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Effect of gender, housing density and the interaction on growth performance and carcass and meat quality of pigs slaughtered at 110 kg body weight

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Abstract

A total of 228 crossbred pigs were used to investigate the effect of gender (gilts and barrows), density at housing (0.84 and 0.76 m^2/pig) and the interaction on growth performance and carcass and merit from 19.4 to 110 kg body weight. Feed intake of gilts increased as the space allowance decreased but no effect was observed in barrows ($p < 0.05$ for the interaction). However, no interaction was observed for average daily gain or feed-to-gain ratio. Barrows had 2.4% less ($p < 0.01$) carcass lean percentage but 9% more ($p < 0.05$) intramuscular fat content than gilts. The concentration of linoleic acid in the outer layer of backfat was higher ($p < 0.05$) for gilts than for barrows when pigs were allocated at 0.84 m^2/pig, but no differences were observed at 0.76 m^2/pig. Also, barrows had 2.7% more ($p < 0.05$) total saturated fatty acids (SFA) in the outer layer of backfat and lower monounsaturated fatty acids (MUFA) ($p < 0.01$) and linoleic acid ($p < 0.05$) content in the inner layer than gilts. Housing density did not affect any of the carcass quality traits studied but an increase in space allowance decreased ($p < 0.05$) MUFA content in both layers. Pigs allocated at 0.84 m^2/pig tended ($p < 0.10$) to have higher SFA content in the inner layer than pigs allocated at 0.76 m^2/pig. We concluded that gilts and barrows respond differently to space allocation in respect to feed intake and unsaturation of backfat. Housing density did not affect growth performance of pigs slaughtered at 110 kg but MUFA content decreased with increases in space allowance.

Additional key words: barrows; fatty acid profile; gilts; pig performance.

Introduction

Group size and floor space allowance influence growth performance (Edmonds *et al.,* 1998; Hyun *et al.,* 1998), health status (Oh *et al.,* 2010) and animal welfare (Spoolder *et al.,* 2000) in pigs. The European Union legislation (DOUE, 2009) demands a minimum space that varies with the body weight (BW) of the pigs; 0.30, 0.40, 0.55, 0.65 and 1.00 m^2/pig from 20 to 30, 30 to 50, 50 to 85, 85 to 110 and over 110 kg BW, respectively. However, under practical conditions, pigs are allocated at the same density from the beginning to the end of the fattening period. In general, average daily feed intake (ADFI) decreases with crowding (Gonyou & Stricklin, 1998) and consequently, excessive pig density hinders growth performance (Kornegay *et al.,* 1993). However, pig meat produced per square meter increases with increasing rearing density and therefore, higher densities may result in improved profitability. In addition, a reduction in space allowance

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Abbreviations used: ADFI (average daily feed intake); ADG (average daily gain); BF (backfat); BW (body weight); C14:0 (miristic acid); C16:0 (palmitic acid); C18:1 (oleic acid); C18:2 (linoleic acid); C18:3 (linolenic acid); F:G (feed-to-gain ratio); GE (gender); HD (housing density); IMF (intramuscular fat); LT (*longissimus thoracis* muscle); MUFA (monounsaturated fatty acid); pH_{24} (pH at 24 h *postmortem*); PUFA (polyunsaturated fatty acid); *r* (Pearson correlation coefficient); SEM (standard error of the mean); SFA (saturated fatty acid).

results in increased incidence of abnormal behavior, including nosing, aggressions and tail biting (Anil *et al.,* 2007).

Housing density might affect growth performance (Brumm, 2004) and carcass quality (Hamilton *et al.,* 2003a) of gilts and barrows in different ways because voluntary ADFI is lower in gilts than in barrows and the hierarchy relationships could be different between sexes. Consequently, crowding might affect differently feed-to-gain ratio (F:G), carcass fat and other productive traits of gilts and barrows. Therefore, under commercial conditions, the utilization of different densities according to sex might optimize the use of facilities as well as improve carcass and meat quality of the pigs.

The fatty acid profile of backfat (BF) might influence fresh and cured meat quality traits. Patton *et al.* (2008) reported that a reduction in space allocation (0.70 *vs.* 1.13 m^2/pig) from 59 to 71 kg BW did not affect ADFI but resulted in a more saturated fatty acid profile of BF. The authors have not found any study comparing growth performance, carcass quality, meat composition and fatty acid profile of BF of gilts and barrows of high growth potential lines (average daily gain, ADG > 900 g d^{-1}) housed at different densities under commercial conditions. The objective of this research was to compare the response to space allocation of gilts and barrows from 20 to 110 kg BW.

Material and methods

Husbandry and diets

All the experimental procedures used in this study were approved by the Animal Ethics Committee of Universidad Politécnica de Madrid and were in compliance with the Spanish guidelines for the care and use of animals in research (BOE, 2007).

In total, 228 pigs, half gilts and half barrows, of 61 ± 2 days of age (19.4 ± 0.62 kg BW), resulting of the mating of Large White sires to Landrace × Large White dams (Topigs, Helvoirt, The Netherlands), were obtained from a commercial farm and used to study the influence of gender (gilts and barrows) and housing density (0.84 and 0.76 m^2/pig), which is a 10.5% increase in space allocation, on productive performance, carcass quality traits, meat composition and fatty acid profile of BF. Space allocation was achieved by varying the number of pigs per pen (9 *vs.* 10 pigs, respectively). In the event of individual pig removal, pigs per pen were not adjusted and therefore, housing density of this individual pen was reduced.

From birth to the beginning of the experiment, pigs were managed according to standard commercial procedures. Surgical castration of the males was carried out under prolonged analgesia by an experienced veterinarian (DOUE, 2009) at 4 ± 1 days of age (57 days before the beginning of the trial). On arrival to the experimental farm (beginning of the trial), pigs were individually tagged and allotted to 24 pens according to initial BW (same mean BW per pen) and gender and six pens were "assigned" at random to each treatment. The pigs were housed in a naturally ventilated finishing commercial barn in 2.3 m × 3.3 m pens with 80% slatted concrete floors. The height of the building was 2.6 m at the lateral wall sides and of 4.2 m at the center, resulting in a space volume allowance of 3.2 m^3/pig. Temperature and relative humidity was monitored daily and varied from 30 ± 3.0°C and 56 ± 3.0% (August, beginning of the experiment) to 8 ± 2.8 ºC and 76 ± 4.0% (November, end of the experiment), respectively.

The pens were provided with an individual wet/dry feeder (Lean Machine, Big Dutchman International GmbH, Vechta, Germany) in the solid part of the pen with a diameter of 30 cm and two nipple drinkers located on either side of the feed opening (10 cm). Feed in mash form and tap water were available for *ad libitum* consumption throughout the trial. Water flow of the drinkers was maintained at 1.7 L min^{-1}. The feeding program was common for all the pigs and consisted in a series of three diets (61 to 77 days, 77 to 125 days and 125 days to slaughter at 159 days of age) based on cereals and soybean meal that met or exceeded the nutrient requirements of pigs at these BW (FEDNA, 2006). The ingredient composition and the calculated (FEDNA, 2003) and determined (AOAC, 2000) nutrient content of the diets are shown in Table 1.

Growth performance

Individual BW and feed consumption per pen were recorded at 61, 77, 125, 146 and 159 days of age (0, 16, 64, 85 and 98 days on trial) and the data were used to calculate ADG, ADFI and F:G per replicate by period and cumulative. Pigs that died during the experiment were weighed and the data were included in the calculations of F:G. All pigs were slaughtered

Table 1. Ingredient composition and nutrient content of diets (%, as-fed basis, unless otherwise indicated)

Item	61 to 77	77 to 125	125 to 159
Ingredient			
Barley	17.34	24.96	6.91
Wheat	36.4	28.0	23.3
Bakery by-product	15.0	15.0	15.0
Field peas	5.0	5.0	—
Soybean meal, 47 g CP[1] kg^{-1}	20.0	14.95	10.5
Sunflower meal, 32 g CP kg^{-1}	—	3.0	4.5
Rapeseed meal, 37.9 g CP kg^{-1}	—	3.0	4.0
Animal fat	3.3	3.7	3.74
Calcium carbonate	0.55	0.91	0.88
Dicalcium phosphate	1.10	0.45	0.28
Sodium chloride	0.20	0.20	0.20
L-lysine, 50 g kg^{-1}	0.63	0.46	0.44
Methionine-OH, 88 g kg^{-1}	0.14	0.08	0.01
L-threonine, 98 g kg^{-1}	0.14	0.09	0.04
Vitamin and mineral premix[2]	0.20	0.20	0.20
Calculated composition[3]			
Net energy, kcal kg^{-1}	2,460	2,460	2,460
Digestible lysine	1.05	0.87	0.73
Digestible met + cys	0.63	0.54	0.44
Digestible threonine	0.63	0.53	0.42
Determined composition[4]			
Dry matter	90.0	89.9	89.8
Crude protein	18.4	16.5	14.8
Ash	5.9	5.6	5.0
Ether extract	5.5	5.6	5.6
Total phosphorus	0.56	0.45	0.41
Calcium	0.61	0.60	0.57

[1] Crude protein. [2] Provided the following (per kilogram of complete diet): 6,000 IU vitamin A (trans-retinyl acetate); 1,200 IU vitamin D_3 (cholecalciferol); 11 IU vitamin E (all-*rac*-tocopherol acetate); 0.5 mg vitamin K (bisulphate menadione complex); 0.2 mg thiamin (thiamine-mononitrate); 2.5 mg riboflavin; 0.2 mg pyridoxine (pyridoxine HCl); 15 µg vitamin B_{12} (cyanocobalamin); 8 mg d-pantothenic acid (d-Ca pantothenate); 15 mg niacin; 350 mg choline (choline chloride); 16 mg copper ($CuSO_4 \cdot 5H_2O$); 75 mg iron ($FeSO_4 \cdot 7H_2O$); 40 mg manganese ($MnSO_4 \cdot H_2O$); 110 mg zinc (ZnO); 0.1 mg cobalt ($CoSO_4 \cdot 7H_2O$); 0.3 mg selenium (Na_2SeO_3); 0.8 mg iodine (calcium iodate); and phytase (Natuphos 5,000, BASF Española, Barcelona, Spain), 500 phytase units. [3] According to FEDNA (2003). [4] In duplicate.

the same day with an average BW of 108.6 ± 2.67 kg BW for gilts and 110.8 ± 2.22 kg BW for barrows.

Carcass quality

The BF depth at P2 site (65 mm off the midline over the last rib) was measured in all pigs using a portable real-time ultrasound scanner (Model ACO37L, Vetko Plus, Noveko, Quebec, Canada) as described by Morales *et al.* (2011) at 125, 146 and 159 days of age (64, 85 and 98 days on trial) with the last measurement corresponding to the evening before slaughter. Images were frozen and recorded using the software provided by the ultrasound equipment.

The day of slaughter, pigs were weighed after a feed fasting period of 12 h and transported 300 km to the abattoir where they were allowed a 12 h rest period with full access to water but not to feed. Pigs were stunned in a 90% CO_2 atmosphere and then slaughtered, exsanguinated, scalded at 65 °C, skinned, eviscerated and split down the centre of the vertebral column according to standard commercial procedures. The hot carcass weight was individually recorded and used to calculate individual carcass yield. Carcass lean content was measured using the Autofom classification system (Carometec Spain, S.L., Barcelona, Spain) as described by Busk *et al.* (1999). The head was removed at the atlanto-occipital junction and the carcasses were suspended in the air and refrigerated at 2 °C (with an air speed in the chilling room of 1 m s^{-1} and 90% relative humidity) for 2 h. At 2 h *postmortem*, the subcutaneous BF depth between the third and fourth last ribs on the middle of the carcass was measured in the left side of each carcass using a flexible ruler with a precision of 0.5 mm. In addition, the pH of the *longissimus thoracis* (LT) muscle was measured in duplicate at 24 h *postmortem* (pH_{24}) using a pH meter (NWK-Thien, Model K21, Landsberg, Germany) equipped with a glass electrode. Before measurement, the instrument was calibrated with pH 7.00 ± 0.02 and 4.00 ± 0.02 buffers. Incisions were made through the skin and subcutaneous fat, and the pH probe was inserted into the selected points as described by Stalder *et al.* (1998).

Carcasses were fabricated according to the simplified European Community reference method (Branscheid *et al.,* 1990). Hams and loins were kept in the chilled room at 4 °C for 24 h and then the weights of the untrimmed hams and loins (right and left) were recorded (chilled weight). Then, hams were trimmed of external fat and weighed again (trimmed weight). The trimming consisted of eliminating part of the external fat and skin to fit commercial requirements and was performed by qualified personnel of the abattoir. Data on ham and loin weights were used to calculate chilled and trimmed ham yield and chilled loin yield, respectively. Because of the design of the processing line of the slaughter-

house and the method of carcass dissection, shoulder weights were not recorded.

Meat composition and fatty acid profile of BF

After carcass data collection, a 300 g sample of LT was excised at the last rib from four pigs randomly chosen from each pen and processed as indicated by Serrano *et al.* (2009a). The intramuscular fat (IMF), crude protein and moisture content of the LT were determined with a near-infrared reflectance meat analyzer (Foss 6500 Spectrophotometer, Foss Analytical, Barcelona, Spain) and measured between 400 and 2,200 nm using the fiber optic probe over an area of 0.50 cm^2. The samples were trimmed free of intermuscular fat and connective tissue and then minced and distributed into a cup ring equipped with a 140 mm diameter and 15 mm deep plate. The monochromator contained a 50-W tungsten lamp and a diffraction grating that created monochromatic light.

The BF samples, including the outer and the inner fat layers, the skin and the lean, were taken in the coxal region from two carcasses per pen chosen at random at the level of the last rib (10 cm from the coccyx). The fatty acid profile of these samples was determined as described by Peinado *et al.* (2008). Briefly, BF samples were vacuum packaged in individual plastic bags and frozen at –20 °C until subsequent analyses. Subcutaneous BF samples were separated into outer and inner layers which were independently analyzed for fatty acid composition. Lipids were extracted by the procedure proposed by Bligh & Dyer (1959). Fat extracts were methylated in the presence of sodium methilate (Christie, 1982) and analyzed by gas chromatography using a 6890 Hewlett Packard gas chromatograph and a 30 m × 0.32 mm × 0.25 μm cross-linked polyethylene glycol capillary column. A temperature program of 170 to 245 °C was used. The injector and detector were maintained at 250 °C. The carrier gas (nitrogen) flow rate was 3 mL min^{-1}. The percentages of saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) were calculated.

Statistical analysis

Data were analyzed as a completely randomized design with four treatments arranged factorially with two genders and two housing densities using the MIXED procedure of SAS (1990). The model included gender and housing density as main effects as well as the interaction between them. Each treatment was replicated six times and the experimental unit was the pen, with nine or ten pigs for growth performance data (depending on treatment), seven pigs for carcass quality traits, four pigs for meat composition and two pigs for fatty acid profile of BF. Data in tables are presented as means. An α value of < 0.05 was considered as a significant difference and α values between 0.05 and 0.10 were considered a tendency. Treatment means were separated using the Tukey test. In addition, the Pearson correlation coefficient (r) between cumulative ADFI and the C18:2 content of BF was calculated. The homogeneity of the variance of BW of the pigs at slaughter for each treatment was determined using a t-test.

Results

Growth performance

Mortality (0.88%) was low and not related to treatment (data not shown). In fact, only two pigs (one from each housing density treatment) died during the experiment. For the entire experimental period, an interaction between gender and housing density was observed for ADFI; a reduction in space allowance from 0.84 to 0.76 m^2/pig increased ($p < 0.05$) ADFI in gilts by 4% whereas no effect was observed in barrows (Table 2). However, no significant interaction between gender and housing density was detected for ADG or F:G.

From 61 to 77 days of age, barrows grew more and were more efficient than gilts ($p < 0.01$). Also from 77 to 125 days of age, barrows grew more and ate more feed than gilts ($p < 0.01$). However, barrows tended to be less efficient than gilts ($p < 0.10$). From 125 to 159 days of age, barrows had 10.3% higher ($p < 0.001$) ADFI but similar ADG than gilts. Consequently, F:G was 8.0% worse ($p < 0.01$) for barrows than for gilts. For the entire experimental period, barrows had higher ADFI (2.46 *vs.* 2.28 kg; $p < 0.001$) and ADG (0.940 *vs.* 0.904 kg; $p < 0.01$) and worse F:G (2.62 *vs.* 2.52; $p < 0.01$) than gilts. Therefore, BW at slaughter was higher ($p < 0.05$) for barrows than for gilts (110.8 *vs.* 108.6 kg BW). Uniformity of BW at slaughter was not affected by gender (data not shown).

In general, housing density did not affect any of the productive traits studied except ADFI from 61 to 77 days of age that was 50 g d^{-1} higher ($p < 0.01$) in pigs housed at the higher space allowance than in pigs housed

Table 2. Effects of gender (GE, gilts or barrows) and housing density (HD)[1] on average daily gain (ADG), average daily feed intake (ADFI) and feed-to-gain ratio (F:G) of pigs from 61 to 159 days of age

HD, m²/pig	Gilts		Barrows		SEM[2]	Probability[3]		
	0.84	0.76	0.84	0.76		GE	HD	GE*HD
Initial body weight, kg	20.0	20.0	18.8	18.9	0.070	***	NS	NS
Final body weight, kg	108.3	108.9	111.5	110.1	1.02	*	NS	NS
From 61 to 77 days of age (0 to 16 days on trial)								
ADG, kg	0.725	0.717	0.801	0.762	0.01755	**	NS	NS
ADFI, kg	1.24	1.22	1.29	1.21	0.0158	NS	**	NS
F:G[7]	1.72	1.69	1.62	1.59	0.0267	**	NS	NS
From 77 to 125 days of age (16 to 64 days on trial)								
ADG, kg	0.946	0.945	0.999	0.972	0.01299	**	NS	NS
ADFI, kg	2.14	2.20	2.37	2.29	0.0492	**	NS	NS
F:G	2.26	2.33	2.37	2.35	0.0342	†	NS	NS
From 125 to 159 days of age (64 to 98 days on trial)								
ADG, kg	0.921	0.945	0.941	0.954	0.01911	NS	NS	NS
ADFI, kg	2.82	3.00	3.21	3.20	0.0486	***	NS	†
F:G	3.08	3.17	3.41	3.35	0.0701	**	NS	NS
From 61 to 159 days of age (0 to 98 days on trial)								
ADG, kg	0.901	0.907	0.947	0.932	0.01049	**	NS	NS
ADFI, kg	2.23[c]	2.32[b]	2.49[a]	2.43[a]	0.0338	***	NS	0.04
F:G	2.48	2.55	2.63	2.61	0.0284	**	NS	NS

[1] 0.84 or 0.76 m²/pig (9 and 10 pigs per pen, respectively). [2] Six replicates of nine (0.84 m²/pen) or ten (0.76 m²/pen) pigs each. [3] NS: not significant; † $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. [a-c] Within a row, means without a common superscript differ ($p < 0.05$).

at the lower space allowance. Body weight uniformity at slaughter was not affected by housing density (109.9 ± 2.30 *vs.* 109.5 ± 3.04 kg BW for 0.84 and 0.76 m²/pig, respectively; data not shown).

Carcass quality, meat composition and fatty acid profile of BF

No interactions between gender and housing density were observed for any of the carcass quality traits studied (Table 3). Carcass yield was not affected by gender but carcass lean was 2.4% higher ($p < 0.01$) for gilts than for barrows. The BF depth measured *in vivo* at 125, 146 and 159 days of age was higher ($p < 0.05$) for barrows than for gilts but no differences between genders were observed for BF measured *postmortem*. Chilled and trimmed ham yields and loin weight and yield were higher ($p < 0.05$) for gilts than for barrows. Space allowance did not affect any of the carcass quality traits studied.

No interactions between gender and housing density were observed for any of the meat traits studied (Table 3). Meat from barrows had more IMF (3.7 *vs.* 3.4%; $p < 0.05$) and less protein (22.8 *vs.* 23.1%; $p < 0.05$) and tended to have lower moisture (72.6 *vs.* 72.8%; $p < 0.10$) content than meat from gilts. Space allowance did not affect meat composition.

Although differences between treatments were quantitatively small, the fatty acid profile of BF of gilts and barrows from lines with high growth potential responded differently to changes in housing densities, with some interactions between gender and housing density observed for the profile of the outer layer of BF (Table 4). The concentration of linoleic (C18:2) and linolenic (C18:3) acid in the outer layer of BF was higher ($p < 0.05$) for gilts than for barrows when pigs were allocated at 0.84 m²/pig. However, when pigs were allocated at 0.76 m²/pig, no differences were observed between genders. Independent of the space allowance, gilts had more ($p < 0.05$) C18:2 and C18:3 contents than barrows. However, barrows had more ($p < 0.05$) SFA content in the outer layer than gilts mostly because of the higher ($p < 0.05$) miristic (C14:0) and palmitic (C16:0) acid contents. In the inner layer, the more noticeable effect detected was

Table 3. Effects of gender (GE, gilts or barrows) and housing density (HD)[1] on carcass quality and meat composition (%) of pigs slaughtered at 110 kg body weight

HD, m²/pig	Gilts		Barrows		SEM[2]	Probability[3]		
	0.84	0.76	0.84	0.76		GE	HD	GE*HD
Backfat depth, mm								
At 125 days	13.7	14.2	15.4	14.9	0.48	*	NS	NS
At 146 days	15.6	15.4	16.6	16.6	0.43	*	NS	NS
At 159 days	16.4	16.4	18.0	17.4	0.53	*	NS	NS
Carcass weight, kg	89.1	91.9	92.4	91.5	1.26	NS	NS	NS
Carcass yield, %	78.2	79.1	77.9	78.9	0.61	NS	NS	NS
Carcass lean, %	51.8	52.8	51.2	50.9	0.41	**	NS	NS
Backfat, mm	25.2	25.4	26.3	25.7	0.45	NS	NS	NS
pH 24 h	5.75	5.63	5.68	5.77	0.0583	NS	NS	NS
Chilled ham[4]								
Weight, kg	13.3	13.7	13.4	13.3	0.17	NS	NS	NS
Yield, %	15.0	14.9	14.5	14.6	0.14	*	NS	NS
Trimmed ham								
Weight, kg	11.9	12.2	11.9	12.0	0.15	NS	NS	NS
Yield, %	13.4	13.3	12.9	13.0	0.13	**	NS	NS
Chilled loin[4]								
Weight, kg	5.38	5.38	5.15	5.27	0.0819	*	NS	NS
Yield, %	6.03	5.88	5.58	5.75	0.0906	**	NS	†
Meat composition, %								
Intramuscular fat	3.3	3.4	3.6	3.7	0.14	*	NS	NS
Protein	23.0	23.1	22.8	22.7	0.11	**	NS	NS
Moisture	72.9	72.6	72.5	72.6	0.12	†	NS	NS

[1] 0.84 or 0.76 m²/pig (9 and 10 pigs per pen, respectively). [2] Six replicates of seven and four samples per replicate for carcass quality and meat traits, respectively. [3] NS: not significant; † $p < 0.10$; * $p < 0.05$; ** $p < 0.01$. [4] For 24 h at 4 °C.

for oleic (C18:1; $p < 0.01$), C18:2 ($p < 0.05$) and MUFA ($p < 0.01$) contents that were higher for gilts than for barrows. Housing density had little quantitative effect on fatty acid profile of the outer layer of BF with the main difference observed for MUFA content that was lower ($p < 0.05$) for pigs hold at the higher space allowance due to the lower content in C18:1 ($p < 0.05$). Similarly, the C18:1 and MUFA content of the inner layer of BF were higher ($p < 0.01$) in pigs housed at 0.76 m²/pig than in pigs housed at 0.84 m²/pig.

Discussion

Growth performance

The authors have not found any research comparing productive performance of gilts and barrows at different space allowance to compare with the current results. A 10.5% increase in space allocation decreased ADFI in gilts by 4% but did not have any effect in barrows. Therefore, gilts and barrows from lines characterized for their high growth potential, responded to changes in housing densities similarly to pigs with lower growth potential. Feed intake depends on many factors which interact each other in a complex way. Thus, housing density above a certain level, may have negative effects on feed intake particularly if accessibility to feeders is limited which, in turn, is affected by pig voracity and time spent eating. In fact, some differences in growth performance between sexes might be related to variation in feeding patterns (de Haer & de Vries, 1993). Hyun & Ellis (2001) and Renaudeau *et al.* (2006) observed that barrows had a higher feeder occupation time per day and higher feed intake per visit than gilts. Also, Val-Laillet *et al.* (2010) suggested that a larger meal suppresses appetite for longer than a smaller

Table 4. Effects of gender (GE, gilts or barrows) and housing density (HD)[1] on fatty acid profile of the outer and inner layers of the backfat of pigs slaughtered at 110 kg body weight

HD, m²/pig	Gilts		Barrows		SEM[2]	Probability[3]		
	0.84	0.76	0.84	0.76		GE	HD	GE*HD
Outer layer								
C14:0	1.25	1.24	1.31	1.28	0.0225	*	NS	NS
C16:0	21.49	21.67	22.16	22.26	0.234	*	NS	NS
C16:1	2.35	2.51	2.44	2.40	0.0715	NS	NS	NS
C18:0	12.56	11.81	12.38	12.55	0.328	NS	NS	NS
C18:1	44.60	45.20	43.61	45.65	0.607	NS	*	NS
C18:2	10.14[a]	9.73[ab]	9.34[b]	9.63[ab]	0.158	*	NS	*
C18:3	0.65[a]	0.62[ab]	0.59[b]	0.61[ab]	0.0122	*	NS	*
C20:1	1.10	1.08	1.13	1.16	0.0489	NS	NS	NS
Others[4]	5.79	6.15	7.04	4.46	—	—	—	—
SFA[5]	36.08	35.56	36.66	36.94	0.428	*	NS	NS
MUFA[6]	48.46	49.26	47.61	49.67	0.658	NS	*	NS
PUFA[7]	15.33	15.14	15.68	13.34	0.867	NS	NS	NS
Inner layer								
C14:0	1.24	1.22	1.27	1.23	0.0276	NS	NS	NS
C16:0	22.67	22.49	23.07	22.71	0.296	NS	NS	NS
C16:1	2.11	2.30	2.16	2.15	0.0680	NS	NS	NS
C18:0	15.01	13.88	14.70	14.53	0.320	NS	†	NS
C18:1	43.50	44.29	41.91	43.42	0.365	**	**	NS
C18:2	9.90	10.01	9.25	9.47	0.229	*	NS	NS
C18:3	0.64	0.64	0.59	0.61	0.0158	*	NS	NS
C20:1	1.02	1.01	1.03	1.06	0.0322	NS	NS	NS
Others	3.94	4.16	6.29	4.83	—	—	—	—
SFA	39.76	38.49	39.93	39.41	0.443	NS	†	NS
MUFA	47.00	48.03	45.49	47.04	0.409	**	**	NS
PUFA	13.25	13.48	14.87	13.55	0.556	NS	NS	NS

[1] 0.84 or 0.76 m²/pig for pens (9 and 10 pigs per pen, respectively). [2] Six replicates of two carcasses each per treatment. [3] NS: not significant; †$p < 0.10$; *$p < 0.05$; **$p < 0.01$. [4] Σ(C10:0 + C12:0 + C15:0 + C15:1 + C17:0 + C17:1 + C18:4 + C20:0 + C20:3 + C20:4 + C20:5 + C22:5 + C22:6). [5] Saturated fatty acids: Σ(C10:0 + C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0). [6] Monounsaturated fatty acids: Σ(C15:1 + C16:1 + C17:1 + C18:1 + C20:1). [7] Polyunsaturated fatty acid: Σ(C18:2 + C18:3 + C18:4 + C20:3 + C20:4 + C20:5 + C22:5 + C22:6).

meal. In addition, Renaudeau *et al.* (2006) reported that gilts had a higher diurnal feed intake (as percentage of the total) than barrows. A possible explanation of the different response in feed intake between gilts and barrows observed in the current experiment might be that, under the particular productive conditions used, there was a competition for feeder space in gilts, but not in barrows. No interaction gender × housing density were observed for ADG or F:G and consequently, the practical interest of this observation is limited. Barrows had 3.9% higher ADG and 4.0% worse F:G than gilts, in agreement with most published research (Leach *et al.,* 1996; Latorre *et al.,* 2003a). The better growth rate and poorer feed efficiency of barrows as compared to gilts was consistent with their greater ADFI and higher carcass fat content.

During the entire experimental period, housing density did not affect growth performance. Although the housing densities used were quite different, the results of the current trial agree with the finding of Hyun *et al.* (1998) who did not observe any difference in the proportion of time spent by pigs in front of the feeders from 35 to 55 kg BW when housed at 0.25 or 0.56 m²/pig. Also, Gonyou & Stricklin (1998) reported no effect of space allowance on feed efficiency of pigs from 25 to 100 kg BW in agreement with the results of the current trial. In contrast, Brumm *et al.* (2001) reported that a decrease in space allowance of 39% (from 0.78 to 0.56 m²/pig) from 20 to 110 kg BW resulted in a 6.1% decrease in ADG. Moreover, White *et al.* (2008) observed that ADG and ADFI were reduced and F:G was hindered in pigs slaughtered at

108 kg BW when the space allocation was decreased from 0.93 to 0.66 m^2. Similarly, Moser *et al.* (1985) showed a reduction in ADFI in pigs from 55 to 100 kg BW when pen space was reduced from 0.74 to 0.56 m^2/pig. The reasons for the discrepancies among authors in respect to the effect of housing density on growth performance are not known but variables such as space densities compared (Gonyou & Stricklin, 1998), temperatures reached during the experiment (Kerr *et al.,* 2005; White *et al.,* 2008), number and type of feeders and drinkers (Hyun *et al.,* 1998), type of floor (English *et al.,* 1988), genetic background and age of the pigs (Hamilton *et al.,* 2003a,b) and energy concentration of the diets (Brumm & Miller, 1996) might affect the response of pigs. For example, Gonyou & Stricklin (1998) reported that ADFI and ADG were not affected with space allowances above 0.76 m^2/pig. Kerr *et al.* (2005) suggested that the decrease in ADFI with a reduction in space allocation was more pronounced at high temperatures. In this respect, White *et al.* (2008) reported that up to 50% of the negative effects of high temperatures on growth performance was compensated when pig density was reduced by 41% (0.66 *vs.* 0.93 m^2/pig). In this respect, Mikesell & Kephart (1999) reported that pigs appeared to become less competitive and spent less time eating as they aged. Unfortunately, most published reports do not include information on management practices and thus, no practical conclusions can be drawn. It could be speculated that the negative effects of high densities at housing will be higher for pigs with a high growth potential than for standard pigs. In the current trial, pigs had an average ADG of 922 g but final BW was not affected by space allowance, in agreement with results of Wolter *et al.* (2003) and Brumm (2004) with pigs growing less than 820 g d^{-1}. The small differences observed in the current trial between the two housing densities tested might have resulted because density differ only 10.5% in this research whereas in other researches the differences were higher (30-40%).

In the present experiment, BW uniformity was not affected by housing density, results that agree with data of Hamilton *et al.* (2003a) in pigs slaughtered at 120 kg BW reared on pens with floor space varying from 0.74 to 0.56 m^2. Similarly, Gonyou & Stricklin (1998) reported no differences in BW uniformity in pigs reared with a space allowance of 0.30, 0.38 and 0.47 m^2/pig from 25 to 46 kg BW and of 0.58, 0.76 and 0.94 m^2/pig from 46 kg BW to slaughter at 97 kg BW. The results of the current trial, together with the above information, indicate that probably pigs slaughtered at 110 kg BW do not need more than 0.76 m^2/pig to maximize growth performance.

Carcass quality, meat composition and fatty acid profile of BF

No interactions between gender and housing density were observed for any of the carcass quality traits studied, in agreement with data reported by Brumm (2004) comparing gilts and barrows kept at 0.58 or 0.74 m^2/pig (18 *vs.* 14 pigs/pen) from weaning to slaughter at 168 days of age. Therefore, gilts and barrows from lines with high growth performance did not respond differently to pigs from lines with lower growth performance to changes in housing densities. Gender did not influence carcass yield, consistent with data reported by Latorre *et al.* (2003b). However, Langlois & Minvielle (1989) observed higher yields for gilts than for barrows. The reasons for the discrepancies among authors are not known but might be related to differences in the method used for trimming the reproductive system at the abattoir (Latorre *et al.,* 2003b). Also, different final BW between sexes can interact with carcass yields, since both parameters are correlated. Barrows had higher BF depth, measured *in vivo* at 125, 146 and 159 days of age, than gilts, data that are consistent with results of Cisneros *et al.* (1996). The proportion of primal lean cuts was greater for gilts than for barrows, in agreement with data reported by Leach *et al.* (1996).

Space allowance did not affect any of the carcass traits studied, in agreement with data reported by O'Doherty & McKeon (2000) in intact males and Hamilton *et al.* (2003a) comparing gilts and barrows. However, Edmonds *et al.* (1998) reported also similar BF depth values when comparing housing densities of 0.37 *vs.* 0.50 m^2/pig from 55 to 91 kg BW and of 0.60 *vs.* 0.74 m^2/pig from 91 to 127 kg BW. All this information suggests that, under most circumstances, density at housing within certain limits will not have any effect on carcass traits.

No interactions between gender and housing density were observed for any of the meat traits studied. Therefore, gilts and barrows from lines with high growth performance did not respond differently to pigs from lines with lower growth performance to changes in housing densities. In the current experiment, LT muscle from barrows had more IMF than LT muscle from gilts, in agreement with data of Leach *et al.* (1996).

Cisneros *et al.* (1996) reported also higher marbling scores in barrows than in gilts. Housing density did not affect the IMF content of the meat in agreement with data of Patton *et al.* (2008) comparing densities of 0.70 and 1.13 m^2/pig from 59 to 71 kg BW. Also, the data indicate that density at housing does not have any effect on pork meat composition.

The concentration of C18:2 and C18:3 in the outer layer of BF were higher for gilts than for barrows when pigs were allocated at 0.84 m^2/pig. However, when pigs were allocated at 0.76 m^2/pig, no differences were observed between genders. An increase in these two fatty acids reduces the consistency of BF, hinders water migration and the rate of moisture loss during the curing process and increases lipid oxidation rate, leading to negative effects on the color and flavor of fresh and cured pork products (Ruiz-Carrascal *et al.,* 2000). Therefore, carcasses from barrows reared at low housing density may be better adapted for the production of dry-cured products than carcasses from gilts reared at higher housing densities. However, the differences were quantitatively small, and the differentiation in the management between sexes for this purpose may not be of interest under commercial conditions. In the current study, the average C18:2 content of BF was 9.9% for gilts and 9.4% for barrows, values that were significantly different but in both cases acceptable for the production of high-quality dry-cured primal cuts (Peinado *et al.,* 2011). The authors have not found any research that studied the effects of gender and housing density on fatty acid profile of BF to compare with the current results. However, these data support previous finding indicating different effect of housing density on feed intake in gilts and barrows. In fact, in the current trial a negative correlation ($r = -0.520$; $p < 0.01$) was observed between cumulative feed intake and the C18:2 content of BF as previously reported by Wood *et al.* (1989).

Barrows had higher SFA content in the outer layer and lower of MUFA in the inner layer of BF than gilts. These data are consistent with results of Smithard *et al.* (1980) who found that BF from barrows was more saturated than BF from gilts. In this respect, Serrano *et al.* (2009b) reported a positive correlation between BF depth and SFA content of BF. Housing density had little effect on fatty acid profile of the outer layer of BF with the main difference found for MUFA content that was lower for pigs hold at the higher space allowance. The difference in MUFA content observed in the inner layer of BF was due to the higher C18:1 content of pigs kept at the lower housing density. The information available on the influence of housing density on fatty acid profile of BF is scarce. Patton *et al.* (2008) reported that BF from pigs provided less space (0.70 m^2/pig) was more saturated and had higher percentages of PUFA than BF from pigs provided with more space (1.13 m^2/pig). However, in the research of Patton *et al.* (2008), pigs were slaughtered at 71 kg BW, whereas in the current trial average BW at slaughter was 110 kg.

We conclude that gilts and barrows respond slightly different to space allocation in respect to feed intake and unsaturation of backfat. Barrows had higher ADG but worse F:G than gilts. Also, barrows had less carcass lean but more IMF content than gilts. However, gilts had higher ham and loin yields than barrows. Under the conditions of the current experiment, housing density did not affect growth performance of pigs slaughtered at 110 kg but MUFA content decreased with increases in space allowance.

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