Journal of Animal and Feed Sciences, 16, 2007, 621–635

Effect of the feeding level during the fattening phase on the productive parameters, carcass characteristics and quality of fat in heavy pigs*

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(Received 2 July 2007; revised version 24 September 2007; accepted 21 November 2007)

ABSTRACT

The objective of this experiment was to study the effect of feeding restriction carried out at the beginning or at the end of the finishing period on the productive results, carcass characteristics and fat quality of Iberian pigs fattened with feed in confinement. During the finishing period (77 days, from 100 to 150 kg of liveweight), the Iberian pigs were given the following feeding treatments: 1. R+AL (restricted feeding from the beginning of finishing period to 43 days later and *ad libitum* feeding from 44 days to the slaughter); 2. AL+R (*ad libitum* feeding from the beginning of the finishing period to 43 days later and restricted feeding from 44 days to slaughter); 3. C: constant feeding. The productive results (weight at slaughter, average daily gain and carcass weight) were higher ($P<0.001$) in C pigs than in R+AL and AL+R. The treatment had not significant influence on carcass characteristics except for the variables dorsal fat thickness and ham weight with respect to carcass weight. The concentration of C18:1n-9 and total MUFA proportions observed in subcutaneous backfat were higher in AL+R and C groups than in R+AL ($P<0.05$), while the C18:0 and total saturated fatty acids proportions were lower in AL+R and C pigs than in R+AL ($P<0.01$). The dietary treatment had not significant influence on the fatty acids proportions detected in the intramuscular and in liver fat. The results obtained in this experiment suggest the future development of other experimental designs, to improve the productive results and quality of Iberian pigs fed with feed in confinement by means of feeding restriction strategies.

KEY WORDS: restriction feeding, productive parameters, carcass quality, fat quality, Iberian pig

* Supported by INIA-RT-2004-00053
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INTRODUCTION

Feed restriction as a farm animal production strategy can prevent an excessive lipid deposition during the finishing period and induce economical benefits. Restriction followed by *ad libitum* feeding produces a phenomenon of compensatory growth (McMeekan, 1940) that influences carcass composition (Donker et al., 1986). Hence, it has been reported in pigs of improved genotypes that feed restriction during the growing period (from 30-70 kg liveweight) reduces lean and adipose tissue at the carcass level, while from 70 to 110 kg liveweight the compensatory growth feeding strategy increases adipose but not lean tissue (Heyer and Lebret, 2007). The effect of feed restriction on total fatness could be of higher magnitude in heavy pigs (up to 160 kg liveweight) produced to obtain quality meat products. One example of heavy pig is the Iberian pig, fed mixed diets in confinement. Nowadays, the range of quality among the different types of products from the Iberian pig is determined by the fatty acid profile of fat (Rey et al., 2006). However, there is not information on the possible effects of the feed ingestion level during the fattening period on the quality characteristics (fatty acid profile of the subcutaneous, intramuscular and liver fat) in Iberian pigs fed in confinement.

Iberian pigs fed mixed diets during the fattening phase (from 100-150 kg) usually receive - a daily amount of feed that approaches 80-85% of the *ad libitum* ingestion with the purpose of avoiding overload of the digestive system and an excessive fattening that would penalize the carcass yield at slaughter (at least ten months of age according to the Spanish Quality Rule). The results obtained in previous experiments carried out on compensatory growth in pigs of improved genotypes selected for the production of lean meat (Donker et al., 1986; Critser et al., 1995; Daza et al., 2007a), suggested to consider the possibility that an initial restriction of the energy ingestion in the fattening phase of heavy pigs could lead to an improvement of the productive results, carcass characteristics and fat composition. On the other hand, an energy restriction at the end of the finishing period could reduce the fattening and improve carcass yield without a significant alteration in the fatty acid profile.

Hence, the objectives of the present experiment were to study the influence of an energy restriction carried out either at the beginning or at the end of the finishing phase on the productive parameters, carcass characteristics and fat composition (fatty acid profile of subcutaneous, intramuscular and liver fat) of heavy pigs such as the Iberian pig fed in confinement.

MATERIAL AND METHODS

Animals and diets

Twenty four castrated male Torbiscal pigs (El Deheson del Encinar, Junta de Comunidades de Castilla-La Mancha, Oropesa, Toledo, Spain) were selected at 52.2 kg SEM±1.3 kg liveweight and approximately 6 months old. From 52.2 to approximately 100 kg (152 days from June to November), pigs received a commercial diet (1.7 kg/day). In the last fattening phase (from 97.7±2.6 kg) pigs were randomly distributed in three groups. Each pig was located in an individual pen (8 m^2) to control the feed ingestion. One group (R+AL) was fed a restriction feeding of 2.5 kg feed/day during the first 43 days of the fattening phase, followed

Table 1. Ingredient and chemical composition of the experimental diets

Pre-fattening		Fattening phase	
Ingredients	%	*Ingredients*	%
barley	70.46	barley	49.00
wheat	2.55	wheat	20.00
sunflower flour (30)	12.18	maize	8.00
soya flour (44)	8.68	sunflower flour (30)	16.00
high oleic sunflower oil	3.00	high oleic sunflower oil	5.00
lysine HCL	0.13	calcium carbonate	1.20
calcium carbonate	0.70	dicalcium phosphate	0.20
dicalcium phosphate	1.30	sodium chloride	0.40
sodium chloride	0.30	mineral vitamin mix	0.20
mineral vitamin mix	0.70		
Nutrients, g/100 g feed		*Nutrients, g/100 g feed*	
DE, Kcal /kg[1]	3091.00	DE, Kcal /kg[1]	3427.2
dry matter	89.05	dry matter	89.2
crude protein	14.34	crude protein	13.21
crude fat	3.74	crude fat	7.02
crude fibre	5.71	crude fibre	6.27
lysine[1]	0.69	lysine[1]	0.51
calcium[1]	0.62	calcium[1]	0.61
digestive phosphorus [1]	0.31	digestive phosphorus [1]	0.43
Fatty acids, g/100 g fatty acids		*Fatty acids, g/100 g fatty acids*	
C16:0	13.50	C16:0	9.93
C18:0	3.51	C16:1 n-9	1.35
C18:1 n-9	42.01	C18:0	4.02
C18:2 n-6	37.70	C18:1 n-9	56.83
C18:3 n-3	1.61	C18:1 n-7	1.34
		C18:2 n-6	20.16
		C18:3 n-3	0.34

[1] calculated values

by *ad libitum* feeding until slaughter (34 days). A second group (AL+R) was fed *ad libitum* during the first 43 days of the fattening phase, followed by a restriction feeding (2.5 kg feed/day) during the last 34 days until slaughter. The third group (C) received 4 kg feed /day during the whole fattening phase (77 days) (this feeding program is the most commonly used in the fattening phase for the Iberian pig reared indoors). All pigs were weighed at the beginning of the experiment, at the initial of the fattening phase, after 43 days of the initial fattening phase, and 18 h before slaughter. Water was provided *ad libitum*. The chemical and major fatty acids composition of the formulated experimental diets, are shown in Table 1.

Determination of the compositional analysis of feeds (in triplicate) was carried out according to AOAC (1996). Fatty acids of diets were extracted and quantified by the one-step procedure of Sukhija and Palmquist (1988) from lyophilized samples. Fatty acid methyl esters were analysed by gas chromatography using a Hewlett Packard HP-5890 (Avondale, PA, USA) gas chromatograph equipped with a flame ionization detector and a capillary column (HP-Innowax, 30 m length × 0.32 mm internal diameter and 0.25 μm polyethylene glycol-film thickness) (Lopez-Bote et al., 2002).

In vivo sample collection

Backfat biopsy samples were taken at the beginning of the fattening phase and 43 days after, at the level of the tail using a metal cylinder (diameter 0.25 cm) with a sharpened edge. All necessary precautions were taken to prevent animal discomfort during and after the *in vivo* sampling processes. This included tranquillization with 40 mg of azaperon (Stressnill, Labopica, Madrid) 1 h before biopsy and local anaesthesia with 2% lidocaine-HCl, immediately prior to sample collection. Afterwards, animals received a 2 ml penicillin intramuscular injection (300 000 IU ml-1, Labopica, Madrid). Backfat samples were separated into outer and inner layers which were independently analysed for fatty acid composition.

Slaughter, sample collection and chemical analysis

Animals were stunned and slaughtered at a local slaughter house (Talavera de la Reina, Toledo, Spain) at a liveweight of approximately 153.8±2.0 kg. The following measurements were taken: carcass weight, internal length of the carcass, left ham length, left ham perimeter, left ham weight, left shoulder weight, ham %, shoulder %, and subcutaneous fat thickness at the level of the last rib.

Samples of liver were taken at the slaughter time. Samples of *Longissimus dorsi* muscle at the level of the last rib were taken at cutting (24 h after slaughter), weighed, vacuum-packed in low-oxygen permeable film and kept frozen at -20ºC

until analysis. Backfat samples were also taken after slaughter at the level of the last rib and separated into outer and inner layers which were independently analysed for fatty acid composition. Analyses were carried out within three weeks of slaughter.

Subcutaneous fat (inner and outer layers) was extracted using the method of Bligh and Dyer (1959). Intramuscular and hepatic neutral and polar lipids were extracted by consecutive solvent elution with dichloromethane and dichloromethane/methanol (90/10 v/v) according to Marmer and Maxwell (1981). Fat extracts were methylated in the presence of sulphuric acid and analysed as described for feed fatty acids.

Statistical analysis

The data were analysed as a completely randomised design using the statistical program Statgraphics-Plus (version 5.1, 2001). The individual pig was the experimental unit for analysis of all data. The results were analysed by a covariate analysis in which treatment was the fixed effect and initial weight the covariate. If covariate was not statistically significant ($P>0.05$) it was removed from the model. The comparative analysis between means was conducted using the Duncan t-test.

Data are presented as the mean of each group and the mean standard error (SEM) together with the significance levels.

RESULTS AND DISCUSSION

Productive parameters

During the previous period to fattening (152 days from June-November) the average daily gain of the pigs was 298.9±16.8 g and significant differences were not detected for the three groups of pigs (R+AL:301.3; AL+R:294.1 and C:301.3). The average daily consumption of feed per pig was 1.72 g during that period.

The productive results obtained during the finishing phase according to the applied feeding pattern are given in Table 2. The average daily gain (ADG) was significantly higher in the pigs that received a constant amount of feed (C) when compared with those that were restricted at the beginning (R+AL) or at the end of the finishing period (AL+R). Moreover, the group of pigs restricted at the end of the fattening phase showed a higher ADG than those restricted to the beginning. The restricted pigs consumed less feed that those that received a constant feeding (C) and the lowest average daily feed intake (ADFI) was for the pigs fed R+AL.

Table 2. Effect of the feeding level on productive parameters of Iberian pigs fed in confinement

Feeding level	R+AL	AL+R	C	SEM	P<F	P cov initial weight
Initial weight, kg	99.1	95.9	98.2	2.6	0.69	-
Weight at 43 days, kg	115.6[a]	146.2[b]	135.9[c]	1.48	0.0001	0.0001
Final weight, kg	148.6[a]	153.6[b]	159.3[c]	2.0	0.004	0.0015
Carcass weight, kg	116.7[a]	122.5[b]	124.7[b]	1.4	0.002	0.0001
ADG_1, g	409.9[a]	1133.7[b]	886.6[c]	35.5	0.0001	0.15
ADG_2, g	963.2[a]	231.6[b]	685.7[c]	43.3	0.0001	0.07
ADG, g	661.2[a]	726.0[b]	800.3[c]	25.9	0.004	0.023
$ADFI_1$, kg	2.5[a]	4.8[b]	4.0[c]	0.07	0.0001	0.61
$ADFI_2$, kg	4.9[a]	2.5[b]	4.0[c]	0.072	0.0001	0.90
ADFI, kg	3.5[a]	3.8[b]	4.0[c]	0.050	0.0001	0.64
IT_1, kg/kg	6.38[a]	4.23[b]	4.54[b]	0.31	0.0001	0.35
IT_2, kg/kg	5.07[a]	11.91[b]	6.11[a]	0.86	0.0001	0.33
IT, kg/kg	5.44	5.19	5.06	0.15	0.21	0.024

SEM - standard error of the mean, ADG_1 - average daily gain during the fattening phase (from 0 to 43 days), ADG_2 - average daily gain during the fattening phase (from 43 to 77 days), ADG - average daily gain during whole period of fattening (0-77 days), $ADFI_1$ - average daily feed ingestion during the fattening phase (0-43 days), $ADFI_2$ - average daily feed ingestion during the fattening phase (from 43 to 77 days), ADFI - average daily feed ingestion during the fattening phase (0-77 days)
IT_1 - transformation index of feed from the beginning of the fattening phase until 43 days, IT_2 - transformation index of feed from 43 days to final period of fattening (77 days), IT - transformation index during the fattening period (from 0 to 77 days)
values with different superscript are significantly different at $P<0.05$

However, the feeding pattern did not have a significant statistically influence on the total transformation index of the feed (IT). As expected, the feed restriction had a negative effect on the transformation index of the feed and it was especially marked in the pigs restricted at the end of the fattening that had higher liveweight (due to the previous *ad libitum* feeding) and consequently dedicated an important fraction of the feed to satisfy its maintenance necessities.

The group that was restricted in the beginning (R+AL) showed from 43-77 days a higher feed consumption ($ADFI_2$) and average daily gain (ADG_2). These results are in agreement with those reported by Critser et al. (1995) and Daza et al. (2007a). However, R+AL group did not reach the ADG of the pigs that received a constant feeding (C). Not completed compensatory growth have also been evidenced in other experiments carried out with pigs of improved genotypes for the production of lean meat (Prince et al.,1983; Donker et al., 1986) and in Iberian pigs fattened in free-range (Daza et al., 2005a) and with feed in confinement (Daza et al., 2007a). On the other hand, the restriction applied at the end of the finishing period (AL+R) was too severe and produced the lowest ADG_2 and consequently, a lower total ADG than those pigs that received a constant feeding.

Carcass yield and characteristics

The feeding pattern did not have statistically significant influence on the carcass characteristics except for the percentage of ham and fat thickness at the level of the last rib (Table 3). The ham percentage was significantly higher in the

Table 3. Effect of the feeding level on carcass parameters of Iberian pigs fed in confinement

Feeding level	R+AL	AL+R	C	SEM	P<F
Carcass yield, %	78.7	79.5	78.3	0.9	0.69
Carcass length, cm	81.9	82.5	82.8	0.57	0.51
Ham length, cm	43.9	43.2	43.5	0.43	0.47
Ham perimeter, cm	72.1	72.4	73.1	0.66	0.59
Ham weight, kg	14.2	14.1	14.5	0.24	0.62
Shoulder weight, kg	9.8	9.9	10.0	0.26	0.86
Ham, %	12.1^{a}	11.8^{b}	11.6^{b}	0.13	0.04
Shoulder, %	8.3	8.1	8.0	0.19	0.50
Subcutaneous fat thickness, mm	44.0^{a}	47.2^{ab}	48.8^{b}	1.0	0.02
Intramuscular neutral lipids, %	4.7	4.0	3.8	0.58	0.55
Intramuscular polar lipids, %	1.1	1.0	1.1	0.15	0.90
Intramuscular fat, %	5.7	5.0	5.0	0.68	0.66

SEM - standard error of the mean
values with different superscript are significantly different at P<0.05

pigs that were restricted at the beginning of the fattening period than in the other two groups. Moreover, the correlation coefficient among the ham percentage and the carcass weight was r=-0.56 (P<0.004). The reduction of the ham percentage according to the increase of the carcass weight was also observed by Menaya et al. (1998). The fat thickness was significantly higher in the pigs that received a constant feeding (C) that in those restricted during the first 43 days (R+AL) and not significant differences were detected with the group restricted at the end of the period (AL+R). The correlation between the ham percentage of the ham and shoulder and the fat thickness was negative (r=-0.46; P<0.023 and r=-0.37; P<0.05, respectively) which is in agreement with the results found by Aparicio (1987) in Iberian pigs.

Moreover, in Iberian pigs the carcass yield increased with the slaughter weight (Menaya et al., 1998). However, in the present experiment, the range of the slaughter weight was small and consequently, significant variations of the carcass yield were not detected. Similar results were found previously (Daza et al., 2007a).

Hence, the initial hypothesis that a restriction at the end of the finishing period would lead to a reduction of the fattening and so to an increase of the carcass yield has not been verified in this experiment.

Backfat, muscle and liver fatty acid profile

The fatty acid composition of the subcutaneous fat, outer and inner layers, at 43 days are presented in Table 4. The pigs that received a restricted feeding during this phase (R+AL) had, at the end of the same, lower C18:1 n-9 and

Table 4. Effect of the feeding level on fatty acid profile (%) of subcutaneous fat at 43 days of fattening in Iberian pigs fed in confinement

Fatty acid	Outer	Inner	SEM	R+AL	AL+R	C	SEM	P layer	P treatment	P layer × treatment
C16:0	20.57^{a}	21.28^{b}	0.150	20.74	21.00	20.74	0.180	0.001	ns	ns
C18:0	9.76^{a}	11.08^{b}	0.120	10.12	10.65	10.49	0.150	0.0001	ns	ns
C18:1 n-9	48.48^{a}	46.95^{b}	0.250	46.68^{a}	48.62^{b}	47.83^{b}	0.310	0.0001	0.0003	ns
C18:2 n-6	10.00^{a}	10.65^{b}	0.130	11.56^{a}	9.43^{b}	10.00^{c}	0.150	0.001	0.0001	ns
C18:3 n-3	0.58^{a}	0.66^{b}	0.009	0.70^{a}	0.57^{b}	0.60^{c}	0.011	0.0001	0.0001	0.011
SAT	32.16^{a}	34.25^{b}	0.250	33.00	33.26	33.35	0.310	0.0001	ns	ns
MONO	55.64^{a}	53.08^{b}	0.250	53.20^{a}	55.34^{b}	54.54^{b}	0.320	0.0001	0.0001	ns
POLY	12.20^{a}	12.67^{b}	0.160	13.79^{a}	11.39^{b}	12.11^{c}	0.200	0.05	0.001	0.024
Σ n-6	10.19^{a}	10.85^{b}	0.130	11.79^{a}	9.60^{b}	10.17^{c}	0.160	0.0011	0.0001	ns
Σ n-3	1.14	1.13	0.048	1.17	1.07	1.18	0.059	ns	ns	0,02
Σn-6/ Σn-3	9.29	9.65	0.250	10.08	9.23	9.11	0.310	0.031	ns	ns
C16:1n-7/C16:0	0.087^{a}	0.078^{b}	0.002	0.08	0.08	0.08	0.002	0.0001	ns	ns
C18:1n-9/C18:0	4.99^{a}	4.26^{b}	0.067	4.68	4.60	4.61	0.087	0.0001	ns	ns
MONO/SAT	1.77^{a}	1.55^{b}	0.020	1.62	1.67	1.64	0.023	0.0001	ns	ns
POLY/SAT	0.38	0.37	0.008	0.42^{a}	0.34^{b}	0.36^{b}	0.017	ns	0.0001	ns

SEM - standard error of the mean
values with different superscript are significantly different at $P<0.05$

MUFA and higher C18:2 n-6, C18:3 n-3, PUFA and n-6 than the other two groups of pigs (AL+R and C). The increase of the energy ingestion generates an increment of the proportions of saturated fatty acids and MUFA due in part to an increase of the lipogenic (Bee et al., 1999, 2002) and of the steatoryl-CoA-desaturase enzymes (Enser, 1975; Daza et al., 2007a) at the same time that the proportions of the fatty acid C18:2 n-6, C18:3 n-3 and total PUFA decrease. In this experiment we estimated the activity of the enzyme steatoryl-CoA-desaturase (ECD), using the calculation of insaturation indexes (C16:1n-7 /C16:0 and C18:1n-9/C18:0). The activity of the enzyme ECD, from the beginning of the experiment up to 43 days later, was not significantly affected by the treatment. However, Daza et al. (2007a) observed that a lower feeding level followed by a higher one does not mean an immediate increase of the lipogenic activity of the fatty acid synthetase enzyme (FAS). The higher pro-

portion of C18:1 n-9 and MUFA in the AL+R group and C would be explained by the highest ingestion of feed and therefore, a higher ingestion of those fatty acids. In the R+AL group an inhibition of the ECD enzyme could also have occurred due to the high proportion of the PUFA which is in agreement with the data reported by Enser (1973) and Bee et al. (2002). The saturated fatty acids and those derived from the *de novo* synthesis are the main source for the ECD (Enser and Roberts, 1982).

Moreover, significant interactions of the feeding treatment and the fat layer were also found on the proportion of C18:3 n-3, total n-3 and PUFA. Hence, the external layers were more susceptible to changes in the fatty acid proportions as affected by the feeding than the inner layer.

In Table 5 can be observed that at slaughter pigs receiving the feeding pattern AL+R and C had significantly higher proportions of C18:1 n-9 and MUFA and lower C18:0 and SAT than the group R+AL. However, no significant differences were detected for the C16:0, C18:2 n-6, C18:3 n-3, n-6, n-3 and PUFA. In this case, the activity of the ECD enzyme estimated as C18:1 n-9 /C18:0 was significantly higher for the groups AL+R and C than for R+AL group. The higher proportions in C18:0, C18:1 n-9 and MUFA and the lower proportions in PUFA of

Table 5. Effect of the feeding level on fatty acid profile (%) of subcutaneous fat at slaughter in Iberian pigs fed in confinement

Fatty acid	Outer	Inner	SEM	R+AL	AL+R	C	SEM	P layer	P treatment	P layer × treatment
C16:0	19.90^{a}	20.70^{b}	0.110	20.26	20.32	20.32	0.130	0.0001	ns	0.05
C18:0	9.31^{a}	11.06^{b}	0.130	10.64^{a}	9.86^{b}	10.05^{b}	0.160	0.0001	0.006	ns
C18:1 n-9	51.02^{a}	49.17^{b}	0.200	49.59^{a}	50.26^{b}	50.43^{b}	0.250	0.0001	0.05	ns
C18:2 n-6	9.09^{a}	9.50^{b}	0.110	9.47	9.3	9.11	0.140	0.014	ns	ns
C18:3 n-3	0.50^{a}	0.56^{b}	0.010	0.54	0.53	0.52	0.010	0.0001	ns	ns
SAT	30.96^{a}	33.57^{b}	0.190	32.79^{a}	31.84^{b}	32.16^{b}	0.230	0.0001	0.017	ns
MONO	58.04^{a}	55.15^{b}	0.200	55.85^{a}	57.01^{b}	56.92^{b}	0.250	0.0001	0.003	ns
POLY	10.99	11.28	0.140	11.35	11.14	10.92	0.180	ns	ns	ns
Σ n-6	9.24^{a}	9.66^{b}	0.110	9.63	9.46	9.26	0.190	0.012	ns	ns
Σ n-3	1.75^{a}	1.62^{b}	0.035	1.72	1.68	1.66	0.043	0.008	ns	ns
Σn-6/ Σn-3	5.29^{a}	5.99^{b}	0.076	5.67	5.64	5.61	0.093	0.0001	ns	ns
C16:1n-7/ C16:0	0.084^{a}	0.070^{b}	0.002	0.073^{a}	0.080^{b}	0.077^{ab}	0.002	0.0001	0.042	ns
C18:1n-9/ C18:0	5.52^{a}	4.47^{b}	0.073	4.77^{a}	5.15^{b}	5.07^{b}	0.090	0.0001	0.033	ns
MONO/ SAT	1.88^{a}	1.64^{b}	0.015	1.71^{a}	1.80^{b}	1.78^{b}	0.019	0.0001	0.0053	ns
POLY/SAT	0.36^{a}	0.34^{b}	0.005	0.35	0.35	0.34	0.007	0.019	ns	ns

SEM - standard error of the mean
values with different superscript are significantly different at $P<0.05$

the group AL+R and C led to an increase of the activity of the ECD and so higher proportions of C18:1 n-9 and MUFA in the subcutaneous fat. Kouba et al. (1997) found that the high activity of the enzyme ECD was related with high proportions of oleic acid in the tissues. The restriction (2.5 kg/day) applied to the pigs AL+R during the last 34 days of the experimental period was not sufficiently severe to produce a reduction of the proportions of the SAT and MUFA and to increase PUFA. However, it should be observed that in the last phase (from 43 days to slaughter) the proportion of C18:1 n-9 increased more in the pigs R+AL than in AL+R and C (2.91, 1.64 and 2.60%, respectively; SEM=0.009; $P<0.01$), what could mean that if during this phase the pigs R+AL had more ingestion capacity probably then the proportion of oleic acid in the subcutaneous fat would have been higher than that for the pigs AL+R and C.

In addition, the subcutaneous fat of the outer layer had higher proportions of C18:1 n-9 and MUFA and lower C16:0, C18:0 and SAT than the inner layer. These results are in agreement with those observed by Migdal et al. (2001), López-Bote et al. (2002), Rey et al. (2005) and previously by Dean and Hildritch (1933) who reported that the degree of unsaturation from the outer to inner backfat layer was inversely related to the environmental temperature. The proportions of C18:2 n-6, C18:3 n-3, n-6 and PUFA were higher in the inner layer than in the outer 43 days after the beginning of the experiment. At slaughter, the inner layer had higher concentrations of C18:2 n-6, C18:3 n-3 and n-6 than the outer. However, the outer layer had a higher proportion in n-3 fatty acids (C20:5 n-3 and C22:6 n-3) (0.11 vs 0.09% and 0.51 vs 0.028%, respectively; $P<0.05$). The PUFA proportion according to the subcutaneous layer was very variable. In this way, Daza et al. (2005b) in crossed Iberian x Duroc pigs fed with feed in confinement and Rey et al. (2005) in Iberian pigs found that the outer layer was more unsaturated than the inner, while Daza et al. (2007a) found the opposite results in Iberian pigs fattened with feed in confinement. It seems that when feed is rich in PUFA the differences among the accumulated proportions of such fatty acids in the external and internal layers can be diminished or it can be even higher in the inner (Bee et al., 2002; López-Bote et al., 2002). In a previous study, Mac Grath et al. (1968) reported that when pigs were fed with a tallow supplemented diet there was a temperature gradient from the outer to inner backfat layer inversely related to total fat unsaturation, while no clear relationship was detected when pigs were fed with a maize oil-supplemented diet. Consequently these authors concluded that the relationship between depot fat unsaturation and environmental temperature is influenced by the polyunsaturated fatty acids received by the feeding.

The fatty acid profile of the intramuscular fat according to the feeding pattern is shown in Table 6. The feeding level neither affected the composition of the intramuscular fat in the *Longissimus dorsi* muscle neither the ECD activity.

Kuhn et al. (1995, 1997) found that a reduction of the feed ingestion did not affect the fatty acid composition of the intramuscular fat. So, to find differences in the proportions of saturated fatty acids and MUFA, changes in the feed ingestion should be high (close to 30%). Kondracki (2000) and Rey et al. (2005) did not detect differences among the proportions of saturated, MUFA and PUFA in the

Table 6. Effect of the feeding level on fatty acid profile (%) of *Longissimus dorsi* muscle in Iberian pigs fed in confinement

Fatty acid	R+AL	AL+R	C	SEM	P<F
Neutral lipids					
C16:0	25.49	24.84	24.69	0.450	ns
C18:0	11.61	11.31	10.95	0.510	ns
C18:1 n-9	47.86	48.43	48.89	0.700	ns
C18:2 n-6	2.76	2.99	3.18	0.150	ns
C18:3 n-3	0.14	0.16	0.17	0.008	ns
SAT	38.99	37.97	37.46	0.960	ns
MONO	57.47	57.23	58.52	0.850	ns
POLY	3.53	3.75	4.01	0.220	ns
Σ n-6	2.98	3.16	3.40	0.190	ns
Σ n-3	0.55	0.59	0.61	0.033	ns
Σn-6/ Σn-3	5.41	5.37	5.55	0.110	ns
Polar lipids					
C16:0	22.15	22.27	22.16	0.340	ns
C18:0	9.53	9.05	8.76	0.290	ns
C18:1 n-9	35.49	33.74	34.60	1.250	ns
C18:2 n-6	14.81	16.38	16.42	1.170	ns
C18:3 n-3	0.29	0.30	0.30	0.013	ns
SAT	32.71	33.29	32.40	0.520	ns
MONO	43.76	41.80	42.56	1.450	ns
POLY	22.95	25.48	25.03	1.810	ns
Σ n-6	20.79	23.09	22.85	1.650	ns
Σ n-3	2.16	2.39	2.18	0.180	ns
Σn-6/ Σn-3	9.58	9.73	10.65	0.400	ns

SEM - standard error of the mean
values with different superscript are significantly different at P<0.05

neutral and polar lipids of the intramuscular fat in Iberian pigs fed acorn, or acorn and grass in confinement. Qualitative important changes are needed in the feeding type during the period of finishing (for example free-range feeding vs a mixed diet in confinement) to detect changes in the intramuscular fat (Tejeda et al., 2002). As it was expected, the proportions of saturated fatty acids and MUFA were higher in the neutral than in the polar lipids, while PUFA were higher in the polar than in

the neutral lipids. These results are in agreement with those reported by Warnants et al. (1999), Bee et al. (2002) and Rey et al. (2005).

In Table 7 is shown the fatty acid profile in the liver fat according to the feeding level. The pigs that were restricted at the end of the period (AL+R) had higher proportions of C22:6 n-3 ($P<0.05$) and total n-3 fatty acids ($P<0.05$) in the neutral lipids than the other two groups of pigs. However, differences were not statistically different in the remaining fatty acids. In accordance with Ruiz et al. (1998) the profile of the fatty acids in the liver fat is a faithful reflection of the fatty acid composition of the plasma and therefore, of the recent feeding received by the pigs. Hence, it should be expected that differences among the different experimental treatments in the liver fat were not detected. Do-

Table 7. Effect of the feeding level on fatty acid profile (%) of liver in Iberian pigs fed in confinement

Fatty acid	R+AL	AL+R	C	SEM	P<F
Neutral lipids					
C16:0	12.90	12.31	12.63	0.540	ns
C18:0	21.00	22.18	21.83	0.720	ns
C18:1 n-9	25.53	24.35	24.15	0.920	ns
C18:2 n-6	12.38	12.15	12.75	0.260	ns
C20:4 n-6	16.71	17.64	17.26	0.720	ns
C18:3 n-3	0.38	0.39	0.40	0.033	ns
C22 :6 n-3	1.29[a]	1.81[b]	1.50[a]	0.130	0.036
SAT	35.60	35.78	35.97	0.330	ns
MONO	30.21	28.67	28.67	1.020	ns
POLY	34.19	35.54	35.36	0.870	ns
Σ n-6	29.09	29.79	30.01	0.830	ns
Σ n-3	4.65[a]	5.35[b]	4.93[a]	0.170	0.03
Σn-6/ Σn-3	6.31[a]	5.59[b]	6.15[a]	0.260	0.14
Polar lipids					
C16:0	14.11	14.08	13.12	0.390	ns
C18:0	28.37	28.74	29.85	0.540	ns
C18:1 n-9	18.30	18.24	17.15	0.550	ns
C18:2 n-6	13.47	12.94	13.72	0.320	ns
C20:4 n-6	17.35	17.37	17.61	0.460	ns
C18:3 n-3	0.25	0.28	0.24	0.019	ns
SAT	43.78	43.92	44.38	0.370	ns
MONO	21.30	21.13	20.00	0.620	ns
POLY	34.91	34.95	35.62	0.570	ns
Σ n-6	30.82	30.31	31.33	0.520	ns
Σ n-3	3.82	4.42	4.06	0.210	ns
Σn-6/ Σn-3	8.24	6.93	7.92	0.440	ns

SEM - standard error of the mean
values with different superscript are significantly different at $P<0.05$

cosahexanoic acid (C22:6 n-3) comes from the linolenic acid (C18:3 n-3) by the enzyme activity which also produces the transformation of the linoleic acid (C18:2 n-6) in arachidonic acid (C20:4 n-6). In the present experiment the increase in the proportion of C22:6 n-3 of the AL+R group was probably due to a higher enzyme activity and was responsible of the higher content of the total n-3 fatty acids because the other n-3 (C18:4 n-3, C20:5 n-3 and C22:5 n-3) did not change by the feeding, the ratio n-6/n-3 being more favourable in the group AL+R than in the remaining groups. The polar lipids of the liver fat were more saturated and less monounsaturated that the neutral lipids and the proportions of total PUFA were similar in both classes of lipids. These results are in agreement with those observed by Daza et al. (2007b) in Iberian pigs fattened in confinement.

CONCLUSIONS

It is concluded, that the restriction of the energy ingestion at the beginning or at the end of the period of finishing Iberian pigs fed in confinement does not produce an improvement of the productive results, quality of the carcass and quality of the fat when it is compared with a model of conventional constant feeding (average daily ingestion of 83% of the amount of feed received *ad libitum* during the fattening phase). So, the restriction of feed could be interesting from the economic point of view for producers.

ACKNOWLEDGEMENTS

Authors are thankful to Remedios Prieto and Pilar Ciria for technical assistance.

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