 *vs* 10.2; $P<0.01$), tended to be lighter (48.2 *vs* 46.6; $P<0.10$) and showed more intense colour (11.6 *vs* 10.3; $P<0.01$ for c* and 98.3 *vs* 101.8; $P<0.05$ for Hº) than loins from gilts. Water holding capacity was not affected by gender ($P>0.10$) but resistance to cutting was lower in barrows than in gilts (2.05 *vs* 2.23 kg; $P<0.05$).

Longissimus dorsi moisture decreased ($R^2=0.13$, $P<0.05$) and IMF increased linearly ($R^2 = 0.19$, $P<0.05$) as SW increased at 0.22 and 0.23%, respectively, for every 10 kg of SW. Lightness decreased linearly ($R^2=0.13$, $P<0.05$) as SW increased but there was no influence of SW on any remaining colour traits. The SW did not affect shear force values ($P>0.10$) but increased water holding capacity. Thawing losses ($R^2 = 0.18$, $P<0.001$) and cooking losses ($R^2 = 0.11$, $P<0.01$) reduced linearly by 1.17 and 1.04 %, for every 10 kg above 120 kg BW.

Fatty acid profile of subcutaneous fat

No significant interaction for gender × SW was observed for any of the FAs studied. Therefore only main effects and the linear response to SW are presented (Table 3). Backfat from barrows had higher levels of C10:0 (0.069 *vs* 0.054%; $P<0.05$), C12:0 (0.074 *vs* 0.064%; $P<0.001$), C14:0 (1.340 *vs* 1.228%; $P<0.05$), C16:0 (24.09 *vs* 23.15%; $P<0.001$) and C20:0 (0.210 *vs* 0.195%; $P<0.05$) than the backfat from gilts. Therefore,

Table 2. The effect of gender and slaughter weight on *Longissimus dorsi* muscle characteristics of pigs intended for production of Teruel dry-cured ham

Variable	Gender				Slaughter weight (SW, kg)						Linear response to SW		
	Barrows	Gilts	SE (n=40)	*P*	120	125	130	135	140	SE (n=16)	R^2	Slope	*P*
Chemical composition (%)													
Moisture	74.2	74.6	0.12	*	74.7	74.6	74.5	74.2	74.2	0.20	0.13	-0.022	*
Intramuscular fat	3.21	2.53	0.14	**	2.54	2.71	2.99	3.01	3.00	0.22	0.19	+0.023	*
Protein	22.6	22.8	0.08		22.8	22.7	22.5	22.8	22.8	0.13			
Colour traits													
Lightness, L*	48.2	46.6	0.61	+	50.0	47.2	46.4	48.3	45.3	0.96	0.13	-0.142	*
Redness, a*	-1.63	-2.08	0.20		-1.39	-1.95	-2.19	-1.84	-1.90	0.32			
Yellowness, b*	11.4	10.2	0.24	**	11.5	10.5	10.6	10.9	10.5	0.38			
Chroma, c*	11.6	10.3	0.24	**	11.6	10.6	10.9	10.9	10.8	0.38			
Hue angle, Hº	98.3	101.8	1.08	*	97.6	100.2	100.4	100.5	101.6	1.71			
Water holding capacity (%)													
Thawing loss	4.12	4.08	0.34		5.50	5.05	3.66	3.21	3.06	0.54	0.18	-0.117	***
Cooking loss	12.2	12.7	0.41		13.6	12.6	12.8	12.7	10.4	0.65	0.11	-0.104	**
Shear force (kg)	2.05	2.23	0.06	*	2.28	2.17	2.00	2.19	2.05	0.10			

SE = standard error of the mean. *P* = significance. +: $P<0.10$, *: $P<0.05$, **: $P<0.01$, *** $P<0.001$.

Table 3. The effect of gender and slaughter weight on the fatty acid composition (%) of the subcutaneous fat of pigs intended for production of Teruel dry-cured ham

Fatty acid	Gender				Slaughter weight (SW, kg)						Linear response to SW		
	Barrows	Gilts	SE (n=40)	*P*	120	125	130	135	140	SE (n=16)	R^2	Slope	*P*
C10:0	0.069	0.054	0.001	*	0.057	0.058	0.055	0.055	0.060	0.002			
C12:0	0.074	0.064	0.001	***	0.067	0.068	0.071	0.067	0.072	0.002	0.27	+0.0002	+
C14:0	1.340	1.228	0.031	*	1.269	1.278	1.352	1.283	1.239	0.049			
C15:0	0.064	0.065	0.002		0.072	0.060	0.066	0.062	0.062	0.003			
C15:1	0.011	0.010	0.000		0.012	0.010	0.011	0.010	0.010	0.001	0.06	+0.0001	+
C16:0	24.091	23.152	0.153	***	23.056	23.663	23.807	23.750	23.830	0.242	0.23	+0.0295	*
C16:1n-9	0.325	0.370	0.007	**	0.391	0.328	0.338	0.335	0.345	0.011			
C16:1n-7	2.125	1.927	0.049	**	1.968	2.108	1.958	2.104	1.994	0.078			
C17:0	0.396	0.397	0.013		0.432	0.373	0.403	0.383	0.391	0.020			
C17:1	0.333	0.325	0.009		0.337	0.319	0.351	0.313	0.325	0.014			
C18:0	12.776	12.681	0.186		12.629	12.414	12.332	13.053	13.215	0.294			
C18:1n-9	39.958	40.105	0.238		39.119	40.587	40.155	40.326	39.972	0.376			
C18:1n-7	2.502	2.438	0.048		2.397	2.507	2.353	2.580	2.515	0.076			
C18:2	12.888	14.050	0.226	***	14.887	13.166	13.163	13.188	12.942	0.357	0.24	-0.0069	***
C18:3	0.914	0.990	0.016	**	1.044	0.926	0.950	0.933	0.907	0.025	0.21	-0.0045	**
C18:4	0.107	0.113	0.003		0.109	0.108	0.113	0.103	0.117	0.004	0.07	+0.0003	+
C20:0	0.210	0.195	0.005	*	0.208	0.202	0.195	0.206	0.201	0.008			
C20:1	1.021	0.972	0.018	+	1.015	1.012	0.988	0.979	0.988	0.028			
C20:3n-9	0.628	0.671	0.011	**	0.731	0.641	0.626	0.620	0.631	0.018	0.22	-0.0038	***
C20:4n-6	0.171	0.184	0.005	+	0.200	0.168	0.165	0.182	0.173	0.008	0.10	-0.0010	*
SFA[1]	39.01	37.84	0.308	**	37.79	38.12	38.24	38.86	39.07	0.487	0.13	+0.0476	+
MUFA[2]	46.28	46.15	0.292		45.24	46.87	46.70	46.11	46.15	0.462			
PUFA[3]	14.71	16.01	0.253	***	16.97	15.08	15.02	15.03	14.77	0.401	0.24	-0.0786	***
UFA[4]	60.99	62.16	0.308	**	62.21	61.88	61.72	61.14	60.92	0.487	0.13	-0.0476	+

[1] Σ Saturated fatty acids = C10:0 + C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0. [2] Σ Monounsaturated fatty acids = C15:1 + C16:1n-9 + C16:1n-7 + C17:1 + C18:1n-9 + C18:1n-7 + C20:1. [3] Σ Polyunsaturated fatty acids = C18:2 + C18:3 + C18:4 + C20:3n-9 + C20:4n-6. [4] Σ Unsaturated fatty acids = MUFA + PUFA. SE = standard error of the mean. *P* = significance. +: $P<0.10$, *: $P<0.05$, **: $P<0.01$, *** $P<0.001$.

fat from barrows had a higher proportion of SFAs than that from gilts (39.01 *vs* 37.84%; $P<0.01$). In contrast, subcutaneous fat from gilts had a higher proportion of PUFAs than that from barrows (16.01 *vs* 14.71%; $P<0.001$) because of the higher level of C18:2 (14.05 *vs* 12.89%; $P<0.001$), C18:3 (0.990 *vs* 0.914%; $P<0.01$), C20:3n-9 (0.671 *vs* 0.628%; $P<0.01$) and C20:4n-6 (0.184 *vs* 0.171%; $P<0.10$). Fat from barrows had a lower proportion of C16:1n-9 (0.325 *vs* 0.370% $P<0.01$) but a higher percentage of C16:1n-7 (2.125 *vs* 1.927%; $P<0.01$) and of C20:1 (1.021 *vs* 0.972%; $P<0.10$) than that from gilts. Finally there was no effect of gender on MUFA content (46.28 *vs* 46.15%, for barrows and gilts, respectively; $P>0.10$). The proportion of UFAs was higher in gilt backfat than in backfat from barrows (62.16 *vs* 60.99%; $P<0.01$).

The SFA% tended to increase linearly as SW increased ($R^2 = 0.13$; $P<0.10$) at 0.476% for every 10 kg above 120 kg BW because of a linear increase in C12:0 ($R^2 = 0.27$, $P<0.10$) and C16:0 ($R^2 = 0.23$, $P<0.05$). The proportion PUFAs decreased linearly as SW increased ($R^2 = 0.24$; $P<0.001$) by 0.786% for every 10 kg at slaughter because of a linear decrease of C18:2 ($R^2 = 0.24$, $P<0.001$), C18:3 ($R^2 = 0.21$, $P<0.01$), C20:3n-9 ($R^2 = 0.22$, $P<0.001$) and C20:4n-6 ($R^2 = 0.10$, $P<0.05$). There was no effect of SW on MUFA content ($P>0.10$). The percent UFA tended to decrease linearly as SW increased at 0.476% for every 10 kg between 120 and 140 kg BW ($R^2 = 0.13$; $P<0.10$).

Principal component analysis

The PC results are shown in Figures 1 and 2. The four first PCs explain 71.3% of the total variation (26.9, 19.3, 14.7 and 10.3%, respectively). Each PC represents an independent cause of variation, thus traits near each other are positively correlated, traits separated by 90º are independent, and traits separated by 180º are negatively correlated. All PCs are linear combinations of the traits, but a trait far from the origin that lies close to a PC is predominant in defining the PC.

Figure 1 shows a plot of the traits on the two first PCs. Two groups of variables were distinguished close to the first PC (PC_1) far from the origin. The first group included the PUFA, moisture and Hº value of the LD. These variables were positively correlated with each other and negatively correlated with the other group, consisting of IMF, a*, b* and c* values of the LD, lying near PC_1 on the opposite side. The second PC (PC_2) is essentially explained by UFA and cooking and thawing losses, as an independent cause of variation. On the opposite side of PC_2 is SFA. The Warner-Bratzler shear force, protein, MUFA and the L* value were not well represented by the first two PCs, lying nearer the origin.

Figure 2 shows projection of data in the first two PCs. In Figure 2a, data are plotted by gender. Barrows are located on the right side and gilts are located on the left side of the Figure. In Figure 2b, data are plotted by SW. The points are overlap in the centre, due to the variability of the population. However, the corresponding data for pigs slaughtered at 120 kg BW seems to spread up to the left. Corresponding data for pigs slaughtered at 140 kg BW seems to be spread down to the right. It is difficult to discriminate among intermediate SW pigs (125, 130 and 135 kg BW) because they overlap in the centre.

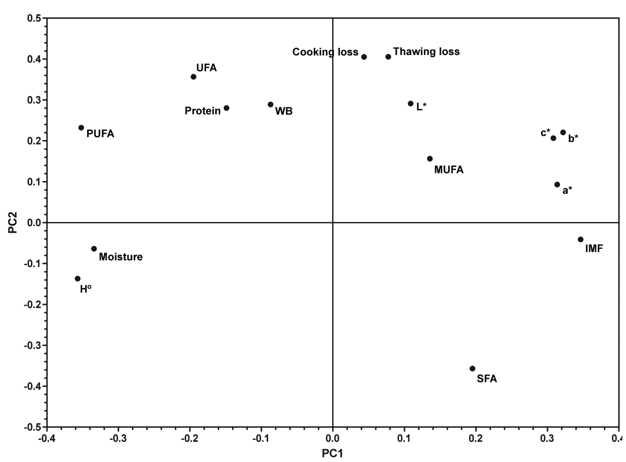

Figure 1. Projection of the variables studied in the plane defined by the two first principal components calculated from loin and subcutaneous fat data sets. L*: lightness, a*: redness, b*: yellowness, c*: chroma, Hº: hue angle, IMF: intramuscular fat, WB: Warner-Bratzler shear force, SFA: saturated fatty acids, MUFA: monounsaturated fatty acids, PUFA: polyunsaturated fatty acids, UFA: unsaturated fatty acids.

Discussion

Longissimus dorsi traits

Effect of gender

The LD from barrows had higher IMF and lower moisture levels than the LD from gilts, which is in line with the fatter carcasses observed in barrows from the same pigs reported by Latorre *et al*. (2008a). These results agree with those of Leach *et al*. (1996) and Correa *et al*. (2006). Cisneros *et al*. (1996) found higher marbling scores in barrows than in gilts. In this study, the IMF percentage was higher than that reported by Latorre *et al*. (2003, 2004) who worked with Pietrain × Large White sired-pigs which were slaughtered at similar weights and were also intended for dry-cured products. However, it is widely accepted that Duroc is a fatter breed than the Pietrain.

Several researchers have indicated that meat colour, determined by visual score, objective parameters or myoglobin content is independent of gender (Barton-Gade, 1987; Leach *et al*., 1996). However, we detected that the LD from barrows tended to be lighter (higher L*), yellower (higher b*) and had more intense colour (higher c* and lower Hº) than the LD from gilts. Latorre *et al*. (2009) also found a higher L* value in the loin from barrows than in gilts in heavy pigs intended for dry-cured ham and Nold *et al*. (1999) reported that muscles from gilts were darker than muscles from barrows. The reason could be the higher amount of IMF in barrows, which could give a more brilliant and yellow aspect.

Water holding capacity was similar between genders. This confirms previous observations of Weatherup *et al*. (1998) and Maiorano *et al*. (2007). However, in this study, shear force values were lower in the LD of barrows than in that of gilts which agrees with Latorre *et al*. (2004, 2009). The lower tenderness in the cooked LD of gilts could be due, least in part, to a lower level of IMF proportion and higher cooking losses, although not significant, which would reduce the moisture content of the cooked loin.

It is generally accepted that the eating quality of pork, determined by tenderness, juiciness and flavour, is similar for barrows and gilts (Cisneros *et al*., 1996;

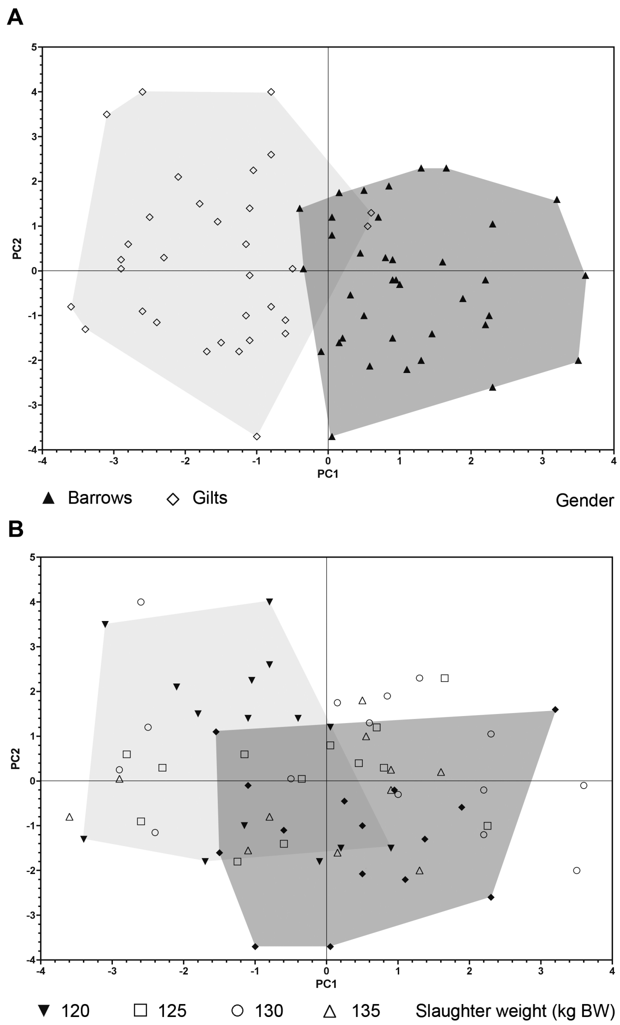

Figure 2. Projection of the data studied by gender (A) and by slaughter weight (B) in the plane defined by the two first principal components calculated from loin and subcutaneous fat data sets. In part A, the areas include gilts (clear) and barrows (dark) regardless of slaughter weight. In part B, the areas include pigs slaughtered at 120 kg BW (clear) and 140 kg BW (dark) regardless of gender.

Leach *et al.*, 1996). However, Gou *et al.* (1995) observed that hams from barrows had whiter subcutaneous fat, were more marbled and had less loss during dry-curing than hams from gilts. They recommended the use of barrows when were intended for dry-curing.

Effect of slaughter weight

The amount of moisture in the loin fell and the IMF proportion increased as SW increased. This agrees with Weatherup *et al.* (1998) and Latorre *et al.* (2003). Cisneros *et al.* (1996) reported that the decrease in moisture and the increase in IMF with SW were linear at 0.35 and 0.27 percentage units, respectively. These values are not far from our results of 0.22 and 0.23 percentage units, respectively. The benefits of IMF on sensory properties of pork are clear. Higher IMF is associated with more juiciness and greater meat acceptability (Barton-Gade, 1987).

In some previous studies no effect of SW on meat colour has been detected (Weatherup *et al.*, 1998; Correa *et al.*, 2006). However, other work reported that pork colour increased as SW increased (Cisneros *et al.*, 1996; Nold *et al.*, 1999). In our study the L* value decreased linearly with SW, in agreement with Latorre *et al.* (2004) and Maiorano *et al.* (2007). Remaining colour traits were not affected by SW.

Thawing and cooking losses decreased as SW increased, as reported by Fischer *et al.* (2006). This suggests that meat water holding capacity is higher in heavier pigs. Peinado *et al.* (2008) also found that drip losses decreased in pigs slaughtered between 114 and 122 kg BW. However, despite decreased cooking losses and increased IMF, which might increase tenderness, SW had no significant effect on shear force values of cooked pork as found by Weatherup *et al.* (1998).

Fatty acid profile of subcutaneous fat

Effect of gender

Barrows had higher SFA and lower PUFA proportions than gilts, which agrees with Latorre *et al.* (2009) who compared both genders of pigs slaughtered at 130 kg BW. In our study, the higher SFA percentage found in barrows was mainly due to a higher proportion of C12:0 and C16:0 acids. Piedrafita *et al.* (2001) also detected a higher percentage of C16:0 acid in barrows than in gilts.

A higher UFA proportion in gilts than in barrows was reported by Latorre *et al.* (2009) in heavy pigs which agrees with this study. Lo Fiego *et al.* (2005) concluded that, although gender had no significant effect on lipid quality, gilts had a slight tendency toward a higher degree of unsaturation. In this study, the higher UFA proportion in gilts was due to the higher PUFA percentage, and was mainly due to higher proportion of C18:2 and C18:3 acids which agrees with Piedrafita *et al.* (2001) and Peinado *et al.* (2008). Both C18:2 and C18:3

acids are completely derived from the diet and thus would be related to feed intake. The C18:2 acid plays an important role in human nutrition because it can reduce firmness and cohesiveness of adipose tissue and increase the fat oxidation rate (Wood *et al*., 2008).

Effect of slaughter weight

The proportion of SFAs tended to increase linearly as SW increased. This was mainly due to increased C16:0, which agrees with the results of Lo Fiego *et al*. (2005) who worked with pigs slaughtered between 150 and 175 kg BW intended for Parma ham manufacture. Scott *et al*. (1981) concluded that leaner pigs had a lower ability to synthesize combined FAs with greater mobilization than fatty pigs, which results in adipose depots with more unsaturated fatty acids. In this study the MUFA percentage did not appear to be influenced by live weight but the PUFA proportion decreased as SW increased, mainly due to a linear decrease in C18:2 and C18:3 acids which agrees with Lo Fiego *et al*. (2005). Several studies have demonstrated an inverse relationship between the proportion of C18:2 in the subcutaneous adipose tissue and backfat depth in pigs (Wood *et al*., 2008). Latorre *et al*. (2008a) found that backfat depth increased linearly in pigs used in this study.

Overall the data suggest an inverse relationship between the degree of lipid unsaturation and SW. The differences are likely to be caused by the greater carcass fatness of heavier pigs. The highest variation was in the percentage of PUFA which are mainly of dietary origin, which may be more diluted in the greater quantity of lipids present in the heavier carcasses (Lebret and Mourot, 1998).

Principal component analysis

Principal component analysis has seldom been used to describe the relationship between the LD and fat quality in pigs. The IMF is one of the most important criteria to evaluate meat quality, especially when pigs are intended for manufacture of dry-cured products. In this study there was a high negative correlation between IMF and the proportion of moisture, as found by Latorre *et al*. (2008b) who reported a positive correlation (+0.81) between IMF and dry matter in three pig genotypes. Water is an important constituent of lean tissue but only small amounts of water are found in fat tissues.

On the other hand, IMF was negatively correlated with PUFA and UFA but had a moderate positive correlation with SFA, which agrees with the results of Díaz *et al*. (2005), who worked with lambs. There was also a positive correlation between IMF and a*, b* and c* values which agrees with Latorre *et al*. (2008b) who observed it in pigs slaughtered at 95 kg BW.

Both Figures 1 and 2 indicate that IMF, SFA, MUFA, a*, b* and c* are located where most of the corresponding data to barrows (Figure 2a) or heavier pigs (Figure 2b) lay. The data for PUFAs and UFAs are located where most of the corresponding data for gilts or lighter pigs was located. Raes *et al*. (2004) concluded that SFAs and MUFAs increase faster than PUFAs as fatness increases, leading to a reduced relative proportion of PUFAs. This all suggests that barrows are usually heavier and have more marbled meat with more saturated fat than gilts.

Both barrows and gilts, at any of the slaughter weight sampled had loin and fat quality compatible with the manufacture of PDO Teruel dry-cured hams. Generally, barrows had better loin quality and worse fat composition than gilts but pigs of both genders can be used for fresh meat and production of dry-cured products. An increase in SW from 120 to 140 kg BW impaired subcutaneous fat quality but improved some aspects of the LD which are desirable for pork destined to be used for Teruel dry-cured ham manufacture.

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