

Body composition and blood parameters of newborn piglets from Alentejano and conventional (Large White × Landrace) genotype

R. Charneca^{1*}, J. L. T. Nunes¹ and J. Le Dividich²

¹ Universidade de Évora, Departamento de Medicina Veterinária, Instituto de Ciências Agrárias e Ambientais Mediterrânicas, Apdo. 94, 7002-554 Évora, Portugal

² INRA UMR1079 Systèmes d'Élevage, Nutrition Animale et Humaine, F-35590 Saint-Gilles, France

Abstract

This study aimed to compare the body composition and some blood parameters [(glucose, albumin and insulin-like growth factor 1 (IGF-1)] of newborn piglets farrowed by unselected Alentejano (AL) or conventional genotype [Large-White Landrace (LL)]. Carcasses (12 of each genotype) and blood samples were obtained from a total of 34 litters (18 AL, 16 LL). Gestation length was 4d shorter in AL sows compared with LL sows. When adjusted for birth weight, carcasses of AL piglets showed higher percentages of dry matter ($P < 0.05$) and crude protein ($P < 0.01$) and tended to have higher lipid content ($P = 0.091$) than carcasses of LL piglets. Relative to body weight, the AL piglets had heavier livers ($P < 0.05$) than LL piglets but glycogen content was similar in both genotypes. *Longissimus dorsi* muscle of AL piglets contained more protein ($P < 0.01$), but glycogen, DNA and RNA contents were similar in both genotypes. The blood from the AL piglets had higher levels of glucose ($P < 0.01$), albumin (when adjusted for birth weight) ($P < 0.05$) and IGF-1 ($P < 0.05$) than blood from the LL piglets. On the bases of body composition and studied blood parameters, AL piglets seem to be more mature at birth than LL piglets despite a shorter gestation length.

Additional key words: body protein, energy stores, Iberian neonatal pig, maturity, plasma parameters.

Resumen

Composición corporal y parámetros sanguíneos de lechones Alentejanos y Large White × Landrace recién nacidos

El objetivo de este estudio fue comparar la composición corporal y los parámetros sanguíneos [albúmina, glucosa y factor de crecimiento insulínico tipo 1 (IGF-1)] de lechones recién nacidos procedentes de cerdas de raza no seleccionada Alentejana (AL) y de genotipo convencional [Large-White × Landrace (LL)]. Se analizaron muestras de sangre y canal (12 de cada genotipo) de un total de 34 camadas (18 AL y 16 LL). Las cerdas AL presentaron gestaciones 4 días más cortas que las cerdas LL. Cuando se ajustaron para el peso al nacimiento, los canales de los lechones AL presentaron mayores porcentajes de materia seca ($P < 0,05$) y proteína bruta ($P < 0,01$) y tendieron a presentar un mayor contenido en grasa ($P = 0,091$) que los canales de los lechones LL. Con relación al peso corporal, los lechones AL tuvieron hígados más pesados ($P < 0,05$), pero su contenido en glicógeno fue similar en los dos genotipos. El músculo *Longissimus dorsi* (LD) de los lechones AL contuvo más proteínas ($P < 0,01$) que el LD de los lechones LL. Sin embargo, el contenido en glicógeno, ADN y ARN fue similar para los dos genotipos. Los lechones AL presentaron mayores concentraciones plasmáticas de glucosa ($P < 0,01$), albúmina (ajustada para el peso al nacimiento) ($P < 0,05$) e IGF-1 ($P < 0,05$) que los lechones LL. A pesar de la gestación más corta, teniendo en consideración la composición corporal y los parámetros sanguíneos estudiados, los lechones AL parecen ser más maduros al nacimiento que los lechones LL.

Palabras clave adicionales: cerdo Ibérico neonato, madurez, parámetros plasmáticos, proteína corporal, reservas energéticas.

* Corresponding author: rmcc@uevora.pt

Received: 28-04-09; Accepted: 19-02-10.

Abbreviations used: AL (Alentejano breed), BFT (backfat thickness), CP (crude protein), DE (digestible energy), DM (dry matter), G6-Pase (glucose-6-phosphatase), IB (Iberian breed), IGF-1 (insulin-like growth factor 1), LD (*Longissimus dorsi* muscle), LL (Large-White × Landrace), LR (Landrace), LW (Large-White), Pi (inorganic phosphate), SEM (standard error of mean).

Introduction

Alentejano swine (AL) is a primitive Iberian breed (IB) raised all over the Southwest region of the Iberian Peninsula. The AL breed is well-adapted to utilise acorns and is raised mainly in an extensive system, under oak canopy (green and cork) in Alentejo region (Portugal). In most farms, sows are raised in outdoor parks. Due to the seasonal and annual variations in natural resources in the Mediterranean *Quercus* woodland ecosystem (acorns production from October to March, pasture in autumn and spring), they are usually supplemented with standard commercial feeds.

Iberian breeds have a remarkable ability to deposit fat as intramuscular and external fat (López-Bote, 1998) but a reduced potential for protein deposition (Nieto *et al.*, 2002). Nevertheless, they have an important commercial value in the local economy through their long dried cured hams and sausages. However it is not known whether their ability to deposit fat is already expressed at birth. Further, compared to conventional breeds (*e.g.*, Large White), reproductive performance of the IB breeds is quite low. Litter size ranges from 7.4 to 8.4 total born (Dobao *et al.*, 1988; Marques, 2001) while pre-weaning mortality of piglets can be as high as 28-29% (Marques *et al.*, 1996; Robledo *et al.*, 2008). Iberian sows have a gestation length by approximately 4d shorter than conventional sows (De Juana Sardón, 1954; Nunes, 1993). In pigs, growth rate of the foetuses (McPherson *et al.*, 2004), and vital deposition of energy reserves (Okai *et al.*, 1978) accelerate markedly during the last few days of gestation. However, to what extent these are affected by the shorter gestation length of the IB sows has not been determined.

Less is known on the early stages of development of the IB pig. Usually, premature birth (4-5d before the normal term) reduces birth weight of piglets and enhances post-natal mortality (Yamada *et al.*, 1982). Compared to the genetically obese Ossabaw (Stone *et al.*, 1985) or Meishan piglets (Herpin *et al.*, 1993), newborns from lines selected for lean tissue growth have less dry matter and protein concentrations in their body and lower liver weight. Further, 21 years of genetic selection of the French Large-White (LW) on lean growth and litter size also resulted in similar effects on the newborns (Canario *et al.*, 2007b).

This study aims to compare the body composition and some blood parameters of newborn piglets farrowed by the unselected AL, reared as in practice, or by

a more conventional [LW × Landrace (LR)] genotype sow.

Material and methods

Animals and facilities

The experiment was conducted according to the European Community regulations concerning the production of experimental animals (European Communities Council Directive 86/609/EEC). The experiment was carried out in the Experimental Centre of Mitra of the University of Évora (Portugal) from February 2005 to August 2006. The AL sows were mated by AL boars whereas Large-White × Landrace (LL) sows were mated by a LW boar. Sow parity number ranged from 3.7 ± 0.6 to 4.0 ± 0.6 for AL and LL sows, respectively. Litters were followed until 28d post-partum.

During the whole gestation, LL sows were kept in groups of 3 to 4 sows, as homogeneous as possible in live-weight and age, in indoor facilities on concrete flooring. To control mating and to determine the duration of gestation, AL sows were kept in group of 3 to 4 sows in indoor facilities until gestation was confirmed by ultrasonic (Aloka; Model: SSD-210DX II, with a 5 Mhz linear probe) diagnosis (\sim d 28 after mating). Thereafter, they were moved to and raised in groups of 12-15 sows in an outdoor park (4.5 ha) where they had access to floorless huts. Alentejano sows farrowed in conventional farrowing crates (indoor farrowing house) due to experimental purposes (piglets slaughter and bleeding, colostrum and milk samples collection). Sows were fed with commercial diets for gestating and lactating sows. Diets were based on cereals and soybean meal and contained (per kg diet, calculated values) 160 g crude protein (CP), 7 g lysine and 13.4 MJ digestible energy (DE) (gestation) and 170 g CP, 10.5 g lysine and 13.8 MJ DE (lactation). During gestation, LL sows were fed twice daily at the rate of 2.5-3.0 kg d⁻¹ until farrowing. Alentejano sows were fed with the same commercial diets as LL sows, at the exception that the rate of feeding was restricted to 1.5-2 kg d⁻¹ during gestation. However, for 6 out of the 18 AL sows which had access to acorns, feed supply was restricted to 1 kg d⁻¹. For both genotypes no feed was provided during the farrowing day, after which feed supply was gradually increased until *ad libitum*. In the outdoor park they were fed once daily the same type and amount of feed. Feed was spread in the field in order to reduce compe-

tition between sows. At mating and one day before the expected farrowing date, AL and LL sows weighed 127 ± 12 kg and 161 ± 14 kg, and 173 ± 9 kg and 227 ± 11 kg, respectively. Due to the fact that sows were kept in groups, individual feed intake was not determined. In all facilities, water was available from a low-pressure nipple-drinker.

Measurements

A total of 34 litters (18 AL, 16 LL) were used for the determination of body composition and blood sampling at birth. Sows farrowed naturally and all farrowings were supervised. On the day after farrowing the backfat thickness (BFT) was determined on P2 site (Dourmad *et al.*, 2001). The body composition of piglets at birth was determined on 12 AL and 12 LL piglets (one piglet per litter). Of the 12 AL piglets, six were farrowed by AL sows which had access to acorns during gestation. At birth, randomly chosen piglets were dried, weighed and exsanguinated. Duration of these operations did not exceed 3 to 4 min. The digestive tract, lungs, heart and liver were removed and the liver (without gall bladder) was weighed. *Longissimus dorsi* muscle (LD) samples (5-6 g) were taken. The liver and LD samples were frozen in liquid N₂ and stored at -20°C until analysed. Piglet carcasses without the digestive tract, liver, lungs and heart were also frozen and stored at -20°C until subsequent mincing and homogenization. Blood samples (~ 1.0 - 1.5 mL) were collected into heparinised tubes after umbilical cutting for the determination of glucose, albumin and insulin-like growth factor 1 (IGF-1). Samples were immediately centrifuged at 1,400 g during 10 min and the plasma removed and stored at -20°C until analysed. Glucose was determined on 63 AL piglets from 15 litters and on 91 LL piglets from 14 litters. Albumin was determined on 89 piglets (45 AL and 44 LL piglets from 13 and 10 litters, respectively). Piglets were chosen so that within each genotype they had the same gestational age, *i.e.*, 111 ± 1 and 115 ± 1 d for AL and LL piglets, respectively. Within a litter, piglets having a birth body weight higher than litter average birth body weight were considered heavy and the others were considered light. For IGF-1, samples were from 3 piglets per litter (5 AL and 6 LL litters) chosen as being heavy, medium (a medium piglet had the closest birth body weight to the litter mean birth weight) or light within litter.

Analyses

Dry matter (DM), CP, lipid, fatty acids and ash content of the ground carcasses were determined. The DM was determined after drying at 102°C until constant weight. The CP ($N \times 6.25$) was determined according to Dumas method using a LECO (Ref. FP-528, LECO Corporation, St Joseph MI, USA) nitrogen/protein determinator. Total lipid content was measured according to Folch *et al.* (1957) and methyl esters were obtained. Fatty acids were determined by gas phase chromatography (Chromatographer: GC-FID HP 6809 Series). The ash content was determined after incineration at 550°C for 3 h. Glycogen concentration of liver and LD was measured as previously described by Le Dividich *et al.* (1991). Glucose-6-phosphatase activity (G6-Pase), a key gluconeogenic enzyme, was measured according to Harper (1965). The inorganic phosphate (Pi) released was determined as described by Fiske and Subbarow (1925). The concentrations of CP, DNA and RNA of LD were determined by the methods of Lowry *et al.* (1951), Labarca and Paigen (1980) and Munro and Fleck (1969), respectively. Plasma concentration of glucose and albumin were determined using commercial kits (Sentinel Diagnostics, Milan, Italy) and by bromocresol colorimetry (Roche Diagnostics GmbH, Mannheim, Germany, kit. no. 1970569). Plasma IGF-1 concentrations were determined by radioimmunoassay according to Louveau and Bonneau (1996) after formic acid and ethanol extraction.

Statistical analyses

All data were analysed using the SPSS software, vers. 16.0 (SPSS, 2007). Because of the small number of the samples of sows, parity was not taken into account.

Sows reproductive traits, BFT, carcass traits, liver and LD composition and plasma concentrations of glucose, albumin and IGF-1 data were analysed using the general linear model (GLM) procedure with the one-way analysis of variance (ANOVA) using genotype as a fixed effect. The effects of gestation diet (access to acorns *vs* no access to acorns) on carcasses fatty acid composition were analysed according to a similar procedure using genotype and diet as fixed effects. Because birth weight has been reported to have an effect on body composition both between and within-litter (De Passillé and Hartsock, 1979; Rehfeldt and

Kuhn, 2006), data of body composition and blood plasma were adjusted by covariance using birth weight as covariate.

For plasma glucose concentrations, analysis of covariance was performed using genotype as a fixed effect and the time since the onset of farrowing as a covariate. For plasma albumin and IGF-1 concentrations, a GLM ANOVA was performed using two (light or heavy) and three (light, medium or heavy) birth weight classes for albumin and IGF-1, respectively, as a fixed effect.

Differences were considered significant at $P < 0.05$ whereas values between 0.05 and 0.10 were considered as trends. When adequate, means were separated by Tukey test.

Results

Backfat thickness at farrowing was not significantly different between genotypes (21.6 ± 1.3 mm vs 20.5 ± 1.4 mm for AL and LL sows, respectively; $P > 0.05$). Reproductive and productive traits of AL and LL sows are shown in Table 1. The AL sows had shorter gestation length ($P < 0.001$) than LL sows but no differences were detected between genotypes for farrowing duration. Litter size (total and born alive), litter weight of piglets born alive ($P < 0.001$) as well as individual birth weight ($P < 0.02$) were also lower in AL than in LL sows. Mortality rate (% born alive) between birth and 28d of age was higher in AL than in LL litters (25.1 vs 13.3% , $P < 0.05$).

The AL piglets used for the body composition study were lighter at birth and had lighter carcasses compared with LL piglets ($1,181 \pm 36$ g vs $1,319 \pm 36$ g,

Table 1. Alentejano (AL) and Large-White \times Landrace (LL) sows reproductive and productive traits

Traits	AL (n = 18)	LL (n = 16)	P-value
Gestation length (d)	111.1 \pm 0.3	115.1 \pm 0.3	1.2×10^{-11}
Duration of farrowing (min)	143 \pm 19	190 \pm 20	0.162
Litter size (n litter ⁻¹)			
Total born	7.9 \pm 0.7	13.3 \pm 0.8	1.1×10^{-5}
Born alive	7.7 \pm 0.6	11.8 \pm 0.7	1.2×10^{-4}
Stillbirths	0	0.9 \pm 0.3	0.016
Mummified	0.2 \pm 0.2	0.6 \pm 0.2	0.093
Litter weight (g) ¹	8,999 \pm 790	15,648 \pm 837	2.1×10^{-6}
Individual birth weight (g) ¹	1,185 \pm 39	1,339 \pm 42	0.019

Each value represents the least squares mean \pm SEM for each genotype. ¹ Live born piglets.

Table 2. Carcass composition at birth of Alentejano (AL) and Large White \times Landrace piglets (LL)¹

Variable	AL	LL	P-value
<i>Without adjustment for piglet weight</i>			
Dry matter (%)	22.3 \pm 0.34	21.4 \pm 0.34	0.092
Protein (%)	13.1 \pm 0.27	12.3 \pm 0.27	0.061
Lipids (%)	1.65 \pm 0.08	1.50 \pm 0.08	0.200
Ash (%)	4.37 \pm 0.14	4.55 \pm 0.1	0.401
<i>With adjustment for piglet weight</i>			
Dry matter (%)	22.53 \pm 0.34	21.15 \pm 0.34	0.015
Protein (%)	13.29 \pm 0.27	12.09 \pm 0.27	0.009
Lipids (%)	1.69 \pm 0.09	1.46 \pm 0.09	0.091
Ash (%)	4.43 \pm 0.17	4.50 \pm 0.17	0.795

Each value represents the least squares mean \pm SEM for each genotype. ¹ Measurements were made on 12 piglets per genotype at the exception of ash (7 piglets per genotype).

$P < 0.05$ for birth weight and 953 ± 31 g vs $1,088 \pm 31$ g, $P < 0.01$ for carcasses). Data on carcass composition of piglets at birth are shown in Table 2. With the exception of ash, when adjusted for birth weight, carcasses of AL piglets had higher percentage of dry matter ($P < 0.05$) and protein ($P < 0.01$) than carcasses of LL piglets. The carcasses of AL piglets tended ($P < 0.10$) to have higher lipid content than carcasses of LL piglets. However, AL piglets had similar body fat content whether gestating sows had access to acorns. The LD of AL piglets contained more protein than the LD of LL piglets (95.4 ± 2.8 mg g⁻¹ vs 79.7 ± 3.1 mg g⁻¹, $P < 0.01$). The difference tended to persist ($P < 0.10$) when data were adjusted for birth weight. However, DNA and RNA were unaffected by genotype even after adjustment for birth weight. In AL piglets, non-adjusted data for DNA and RNA were 1.77 ± 0.09 mg g⁻¹ and 1.10 ± 0.04 mg g⁻¹, respectively. Corresponding values for LL piglets were 1.81 ± 0.10 mg g⁻¹ and 1.05 ± 0.04 mg g⁻¹, respectively. There was a tendency for the RNA/protein ratio to be lower in AL piglets than in LL piglets (11.6 ± 0.6 μ g g⁻¹ vs 13.2 ± 0.7 μ g g⁻¹, $P < 0.10$). Genotype had no effect on muscle glycogen concentrations averaging 8.8%. At the exception of fatty acids composition of the body lipids, there was no significant difference between piglets farrowed by AL sows having access or not to acorns during gestation. Data on fatty acid composition of the body lipids extracts are given in Table 3. When piglets born to sows exclusively fed the commercial diets (AL sows deprived of

Table 3. Fatty acid composition of lipid fraction in carcasses of AL (Alentejano breed) and LL (Large White × Landrace crossbred) piglets at birth

Fatty acids ¹ (%)	AL (12)		LL (12)	P-value
	Acorns during gestation		—	
	+ (6)	– (6)		
C14:0	3.33 ± 0.13 ^{ab}	3.09 ± 0.13 ^a	3.54 ± 0.09 ^b	0.031
C16:0	31.88 ± 0.53 ^a	34.03 ± 0.53 ^b	33.69 ± 0.37 ^b	0.016
C16:1	6.63 ± 0.26	6.13 ± 0.26	6.49 ± 0.19	0.390
C18:0	13.26 ± 0.52	14.51 ± 0.52	13.55 ± 0.37	0.218
C18:1	33.43 ± 0.64 ^a	30.89 ± 0.64 ^b	30.36 ± 0.45 ^b	0.003
C18:2	4.44 ± 0.28	4.32 ± 0.28	4.79 ± 0.20	0.335
C18:3	0.45 ± 0.04 ^{ab}	0.32 ± 0.04 ^b	0.49 ± 0.03 ^a	0.014
C20:1	0.45 ± 0.02	0.44 ± 0.02	0.45 ± 0.02	0.936
C20:2	0.58 ± 0.05	0.59 ± 0.05	0.63 ± 0.04	0.701
C20:4	5.55 ± 0.26	5.67 ± 0.26	6.02 ± 0.18	0.293

Each value represents the least squares mean ± SEM for each genotype. ¹ % of the identified fatty acids.

acorns and LL sows) are compared, AL piglets had less C14:0 ($P < 0.05$) and C18:3 ($P < 0.02$). Within AL piglets, those born to sows having access to acorns during gestation had more C18:1 ($P < 0.01$) and less C16:0 ($P < 0.02$) than those farrowed by sows without access to acorns. Data on liver weights, glycogen contents and G6-Pase activity are presented in Table 4. Genotype has no significant effect on the absolute weight of the liver. However, relative to birth weight, liver was 12.1% ($P < 0.05$) heavier in AL piglets. No significant difference between genotypes was observed on hepatic glycogen contents or G6-Pase activity.

In both genotypes, blood glucose concentration was not dependent on birth weight, but was positively correlated with the time elapsed since the onset of

farrowing ($r = 0.276$; $P < 0.001$). Values adjusted for the time since the onset of farrowing were 637 ± 22 and 541 ± 19 mg mL⁻¹ ($P < 0.01$) in AL and LL piglets, respectively.

Plasma albumin concentrations adjusted to birth weight averaged 6.6 ± 0.3 mg mL⁻¹ in AL piglets that was higher ($P < 0.05$) than the 5.5 ± 0.3 mg mL⁻¹ found in LL piglets. Values for plasma albumin concentrations of light ($1,026 \pm 35$ g) and heavy ($1,288 \pm 31$ g) AL piglets were 5.2 ± 0.5 and 7.1 ± 0.4 mg mL⁻¹ ($P < 0.01$), respectively. In LL piglets no significant differences were observed between birth weight categories. In AL but not in LL piglets, there was a positive within-litter correlation between plasma albumin concentrations and birth weight ($r = 0.34$; $P < 0.01$).

Plasma IGF-1 concentrations were higher in AL than in LL piglets (19.7 ± 2.9 vs 11.5 ± 2.7 ng mL⁻¹, $P < 0.05$). In both genotypes, plasma IGF-1 concentrations did not depend on birth weight.

Table 4. Liver weights, glycogen contents and glucose-6-phosphatase (G6-Pase) activity of AL (Alentejano breed) and LL (Large White × Landrace crossbred) piglets at birth.

Trait ¹	AL	LL	P-value
Weight (g)	41.0 ± 1.6	39.9 ± 1.6	0.627
Weight (g) ²	42.4 ± 1.5	38.5 ± 1.5	0.099
Weight (g kg birth weight ⁻¹)	34.7 ± 1.1	30.5 ± 1.1	0.024
Glycogen (%)	15.5 ± 1.0	14.8 ± 1.0	0.619
Glycogen (%) ²	15.5 ± 1.0	14.8 ± 1.0	0.683
Glycogen (g kg birth weight ⁻¹)	5.4 ± 0.4	4.6 ± 0.4	0.214
G6-Pase activity (µmol P min ⁻¹ g ⁻¹)	13.1 ± 2.7	11.9 ± 2.9	0.771

Each value represents least squares mean ± SEM for each genotype. ¹ There were 12 piglets per genotype, at the exception of G6-Pase activity (6 piglets per genotype). ² Adjusted for birth weight.

Discussion

The gestational feeding regimens were different between genotypes and individual ingestion was not measured. During most part of the gestation period AL sows were reared under typical production system of the breed in Alentejo region, in outdoor extensive conditions without control of their physical activity. However, with the exception of an extremely low level

of feeding, *i.e.*, 0.45 kg d⁻¹ from d 85 to farrowing (Ojamaa *et al.*, 1980), or a severe protein deficiency (Pond *et al.*, 1969), most of the studies (Yen *et al.*, 1982; Hausman *et al.*, 1991; Ruwe *et al.*, 1991) reported no significant influence of gestational feeding (frequency, quantity, composition) both on birth weight or body composition of newborn piglets. The only exception is the fatty acids composition that can be influenced by the gestational feeding composition in fatty acids (Gerfault *et al.*, 1999; Rooke *et al.*, 2001) as has been observed in the current trial. Therefore, the observed differences between newborn of the two genotypes studied, should be largely attributed to differences in production systems (genotype + environment) and not to the different feeding regimens. Also, despite differences in feeding quantities and physical activity, body condition at farrowing of AL sows, estimated from the depth of subcutaneous fat just after farrowing was similar to that of LL sows.

On the whole, reproductive performance results of AL sows in this experiment are largely similar to those reported by Charneca (2001) and by Marques (2001). Briefly, AL sows are less prolific than LL sows, have a lower duration of gestation (Nunes, 1993) while piglets are lighter at birth and present a higher mortality rate until weaning.

Whereas carcass chemical composition of the LL piglets agrees with those previously reported for this genotype (Herpin *et al.*, 1993; Canario *et al.*, 2007b), results of this study indicate that AL piglets differ markedly at birth from LL piglets on body composition, plasma glucose, albumin and IGF-1 concentrations. After adjustment for birth weight, the AL newborns possess more dry matter and protein contents than LL piglets while body fat only tends to be higher in AL piglets. It is relevant to notice that despite the capacity for protein synthesis estimated from the RNA/protein ratio (Attaix *et al.*, 1988) tended to be lower in AL piglets, the percentage of body protein was higher than in LL piglets. This and the modest difference in the percentage of body fat between AL and LL piglets are the reverse of what has been reported for these pigs at seven weeks of age (Freire *et al.*, 1998) and older (Nunes, 1993; Nieto *et al.*, 2002). Perhaps, as in the Meishan pig (Bonneau *et al.*, 1990), protein deposition in older AL pigs is limited by the number of muscle fibers which is fixed at birth. The Meishan pig has less muscle fibers at birth. This remains to be determined in AL piglet. However that may be, present results are largely similar to those reported when

foetuses from obese and lean strains of pigs (Hoffman *et al.*, 1983; Stone *et al.*, 1985) and, newborns from Meishan breed and those from a line highly selected for muscle growth are compared (Herpin *et al.*, 1993). Genetic selection on lean growth and litter size from 1977 to 1998 also resulted in similar differences in the body composition of the newborns (Canario *et al.*, 2007b).

Although total body fat content at birth was similar in AL piglets, those born from sows which consume acorns had more C18:1 in their body fat than those born to AL sows deprived of acorns or LL piglets. Acorns contain high level of C18:1 (higher than 60% of fatty acids, Rey *et al.*, 1997). This would suggest that some dietary fatty acids could cross the porcine placenta, in agreement with Gerfault *et al.* (1999) and Rooke *et al.* (2001). Further, colostrum from sows fed acorns during gestation is found to contain more fat with a higher proportion of C18:1 (Charneca, 2001). These and the fact that oleic acid is the most readily fatty acid oxidized by the newborn pig (Schmidt and Herpin, 1998) suggest that feeding acorns to gestating sows would be of interest for the energy metabolism of the newborn pig.

In this study, AL piglets had relative heavier livers but there was no significant effect of genotype on liver glycogen stores. Indeed, hepatic gluconeogenic capacity is not affected by genotype as illustrated by the activity of the G6-Pase. Further, muscle glycogen concentration is not affected by genotype. Therefore, despite a 4 days difference in gestation length, glycogen reserves are similar in both genotypes. These results agree with those reported when comparing piglets born from obese Meishan sows to those born from a line highly selected for muscle growth (Herpin *et al.*, 1993) while genetic selection for lean growth and litter size from 1977 to 1998 also resulted in a decrease in the relative weight of the liver (Canario *et al.*, 2007b).

There was an effect of genotype on plasma glucose, albumin and IGF-1 concentrations, all being higher in AL piglets. These results agree with what has been observed when comparing piglets born to obese Meishan sows to those born to a line highly selected for muscle growth (Herpin *et al.*, 1992, 1993). Genetic selection for lean growth and litter size from 1977 to 1998 also resulted in similar changes in plasma parameters (Canario *et al.*, 2007b). Plasma glucose concentrations are variable at birth, increasing during the course of parturition (Herpin *et al.*, 1996). However, in this study data were adjusted to birth time. There-

fore, the higher plasma glucose concentrations found in AL piglets might be a trait of this breed. In some studies, the within-litter plasma albumin (Stone and Christenson, 1982; Wise *et al.*, 1991) and IGF-1 concentrations (Herpin *et al.*, 1992) are positively related to birth weight. In the present study only the within-litter plasma concentration of albumin was positively correlated to birth weight in AL piglets, suggesting that plasma albumin and IGF-1 concentrations are not invariably correlated with birth weight.

Overall, both vital deposition of energy reserves and chemical body composition are not impaired in Alentejano newborns despite a shorter gestation length. Further, increased body protein at birth, relative liver weight (Herpin *et al.*, 1993; Canario *et al.*, 2007b) and plasma albumin (Stone and Christenson, 1982; Wise *et al.*, 1991) are considered as good indexes of development and maturity. Similarly, level of plasma IGF-1 is considered to be indicative of the maturity of the IGF axis (Greenwood *et al.*, 2002). On these bases, piglets born from Alentejano sows are expected to be more mature at birth than those born from conventional sows. Further, similar to the Meishan female (Legault and Caritez, 1983), the onset of puberty occurs earlier in the IB female (González-Añover *et al.*, 2009) than in modern commercial crosses (LW × LR) when fed similarly. This and the greater maturity at birth would indicate that the IB swine is more precocious than conventional swine. Genetic selection for lean growth and litter size from 1977 to 1998 also resulted in a shorter, but to a lesser extent, duration of gestation (Canario *et al.*, 2007a). However, this shorter gestation length was associated with a less maturation of piglets (Canario *et al.*, 2007b). Therefore, a shorter gestation length may be specific for the Alentejano breed.

In conclusion, the shorter gestation length of AL sows has no negative effect on the energy stores of the newborn. However, the body protein content at birth is markedly higher in AL than in LL piglets suggesting that studies are required to determine the muscle histochemical and biochemical characteristics at birth. This would help to understand the low potential of the growing animal to deposit protein. Further, the reduction of piglet mortality is an important goal during the neonatal period. In this respect, future research should focus on the early nutrition (colostrum consumption) and the acquisition of passive immunity of piglets as well on the mothering ability of the sows.

Acknowledgements

The authors wish to thank the Fundação Eugénio de Almeida (Portugal) for the scholarship assigned to the first author that partially financed this study. The technical assistance of Françoise Thomas for analysing several samples is also acknowledged.

References

- ATTAIX D., AUROUSSEAU E., BAYLE G., ROSOŁOWSKA-HOSZCZ D., ARNAL M., 1988. Respective influences of age and weaning on skeletal and visceral muscle protein synthesis in the lamb. *Biochem J* 256, 791-795.
- BONNEAU M., MOUROT J., NOBLET J., LEFAUCHEUR L., BIDANEL J.P., 1990. Tissue development in Meishan pigs: muscle and fat development and metabolism and growth hormone regulation by somatotrophic hormone. In: 41st EAAP Annual Meeting. Satellite Symposium on Chinese Pigs, Toulouse, 5-6 July (Molénat M., Legault C., eds). pp. 199-213.
- CANARIO L., RYDHMER L., GOGUÉ J., TRIBOUT T., BIDANEL J.P., 2007a. Estimation of genetic trends from 1977 to 1998 for farrowing characteristics in French Large-White breed using frozen semen. *Animal* 1, 929-938.
- CANARIO L., PÈRE M.C., TRIBOUT T., THOMAS F., DAVID C., GOGUÉ J., HERPIN P., BIDANEL J.P., LE DIVIDICH J., 2007b. Estimation of genetic trends from 1977 to 1998 of body composition and physiological state of Large-White pigs at birth. *Animal* 1, 1409-1413.
- CHARNECA R., 2001. Estudo comparativo da composição química do colostro e do leite de porcas de raça alentejana e porcas Large-White × Landrace (efeitos sobre a sobrevivência neo-natal, o crescimento e a composição corporal dos leitões). Master's thesis. Superior Institute of Agronomy, Technical University of Lisbon. 88 pp. [In Portuguese].
- DE JUANA SARDÓN A., 1954. El cerdo de tipo ibérico en la provincia de Badajoz. *Cons Sup Inv Cient (CSIC), Dept Zootecnia, Córdoba*. [In Spanish].
- DE PASSILLÉ A.M.B., HARTSOCK T.G., 1979. Within- and between-litter variation of proximate composition in newborn and 10-day-old Landrace swine. *J Anim Sci* 49, 1449-1457.
- DOBAO M.T., RODRIGÁÑEZ J., SILIO L., TORO M.A., 1988. Iberian pig production in Spain. *Pigs News and Information* 9(3), 277-282.
- DOURMAD J.Y., ÉTIENNE M., NOBLET J., 2001. Mesurer l'épaisseur de lard dorsal des truies pour définir leurs programmes alimentaires. *INRA Productions Animales* 14(1), 41-50. [In French].
- FISKE C.H., SUBBAROW Y., 1925. The colorimetric determination of phosphorus. *J Biol Chem* 66, 375-400.

- FOLCH J., LEES M.M., SLOANNE-STANLEY G.H., 1957. A simple method for the isolation and purification of total lipids from animal tissues. *J Biol Chem* 226, 497-509.
- FREIRE J.P.B., MOUROT J., CUNHA L.F., ALMEIDA J.A.A., AUMAITRE A., 1998. Effects of the source of dietary fat on postweaning lipogenesis in lean and fat pigs. *Ann Nutr Metab* 42, 90-95.
- GERFAULT V., MOUROT J., ETIENNE M., MOUNIER A., 1999. Influence de la nature des lipides dans le régime de gestation de la truie sur ses performances et la composition corporelle des porcelets à la naissance. *Journées de la Recherche Porcine en France* 31, 191-197. [In French].
- GONZÁLEZ-AÑOVER P., ENCINAS T., GÓMEZ-IZQUIERDO E., SANZ E., LETELIER C., TORRES-ROVIRA L., PALLARES P., SÁNCHEZ-SÁNCHEZ R., GONZÁLEZ-BULNES A., 2009. Advanced onset of puberty in gilts of Thrifty genotype (Iberian Pig). *Reprod Domest Anim*. doi: 10.1111/j.1439-0531.2009.01476.x.
- GREENWOOD P.L., HUNT A.S., SLEPETIS R.M., FINNERTY K.D., ALSTON C., BEERMAN D.H., BELL A.W., 2002. Effects of birth weight and postnatal nutrition on neonatal sheep: III Regulation of energy metabolism. *J Anim Sci* 80, 2850-2861.
- HARPER A.E., 1965. Determination of glucose-6-phosphatase. In: *Methods of enzymatic analysis* (Bergmeyer H.U., ed), Academic Press, NY. pp. 788-792.
- HAUSMAN D.B., SEERLEY R.W., MARTIN R.J., 1991. Effect of excess dietary fat during the third trimester of pregnancy on maternal, placental, and fetal metabolism in the pig. *Biol Neonate* 59, 257-267.
- HERPIN P., LE DIVIDICH J., DUCHAMP C., DAUNCEY M.J., 1992. Relation between plasma concentration of insuline-like growth factor-1 and birth-weight in pigs. *J Physiol* 446, 276.
- HERPIN P., LE DIVIDICH J., AMARAL N., 1993. Effect of selection for lean tissue growth on body composition and physiological state of the pig at birth. *J Anim Sci* 71, 2645-2653.
- HERPIN P., LE DIVIDICH J., HULIN J.C., FILLAUT M., DE MARCO F., BERTIN R., 1996. Effects of the level of asphyxia during delivery on viability at birth and early postnatal vitality of newborn pigs. *J Anim Sci* 74, 2067-2075.
- HOFFMAN E.C., WANGSNESS P.J., HAGEN D.R., ETHERTON T.D., 1983. Fetuses of lean and obese swine in late gestation: body composition, plasma hormones and muscle development. *J Anim Sci* 57, 609-620.
- LABARCA C., PAIGEN K., 1980. A simple, rapide and sensitive DNA assay procedure. *Anal Biochem* 102, 344-352.
- LE DIVIDICH J., MORMÈDE P., CATHELIN M., CARITEZ J.C., 1991. Body composition and cold resistance of the neonatal pig from European (Large White) and Chinese (Meishan) breeds. *Biol Neonate* 59, 268-277.
- LEGAULT C., CARITEZ J.C., 1983. L'expérimentation du porc chinois en France. I- Performances de reproduction en race pure et en croisement. *Génét Sél Evol* 15(2), 225-240. [In French].
- LÓPEZ-BOTE C.J., 1998. Sustained utilization of the Iberian pig breed. *Meat Sci* 49(Suppl 1), S17-S27.
- LOUVEAU I., BONNEAU M., 1996. Effect of growth hormone infusion on plasma insuline-like growth factor-1 in Meishan and Large-White pigs. *Reprod Nutr Dev* 36, 301-310.
- LOWRY O.H., ROSEBROUGH N.J., FARRA L., RONDALL R.J., 1951. Protein measurement with the Folin phenol reagent. *J Biol Chem* 193, 265-275.
- MARQUES P.N.G., 2001. Características produtivas e reprodutivas do porco Alentejano—Influências genéticas e ambientais. Doctoral thesis. University of Évora, Portugal. 223 pp. [In Portuguese].
- MARQUES P., TIRAPICOS NUNES J.L., COLAÇO J., ALMEIDA J.A., 1996. Influence de la mortalité dans la productivité de la truie Alentejana. *Produzione Animale IX* (III Série, Num Spec), 19-22. [In French].
- MCPHERSON R.L., JI F., WU G., BLANTON J.R., KIM S.W., 2004. Growth and compositional changes of fetal tissues in pigs. *J Anim Sci* 82, 2534-2540.
- MUNRO H.N., FLECK A., 1969. Analysis of tissues and body fluids for nitrogenous constituents. In: *Mammalian Protein Metabolism n° 3* (Munro H.N., ed). Academic Press, NY. pp. 423-525.
- NIETO R., MIRANDA A., GARCÍA M.A., AGUILERA J.F., 2002. The effect of dietary protein content and feeding level on the rate of protein deposition and energy utilization in growing Iberian pigs from 15 to 50 kg body weight. *Brit J Nutr* 88, 39-49.
- NUNES J.L.T., 1993. Contributo para a reintegração do porco Alentejano no Montado. Doctoral thesis. Univ Évora, Portugal. 230 pp. [In Portuguese].
- OJAMAA K.M., ELLIOT J.I., HARTSOCK T.G., 1980. Effects of gestation feeding level on glycogen reserves and blood parameters in the newborn pig. *J Anim Sci* 51, 620-628.
- OKAI D.B., WYLLIE D., AHERNE F.X., EWAN R.C., 1978. Glycogen reserves in the fetal and newborn pig. *J Anim Sci* 46(2), 391-401.
- POND W.G., STRACHAN D.N., SINHA Y.N., WALKER Jr. E.F., DUNN J.A., BARNES R.H., 1969. Effect of protein deprivation of swine during all or part of gestation on birth weight, postnatal growth rate and nucleic acid content of brain and muscle of progeny. *J Nutr* 99, 61-67.
- REHFELDT C., KUHN G., 2006. Consequences of birth weight for postnatal growth performance and carcass quality in pigs as related to myogenesis. *J Anim Sci* 84 (E Suppl), E113-E123.
- REY A.I., LÓPEZ-BOTE C.J., SANZ ARIAS R., 1997. Effect of extensive feeding on α -tocopherol concentration and oxidative stability of muscle microsomes from Iberian pigs. *Anim Sci* 65, 515-520.
- ROBLEDÓ J., VARGAS J.D., GONZÁLEZ F., PRIETO L., ANDRADAS J.A., APARICIO M., 2008. Animal welfare and production in the Iberian pig. *Proc 6th International Symposium on the Mediterranean Pig*. Messina-Capo

- d'Orlando. Italy October 11-13, 2007 (Nanni Costa L., Zambonelli P., Russo V., eds). pp. 146-152 [on line]. Available in <http://amsacta.cib.unibo.it/archive/00002513/> [18 July, 2009].
- ROOKE J.A., SINCLAIR A.G., EDWARDS S., 2001. Feeding tuna oil to the sow at different times during pregnancy has different effects on piglet long-chain polyunsaturated fatty acid composition at birth and subsequent growth. *Brit J Nutr* 86, 21-30.
- RUWE P.J., WOLVERTON C.K., WHITE M.E., RAMSAY T.G., 1991. Effect of maternal fasting on fetal and placental lipid metabolism in swine. *J Anim Sci* 69, 1935-1944.
- SCHMIDT I., HERPIN P., 1998. Carnitine palmitoyl-transferase I (CPT I) activity and its regulation by malonyl-CoA are modulated by age and cold exposure in skeletal muscle mitochondria from newborn pigs. *J Nutr* 128, 886-893.
- SPSS, 2007. Statistical package for the social sciences. Version 16.0, SPSS Inc., Chicago, IL.
- STONE R.T., CHRISTENSON R.K., 1982. The relationship of fetal weight to serum albumin and alpha-fetoprotein in swine. *J Anim Sci* 55, 818-825.
- STONE R.T., CAMPION D.R., KLINDT J., MARTIN R.J., 1985. Blood parameters and body composition in fetuses from reciprocal crosses of genetically lean and obese swine. *Proceeding of the Society for Experimental Biology and Medicine* 180, 191-195.
- WISE T., STONE R.T., VERNON M.W., 1991. Relationships of serum estradiol, cortisol and albumin concentrations with pig weight at 110 days of gestation and at birth. *Biol Neonate* 59, 114-119.
- YAMADA Y., AUMAITRE A., LE DIVIDICH J., 1982. Influence d'une naissance prématurée sur les taux de protéines et d'albumine du serum sanguin des porcelets. *Ann Zootech* 31(3), 301-310. [In French].
- YEN J.T., EICHNER R.D., ARNOLD R.J., POND W.G., 1982. Tissue glycogen levels in dams and fetuses as affected by fasting and refeeding pregnant sows. *J Anim Sci* 54(4), 796-799.