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The effect of a high monounsaturated fat diet on body weight, backfat and loin muscle growth in high and medium-lean pig genotypes

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Abstract

The objective of this study was to evaluate whether the use of a diet rich in oleic acid could have an effect on daily weight gain, backfat and loin muscle (*Longissimus thoracis*) depth. One hundred and ninety-two barrows and gilts, from two genotypes were fed a grain and soy diet (CONTROL with 28% C18:1) or a similar diet enriched with oleic acid (HO with 43% C18:1, Greedy-Grass OLIVA®). The pigs were housed in 16 pens in groups of 12 according to their sex, diet and genotype. From 75 days of age every three weeks, the pigs were weighed and the backfat and loin muscle depth were ultrasonically recorded (PIGLOG®). The inclusion of the dietary fat had no significant effect on the growth variables nor on the backfat and loin muscle depth measurements taken. However, the barrows resulted in higher live weight and backfat compared to the gilts at the end of the trial. Conversely, the gilts showed higher loin depth. Moreover, York-sired pigs were heavier than Pietrain-sired pigs during the whole trial and showed higher backfat at the last two measurements. Pietrain-sired pigs had higher loin muscle depth at the last measurements. The results of the present study suggest that the addition of a dietary fat into diets aiming at modifying the meat fatty acid profile has no detrimental effects on performance variables, or on backfat and loin muscle growth and thus, no negative economic impact for producers.

Additional key words: backfat depth; loin muscle depth; monounsaturated fatty acids; sex.

Resumen

Efecto de una dieta rica en ácidos grasos monoinsaturados sobre el peso vivo, el espesor de grasa dorsal y la profundidad de lomo en cerdos de alto y medio crecimiento magro

El objetivo de este estudio consistió en evaluar si administrar una dieta rica en ácido oleico en cerdos de engorde ejercía algún efecto sobre la ganancia de peso, el espesor de grasa dorsal y la profundidad del músculo *Longissimus thoracis*. Ciento noventa y dos machos castrados y hembras de los genotipos (Landrace*Large White)*Pietrain y (Landrace*Large White)*York recibieron una dieta de cereales y soja (CONTROL con 28% C18:1) o una dieta similar rica en ácido oleico (HO con 43% C18:1, Greedy-Grass OLIVA®). Los cerdos se alojaron en 16 corrales en grupos de 12, según su dieta, sexo y genotipo. A partir de los 75 días de vida, y a continuación cada tres semanas, los animales se pesaron y se midió mediante ultrasonidos (PIGLOG®) el espesor de grasa dorsal y la profundidad de lomo. No se detectaron diferencias en la ganancia media diaria ni en el espesor de grasa dorsal y lomo entre los cerdos alimentados con dieta HO y dieta CONTROL. En cambio, los machos castrados presentaron un mayor peso vivo y un mayor espesor de grasa dorsal que las hembras. Estas, en cambio presentaron una mayor profundidad de lomo. Los cerdos cruzados con York fueron más pesados durante toda la prueba y presentaron un mayor espesor de grasa dorsal que los cruzados con Pietrain. Los animales del genotipo Pietrain presentaron una mayor profundidad de lomo durante las dos últimas mediciones. Los resultados de este estudio muestran que el uso de grasas altas en ácido oleico para modificar el perfil de ácidos grasos de la carne no perjudica los resultados productivos de los animales que toman dichas dietas.

Palabras clave adicionales: ácidos grasos monoinsaturados; grasa dorsal; profundidad de lomo; sexo.

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Introduction

The presence of fat in pork meat and other pork products often has negative connotations for the consumer, because fat is associated with a high energy content and pathologic problems such as obesity, cardio-vascular disease and cancer (Lopez-Bote *et al.*, 2005). The American Heart Association (Neville, 1990) recommends a balanced diet, with low lipid, low cholesterol and saturated fatty acid levels, and higher levels of unsaturated fatty acids.

The interest in the fatty acid profile of pork meat and in ways of manipulating it in order to make it healthier for the consumer, has increased in the last years. As a consequence, much research into pork fat modification has been done using diets containing different fat sources, including diets with high monounsaturated fats. Monounsaturated fatty acids (MUFA), particularly oleic acid have received favourable promotion with regards to human health, as they decrease the risk of cardiovascular diseases and high blood pressure and are associated with the immune system (Ruiz-Gutierrez *et al.*, 1996). Moreover, MUFA are of special interest for pork processors, as they present a lower risk compared to polyunsaturated fatty acids (PUFA) of generating lipid oxidation, a process with adverse effects on the quality of the meat (Wood *et al.*, 2003). During the last decades, different sources of vegetable oil with high oleic acid content have also been used (St. John *et al.*, 1987; Rhee *et al.*, 1988; Miller *et al.*, 1990; Myer *et al.*, 1992). Olive oil, wich is easily available in Spain, is high in oleic acid and could be used as a valuable way to increase the level of monounsaturated and total unsaturated acids of the diet and of the carcass fat, as is commonly performed in Iberian pigs (Gonzalez *et al.*, 2005). However, previous research has found that formulating diets with added fats high in MUFA may modify variables such as average daily gain (Castell, 1977) or feed efficiency (Busboom *et al.*, 1991; Myer *et al.*, 1992). These are key factors to be taken into account when evaluating the effect of diets on productive results, as they are closely related to the economic benefit of pig producers.

As different pork markets require different product specifications, the two genotypes used in the study presented different market orientation. Pietrain-sired pigs, with high lean growth, are optimal for fresh meat production. However, York-sired pigs, are adequate for the dry cured product industry as they guarantee an adequate fat cover in the cuts that are cured. As a consequence of this, it is important to evaluate the growth for backfat (BF) and loin muscle (LT) in each genotype in order to ensure that dietary treatment does not modify their growth characteristics. Ultrasonic technologies have been used since 1950, among other systems, for evaluating BF and LT depth in live animals (Wild, 1950; Hazel & Kline, 1959) and are still nowadays used by many pig producers to measure these traits.

The objective of this study was to evaluate the effect of a diet enriched with MUFA on growth, level of BF, and LT depth of barrows and gilts from two genotypes. This study is part of a broader investigation in which the effect of diets rich in oleic acid on carcass and meat quality (mainly on fat acid profile) has also been evaluated. These results are available from Mas *et al.* (2010, 2011) for Pietrain and York-sired pigs, respectively.

Material and methods

Animals and diets

Experimental procedures were approved by the ethical committee at IRTA (Institute for Food and Agricultural Research and Technology). One hundred and ninety-two pigs of two sexes and from two genotypes (York-sired barrows, n = 48; Pietrain-sired barrows, n= 48; and York-sired gilts, n = 48, and Pietrain-sired gilts, n = 48) provided by UPB España S.A. were initially included in the study. Genotypes were crosses of Landrace *Large White sows with Pietrain (negative for the halothane gene, NN) or with the commercial line York (highly muscled Large White) boars (both provided by UPB España SA). All piglets were born within 1 week and only up to 4 piglets per litter were chosen. At an average age of 61 days, the pigs were housed in a grower-finisher unit with a fully slatted floor, and were given *ad libitum* access to feed and water. The farm has natural ventilation and a heater was provided to maintain the room at an average tem-

Abbreviations used: BF (backfat); HO (high oleic); LT (*Longissimus thoracis*); MUFA (monounsaturated fatty acids); PUFA (polyunsaturated fatty acids).

perature of 18-20ºC. Animals were allocated to pens according to their sex, genetics and dietary treatment, so that there were initially two pens of 12 pigs for each combination of sex, crosbred and diet (*i.e.* initially 48 pigs of each sex were assigned to each dietary treatment). The study was initiated in December and terminated in April. All animals were slaughtered at the end of the study, at an average slaughter weight of 108.9 ± 6.4 kg and an average age of 200 days for the crosses with Pietrain and 119.6 ± 5.7 kg and an average age of 204 days for the crosses with York. A total of 17 animals were removed from the study during the growing-finishing period due to disease or death but the removals were not related to treatment.

Animals were fed one of two growing diets from 30 to 60 kg live weight: (1) grain and soy diet (CONTROL), and (2) grain and soy plus high oleic acid supplement (HO). The high oleic supplement was included at the level of 14 g kg^{-1} (1.4%) from 30 to 60 kg animal live weight. From 60 kg to slaughter the level of high oleic supplement for the HO-diet group was increased to 38 g kg^{-1} (3.8%). The high oleic supplement (Greedy-grass OLIVA®) is a by-product of the olive industry composed of a mixture of calcium-salts rich in oleic acid and contains 83% crude fat, 12% ash, 7% calcium in ashes, 5% moisture, and provides 6,110 kcal kg^{-1} net energy. Greedy-grass OLIVA® was provided by Grupo Omega de Nutrición Animal (Arganda del Rey, Madrid, Spain). Determined ration composition of the growing (from 30 to 60 kg live weight) and finishing (from 60 kg live weight until slaughter) diets and dietary fatty acid composition of the finishing diets are shown in Table 1 and Table 2, respectively. Dietary treatments were formulated to contain similar nutrient and energy percentages, and to meet the nutritional requirements of the growing-finishing diets at these

Table 1. Ingredients and determined composition of growing (30-60 kg live weight) and finishing (60 kg live weight-slaughter) experimental diets[1]

	Growing diet (30-60 kg)		**Finishing diet (60 kg-slaughter)**	
	CONTROL	**HO**	**CONTROL**	**HO**
Ingredients, g kg^{-1}				
Corn	250	85	250	50
Barley	237	393	268	471
Wheat	200	200	200	200
Soy	252	247	222	202
Fat	30	30	29	14
Lysine	3	3	3	3
Threonine	1	1	1	1
Vitamin and mineral premix[2]	4	4	4	4
Sodium bicarbonate	1	1	2	–
Bicalcium phosphate	13	12	11	11
Calcium carbonate	6	7	6	1
Salt	3	3	4	5
Greedy-grass OLIVA®	–	14	–	38
Composition				
Crude protein (%DM)[3]	18	18	16.7	16.5
Crude fat (%DM)	4.6	4.9	4.6	4.9
Crude fibre (%DM)	12.9	13.8	13.1	14.2
Ashes (%DM)	5.1	5.2	4.9	4.9
Lysine (%DM)	1.1	1.1	1.0	1.0
Phosphorus (%DM)	0.6	0.6	0.6	0.6
Calcium (%DM)	0.70	0.70	0.70	0.70
NE[4], MJ kg^{-1}	10.21	10.25	10.24	10.31
ME[5], MJ kg^{-1}	13.81	13.81	13.81	13.81

[1] CONTROL: grain and soy; HO: grain and soy plus high oleic supplement (Greedy-grass OLIVA®: 1.4% growing and 3.8% finishing diet). [2] 40 mg Mn, 1 mg I, 0.25 mg Co, 100 mg Zn, 10 mg Cu, 145 mg Fe, 0.15 mg Se, 10,000 IU vitamin A, 1,000 IU vitamin D_3, 15 mg vitamin E, 1 mg vitamin K_3, 1 mg vitamin B_1, 2 mg vitamin B_2, 1 mg vitamin B_6 , 0.02 mg vitamin B_{12}, 15 mg niacin, and 8 mg d-pantothenate were provided per kilogram of feed. [3] DM: dry matter. [4] NE: net energy. [5] ME: metabolic energy.

Table 2. Determined fatty acid composition of the finishing diet (from 60 kg live weight to slaughter)[1]

Fatty acid[2], %	Diet	
	CONTROL	HO
14:0, *myristic*	0.55	0.28
16:0, *palmitic*	18.08	15.86
16:1, *palmitoleic*	1.03	0.71
18:0, *stearic*	7.77	5.61
18:1, *n-9 oleic*	27.92	42.82
18:2, *n-6 linoleic*	37.99	28.59
18:3, *n-3 linolenic*	3.38	2.97
20:4, *n-6 arachidonic*	0.07	ND[3]
20:5, *n-3 EPA*[4]	0.18	0.06
SFA[5]	27.59	23.18
MUFA[6]	30.14	44.84
PUFA[7]	42.27	31.98

[1] CONTROL: grain and soy; HO: grain and soy plus high oleic supplement (Greedy-grass OLIVA®: 1.4% growing and 3.8% finishing diet). [2]Major selected fatty acids. [3]ND: under detection limit. [4] EPA: eicosapentaenoic acid. [5]SFA: saturated fatty acids (C4:0, C6:0, C8:0, C10:0, C12:0, C13:0, C14:0, C16:0, C18:0, C20:0, C22:0 and C23:0). [6]MUFA: monounsaturated fatty acids (C16:1, C17:1, C18:1, C20:1, C22:1 and C24:1). [7]PUFA: polyunsaturated fatty acids (C18:2, C18:3, C20:2, C20:3, C20:4 and C20:5).

ages as recommended by FEDNA (2006). The HO diet was formulated to achieve a higher percentage of oleic acid MUFA than the CONTROL diet (44.84 *vs.* 30.14%, respectively). Conversely, the CONTROL diet contained a greater percentage of saturated fatty acids (C14:0, C16:0, and C18:0) and PUFA (C18:2, C18:3, 20:4, and 20:5) compared with the HO diet. The barrow pens were fed using a feeding trolley fitted with an electronic scale to control feed consumption from the day weight control started (Multi Feeding trolley, VlieboTM, The Netherlands). Mean individual feed consumption was calculated in barrows and calculated by dividing the total amount of food distributed by the number of pigs in each pen. Feed conversion rate was calculated by dividing the total food consumption by the weight gain during the period evaluated.

Feed lipids were extracted following the chloroform-methanol procedure of Folch *et al.* (1957), converted afterwards to fatty acid methyl esters using BF_3 and methanolic KOH following the method of ISO 5509-1978 (E), and analyzed using GC (5890 Series II GC, Hewlett Packard, Barcelona, Spain). All samples were methylated in duplicate, and 1 μL was introduced by split injection into a fused silica capillary column (30 m × ID 0.25 mm, BPX 70; 0.25-m film thickness, Texas, USA). Helium was the carrier gas at 30 cm sec^{-1}. The column temperature, initially at 150°C for 1 min, was increased by 4°C min^{-1} to 200°C, and then held at 200°C for 10 min. Individual fatty acid methyl esters were identified by retention time with reference to fatty acid methyl esters standards (FA methyl ester mixture #189-19 L-9495; Sigma Chemical Co., St. Louis, MO, USA).

Body weight and ultrasound measurements

The animals were given a 2-week period to adapt to the farm. The first measurement was only a body weight control that was taken when the animals were 75 days old (Live weight 1, LW1).

At 110 days measurements of body weight (LW2), BF level and LT depth were taken (Backfat 1, BF1; Loin muscle 1, LT1). Subsequently, measurements of weight and of BF and LT depth were taken at 3- or 4-week intervals. Thus, measurement 3 was carried out at 133 days, measurement 4 at 160 days and the final one at 188 days of age. The ultrasound measurements of BF and LT depth were performed with a PIGLOG 105® (A-mode scanner, SFK Technology A/S, Helver, Denmark), at the last rib level and 6.5 cm off the midline. All *in vivo* measurements were taken by the same trained technician. Weight was recorded by electronic scales (Fancom F-Star 125, Digi-starTM, The Netherlands). The average daily gain was calculated from the difference between the initial weight on the starting day and the final weight at the last control then divided by the number of days between the first and last controls.

Statistical analysis

Data from weight, BF and LT depth measurements were analysed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC), to test differences between sexes, treatment diets, or genotypes. For variable body weight, the fixed effects included in the initial model were diet, sex, genotype, measurement number (time effect), and their interactions. As the interactions between diet and genotype and diet and sex showed no effects, they were removed from the model. When analysing the results of the BF and LT depth, the same fixed effects were considered, and live weight measures were included as a covariate. Pen was considered the experimental unit. The covariance structure used was CS (compound symmetry), according to the Schwarz Bayesian Criterion.

The average daily gain of the whole control period was analyzed by analysis of variance using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) as a 2 × 2 × 2 factorial design with sex (barrows and gilts), diet (CONTROL, HO) and genotype (Pietrain and York) and the interactions between them in the model. The initial weight was included as a covariate. As the interactions showed no effect, they were removed from the model.

Results

No significant interaction between diet, sex and genotype were detected for any of the traits studied and therefore only the main effects are presented.

Body weight performance

The evolution of live weight from 76 to 188 days of age showed no differences due to MUFA supplementation throughout the trial (Table 3). No differences were found between dietary treatments for the average daily gain during that period. Results for daily food intake were similar in both dietary treatments (2.472 and 2.505 kg for HO and CONTROL diet respectively, in York-sired pigs; 2.440 and 2.382 kg for HO and CONTROL diet respectively, in Pietrain-sired pigs). Feed conversion ratio was also similar between dietary treatments (2.81 and 2.86 for HO and CONTROL diet respectively, in York-sired pigs; 2.60 and 2.53 for HO and CONTROL diet respectively, in Pietrain-sired pigs).

Regarding sex differences in weight performance, barrows were heavier ($p < 0.05$) than gilts at 160 and 188 days of age. Barrows also resulted in higher values than gilts for the average daily gain ($p < 0.05$). When genotypes were compared, from the first measurement to the measurement at end of the trial, York-sired pigs were heavier ($p < 0.05$) than Pietrain-sired pigs and showed higher ($p < 0.05$) average daily gain than Pietrain-sired pigs.

Loin muscle depth

No effect of the diet was observed in any of the measurements and both HO and CONTROL groups had a similar LT depth at the end of the trial (Table 4).

In relation to sex effects, gilts resulted in higher ($p < 0.05$) values for LT depth than barrows at 133 and 160 days of age. When genotypes were compared, Pietrain-sired pigs presented higher ($p < 0.05$) values for LT depth than York-sired pigs from the beginning to the end of the trial.

Backfat depth

Results showed that dietary treatments did not alter any of the BF measurements carried out during the growing period and both HO and CONTROL groups had a very similar BF level at the end of the trial

Table 3. Least-squares means and standard errors for live weight (LW, kg) and average daily gain (ADG, g d^{-1}) in Pietrain and York-sired barrows and gilts fed the two experimental diets[1] (n = 2 per diet, sex and genotype)

	Diet		Sex		Genotype		SE diet	SE sex	SE genotype	CPER[2]/ RMSE[3]
	HO	CONTROL	Barrows	Gilts	Pietrain	York				
LW1[4]	25.96	26.14	26.27	25.83	24.44^b	27.67^a	1.159	1.160	0.891	5.232[2]
LW2[4]	47.45	48.33	49.72	46.08	44.06^b	51.73^a	1.732	1.735	1.422	5.232[2]
LW3[4]	66.53	66.37	68.59	64.33	63.63^b	70.29^a	1.958	1.961	1.563	5.232[2]
LW4[4]	91.35	91.20	94.65^a	87.65^b	88.19^b	94.35^a	2.410	2.411	1.862	5.232[2]
LW5[4]	105.97	105.23	108.10^c	103.73^d	100.07^b	111.73^a	1.024	1.023	0.792	5.232[2]
ADG[5]	0.723	0.715	0.737^a	0.701^b	0.682^b	0.756^a	0.100	0.100	0.100	0.0189[5]

[1] See Table 1. [2] CPER: covariance parameter estimate of the residual (common for all model). [3] RMSE: root mean square error. [4] Live weight measurements carried out at 76 (LW1), 110 (LW2), 133 (LW3), 160 (LW4) and 188 (LW5) days of age. [5] ADG: average daily gain calculated between 76 and 188 days of age. [a, b] Within a row and for each fix factor, means lacking common superscript letter differ at $p < 0.05$ or [c,d] at $p < 0.1$.

Table 4. Least-squares means and standard errors for *Longissimus thoracis* depth (LT, mm) in Pietrain and York-sired barrows and gilts fed the two experimental diets[1] (n = 2 per diet, sex and genotype)

	Diet		Sex		Genotype		SE diet	SE sex	SE genotype	CPER[2]
	HO	CONTROL	Barrow	Gilts	Pietrain	York				
LT1[3]	38.28	37.65	37.52	38.41	39.24[a]	36.70[b]	0.622	0.658	0.732	2.291
LT2[3]	43.69	43.84	43.37	44.16	45.95[a]	41.58[b]	0.374	0.379	0.300	2.291
LT3[3]	49.17	50.02	48.64[b]	50.54[a]	52.26[a]	46.93[b]	0.679	0.754	0.692	2.291
LT4[3]	52.84	54.05	52.59[b]	54.24[a]	54.62[a]	52.24[b]	0.681	0.822	1.144	2.291

[1] See Table 1. [2] CPER: covariance parameter estimate of the residual (common for all model). [3] *Longissimus thoracis* depth measurements carried out at 110 (LT1), 133 (LT2), 160 (LT3) and 188 (LT4) days of age. [a, b] Within a row, means lacking common superscript letter differ at $p < 0.05$.

(Table 5). However, sex was a source of variation for BF and significant differences appeared, with barrows showing higher ($p < 0.05$) BF measurements compared to gilts in all the controls carried out.

When genotypes were compared, York-sired pigs presented higher ($p < 0.05$) values for BF depth measurements taken at 160 and 188 days of age.

Discussion

Body weight

The use of a high oleic source in the diets of Pietrain and York-sired pigs did not modify any of the growth variables evaluated. Feed intake and food conversion rate in both Pietrain and York-sired barrows was found to be similar in the MUFA supplemented group and the control group. Therefore, increasing the MUFA content of swine diets, with the aim of modifying the fatty acid profile of pork meat without adversely affecting productive results and consequently the economic benefits of producers, seems to be a possibility. The results of the present experiment agree with previous studies where dietary MUFA supplementation were shown to have no impact on the growth rate in swine. Martin *et al.* (2008) reported no effect of MUFA supplementation at two levels (17% and 37%; from 70 kg to 107 kg live weight) on average daily gain or daily consumption in Landrace* Large White gilts. Castell & Falk (1980) and Busboom *et al.* (1991) reported no differences in daily gain between control pigs and those fed a diet containing 20% canola high in MUFA. Lauridsen *et al.* (1999) reported no influence of dietary treatments on growth performance when evaluating the effects of supplementing pigs with both vitamin E and rapeseed oil high in MUFA from 25 to 100 kg live weight. However, Castell (1977) reported a decrease in daily gain in pigs fed diets with rapeseed high in MUFA and related this to a lower feed intake, probably due to the rapeseed inclusion itself or the size of the grain in the diet. Supplementing swine diets with 5 and 10% can-

Table 5. Least-squares means and standard errors for backfat (BF, mm) in Pietrain and York-sired barrows and gilts fed the two experimental diets[1] (n = 2 per diet, sex and genotype)

	Diet		Sex		Genotype		SE diet	SE sex	SE genotype	CPER[2]
	HO	CONTROL	Barrows	Gilts	Pietrain	York				
BF1[3]	5.98	5.95	6.45[a]	5.48[b]	5.94	5.99	0.201	0.202	0.232	0.453
BF2[3]	7.78	7.89	8.63[a]	7.04[b]	7.57	8.11	0.202	0.205	0.254	0.453
BF3[3]	11.01	11.28	12.05[a]	10.24[b]	10.54[b]	11.75[a]	0.259	0.291	0.284	0.453
BF4[3]	12.32	12.26	13.50[a]	11.08[b]	11.61[b]	12.97[a]	0.102	0.180	0.359	0.453

[1] See Table 1. [2] CPER: covariance parameter estimate of the residual (common for all model). [3] Backfat measurements carried out at 110 (BF1), 133 (BF2), 160 (BF3) and 188 (BF4) days of age. [a, b] Within a row, means lacking common superscript letter differ at $p < 0.05$.

ola high in MUFA has been shown to increase weight gain from 57 to 102 kg live weight compared to non–supplemented animals (Myer *et al.*, 1992). This could be due to differences in the energy concentration of the supplemented diets compared to the control diet used in that trial.

Other studies which have evaluated the effect of the inclusion of different fats other than MUFA in swine diets on growth variables have concluded that growth performance variables, such as feed efficiency, are affected by the energy concentration of the diet, whereas fat sources have no effect (Bee *et al.*, 2002; Corino *et al.*, 2008; Apple *et al.*, 2009). The present diets were formulated to have a similar energy concentration, and therefore this may explain the lack of differences in growth performance. Moreover, no differences were seen in feed intake, although results may be interpreted with caution and should be confirmed measuring individual feed intake when possible.

The expected and well-known differences between sexes for weight gain were confirmed, with barrows showing an advantage over gilts at the last two measurements of the trial. The results found are in agreement with previous investigations which have clearly described the performance differences between barrows and gilts, and have reported better growth in barrows due to their greater feed intake and their higher fat deposition compared to gilts (Blasco *et al.*, 1994; Cisneros *et al.*, 1996; Latorre *et al.*, 2003).

The results of the current study also confirmed differences between genotypes in growth rates, with a higher weight from the beginning to the end and a higher average daily gain in York-sired crosses compared to Pietrain-sired pigs. Our results are in line with Hamilton *et al.* (2003) who indicated that genotypes with leaner carcasses, such as Pietrain crosses, present slower growth rates and a lower food intake than medium-lean genotypes. Kanis & Koops (1990) evaluated growth differences between high lean and medium lean genotypes and reported a higher daily gain in fatter genotypes.

Loin muscle depth

Supplementation of MUFA resulted in no differences in LT depth in any *in vivo* measurement taken between animals fed HO and CONTROL diets. This is important in Pietrain-sired pigs, as they are raised for their high lean growth potential. Previous researches on the effect of the inclusion of MUFA in pig diets have not studied the changes in LT depth in live animals. However, evaluation of the LT area carried out in carcasses after slaughter has, in the past, failed to show differences between pigs fed elevated MUFA fat diets and those fed with conventional diets. St. John *et al.* (1987), Miller *et al.* (1990) and Busboom *et al.* (1991) reported no differences in the LT area between control animals and those fed elevated levels of MUFA. This was also confirmed in the second part of the present study in which the LT area and carcass characteristics including lean percentage were evaluated and no differences were found (Mas *et al.*, 2010; 2011). However, other researchers have indicated a reduction of leanness in pigs fed diets containing added fats compared to pigs fed control diets (Pettigrew & Moser, 1991; De la Llata *et al.*, 2001) and related it to the increased energy of the fat supplemented diets, or lack of balance between energy and protein, which can increase fat deposition or affect protein accretion. Bee *et al.* (2002) also indicated that the energy content of swine finishing diets impacts lean pork yields, but that the dietary fat source is of no consequence. In the present study, all the diets were balanced and presented similar energy and protein contents; which may explain why the addition of MUFA into the diet resulted in no differences in LT depth in any genotype.

When sexes were compared, gilts showed higher LT depth than barrows. This is in accordance with previous studies which found higher muscle development in gilts compared to boars (Blasco *et al.*, 1994; Hamilton *et al.*, 2003), as castration reduces the ceiling for protein deposition in barrows (Campbell & Taverner, 1988).

Regarding to differences between genotypes, Pietrain-sired pigs presented higher values at all the measurements taken. Hamilton *et al.* (2003) also reported a higher lean growth in animals such as Pietrain crosses which are selected for this trait. A high potential for lean tissue gain is regarded as a common trait in Pietrain pigs, which produce the most valued carcasses for fresh meat production in Spain (García-Macias *et al.*, 1996).

Backfat

Supplementation with a diet high in MUFA had no effect on BF thickness, no differences being found in any measurement between HO and CONTROL diet fed animals. This is especially important in the York-sired genotype, from which a certain amount of fat in hams and shoulders is required for the dry curing process. No other reports measuring BF in live animals have been found, but other researchers have evaluated the effect of dietary fat on BF depth of carcasses. Similar to the present study, St. John *et al.* (1987) and Myer *et al.* (1992) noted no effect on carcass BF thickness upon feeding high MUFA diets. Others have reported that formulating finishing diets with different fat sources, such as beef tallow (Eggert *et al*., 2007), soy bean oil (Morel *et al*., 2006), or poultry fat (Engel *et al*., 2001) had no effect on average or individual carcass fatness. These results disagree with the review of Petigrew & Moser (1991) and De la Llata *et al*. (2001), indicating that added fat in growing-finishing pig diets generally increases carcass fatness. Similarly, Apple *et al*. (2009) reported that carcasses from pigs fed 5% dietary fat, regardless of source, had greater average BF depths than pigs fed control diets. To explain the discrepancies among studies, it has to be taken into account that when the dietary treatments used in a study are not balanced, the increased energy supplied by fat addition may lead to an increased deposition of adipose tissue in fat supplemented pigs (Miller *et al*., 1990). Again, it has to be taken into account that in the present study, all diets were balanced and presented similar energy and protein content; therefore, this may explain why the addition of MUFA into the diet resulted in no differences in BF.

Barrows had higher BF measurements than gilts in all controls, which agree with many previous reports (Blasco *et al*., 1994; Hamilton *et al*., 2003; Latorre *et al*., 2004). This higher level of fatness in barrows is favoured by castration, as it increases the fat deposition and reduces the ceiling for protein deposition up to 30% (Campbell & Taverner, 1988).

When genotypes were compared York-sired pigs presented higher values than Pietrain-sired pigs for BF at the end of the trial. Other studies have reported differences in BF among breeds, with high lean genotypes showing lower BF levels than other conventional breeds (Langlois & Minvielle, 1989; Blasco *et al*., 1994). Backfat is an important trait in York-sired crosses, as an adequate fat cover is needed in this genotype for the dry curing process of the main cuts. The BF level achieved in York-sired barrows and gilts in the present study are within the requirements of the dry cured products industry in Spain.

This research suggests that the inclusion of a high oleic supplement into swine diets would not affect performance, BF or lean growth, if the diets were properly adjusted for energy concentration. The differences between sexes and genotypes were in line with previous research; barrows resulting in higher BF and heavier weight than gilts at the end of the trial, and gilts showing higher LT depth than barrows. Differences between genotypes showed that York-sired pigs were heavier during the entire trial and had higher BF at the last two measurements than Pietrain-sired pigs. On the other hand, Pietrain-sired pigs showed higher LT depth than York-sired from control 2 to the end of the diet. Moreover, the results showed that the genotypes evaluated would be suitable for their specific pork markets, with Pietrain crosses appropriate for fresh meat production and York crosses for the dry cured product industry.

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