

Prediction of weight and yield of main lean cuts related to carcass weight in heavy pigs intended for Spanish high quality dry-cured ham

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Abstract

The aim of this study was to evaluate the possibility of predicting the weight and yield (as % of carcass) of the main lean cuts related to carcass weight (CW) in pigs intended for Spanish dry-cured ham. A total of 98 Duroc × (Large White × Landrace) pigs were used. Simple regression equations were carried out to find the relations between CW (independent variable) and ham (H), foreleg (F), loin (L) and H+F+L weights and yields (dependent variables). Also, multiple regression equations were carried out to estimate the relations between these dependent variables and other size carcass characteristics (backfat thickness, carcass length, and ham length and perimeter). The best simple relationship between independent and dependent variables was obtained by means of linear functions. The CW explained 84%, 75%, 60% and 89% of the variability of H, F, L and H+F+L weights, respectively, whereas 10%, 10%, 0.15% and 14% of the variability of H, F, L and H+F+L percentages, respectively. The addition of the size carcass characteristics, as independent variables, to the prediction equations of H, F, L and H+F+L weights and yields improved the predictions. The simple and multiple regression equations calculated underestimated the dependent variables, but the mean prediction error and relative prediction error values were low, suggesting that the independent variables considered are good predictors of the dependent variables. It is concluded that CW is an easy and available measurement for industry to predict carcass lean cuts weights in pigs from genetic lines intended for Spanish dry-cured ham.

Additional key words: foreleg, loin, regression equations.

Resumen

Predicción del peso y rendimiento de las principales piezas nobles en relación al peso de la canal en cerdos pesados destinados a jamón curado español de alta calidad

Se utilizaron 98 cerdos Duroc × (Large White × Landrace) destinados a jamón curado para evaluar la posibilidad de predecir el peso y el rendimiento de sus principales piezas nobles en relación al peso de la canal (PC). Se llevaron a cabo ecuaciones de regresión simples para encontrar las relaciones entre el PC (variable independiente) y el peso y rendimiento en canal de los jamones (J), paletas (P), lomos (L) y J+P+L (variables dependientes). Además, se llevaron a cabo ecuaciones de regresión múltiples para estimar la relación entre estas variables dependientes y otras características medidas sobre la canal (espesor de grasa dorsal, longitud de la canal y longitud y perímetro del jamón). La mejor relación simple se obtuvo por medias de funciones lineales. El peso de la canal explicó el 84%, 75%, 60% y 89% de la variabilidad del peso y el 10%, 10%, 0,15% y 14% de la variabilidad del rendimiento de J, P, L y J+P+L, respectivamente. La adición de las medidas tomadas sobre la canal a las ecuaciones de predicción de los pesos y rendimientos de J, P, L y J+P+L mejoró las predicciones. Las ecuaciones de regresión simples y múltiples subestimaron las variables dependientes, pero los errores de predicción medios y relativos fueron pequeños, sugiriendo que las variables independientes son buenos predictores de las variables dependientes. Se concluye que el PC es una medida factible para la industria para predecir el peso de las principales piezas nobles de cerdos destinados a jamón curado español.

Palabras clave adicionales: ecuaciones de regresión, lomo, paleta.

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Introduction

Spain is the world leader in dry-cured hams and forelegs with a total production of 46 million pieces in 2008 (Ministerio Medio Ambiente y Medio Rural y Marino, 2009). Currently, the only dry-cured ham type accepted by the Spanish government (Protected Designation of Origin, PDO) from heavy white pigs is «PDO Teruel ham» and it is passed by the European Union. The production of PDO Teruel ham has increased greatly in recent decades from 2,000 pieces in 1985 to nearly 700,000 in 2008 (Consejo Regulador Denominación Origen Jamón de Teruel, 2009).

The pig crossbreeding used for PDO Teruel ham production is Duroc × (Large White × Landrace) and the regulation of PDO Teruel ham establishes a minimum of 84 kg for carcass weight (CW) and of 16 mm for backfat thickness over the *Gluteus medius* muscle to improve the uniformity and quality of the end product (Boletín Oficial Aragón, 1993). In the production of pigs intended for PDO Teruel ham, the carcass traits, especially the ham (H), foreleg (F) and loin (L) yield (as % of carcass) have an outstanding economic importance for the industry. Therefore, the prediction of the main lean cuts yield by easy and available measurements such as CW could be interesting for producers and industry. It might help to prevent possible problems that appear in the commercial setting (fraudulent practices).

Some previous experiments have calculated, by means of simple regression equations, the relationships between CW and H, F and L weight and yield in heavy pigs (Latorre *et al.*, 2004; Daza *et al.*, 2007). However, to our knowledge, there are not studies that verify the accuracy of such equations to predict carcass joints in pigs intended for PDO Teruel ham.

Therefore, the aim of this study was to assess the possibility of predicting the weight and yield of the main lean cuts in pigs intended for PDO Teruel ham by simple regression equations including the CW as independent variable. Moreover, this experiment valued if the prediction of the named variables could be improved by means of multiple regression equations that included the CW and other carcass characteristics.

Material and methods

Animal welfare and husbandry

All the experimental procedures used in this study were in compliance with the Spanish guidelines for the care and use of animals in research (Boletín Oficial Estado, 2005). A total of 98 Duroc × (Large White × Landrace) pigs, 50 barrows and 48 gilts, from PDO Teruel ham, were used. During the fattening period (60-126.6 kg of body weight, BW) all pigs received a commercial diet that was formulated according to the nutrient composition of ingredients of the Fundación Española Desarrollo Nutrición Animal (2003) to meet or exceed the nutrient requirement of pigs (National Research Council, 1998). The diet was based on cereals and soybean meal and contained per kg of feed 3.27 Mcal of digestible energy, 890.3 g of dry matter, 155.7 g of crude protein and 59.9 g of crude fat (AOAC, 2000). Pigs had free access to water and pelleted feed throughout the trial.

Carcass measurements

The day before slaughter, feed was withheld for 7 h at farm and pigs were weighed and transported 30 km to a commercial abattoir (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 slaughter weight and CW were 126.6 ± 12.6 kg (range = 103.4-156.7 kg) and 100.9 ± 11.2 kg (range = 79.5-126 kg), respectively.

At 45 min *postmortem*, carcass length from the posterior edge of the *Symphysis pubis* to the anterior edge of the first rib, ham length from the anterior edge of the *Symphysis pubis* to the hock joint, and ham circumference at its widest point were measured on the left side of each carcass. Fat depth over the *Gluteus medius* muscle, and backfat thickness at the 10th rib on the midline of the carcass (skin included) were also measured.

The head was removed at the atlanto-occipital junction and carcasses were chilled at 2°C (1 m s⁻¹ of air speed; 90% relative humidity) for 2 h. Then carcasses were processed according to the simplified EC reference method (Branscheid *et al.*, 1990). Afterwards, H, F and L were trimmed of external fat and weighed to calculate trimmed H, F and L yield in carcass (%H, %F, %L and %H+F+L). The trimming consisted of eliminating part of the external fat and skin to fit commercial requirements and the process was performed by qualified personnel of the abattoir.

Regression studies and statistical analyses

Simple regression equations were carried out to find the relationships between CW (independent variable) and H, F, L and H+F+L weight and yield (dependent variables). On the other hand, multiple regression equations were carried out to estimate the relations between these dependent variables and combinations of the carcass characteristics measured. The method of selection of independent variables that better explained the variability of the dependent variables was used. For the definitive selection of the regression equations the statistic of Mallows (1973) was considered. The regression analyses were carried out using the procedure PROC REG of the SAS statistical package (SAS Inst., 1990).

To determine the accuracy of the calculated regression equations, two additional groups of Duroc × (Large White × Landrace) pigs from different Duroc sire line were used. One group consisted of 17 animals, 9 barrows and 8 gilts, from the same Duroc sire line as the initial group of 98 pigs (Asociación Turolense de Industrias Agroalimentarias, Teruel, Spain). The average slaughter weight and CW of this group of pigs

were 131.1 ± 12.1 kg (range = 110.0-146.5 kg) and 104.4 ± 10.2 kg (range = 86.0-118.5 kg), respectively. The other group consisted of 39 animals, 24 barrows and 15 gilts, from a different Duroc sire line (Nucleus, Le Rheu, France). The average slaughter and CW of this group of pigs were 130.0 ± 11.7 kg (range = 102.7-146.7 kg) and 103.0 ± 10.4 kg (range = 79.0-118.4 kg), respectively. Student's *t* test was used to compare actual values of main lean cuts weights between different genetic lines and also to compare actual and predicted values of main lean cuts weights. Correlation coefficients (*r*) between actual and predicted values were calculated using the procedure CORR of the SAS statistical package (SAS Inst., 1990).

Mean prediction error (MPE) and relative prediction error (RPE) were calculated as follows:

$$\text{MPE} = [\sum (\text{observed values} - \text{predicted values})^2 / N]^{0.5}$$

$$\text{RPE} = \text{MPE} / [\sum (\text{observed values}) / N]$$

where N = number of observations.

Results and discussion

Regression equations that relate H, F, L and H+F+L weights and yields with CW in the initial group of 98 pigs are showed in Table 1. The best relationship between independent and dependent variables was obtained by means of linear functions. Other functions (exponential, potential and logarithmic) were also calculated, but the coefficient of determination (R²) and residual standard deviation (RSD) values were lower and higher, respectively than in the linear functions. The CW explained 84%, 75%, 60% and 89% of the variability in H, F, L and H+F+L weights, respectively, whereas CW explained only 10%, 10%, 0.15% and 14% of the

Table 1. Simple linear regression equations between ham (H), foreleg (F), loin (L) and H+F+L weight or yield and carcass weight (CW, kg)^a

Equation	R ² ^b	RSD ^c	P ^d
H (kg) = 1.506 (± 0.517) + 0.113 (± 0.0051) CW	0.84	0.608	***
F (kg) = 1.104 (± 0.383) + 0.0649 (± 0.0038) CW	0.75	0.452	***
L (kg) = 0.0784 (± 0.241) + 0.0284 (± 0.024) CW	0.60	0.283	***
H+F+L (kg) = 2.601 (± 0.743) + 0.208 (± 0.0073) CW	0.89	0.875	***
H (% carcass) = 14.458 (± 0.503) - 0.0158 (± 0.0050) CW	0.10	0.590	**
F (% carcass) = 8.893 (± 0.388) - 0.0128 (± 0.0038) CW	0.10	0.457	**
L (% carcass) = 3.015 (± 0.238) - 0.0000908 (± 0.0023) CW	0.001	0.280	NS
H+F+L (% carcass) = 26.286 (± 0.728) - 0.0286 (± 0.0072) CW	0.14	0.857	***

^a Equations calculated with data from 98 pigs (50 barrows and 48 gilts). ^b Coefficient of determination. ^c Residual standard deviation. ^d Statistical significance; NS: not significant; ***P* < 0.01; ****P* < 0.001.

variability in %H, %F, %L and %H+F+L, respectively. Although CW explained a high variability of main lean cut weights, the handicap of this procedure is that calculations are from died animals. In this respect, Daza *et al.* (2006) found that BIA (bioelectrical impedance analysis) is a rapid and non-invasive technique that might be of value for body composition prediction of live Iberian pigs. However, this procedure is not well developed currently for this aim and these authors concluded that further studies with BIA are needed to validate their potential application. As it was expected, the weight of the H, F, L and H+F+L increased ($P < 0.001$) as CW increased, which is in agreement with data from Latorre *et al.* (2004, 2008) and Daza *et al.* (2007) who worked with heavy pigs. The weights of main lean cuts observed in this experiment were similar to data from Latorre *et al.* (2008) and were slightly higher than those obtained by Cilla *et al.* (2006) in pigs intended for PDO Teruel ham in both cases. On the other hand, although the %L was not affected ($P > 0.05$), the %H ($P < 0.01$), %F ($P < 0.01$) and %H+F+L ($P < 0.001$) decreased as CW increased, which is in agreement with data from Latorre *et al.* (2004, 2008) who reported that H+F+L yield decreased linearly by 0.4 percentage units for each 10 kg increase in slaughter weight in pigs from 120 to 140 kg BW.

Predicted vs actual main lean cuts weights for the group of 17 pigs (from the same genetic line as the initial group of 98 pigs) are shown in Table 2. The simple regression equations calculated underestimated H, F, L and H+F+L weights on average but the MPE and

RPE values were low, which suggests that the CW is a good predictor of H, F, L and H+F+L weights for pigs of the same genetic line than that used for to calculate the regression equations. In addition, according to the Student *t* test, no significant ($P > 0.05$) differences between actual and predicted values were observed and the correlation coefficients between actual and predicted values were highly significant ($P < 0.001$).

Predicted vs actual main lean cuts weights for the group of 39 pigs (from a different genetic line as the initial group of 98 pigs) are also presented in Table 2. The regression equations calculated underestimated H, F, L and H+F+L weights on average, and the MPE and RPE values also were low except for L weight (0.458 kg and 13.92%, respectively). Moreover, according to the Student *t* test, no significant ($P > 0.05$) differences between actual and predicted values were observed, except for the L weight ($P < 0.001$), and the correlation coefficients between actual and predicted values were significant ($P < 0.001$). In Iberian pigs, Daza *et al.* (2007) observed that CW was a good predictor of main lean cuts weights for pigs from one only genetic line, but CW was not a good predictor for pigs from different genetic line due to significant differences in fat weight and in H, F, L and H+F+L weights between different genetic lines. Latorre *et al.* (2003a,b) found significant differences in lean cuts weights between pigs from Dutch and Danish Duroc sire lines and Cilla *et al.* (2006) also detected differences in carcass lean cuts weights according to genetic lines of boar sire within the Duroc breed. The carcass traits variabi-

Table 2. Predicted vs actual ham (H), foreleg (F), loin (L) and H+F+L weights (means \pm standard deviation) for pigs from the same and different genetic line

Lean cut (kg)	Actual value (kg)	Predicted value (kg)	P ^c	MPE ^d (kg)	RPE ^e (%)	r ^f	P ^g
<i>Same genetic line^a</i>							
H	13.18 \pm 1.17	12.90 \pm 1.01	NS	0.617	4.68	0.88	***
F	8.04 \pm 0.69	7.88 \pm 0.66	NS	0.517	6.43	0.77	***
L	3.08 \pm 0.38	3.05 \pm 0.29	NS	0.211	6.85	0.84	***
H+F+L	24.30 \pm 2.08	23.80 \pm 1.95	NS	1.091	4.49	0.87	***
<i>Different genetic line^b</i>							
H	13.47 \pm 1.32	13.19 \pm 1.18	NS	0.524	3.89	0.94	***
F	7.93 \pm 0.71	7.81 \pm 0.67	NS	0.461	5.81	0.79	***
L	3.29 \pm 0.49	3.01 \pm 0.30	*	0.458	13.92	0.61	***
H+F+L	24.69 \pm 2.28	24.11 \pm 2.17	NS	1.039	4.21	0.93	***

^a Values calculated with data from 17 pigs (9 barrows and 8 gilts). ^b Values calculated with data from 39 pigs (24 barrows and 15 gilts). ^c Statistical significance of actual vs predicted means; NS: not significant; * $P < 0.05$. ^d Mean prediction error. ^e Relative prediction error. ^f Correlation coefficient. ^g Statistical significance of r; *** $P < 0.001$.

lity among lines within breeds might be wider than variability among breeds as a consequence of genetic improvement works carried out in the last decades. However, in the current trial and based on the Student *t* test, no significant differences ($P > 0.05$) in carcass lean cut weights (actual values) according to genetic line of Duroc boar sire were observed, which would explain the results presented in Table 2.

The diverse multiple regression models that relate the H, F, L and H+F+L weights and yields with independent variables measured in the carcass are shown in Table 3. The addition of some independent variables measured in the carcass (backfat thickness, carcass length, ham length and ham perimeter) alongside CW, to the prediction equations of the dependent variables H, F, L and H+F+L weights improved the predictions

of the dependent variables because the R^2 and RSD values increased and decreased, respectively (Tables 3 and 1 being compared). Also, the addition of the named independent variables to the prediction equations of the dependent variables %H, %F, %L and % H+F+L improved the predictions of the dependent variables, especially of %H and % H+F+L (R^2 values of 0.62 and 0.44, respectively) (Tables 3 and 1 being compared). It is interesting to notice that the variables CW, backfat thickness, ham length and ham perimeter together explained 62% of the variability in %H which is higher than that obtained by Daza *et al.* (2006) with multiple regression equations in Iberian heavy pigs. Negative relations between H and L weights and %H and %L with backfat thickness were found (Table 3) which agrees with data from Daza *et al.* (2006) in Iberian pigs. It is

Table 3. Multiple regression equations between ham (H), foreleg (F), loin (L) and H+F+L weight (kg) and yield (% of carcass weight) and other carcass traits^a

DV ^b	H	F	L	H+F+L
<i>Joint weight</i>				
Intercept	-11.31***	3.18***	-1.69+	-11.84***
IV ^c				
CW	0.074***	0.075***	0.028***	
BF	-0.025*		-0.021**	0.154***
CL			0.024*	
HL	0.140***		-0.042**	0.164***
HP	0.153***	-0.042**	0.025**	0.173***
Model fit				
P model ^d	***	***	***	***
R^2 ^e	0.93	0.79	0.70	0.94
RSD ^f	0.398	0.426	0.250	0.685
C_p ^g	4.55	2.68	5.43	3.67
<i>Joint yield</i>				
Intercept	2.04	11.14***	2.60***	12.33***
IV				
CW	-0.054***			-0.080***
BF	-0.022*		-0.018**	
CL				
HL	0.132***		-0.026*	0.153***
HP	0.151***	-0.047***	0.235**	0.171***
Model fit				
P model	***	***	***	***
R^2	0.62	0.16	0.16	0.44
RSD	0.394	0.420	0.260	0.684
C_p	5.64	0.95	6.28	4.18

^a Values calculated with data from 98 pigs (50 barrows and 48 gilts). ^b DV: dependent variable. ^c IV: independent variable; CW: carcass weight (kg), BF: backfat thickness (mm), CL: carcass length (cm), HL: ham length (cm), HP: ham perimeter (cm) ^d Statistical significance; + $P < 0.10$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. ^e Coefficient of determination. ^f Residual standard deviation. ^g Mallows statistic.

Table 4. Predicted vs actual ham (H), foreleg (F), loin (L) and H+F+L weights and H yield (means \pm standard deviation) for pigs from the same and different genetic line

Lean cut	Actual value (kg)	Predicted value (kg)	P ^c	MPE ^d (kg)	RPE ^e (%)	r ^f	P ^g
<i>Same genetic line^a</i>							
H (kg)	13.18 \pm 1.17	12.87 \pm 0.99	NS	0.516	3.91	0.73	***
F (kg)	8.04 \pm 0.69	7.83 \pm 0.76	NS	0.569	7.07	0.72	***
L (kg)	3.08 \pm 0.38	3.04 \pm 0.29	NS	0.219	7.11	0.82	***
H+F+L (kg)	24.30 \pm 2.08	23.79 \pm 1.93	NS	0.840	3.46	0.93	***
H (% carcass)	12.79 \pm 0.61	12.45 \pm 0.65	NS	0.893	6.98	0.10	NS
<i>Different genetic line^b</i>							
H (kg)	13.47 \pm 1.32	12.99 \pm 1.37	NS	0.704	5.23	0.94	***
F (kg)	7.93 \pm 0.71	7.72 \pm 0.69	NS	0.500	6.30	0.79	***
L (kg)	3.29 \pm 0.49	2.96 \pm 0.39	*	0.478	14.53	0.68	***
H+F+L (kg)	24.69 \pm 2.28	23.89 \pm 2.18	NS	1.110	4.49	0.94	***
H (% carcass)	13.05 \pm 0.44	12.66 \pm 0.49	*	0.571	4.37	0.57	***

^a Values calculated with data from 17 pigs (9 barrows and 8 gilts). ^b Values calculated with data from 39 pigs (24 barrows and 15 gilts). ^c Statistical significance of actual vs predicted means; NS: not significant; * $P < 0.05$. ^d Mean prediction error. ^e Relative prediction error. ^f Correlation coefficient. ^g Statistical significance of r; NS: not significant; *** $P < 0.001$.

important to notice that Daza *et al.* (2006) used different techniques (weight and ultrasound measurements in live animals) from those used in the current trial to estimate lean cut weights in pig carcasses. As expected, positive relationships between H weight or yield and ham length and ham perimeter were observed, whereas the relationship between %H and CW was negative, in agreement with results obtained before with similar pigs (Latorre *et al.*, 2004, 2008).

The comparison between predicted and actual values of main lean cuts weights for pigs from the same genetic line and a different genetic line to the initial group of 98 pigs are shown in Table 4. As in Table 2, the regression equations calculated underestimated H, F, L and H+F+L weights and %H on average, but the MPE and RPE values were low, which suggests that the independent variables considered are good predictors of those dependent variables. According to the Student *t* test, the correlation coefficients between actual and predicted values were significant ($P < 0.001$), except for the variable %H and no significant ($P > 0.05$) differences between actual and predicted values were found except for L weight and H yield.

Conclusions

It is concluded that CW might be an easy and available measurement for pork industry to predict main

lean cuts weights in carcass, mainly H and H+F+L weights, in pigs from those genetic lines intended for PDO Teruel ham. The calculation of multiple regression equations by means of including carcass measurements of backfat thickness, carcass length, ham length and perimeter, improves the prediction of main lean cuts weights and of ham yield, although, evidently, this method is impractical for producers.

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References

- AOAC, 2000. Official methods of analysis, 17th ed. Association of Official Analytical Chemists International, Gaithersburg, MD, USA.
- BOLETÍN OFICIAL ARAGÓN, 1993. Orden de 29 de julio de 1993, del Departamento de Agricultura, Ganadería y Montes, por la que se aprueba el Reglamento de la Denominación de Origen «Jamón de Teruel» y su Consejo Regulador. BOA 93, 3168-3177. [In Spanish].
- BOLETÍN OFICIAL DEL ESTADO, 2005. Real Decreto Español 1201/2005 sobre la protección de los animales utilizados para experimentación y otros fines científicos. BOE 252, 34367-34391. [In Spanish].

- BRANSCHEID W., DOBROWOLSKI A., SACK E., 1990. Simplification of the EC-reference method for the full dissection of pig carcasses. *Fleischwirtsch* 70, 565-567.
- CILLA I., ALTARRIBA J., GUERRERO L., GISPERT M., MARTÍNEZ L., MORENO C., BELTRÁN J.A., GUARDIA M.D., DIESTRE A., ARNAU J., RONCALES P., 2006. Effect of different Duroc line sires on carcass composition, meat quality and dry-cured ham acceptability. *Meat Sci* 72, 252-260.
- CONSEJO REGULADOR DENOMINACIÓN ORIGEN JAMÓN DE TERUEL, 2009. CRDO Jamón de Teruel. Available in <http://www.jamondeteruel.com>. [July 9, 2009]. [In Spanish].
- DAZA A., MATEOS A., LÓPEZ CARRASCO C., REY A., OVEJERO I., LÓPEZ-BOTE C.J., 2006. Effect of feeding system on the growth and carcass characteristics of Iberian pigs, and the use of ultrasound to estimate yields of joints. *Meat Sci* 72, 1-8.
- DAZA A., OLIVARES A., CORDERO G., LÓPEZ-BOTE C.J., 2007. Prediction of weight of major cuts by means slaughter or carcass weight in Iberian pigs. *Span J Agric Res* 5, 318-321.
- FEDNA, 2003. Tablas FEDNA de composición y valor nutritivo de alimentos para la fabricación de piensos compuestos (De Blas C., Mateos G.G., Rebollar P.G., eds), 2nd ed. Fundación Española Desarrollo Nutrición Animal, Madrid, Spain. [In Spanish].
- LATORRE M.A., MEDEL P., FUENTETAJA A., LÁZARO R., MATEOS G.G., 2003a. Effect of gender, terminal sire line and age at slaughter on performance, carcass characteristics and meta quality of heavy pigs. *Anim Sci* 77, 33-45.
- LATORRE M.A., LÁZARO R., GRACIA M.I., NIETO M., MATEOS G.G., 2003b. Effect of sex and terminal sire genotype on performance, carcass characteristics, and meat quality of pigs slaughtered at 117 kg body weight. *Meat Sci* 65, 1369-1377.
- LATORRE M.A., LÁZARO R., VALENCIA D.G., MEDEL P., MATEOS G.G., 2004. The effect of gender and slaughter weight on the growth performance carcass traits, and meat quality characteristics of heavy pigs. *J Anim Sci* 82, 526-533.
- LATORRE M.A., GARCÍA-BELENQUER E., ARIÑO L., 2008. The effects of gender and slaughter weight on growth performance and carcass traits of pigs intended for dry-cured ham from Teruel (Spain). *J Anim Sci* 86, 1933-1942.
- MALLOWS C.L., 1973. Some comment on C_p . *Technometrics* 15, 661-676.
- MINISTERIO MEDIO AMBIENTE Y MEDIO RURAL Y MARINO, 2009. Anuario estadístico agrario. Available in <http://www.marm.es>. [July 15, 2009]. [In Spanish].
- NATIONAL RESEARCH COUNCIL, 1998. Nutrient requirements of swine, 10th ed. Ntl Acad Press, Washington, DC, USA.
- SAS INST., 1990. SAS user's guide: statistics. Version 6, 4th ed. Statistical Analysis Systems Institute, Inc, Cary, NC, USA.