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Physicochemical and sensorial characteristics of four muscles from commercial crossbred pigs slaughtered at 130 kg body weight

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Abstract

In Spain, a sizeable proportion of pigs are slaughtered above 100 kg of body weight because are mainly intended for dry-cured ham elaboration. The chance of finding pork cuts differentiated by quality, which might be intended for fresh meat consumption, would optimize the production of heavy carcasses. The aim of this work was to evaluate the physicochemical and sensory characteristics of four muscles from heavy pigs. A total of 14 Duroc × (Landrace × Large White) gilts were slaughtered at 130 kg of body weight. From each carcass, the following muscles (two per carcass) were excised: *Longissimus thoracis* (LT), *Psoas major* (PM), *Lattissimus dorsi* (LD) and *Serratus ventralis* (SV). Several physical (color, moisture losses and resistance to cutting), chemical (intramuscular fat content and its fatty acid profile) and sensorial (attributes related to aroma, flavor, texture and acceptability) characteristics were evaluated. The LT had the highest fibrousness and the lowest water holding capacity indicators, tenderness and juiciness. The PM showed the lowest intramuscular fat and monounsaturated fatty acid contents and fibrousness, and the highest moisture, C18:2n6 and polyunsaturated fatty acid proportions. The LD had the highest yellowness and intensity of fat odor and flavor. The SV provided the highest intramuscular fat content and red color, and the lowest resistance to cutting. All muscles had similar score in global acceptability. There were several interesting physicochemical and sensory differences among the muscles studied which suggest that they might be commercialized individually as meat cuts of differentiated quality optimizing the use of heavy pig carcasses.

Additional key words: differentiated quality; heavy pigs; pork meat.

Resumen

Características físicoquímicas y sensoriales de cuatro músculos de cerdos de cruce comercial sacrificados a 130 kg de peso vivo

En España, una proporción considerable de cerdos son sacrificados a pesos elevados destinándose a la elaboración de jamón curado. La posibilidad de encontrar piezas cárnicas de calidad diferenciada, destinadas a consumo en fresco, optimizaría la producción de canales pesadas. El objetivo de este trabajo fue evaluar algunas características físico-químicas y sensoriales de cuatro músculos en 14 hembras Duroc × (Landrace × Large White) sacrificadas a 130 kg de peso vivo. De cada canal se extrajeron (dos por canal) los músculos: *Longissimus thoracis* (LT), *Psoas major* (PM), *Lattissimus dorsi* (LD) y *Serratus ventralis* (SV). Se evaluaron características físicas (color, pérdidas de agua y resistencia al corte), químicas (contenido en grasa intramuscular y su composición en ácidos grasos) y sensoriales (atributos relacionados con el aroma, el flavor, la textura y la aceptabilidad). El LT tuvo la mayor fibrosidad y los menores indicadores de capacidad de retención de agua, terneza y jugosidad. El PM mostró los menores contenidos en grasa intramuscular y ácidos grasos monoinsaturados y también en fibrosidad, y las mayores proporciones en humedad, C18:2n6 y ácidos grasos poliinsaturados. El LD tuvo el mayor tono amarillo, intensidad de olor y flavor a grasa. El SV proporcionó el mayor contenido en grasa intramuscular y color rojo y la menor resistencia al corte. Todos los músculos tuvieron similar puntuación en aceptabilidad global. En conclusión, se detectaron nu-

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Abbreviations used: a* (redness); b* (yellowness); BW (body weight); c* (chroma); DPO (Denomination of Protected Origin); FA (fatty acid); H° (hue angle); IMF (intramuscular fat); L* (lightness); LD (*Lattissimus dorsi*); LT (*Longissimus thoracis*); MUFA (monounsaturated fatty acid); PM (*Psoas major*); PUFA (polyunsaturated fatty acid); SFA (saturated fatty acid); SV (*Serratus ventralis*); UFA (unsaturated fatty acid).

merosas e interesantes diferencias entre los músculos estudiados, lo que sugiere que podrían ser comercializadas individualmente como piezas cárnicas de calidad diferenciada, optimizando así la producción de canales de cerdos pesados.

Palabras clave adicionales: carne de cerdo; cerdos pesados; calidad diferenciada.

Introduction

Spain is the world leader in the production of dry-cured hams and shoulders with a total of 47 million processed pieces in 2011 (MARM, 2011). Currently, there are five Denominations of Protected Origin (DPO) of dry-cured ham in Spain; four of them are from Iberian pigs and the fifth one, named "Teruel ham" is from heavy white (commercial crossbreds) pigs. The production of Teruel ham has increased drastically in recent decades from 2,000 pieces in 1985 to 460,000 in 2011 (Consejo Regulador DPO Jamón Teruel, 2011).

Obviously, the main objective of the pigs intended for Teruel ham is the dry-cured ham production. Literature concerning the factors that affect pig management (Latorre *et al*., 2008a and 2009a), curing process (Larrea *et al*., 2006 and 2007) and sensory properties (Resano *et al*., 2009 and 2010) of this product is relatively abundant.

In contrast with commercial pigs (5-6 months of age and 95-100 kg of body weight (BW) at slaughter), the production system of pigs intended for Teruel ham involves a longer period of time (8 months and 130 kg BW) (BOA, 1993) and the production system of Iberian pigs is even longer (12-14 months and 150-160 kg BW) (López-Bote, 1998). As a consequence, the costs of producing a pig intended for Teruel ham are higher than those of producing a commercial pig but lower than in the case of Iberian pig. Currently, the production costs of Iberian pigs are offset by a higher price of dry-cured products such as hams, shoulders and loins (*Longissimus thoracis* muscle (LT)). In addition, there are specialty meat cuts from those pigs such as *Masseter, Psoas major* (PM), *Lattissimus dorsi* (LD) or *Serratus ventralis* (SV) muscles whose demand has increased significantly in the last years in fresh consumption because of their extraordinaire sensorial properties manifested by consumers (Ventanas *et al*., 2008). In the case of pigs intended for Teruel ham, the production costs are offset only by a higher price of dry-cured hams. Therefore, the possibility of finding interesting differences among these fresh meat pieces might optimize the use of the carcasses from these heavy pigs.

The available scientific information on the quality of the named fresh cuts is scarce, except for LT, and only based on data from Iberian pigs (Muriel *et al*., 2004; Morcuende *et al*., 2007). Therefore the objective of this investigation was to study the physicochemical and sensory characteristics of four muscles (LT, PM, LD and SV) from Duroc × (Landrace × Large White) pigs slaughtered at 130 kg BW which would be intended for fresh meat consumption.

Material and methods

Animal husbandry, slaughtering and sampling

A total of 14 Duroc × (Landrace × Large White) gilts were used for the trial. All pigs were the progeny of Duroc sires (Asociacion Turolense de Industrias Agroalimentarias, Teruel, Spain) and Landrace × Large White dams (Hypor Espana G.P., Barcelona, Spain). Pigs were housed in a natural-environment barn at 1.20 m^2 pig^{-1} and had free access to feed and water. The feeding planning was common for all the animals and diets met or exceeded the requirements recommended for pigs of that BW (NRC, 1998). The composition and the estimated nutritional value (FEDNA, 2003) of the diets are shown in Table 1. Pigs were slaughtered when the average BW of group reached 130 kg (226 ± 3 d of age).

The day previous to slaughter, feed was withheld for 7 h and animals were moved 100 km to a commercial abattoir (Jamones y Embutidos Alto Mijares, S.L., Teruel, Spain), where they were kept in lairage for 10 h with full access to water but not to feed. Pigs were electrically stunned (225 to 380 V/0.5 A for 5 to 6 s), exsanguinated, scalded, skinned, eviscerated, and split down the midline according to standard commercial procedures. The average hot carcass weight was individually recorded. Then, the head was removed at the atlanto-occipital junction and carcasses were suspended in the air and refrigerated at 2 °C (1 m s^{-1}; 90% relative humidity) for 4 h and were then processed. Four kind of muscles (LT, PM, LD and SV) were taken whole from each carcass (two per carcass) by expert staff of the abattoir and weighed individually. From

Table 1. Ingredient composition and estimated analyses of the diet (g kg^{-1}, as-fed basis unless otherwise indicated)

Ingredients	Kg of body weight	
	20 to 70	70 to 130
Corn	250.0	–
Barley	68.5	335.5
Wheat	250.0	300.0
Soybean meal (470 g kg^{-1} CP)	160.0	76.7
Bakery by product meal	100.0	120.0
Rapeseed meal	100.0	100.0
Sunflower meal	10.3	–
Blended fat	38.8	45.5
L-lysine, 50%	3.2	2.3
DL-methionine, 99%	0.4	–
Sodium chloride	3.0	4.0
Calcium carbonate	8.7	9.0
Dicalcium phosphate	2.6	2.5
Vitamins, minerals and aditives[1]	4.5	4.5
Estimated nutrient content[2]		
Net energy (MJ kg^{-1})	9.20	9.75
Crude protein (N × 6.25)	169.4	143.8
Ether extract	66.9	70.2
Total ash	49.0	48.0
Total lysine	10.0	8.6

[1] Supplied per kg diet: vitamin A, (trans-retinyl acetate) 5,000 IU; vitamin D3 (cholecalciferol), 1,000 IU; vitamin E (all-rac-to-copherol-acetate), 10 IU; Cu ($CUSO_4.5H_20$), 10 mg; phytases (3-phytase EC 3.1,3.8 4a1600), 500 Ftu; β-glucanases (endo-1,3(4)-beta-glucanase EC 3.2.1.6 CEE 30), 100 AGL; β-xylanases (endo-1,4-beta-xylanase EC 3.2.1.8 CEE 30), 70 AXC. [2] According to FEDNA (2003).

every LT, a total of 500 ± 25 g was excised at the level of the last rib for the study. All the meat samples were individually vacuum-packed, after measuring the color, and stored at 4 °C during four days ageing period and afterwards frozen at –20 °C until subsequent analyses. The muscles from the left side of each carcass were intended for the physicochemical study and those from the right side for the sensory study.

Physical and chemical determinations

Color was evaluated on fresh samples after 30 min of blooming with a chromameter (CM 2002 Minolta, Minolta Camera, Osaka, Japan), previously calibrated with a pure white color tile, using objective measurements (CIE, 1976). An average of three observations per sample were used to measured the lightness (L*), redness (a*) and yellowness (b*). Additionally, chroma (c*) as $c^* = \sqrt{(a^{*2} + b^{*2})}$ and hue angle (H°) as H° = arctan (b*/a*) were calculated (Wyszcecki & Stiles, 1982).

After freezing, samples were thawed for 24 h at 4 °C, removed from packages, blotted dry and weighed. Thawing loss was calculated by dividing the difference in weight between the fresh and thawed samples by the initial fresh weight. In addition, cooking loss was determined (Honikel, 1998). Briefly, a meat slice was taken from each chop, weighed (150 ± 15 g), placed in a plastic bag and cooked to an internal temperature of 70 °C in a 75 °C water bath (Precisterm, J.P. Selecta S.A., Barcelona, Spain). Internal temperature was monitored during cooking with a handheld temperature probe (Hanna Instruments, Woonsocket, RI 02895, USA).

Cooked samples were allowed to cool at 15 °C 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 loss percentage. Samples were then cut parallel to the long axis of the muscle fibers into rectangular cross-section slices, 10-mm × 10-mm and 30 mm length. Slices (8 per chop) were sheared perpendicular to the fiber 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}.

The intramuscular fat (IMF), crude protein and moisture content of the samples were determined by using a near infrared transmittance meat analyzer (Infratec® 1265, Tecator, Höganäs, Sweden) as was described by Latorre *et al*. (2008a). Firstly, the chops were trimmed free of intermuscular fat, minced and distributed in the cup ring equipped with a plastic bottom plate with 100-mm diameter and 15-mm deep. The monochromator contained a 50 W tungsten lamp and a diffraction grating which created monochromatic light. The measured spectra were separated in the range from 800 to 1,100 nm.

Fatty acid profile of intramuscular fat

The fat was extracted according to Bligh & Dyer (1959). A total of 50 g of minced sample and 50 mL of diethyl ether were mixed in a blade homogenizer (Masticator IUL Instruments, Barcelona, Spain) for 2 to 4 min at room temperature. After filtration, the extract was placed in a rotary evaporator (Büchi R-205, Flawil, Switzerland) provided with a heating bath at

48 ± 2 °C for 3 to 4 min. A sample of 10 ± 0.05 g of extracted fat was dissolved in 20 mL of CH_3OH and in 8 mL of $CHCl_3$. A total of 2 mL of butylated hydroxytoluene (2,6 di-tert-butyl-4-methylphenol) was added as antioxidant. After vigorous shaking at 2,000 rpm for 1 min, the solution was left to decant for 30 min and 0.5 µL were injected into 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, a tubochrom 4 software and a 30 m 0.32 mm capillary column (Supelco Omegawax 320, IA, USA) with a stationary phase (0.25 µm thickness). The inlet and detector temperature was 260 °C and the initial temperature of the oven was 190 °C for 2 min increasing to 205 °C at a rate of 5 °C min^{-1} for 3 min. The carrier gas (helium) flow rate was 0.4 mL min^{-1}. Individual fatty acids (FA) methyl esters peaks were identified by comparisons with their retention times with those of standards (Sigma, St. Louis, MO, USA). The retention time and area of each peak were computed using Agilent software. Data were reported as the proportion of the total area (%) of the injected methyl esters. The percentages of total saturated FA (SFA), monounsaturated FA (MUFA), polyunsaturated FA (PUFA), unsaturated FA (UFA) and also PUFA/SFA ratio were calculated from individual FA percentages.

Sensorial study

Samples were thawed for 24 h at 4 °C, removed from packages, wrapped in aluminum foil and cooked in an industrial double-plate grill (Sammic P8D-2, Azpeitia, Spain) at 200 °C until the internal temperature reached 70 °C, which was monitored by an internal thermocouple (Jenway 2000, Dunmow, England). Once cooked, the external connective tissue was removed and each sample was cut in four portions. Each subsample was immediately wrapped in aluminum foil, marked with a random 3-digit code and kept at 60 °C until the test. To avoid the possible effects of the order of presentation and first-order carry-over effects, the samples were presented to panelists in different orders (Macfie *et al*., 1989). The sensory analysis was performed in individual cabins that had controlled environmental conditions and a red light to obscure meat color (ISO 8589). To cleanse their palate between samples, panelists were given bottled water and breadsticks. The panel included eight selected and trained individuals (ISO 8586-1). The test used a quantitative descriptive method within a complete and balanced design which consisted of three sessions with two plates per session containing four subsamples each randomly selected. The sensory profile and specific training was developed in an additional session using similar samples to the four muscles studied. A profile of 12 sensory attributes of pork grouped in aroma, flavor, texture and acceptability (Table 2) was assessed that used a 10 cm nonstructured lineal scale, which was transformed into a numerical scale (0-100) for the statistical analysis. A free space for considering and writing observations was left to allow panelits to express particular considerations about each sample tasted.

Table 2. Definitions of the descriptors used in the sensory analysis of the meat from Duroc × (Landrace × Large White) pigs slaughtered at 130 kg of body weight

Descriptor	Definition
Pork odor[1]	Odor intensity of cooked pork
Fat odor[1]	Odor intensity of fat or oil
Tenderness[2]	Facility of chewing with the molars
Juiciness[3]	Liquid expels by the sample, during chewing
Fibrousness[4]	Compressibility of cooked pork
Fatiness[5]	Oil expels by the sample
Pork flavor[1]	Flavor intensity of cooked pork
Lactic flavor[1]	Flavor intensity associated to lactic acid
Fat flavor[1]	Flavor intensity of fat or oil
Metallic flavor[1]	Flavor intensity of metal
Acid flavor[1]	Flavor intensity associated to citric acid
Overall acceptability[6]	Whole hedonic acceptation of the product by panelists

[1] 0 = Not detected, 100 = Very intense. [2] 0 = Very tough, 100 = Very tender. [3] 0 = Very dry, 100 = Very juicy. [4] 0 = Not fibrous, 100 = Very fibrous. [5] 0 = Not oily, 100 = Very oily. [6] 0 = Very bad, 100 = Very good.

Statistical analyses

Data for physicochemical characteristics of meat were analyzed as a completely randomized design using the GLM procedure of SAS (1990). The model included the type of muscle as main effect and the number of replicates per treatment was 14. For the sensory data, a previous GLM procedure of SPSS for Windows (2005) was performed including the session, plate and type of muscle for each pannelist as fixed effect. Afterwards, another GLM was performed with the mean per attribute and per muscle obtained from the previously corrected data file. Type of muscle was considered as fixed effect. Duncan's test was used to compare means where the variance analysis indicated a significant effect. A p-value < 0.05 was classified as a significant difference, whereas a p-value between 0.05 and 0.10 was classified as a trend.

Results

The average weight (and the average yield in the carcass) of the whole meat pieces was 5.8 kg (5.68%), 0.73 kg (0.71%), 0.42 kg (0.41%) and 1.16 kg (1.13%) for LT, PM, LD and SV, respectively (data obtained with both pieces per each carcass and not statistically analyzed).

Physical and chemical characteristics

The differences in color traits, moisture losses, shear force and chemical composition among muscles are shown in Table 3. The LT and LD had higher L* value than PM and SV ($p < 0.001$). The a* value decreased ($p < 0.001$) in the order SV > PM > LD > LT, whereas the H° value decreased ($p < 0.001$) in the opposite way (LT > LD > PM > SV). The b* value was lower ($p < 0.01$) in LT, PM and SV than in LD and the c* value was higher ($p < 0.001$) in SV than in LT, with PM and LD in an intermediate position. In respect of water holding capacity, the PM, LD and SV had lower thawing loss than LT ($p < 0.001$). Also PM and LD had lower cooking loss than LT but higher than SV ($p < 0.001$). On the other hand, SV had lower resistance to cutting than LT, PM and LD ($p < 0.001$). Regarding to chemical composition, the moisture content ranged between 63.2 and 76.8% whereas the protein content ranged between 18.2 and 24.3% and the IMF content between 0.4 and 15.9% depending on the muscle. The LT and PM had the highest and SV the lowest protein proportion ($p < 0.001$). Differences ($p < 0.001$) were detected among muscles in the percentage of IMF and moisture proportions showing PM the lowest IMF and the highest moisture contents and SV the highest IMF and the lowest moisture contents, with LT and LD being intermediate.

Table 3. Physical and chemical characteristics of four muscles from Duroc × (Landrace × Large White) pigs slaughtered at 130 kg of body weight

Variable	*Longissimus thoracis*	*Psoas mayor*	*Latissimus dorsi*	*Serratus ventralis*	SE[1] (n = 14)	p[2]
Color traits						
Lightness, L*	47.5^{w}	39.8^{x}	46.0^{w}	38.4^{x}	0.728	***
Redness, a*	0.71^{z}	6.65^{x}	4.82^{y}	9.62^{w}	0.271	***
Yellowness, b*	5.31^{x}	4.55^{x}	6.76^{w}	4.89^{x}	0.396	**
Chroma, c*	5.36^{y}	8.12^{x}	8.45^{x}	10.9^{w}	0.325	***
Hue angle, H°	82.4^{w}	34.0^{y}	54.5^{x}	26.4^{z}	2.374	***
Water holding capacity indicators						
Thawing loss (g kg^{-1})	65.3^{w}	35.4^{x}	35.8^{x}	23.5^{x}	4.46	***
Cooking loss (g kg^{-1})	215^{w}	159^{x}	167^{x}	126^{y}	8.49	***
Shear force, N	28.9^{w}	27.7^{w}	30.9^{w}	22.2^{x}	1.46	***
Chemical composition (g kg^{-1})						
Crude protein	231^{w}	235^{w}	207^{x}	191^{y}	1.87	***
Intramuscular fat	36^{y}	8^{z}	82^{x}	117^{w}	7.73	***
Moisture	732^{x}	759^{w}	708^{y}	688^{z}	6.30	***

[1] Standard error of the mean. [2] ** $p < 0.01$; *** $p < 0.001$. Within a row, means with different superscript letter differ ($p < 0.05$).

Fatty acid profile of intramuscular fat

The differences in FA composition of IMF among muscles are shown in Table 4. The most abundant FAs were C18:1n9 (41.4, 34.5, 42.1 and 41.0% for LT, PM, LD and SV, respectively), C16:0 (24.2, 23.7, 23.9 and 24.1%, respectively), and C18:0 (12.5, 12.7, 13.1 and 13.9%, respectively). No differences among muscles were found in C16:0, C17:1, C20:1n9, SFA or UFA ($p > 0.10$). However, the PM had lower ($p < 0.001$) MUFA and higher ($p < 0.001$) PUFA proportions than LT, LD or SV. The lowest content in MUFA of PM was mainly due to the lower proportion in C16:1 ($p < 0.001$) and C18:1n9 ($p < 0.001$). Also, the highest percentage in MUFA of PM was mainly because of the higher content in C18:2n6 ($p < 0.001$), C20:3 ($p < 0.001$), C20:4n6 ($p < 0.001$), C22:4n6 ($p < 0.001$) and C22:5n3 ($p < 0.001$). As a consequence, PM had higher PUFA/SFA ratio ($p < 0.001$) than the remaining meat pieces.

Sensorial characteristics

The differences in sensory characteristics among muscles are shown in Table 5. The LT had lower pork odor ($p < 0.001$) and juiciness ($p < 0.001$) than the remaining muscles. Also, LT was less tender and more fibrous than PM with LD and SV in an intermediate position ($p < 0.001$). The LT and PM had lower fatiness ($p < 0.001$) and pork flavor ($p < 0.001$) and higher acid flavor ($p < 0.001$) than LD and SV. The PM had higher metallic flavor than LT and LD with SV being intermediate ($p < 0.001$). The LD had higher fat odor ($p < 0.001$)

Table 4. Fatty acid composition (g kg^{-1}) of intramuscular fat of four muscles from Duroc × (Landrace × Large White) pigs slaughtered at 130 kg of body weight

Fatty acid	*Longissimus thoracis*	*Psoas mayor*	*Latissimus dorsi*	*Serratus ventralis*	SE[1] ($n = 14$)	p[2]
C10:0	1.05^{x}	1.11^{w}	0.91^{z}	0.97^{y}	0.021	***
C12:0	0.94^{w}	0.82^{x}	0.86^{wx}	0.91^{w}	0.024	**
C14:0	14.84^{w}	13.77^{x}	1.3.6^{x}	13.96^{x}	0.346	*
C16:0	242.5	236.9	239.5	241.2	2.690	NS
C16:1	32.08^{w}	25.89^{y}	28.63^{x}	28.26^{x}	0.709	***
C17:0	1.78^{x}	2.27^{w}	1.99^{x}	2.00^{x}	0.096	**
C17:1	1.81	1.68	1.96	1.91	0.080	NS
C18:0	125.5^{x}	126.6^{x}	131.1^{wx}	138.6^{w}	3.553	*
C18:1n9	413.6^{wx}	344.8^{y}	421.5^{w}	409.8^{x}	4.166	***
C18:1n7	37.13^{w}	34.63^{x}	33.32^{x}	33.33^{x}	0.652	***
C18:2n6	98.5^{x}	157.0^{w}	99.8^{x}	100.7^{x}	4.095	***
C18:3n3	5.51^{x}	6.61^{w}	6.13^{w}	6.16^{w}	0.208	**
C18:3n7	1.06^{w}	0.89^{x}	1.11^{w}	1.04^{w}	0.036	***
C20:0	1.61^{x}	1.41^{y}	1.82^{w}	1.70^{wx}	0.073	**
C20:1n9	7.37	7.09	7.77	7.88	0.261	NS
C20:3	1.81^{x}	3.73^{w}	1.31^{y}	1.56^{x}	0.103	***
C20:4n6	9.58^{x}	6.48^{w}	6.17^{y}	6.93^{y}	0.918	***
C22:4n6	1.61^{x}	4.01^{w}	1.33^{x}	1.65^{x}	0.129	***
C22:5n3	1.65^{x}	4.12^{w}	1.21^{y}	1.42^{xy}	0.148	***
∑SFA[3]	388.3	382.9	389.7	399.3	6.172	NS
∑MUFA[4]	491.9^{w}	414.1^{x}	493.2^{w}	481.2^{w}	4.849	***
∑PUFA[5]	119.7^{x}	202.9^{w}	117.1^{x}	119.4^{x}	5.340	***
∑UFA[6]	611.7	617.0	610.3	600.6	6.172	NS
PUFA/SFA	0.312^{x}	0.533^{w}	0.303^{x}	0.302^{x}	0.182	***

[1] Standard error of the mean. [2] NS, non-significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Within a row, means with different superscript letter differ ($p < 0.05$). [3] ΣSFA, total saturated fatty acids = C12:0 + + C14:0 + C16:0 + C17:0 + C18:0 + C20:0. [4] ΣMUFA, total monounsaturated fatty acids = C16:1 + + C17:1 + C18:1 + C20:1. [5] ΣPUFA, total polyunsaturated fatty acids = C18:2 + C18:3. [6] ΣUFA, total unsaturated fatty acids = MUFA + PUFA.

Table 5. Sensorial characteristics of four muscles from Duroc × (Landrace × Large White) pigs slaughtered at 130 kg of body weight

Attribute[1]	*Longissimus thoracis*	*Psoas mayor*	*Latissimus dorsi*	*Serratus ventralis*	SE[1] (n = 14)	p[3]
Pork odor	44.5^{y}	51.4^{x}	56.3^{x}	53.6^{x}	1.06	***
Fat odor	30.4^{z}	34.4^{yz}	46.2^{x}	37.3^{y}	1.18	***
Tenderness	40.6^{z}	73.4^{x}	64.7^{y}	63.1^{y}	1.13	***
Juiciness	42.3^{y}	55.2^{x}	53.6^{x}	56.4^{x}	1.09	***
Fibrousness	50.6^{x}	24.6^{z}	31.4^{y}	34.2^{y}	1.19	***
Fatiness	32.6^{y}	32.8^{y}	51.4^{x}	46.7^{x}	1.13	***
Pork flavor	47.0^{y}	50.1^{y}	58.4^{x}	56.7^{x}	1.03	***
Lactic flavor	21.5	20.5	21.9	22.3	0.96	NS
Fat flavor	35.9^{z}	34.2^{z}	58.6^{x}	49.9^{y}	1.24	***
Metallic flavor	18.0^{y}	27.4^{x}	17.3^{y}	22.7^{xy}	1.00	***
Acid flavor	34.3^{x}	37.3^{x}	23.6^{y}	25.1^{y}	1.33	***
Overall liking	47.8^{z}	49.4^{z}	55.4^{x}	53.2^{y}	1.11	†

[1] Measuring by a numerical scale (0-100). [2] Standard error of the mean. [3] NS, non-significant; † $p < 0.10$; *** $p < 0.001$. Within a row, means with different superscript letter differ ($p < 0.05$).

and fat flavor ($p < 0.001$) than PM and LT with SV in an intermediate position. Finally, LD tended to show higher global acceptability than LT and PM with SV being intermediate ($p < 0.10$).

Discussion

The average weight and yield of the whole meat pieces was 5.8 kg (5.68%), 0.73 kg (0.71%), 0.42 kg (0.41%) and 1.16 kg (1.13%) for LT, PM, LD and SV, respectively. In a trial with Iberian pigs (Prieto & Latorre, 2007), the same muscles were studied finding the following results: 3.89 kg (2.88%) for LT, 0.69 kg (0.51%) for PM, 0.46 kg (0.34%) for LD and 1.31 kg (0.97%) for SV. The yields were numerically higher in the pigs of the current study than in the study of Prieto & Latorre (2007). The reason might be mainly that traditional breeds have usually fatter carcasses than commercial crossbreds which is also related to a lower proportion of lean pieces (Rodríguez-Sánchez *et al*., 2010). However, the higher difference was observed in LT and it could be due to the fact that lean pig breeds selected to improve their growth potential have especially higher percentage of glycolytic muscles than traditional breeds (Weiler *et al*., 1995).

Data about LT weight and yield in the present trial were similar to those shown by other authors (6.0 kg and 5.9%, Daza *et al*., 2010; 6.1 kg and 5.9%, Larrea *et al*., 2006) in pigs intended for Teruel ham.

Physical and chemical characteristics

In general, in the literature, there are many reports about LT and few about PM characteristics. Both are the lean pieces more appreciated by the sector of the pork industry in Spain, excepting ham and shoulder. On the other hand, there is scarce information about the quality of the remaining muscles studied in the current trial (LD and SV). All of that did more difficult the present discussion.

The LT and LD had the color with higher lightness, being also LT the most saturated and LD the most yellow. The SV had the most intense and red color. Therefore, the PM had an intermediate color in base on all of these variables. These results confirm those observed in Iberian pigs; Cava *et al*. (2003) found higher L* and lower c* in LT than in SV and Morcuende *et al*. (2007) detected higher L* and lower a* in LT than in PM. Also, higher heme pigments in PM than in LT (282 vs. 148 mg/100 g for LT and PM, respectively) were showed in some reports (Leseigneur-Meynier & Gandemer, 1991). In fact, Laborde *et al*. (1985) classified the pig muscles in three groups: those white glycolytic (*i.e. Longissimus thoracis*), those red oxidative (*i.e. Masseter* and *Diaphragm*) and the remaining (many muscles with intermediate heme content and lactate-dehydrogenase activity).

The color values of LT observed in the current trial were similar to those observed by Rodríguez-Sánchez *et al*. (2009, 2011) in Duroc × (Landrace × Large

White) pigs slaughtered at similar weight. However, the results of the present experiment differ of those found in Iberian pigs where LT had lower L* and higher a* values (Cava *et al*., 2003; Muriel *et al*., 2004). Other studies (Estévez *et al*., 2003) reported that myoglobine and heminic iron were higher in several Iberian lines (Lampiño, Retinto or Torbiscal) than in commercial pigs. Serra *et al*. (1998) and Lindahl *et al*. (2001) reported similar conclusions comparing traditional (Iberian, Hampshire) with commercial (Landrace, Yoskshire) breeds of pigs. It is widely known that the system of production of Iberian pigs has influence on myoglobine content in muscle and also the heminic pigment increase with the age of the animal (Lawrie, 1998) and the physical activity (Jorgensen & Hyldgaard-Jensen, 1975).

The PM, LD and SV had lower thawing loss than LT. In addition, PM and LD had lower cooking loss than LT but higher than SV. In general, the results found in the current work about LT are in the range shown by other authors in pigs intended for Teruel ham (Latorre *et al*., 2009a,b) (3.1-7.4% and 12.7-21.9% for thawing and cooking losses, respectively). On the other hand, SV had lower resistance to cutting than the remaining muscles. It could be related to the high IMF content because a high amount of it make easier the separation of the muscle fibers and provide a higher juiciness (Ventanas *et al*., 2008) and tenderness perception (Cava *et al*., 2003) of meat.

The anatomical location affects the muscle composition (Muriel *et al*., 2002) and it is mainly due to metabolic differences (Andrés *et al*., 2001). In the current trial, the LT and PM had the highest and SV the lowest protein proportion. The PM showed the lowest IMF and the highest moisture contents and SV the highest IMF and the lowest moisture contents, with LT and LD in an intermediate position. The present results confirm those obtained by Morcuende *et al*. (2007) who found higher proportion of IMF in LT than in PM in Iberian pigs (4.84 and 2.64% for LT and PM, respectively) but it does not agree with Alasnier *et al*. (1996) who reported that glycolytic muscles have lower IMF content than oxidative muscles because the first ones use glycogen as energy source instead of fat. According with the present work, other authors have found that the IMF proportion were higher in glycolytic than in oxidative muscles concluding that the difference among muscles, in terms of total lipids, was not consistent (Wood *et al*., 2003). This controversy can be explained considering that the lipidic extract of muscle is constituted not only by lipids located into the fibers but also by those contained in the adipocytes located between fibers (Leseigneur-Meynier & Gandemer, 1991). Therefore differences among muscles might be attributed to different tendencies in the muscles to accumulate adipocytes in the extrafascicular area as a result of several factors (Kauffman & Safanie, 1967).

Data about chemical composition of LT in the present trial were similar to those observed previously in pigs intended for Teruel ham (moisture: 73.2-74.6%, IMF: 2.53-3.71% and protein: 22.8-23.3%) (Latorre *et al*., 2009a,b). The values about IMF are higher than those observed in LT of Large White (1.93%) or synthetic line (1.15%) pigs slaughtered at 108 kg BW (Latorre *et al*., 2008b) but lower in 30-40% in LT and three times in PM than those observed in Iberian pigs (Cava *et al*., 2003) although high variability is detected among genetic lines and crossbreeding (Muriel *et al*., 2004). Estévez *et al*. (2003) showed differences in chemical composition between Iberian and commercial pigs concluding that the reason is the higher capacity of synthesis of fat in traditional breeds having also influences the feeding and the management (Tejeda *et al*., 2002).

Fatty acid profile of intramuscular fat

The FA composition is influenced by the anatomical location and the metabolism of each muscle. Some of the current results confirm those presented by Muriel *et al*. (2004) working with Iberian pigs of 140 kg BW and by Leseigneur-Meynier & Gandemer (1991) with Large White × Pietrain gilts slaughtered at 100 kg BW comparing LT and PM where no differences in SFA were detected but LT had higher MUFA and lower PUFA contents than PM. In both cases, LT had lower linoleic acid than the muscles studied (*Biceps femoris*, PM, *Trapezius* and *Masseter*) which was confirmed by the comparison between LT and PM in the current trial. Other works (Cava *et al*., 2003) also compared glycolytic muscles (LT and SV) with oxidative muscles (*Masseter*) in Iberian pigs slaughtered at 90 kg BW finding small differences among glycolytic muscles, which is confirmed by the lack of differences between LT and SV in the present trial, but showing glycolytic muscles higher PUFA content than oxidative muscles. Similar results were detected in a trial with Iberian pigs slaughtered at 50 kg BW concluding that oxidative muscles are more prone to oxidation and lipolitic de-

terioration than glycolytic muscles (Morcuende *et al*., 2003). Oxidative muscles might have higher PUFA proportion than those glycolytic because of their high content in membranes rich in phospholipids (Leseigneur-Meynier & Gandemer, 1991).

Data about FA profile of IMF of LT are similar to those found in pigs intended for Teruel ham production slaughtered at similar weight (39.3, 49.8 and 10.8% for SFA, MUFA and PUFA, respectively) (Daza *et al*., 2010) but differ from those detected in Iberian pigs which have higher MUFA and lower PUFA proportions in several meat pieces. In fact, MUFA contents higher by 8% in LT and by 14% in PM were detected in pure Iberian or Iberian × Duroc pigs than those found in the present trial (Morcuende *et al*., 2007) although there are high differences among genetic lines and crossbreds (Muriel *et al*., 2004). The high MUFA proportion in meat from Iberian pigs reared outdoor is due to the intake of acorns which are rich in oleic acid (Estévez *et al*, 2003). Finally, the PUFA/SFA ratio is related to the nutritional quality of fat, being recommended a value higher than 0.4 (Wood *et al*., 2008). Therefore, the current results show that the IMF of PM might provide a FA profile more equilibrated for consumers than the rest of pieces.

Sensorial characteristics

The characterization by a trained panel can explain the sensory attributes or characteristics that define the meat and which of them have more influence in its acceptability by consumers. The LT had lower pork odor and juiciness than the remaining muscles. Also, LT was less tender and more fibrous than PM. Tenderness and juiciness are sensory attributes with a high and positive correlation (Huff-Lonergan *et al*., 2002). The higher scores in juiciness showed by PM, LD and SV than LT might be due at least in part to the higher water holding capacity indicators showed by the lower thawing and cooking losses detected instrumentally. The cooking loss not only has influence on meat juiciness but also on visual aspect (Aaslyng *et al.,* 2003).

The LT and PM had lower oiliness and pork flavor and higher acid flavor than LD and SV. The PM had higher metallic flavor than LT and LD. The LD had higher fat odor and fat flavor than PM, LT and SV. The highest score obtained by LD in fat odor and flavor might be due in part to the high IMF content detected instrumentally. The effect of IMF on meat flavor is unquestionable because FAs contain several volatile acid compound precursors which are responsible for the flavor and also because IMF works as a matrix where FAs are accumulated and regulate their progressive liberation (early and later) during the stay in the mouth maintaining the aromatic intensity and persistency. In fact, it has been repeatedly demonstrated that the reduction of lipid content in foods rich in protein reduces the acceptability mainly because of an initial and ephemeral aromatic sensation which disappear very soon resulting in a difficult chewing meat texture in the mouth (Ventanas *et al*., 2008). Also, a higher IMF content can contribute to a higher sensory quality of meat providing a higher juiciness and tenderness (Alonso *et al*., 2010) because IMF stimulates the saliva secretion and helps to chew increasing these attributes (Wood *et al*., 1994). However, in the current trial, no clear relation was detected between IMF and tenderness and juiciness suggesting that other factors also can have influence.

Finally, LD tended to show higher global acceptability than LT and PM with SV being intermediate. The low score in overall acceptability for LT might be due in part to low tenderness and juiciness and high fibrousness detected by the panelists. Alonso *et al*. (2010) consider that tenderness and juiciness are the attributes which affect mainly the global acceptability of meat. Also, Brewer & Lan (1998) concluded that consumers of pork prefer a more intense red color and, although it was not studied by panelists, LT had the lowest a* value detected instrumentally.

As conclusions, several differences were found among the muscles studied in physicochemical characteristics which are of interest due to a presumably different behavior of them during refrigeration display, freezing or culinary practices on the oxidative and lipolytic changes and their shelf-lives. In addition, although the overall liking was similar, the muscles resulted different in many of the sensorial attributes evaluated which would provide a wide and interesting range of desirable sensations for consumers. Therefore, the differences detected among the four muscles suggest that they might be commercialized individually as pig meat cuts of differentiated quality for fresh consumption optimizing the economic value of the heavy pig carcasses.

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