EFFECT OF THE FINISHING DIET ON THE FATTY ACID PROFILES IN ADIPOSE TISSUES OF THE CELTA PIG BREED

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***Abstract*—The effect of the finishing diet on the fatty acid profile in different adipose tissues of the Celta pigs (an autochthonous breed from NW of Spain) was studied. Twenty four pigs were separated in two different groups according to the type of feeding during the finish-fattening period (three months): (1) fed during all their life (16 months) with commercial compound feed and (2) fed with commercial compound feed the first 12 months, with a mixed (commercial compound feed/chestnuts) diet the 13th month, and receiving only a chestnuts diet in the last three months before slaughtering. Fatty acid composition in the subcutaneous fat (rump, dorsal, ventral and covering the *Biceps femoris* muscle) and in the perirenal fat was analysed.**

The perirenal fat showed significant higher values of saturated fatty acids than the subcutaneous fat. Oleic acid showed the largest difference among the five locations. The contents of polyunsaturated fatty acids were similar in all locations and no significant differences were observed linked to the location of the fat in the carcass.

The feeding with chestnuts significantly affected the fatty acid content in perirenal and subcutaneous dorsal fat, above all the contents of linolenic, γ-linolenic, and cis 11, 14 eicosadienoic acids. The linolenic acid content was affected by the diet in all the fat locations.

***Index Terms*— Celta pig breed, finishing diet, chestnuts, fatty acid profile, subcutaneous fat, perirenal fat**

I. INTRODUCTION

Celta pig is an autochthonous swinish breed from NW of Spain. It is characterized by its rusticity and its adaptation to the environment. The carcasses, which are often very fatty, are used in the production of dry-cured meat products, which have a high value on the market and great quality.

Several authors (Franco, Escamilla, García, García-Fontán & Carballo, 2006; Monziols, Bonneau, Davenel & Kouba, 2007) have reported variation in fatty acid composition of different anatomical locations.The influence of diet on the fatty acid composition of animal tissues, particularly muscle and adipose tissue, has been the subjet of much investigations (Wood et al., 2008). Modification of the fatty acid composition of livestock by dietary means is important, not only because of the probable relationship between fatty acid intake, cholesterol and heart disease, but also because of the effect of the fatty acid profile on the oxidative stability of animal tissues. Changing the fatty acid composition of subcutaneous tissue using different diet also changes melting point and fat firmness (Wood et al., 2008).

The NW region is the main area of chestnut production in Spain. At the present time, the chestnuts are underutilized, a situation that contrasts with the high current prices of the animal commercial compound feeds. The use of the chestnuts in the feeding of the Celta pig breed, in a extensive management system, would allow to reduce the production cost and to put in the market products of quality, differentiated, with a high added value and with a healthier fat.

The aims of this research are: 1) to study the differences in the fatty acid profile as a function of the location of the fat deposit in the carcass, and 2) to study the effect of the use of chestnuts in the finishing diet on the fatty acid composition in adipose tissues.

II. MATERIALS AND METHODS

A. Pigs and samples

In order to carry out this study, 24 castrated Celta pigs (males and females) were fed in two different groups: A) Fed during all their life (16 months) with commercial compound feed, and B) Fed with commercial compound feed the first 12 months, with a mixed (commercial compound feed/chestnuts) diet the 13th month, and receiving only a chestnut diet in the last three months before slaughtering. After slaughtering, and after 24 hours of refrigeration, samples of fat from

five deposits: subcutaneous fat (rump, dorsal, ventral and covering the *Biceps femoris* muscle) and perirenal fat, were obtained in each carcass.

B. Analytical methods

The fat of the samples was extracted following the procedure described by De Pedro, Casillas & Miranda (1997). The fatty acid profiles of the lipids were determined using the procedure described by Franco et al. (2006).

Fatty acid methyl esters were analysed by Gas Chromatography using a Thermo Finnigan Trace GC (Thermo Finnigan Trace GC (Thermo Finnigan, Austin, TX, USA). The separation of the different fatty acids was carried out in an Innowax column: 30 m; 25 mm ID; 0.25 mm film thickness (Agilent Technologies, Palo Alto, CA, USA). The temperature of the detector was 250 ºC and that of the injector 230 ºC. The gasses used were air (350 mL/min), hydrogen (335 mL/min) and helium (carrier gas) (30 mL/min).

Results are expressed as percentages of the total fatty acid composition.

C. Statistical analysis

Analysis of variance (ANOVA) with an interval of reliability of 95% ($P<0.05$) was carried out for the comparison of the value of each parameter in the two feeding groups. Means were compared by the least-square difference (LSD) test, using the computer programme Statistica© 5.1 for Windows (Statsoft Inc., Tulsa, OK, USA).

III. RESULTS AND DISCUSSION

Tables 1 and 2 show the fatty acid content in the five adipose tissues in the carcasses of the pigs fed with commercial compound feed and chestnuts, respectively.

Table 1
Fatty acid content in five locations in the carcass of the Celta pig breed fed with commercial compound feed during the finish-fattening period (average ± standard deviation of twelve carcasses)

	Perirenal fat	Subcutaneous fat from rump	Subcutaneous *B. femoris*	Subcutaneous dorsal fat	Subcutaneous ventral fat
C12	0.05±0.01 ^{a}	0.04±0.01 ^{a}	0.04±0.00 ^{a}	0.03±0.02 ^{a}	0.06±0.01 ^{a}
C14	1.28±0.08 ^{ab}	1.20±0.11 ^{a}	1.18±0.08 ^{a}	1.13±0.07 ^{a}	1.34±0.13 ^{b}
C14:1	0.04±0.02 ^{a}	0.04±0.01 ^{a}	0.03±0.01 ^{a}	0.04±0.01 ^{a}	0.04±0.02 ^{a}
C16	27.62±0.81 ^{a}	22.78±1.12 ^{b}	22.53±0.73 ^{b}	22.98±1.05 ^{b}	25.67±1.60 ^{c}
C16:1	1.43±0.19 ^{a}	1.72±0.20 ^{b}	2.11±0.34 ^{c}	1.71±0.22 ^{b}	2.25±0.39 ^{c}
C17	0.33±0.05 ^{a}	0.26±0.03 ^{a}	0.24±0.03 ^{a}	0.29±0.05 ^{a}	0.29±0.06 ^{a}
C17:1	0.16±0.03 ^{a}	0.22±0.04 ^{b}	0.26±0.03 ^{b}	0.24±0.06 ^{b}	0.24±0.05 ^{b}
C18	18.89±1.25 ^{a}	12.21±0.72 ^{b}	11.39±1.00 ^{b}	12.57±1.50 ^{*bc}	13.64±1.69 ^{c}
C18:1	34.54±1.96 ^{*a}	45.48±1.61 ^{b}	47.84±1.37 ^{c}	44.12±2.30 ^{b}	41.99±3.60 ^{d}
C18:2 n-6	13.20±1.32 ^{a}	12.79±0.48 ^{ac}	11.55±0.84 ^{c}	13.59±0.98 ^{a}	11.88±1.36 ^{c}
C18:3 n-3	0.71±0.08 ^{*a}	0.63±0.06 ^{*ab}	0.64±0.06 ^{*ab}	0.67±0.10 ^{*ab}	0.60±0.08 ^{*b}
C20	0.25±0.08 ^{*a}	0.20±0.06 ^{b}	0.17±0.03 ^{b}	0.23±0.07 ^{*ab}	0.19±0.06 ^{b}
C18:3 n-6	0.78±0.20 ^{*a}	1.30±0.17 ^{*b}	1.08±0.05 ^{c}	1.30±0.24 ^{*b}	0.98±0.18 ^{c}
C20:2	0.50±0.08 ^{*a}	0.84±0.14 ^{b}	0.65±0.06 ^{*c}	0.86±0.08 ^{*b}	0.58±0.10 ^{c}
C20:3 n-6	0.05±0.02 ^{*a}	0.06±0.02 ^{a}	0.08±0.04 ^{a}	0.06±0.03 ^{a}	0.07±0.02 ^{*a}
C20:4 n-6	0.11±0.05 ^{a}	0.18±0.03 ^{a}	0.14±0.04 ^{a}	0.14±0.03 ^{a}	0.13±0.05 ^{a}
C24	0.05±0.02 ^{a}	0.04±0.01 ^{a}	0.06±0.02 ^{a}	0.04±0.01 ^{a}	0.06±0.01 ^{a}
S	48.48±1.46 ^{*a}	36.74±1.63 ^{b}	35.62±1.01 ^{b}	37.28±2.37 ^{*b}	41.25±3.04 ^{c}
U	51.52±1.46 ^{*a}	63.26±1.63 ^{b}	64.38±1.01 ^{b}	62.72±2.37 ^{*b}	58.75±3.04 ^{c}
MU	36.17±2.03 ^{*a}	47.46±1.48 ^{bc}	50.25±1.40 ^{c}	46.12±2.39 ^{cd}	44.52±3.67 ^{d}
PU	15.35±1.46 ^{ab}	15.80±0.54 ^{a}	14.13±0.94 ^{b}	16.60±0.91 ^{a}	14.24±1.47 ^{b}

S: sum of saturated fatty acids; MU: sum of unsaturated fatty acids; PU sum of polyunsaturated fatty acids; U: sum of unsaturated fatty acids.

$^{a-c}$ Means within the same row not followed by the same letter differ significantly ($P<0.05$).

* Values that differed significantly ($P<0.05$) when compared the values of the corresponding adipose tissue in the two feeding groups ($P<0.05$).

Statistical analysis of the results, within the same feeding group, showed that the saturated fatty acid content was significantly higher ($P<0.05$) in the perirenal fat. No significant differences were observed in saturated and unsaturated

fatty acid composition between subcutaneous dorsal fat, subcutaneous fat from rump and the adipose tissue covering the *B. femoris* muscle. The unsaturated and saturated fatty acids in subcutaneous ventral fat showed intermediate percentages between the perirenal fat and the other three fat locations. No significant differences (P>0.05) were observed in polyunsaturated fatty acid composition regarding the location of fat deposit in the carcass. Oleic fatty acid percentages showed the greatest variations associated with the location of the fat deposit.

Oleic acid, the most abundant fatty acid in adipose tissues, is synthesized by Δ9-desaturase. The activity of this enzyme could be different in the various adipose tissues. A study indeed showed that the activity of Δ9-desaturase was higher in the subcutaneous adipose tissue than in the perirenal fat, which could explain the difference in the content of monounsaturated fatty acids (Thompson & Allen, 1969).

The difference in composition between the adipose tissues could be due to an adaptation of adipose tissue to temperature, with the aim of keeping the physical fluidity of the lipids in the different deposits (Monziols et al., 2007). The higher melting point of the saturated fatty acids could lead to the conclusion that the perirenal fat is more consistent than the subcutaneous ventral fat, that in turn is more consistent than the subcutaneous dorsal, from rump and covering the *B. femoris* muscle fats.

On the other hand, the differences found in the composition in saturated and unsaturated fatty acids in the different adipose tissues could be due to the diverse exchange velocities of the fatty acids in the different deposits during the life of the pig.

Despite the existence of the above-mentioned differences, the profile of fatty acids was very similar in the five deposits of fat studied. The most abundant fatty acids were oleic and palmitic (representing the sum of these two fatty acids more 60 % of the total fatty acids), followed by stearic and linoleic acids, both reaching similar values in subcutaneous fat. This profile of fatty acids does not differ greatly from those described by other authors in other pig breeds, although the content of oleic acid was higher in Celta pig bred.

In the perirenal and subcutaneous dorsal fats, the percentage of saturated fatty acids was significantly lower (P<0.05) and the percentage of unsaturated fatty acids was significantly higher (P<0.05) in the pigs fed with chestnuts than in those fed with commercial compound feed. Feeding with chestnuts significantly affected the fatty acid content in perirenal and subcutaneous dorsal fat, above all the contents of linolenic, γ-linolenic, and cis 11, 14 eicosadienoic acids. The linolenic acid content was affected by diet in all fat locations. No significant differences (P>0.05) were observed in linoleic acid composition associated to the type of finishing diet.

Table 2
Fatty acids content in five locations in the carcass of the Celta pig breed fed with chestnuts during the finish-fattening period (average ± standard deviation of twelve carcasses)

	Perirenal fat	**Subcutaneous fat from rump**	**Subcutaneous *B. femoris***	**Subcutaneous dorsal fat**	**Subcutaneous ventral fat**
C12	0.05±0.02 ^{a}	0.05±0.03 ^{a}	0.03±0.02 ^{a}	0.03±0.02 ^{a}	0.04±0.02 ^{a}
C14	1.28±0.10 ^{ac}	1.21±0.17 ^{abc}	1.18±0.13 ^{ab}	1.16±0.10 ^{b}	1.30±0.10 ^{c}
C14:1	0.05±0.01 ^{a}	0.04±0.02 ^{ab}	0.03±0.01 ^{b}	0.05±0.02 ^{a}	0.05±0.01 ^{a}
C16	26.67±1.03 ^{a}	22.66±1.61 ^{b}	22.74±1.29 ^{b}	22.50±1.46 ^{b}	25.22±1.42 ^{c}
C16:1	1.52±0.37 ^{a}	1.73±0.17 ^{ac}	2.11±0.32 ^{b}	1.95±0.18 ^{c}	2.27±0.41 ^{b}
C17	0.35±0.09 ^{a}	0.32±0.06 ^{a}	0.29±0.04 ^{a}	0.35±0.07 ^{a}	0.35±0.06 ^{a}
C17:1	0.18±0.07 ^{a}	0.30±0.08 ^{b}	0.29±0.06 ^{b}	0.33±0.08 ^{b}	0.29±0.07 ^{b}
C18	17.85±2.10 ^{a}	12.25±1.29 ^{bc}	11.13±0.88 ^{b}	11.11±1.95 ^{b}	13.11±1.78 ^{c}
C18:1	36.75±2.78 ^{a}	45.82±2.96 ^{b}	47.99±2.25 ^{c}	45.50±2.74 ^{b}	42.06±3.17 ^{d}
C18:2 n-6	12.77±1.82 ^{a}	12.45±0.52 ^{a}	11.32±1.17 ^{b}	13.86±1.54 ^{c}	12.42±1.18 ^{a}
C18:3 n-3	0.90±0.16 ^{a}	0.73±0.08 ^{b}	0.74±0.08 ^{b}	0.76±0.11 ^{b}	0.72±0.09 ^{b}
C20	0.18±0.08 ^{a}	0.19±0.06 ^{a}	0.15±0.06 ^{a}	0.17±0.05 ^{a}	0.18±0.06 ^{a}
C18:3 n-6	0.60±0.15 ^{a}	1.14±0.25 ^{b}	0.99±0.21 ^{cd}	1.09±0.25 ^{bc}	0.86±0.19 ^{d}
C20:2	0.42±0.05 ^{a}	0.72±0.10 ^{b}	0.57±0.13 ^{c}	0.75±0.13 ^{b}	0.51±0.08 ^{c}
C20:3 n-6	0.21±0.10 ^{a}	0.17±0.09 ^{a}	0.19±0.10 ^{a}	0.14±0.08 ^{a}	0.35±0.25 ^{b}
C20:4 n-6	0.18±0.06 ^{a}	0.16±0.03 ^{a}	0.19±0.05 ^{a}	0.18±0.03 ^{a}	0.20±0.07 ^{a}
C24	0.06±0.03 ^{a}	0.06±0.01 ^{a}	0.05±0.03 ^{a}	0.05±0.04 ^{a}	0.06±0.03 ^{a}
S	46.44±2.30 ^{a}	36.74±2.91 ^{b}	35.57±1.50 ^{b}	35.37±3.25 ^{b}	40.26±2.52 ^{c}
U	53.56±2.30 ^{a}	63.26±2.91 ^{b}	64.43±1.50 ^{b}	64.63±3.25 ^{b}	59.74±2.52 ^{c}
MU	38.49±3.07 ^{a}	47.89±2.85 ^{b}	50.43±2.07 ^{c}	47.85±2.79 ^{b}	44.68±3.16 ^{d}
PU	15.07±2.03 ^{ab}	15.37±0.61 ^{a}	13.99±1.52 ^{b}	16.78±1.63 ^{c}	15.06±1.45 ^{ab}

S: sum of saturated fatty acids; MU: sum of unsaturated fatty acids; PU sum of polyunsaturated fatty acids; U: sum of unsaturated fatty acids.

$^{a-c}$ Means within the same row not followed by the same letter differ significantly (P<0.05).

The factors associated with feeding that modify the composition in fatty acids of the tissues of the pig are: the amount of fat and carbohydrates present in the diet, the composition in fatty acids of the feed and the duration of the fattening period (Cava & Nieto, 2001). The chestnuts and the commercial compound feed have high levels of carbohydrates and low levels of fat (less than 5 % of dry matter). The carbohydrates serve as substrate in the synthesis of fat, synthesizing palmitic acid, which in our case shows values of around 22-28 % of total fatty acids. On the other hand, the enzyme Δ9-desaturase would be very active, as it is favoured by the carbohydrates, which would explain partly the high content of monounsaturated fatty acids and especially of oleic acid.

The linoleic acid content of porcine fat is related to the linoleic acid content of the diet. According to the analysis carried out in our laboratory, the chestnuts have higher levels of linoleic acid (around 40 % of total fatty acids) that commercial compound feed used (around 24 % of total fatty acids). The five tissues have high triglyceride contents and these molecules have a low fatty acid turnover rate and metabolic activity; the average triglyceride life has been estimated to be over 180 days (Cunningham, 1968), a time longer than the finish-fattening phase of Celta pigs. Consequently, the concentration of the linoleic acid does not accurately reflect the ingestion of chestnuts during the finish-fattening phase.

The linolenic acid is directly accumulated from the diet. The significantly higher content of linolenic acid in all the fat locations in the pigs fattened only with chestnuts could also be related with the higher content of this fatty acid in the chestnuts (6 % of total fatty acids) than in the commercial compound feed (2.5 % of total fatty acids).

The linoleic acid can play an important role in the regulation of elongation and saturation reactions of the polyunsaturated fatty acids. The differences in the percentages of cis 11, 14 eicosadienoic and cis 11, 14, 17 eicosatrienoic acids of the adipose tissues between pigs fattened with chestnuts and those fed with commercial compound feed could be explained by differences in the desaturation and elongation of endogenous and dietary fatty acids.

IV. CONCLUSION

In the Celta pigs, high percentages of linoleic acid were observed being its content similar in all five locations of the fat in the carcass. Oleic acid showed the largest difference among the five locations. Feeding with chestnuts in the finish-fattening significantly affected the fatty acids content in perirenal and subcutaneous dorsal fat, above all the contents of linolenic, γ-linolenic, and cis 11, 14 eicosadienoic acids. The linolenic acid content was affected by diet in all fat locations. The concentration of the linoleic acid does not accurately reflect the ingestion of chestnuts during the finish-fattening phase. Results of the present study show that analysis of perirenal fat is the best way to investigate the inclusion of chestnuts in the finishing diet of the Celta pig breed.

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