Proceedings of the 4th International Congress
New Perspectives and Challenges of Sustainable Livestock Production
October 7 – 9, 2015

AN OVERVIEW OF PROTEIN NUTRITION OF THE PURE IBERIAN PIG

J. F. Aguilera, L. Lara, M.A. Aguinaga, R. Barea, J. A. Conde-Aguilera, R. García-Valverde, P. Palma-Granados and R. Nieto

Department of Physiology and Biochemistry of Animal Nutrition, Estación Experimental del Zaidín, CSIC, Camino del Jueves, s/n, 18100, Granada, Spain
Corresponding author:rosa.nieto@eez.csic.es
Invited paper

Abstract: An accurate assessment of the animal’s requirements is of utmost importance for a balanced nutrition of farm animals. In this review we describe the results from a series of experiments, performed during the last years by our research group, aiming at assessing the utilization of dietary protein by the Iberian pig throughout the different stages of its productive cycle. Nutritional dose-response studies involving several isoenergetic treatments differing in protein concentration -all with similar aminoacid profile following the ideal protein concept- along with comparative growth and metabolic studies with conventional breeds have been performed. Our observations reveal that the capacity of this breed for protein accretion is rather limited compared to that of conventional or lean breeds at similar stages of growth. They also suggest the need for reducing the concentration of protein in the diet of the Iberian pig to comply with the metabolic profile of this native pig breed. We summarise all the information gathered during the last fifteen year sand provide recommendations on the level and composition of dietary protein in the diet for pure breed animals during the different phases of growth. An adequate nutritional management, particularly dietary protein provision, improves the efficiency of utilization of dietary protein and results in relevant economic, environmental and animal welfare benefits.

Key words: protein nutrition, Iberian pig, amino acids, growth, efficiency

Introduction

One of the metabolic singularities of the pure Iberian pig is its low genetic capacity for lean tissue deposition. The scientific evidence available shows that, in the growing pig, protein deposition is a protein-dependent process below an optimal protein supply per unit of energy. This relationship has been described as a linear function up to a breakpoint beyond which protein deposition becomes largely dependent on energy supply (*Campbell et al., 1984, 1988; Kyriazakis and Emmans, 1992*). In Figure 1 are shown the relative proportions of protein and fat deposited during the growth and fattening of the Iberian pig. For comparison, data on Large-White pigs are also provided. Protein deposition is comparatively lower and fat deposition much higher in Iberian pigs for the body-weight ranges studied, compared with available data from conventional pigs. We measured N retention in a comparative study with Iberian and Landrace gilts of approximately 25 kg BW fed diets of 120 and 160 g crude (ideal) protein/kg (12.0 MJ EM/kg). Nitrogen retention and efficiency of N retention was significantly lower in Iberian gilts, particularly those fed the higher protein content diet (*Rivera-Ferre et al., 2006*). We have aimed also at identifying the primary causes that limit protein accretion in this native pig breed. In this sense, several years ago, we measured by isotopic techniques protein synthesis rates in different muscles and viscera of Iberian and Landrace gilts (*Rivera-Ferre et al., 2005*). Surprisingly, for the 3 muscles studied (*Longissimus dorsi, biceps femoris, semimembranosus*) synthesis rates were 25-30% higher in the Iberian pigs; however, muscles relative weights (g/kg BW) were 20-30% lower. Overall, these findings suggest that in the Iberian pig muscles both protein synthesis and degradation are comparatively higher leading to reduced protein accretion (g/d) and less body protein mass in comparison with conventional pigs. Consequently, the energy cost of protein accretion should be higher in the native breed as both processes require considerable amounts of energy. We have confirmed this in later studies (*Barea et al., 2007; Conde-Aguilera et al., 2011; Nieto et al., 2012*). Along with the higher protein turnover rates, the higher relative weights of viscera (*Rivera-Ferre et al., 2005*) makes the Iberian pig less efficient in the use of dietary protein and energy than its lean counterparts. Therefore, in the light of this metabolic profile, it seems reasonable to design a feeding system adapted to the particular metabolic needs of this native pig breed.

Materials and Methods

We have assessed protein requirement of the Iberian pig by analysing animal growth and protein-deposition responses to variable protein intakes. In this way, both the pig maximum capacity to accrete protein (Pmax, g/d) and the response in protein deposition (PD) to changes in energy intake can be determined. This last concept is called *marginal efficiency of proteindeposition* and it represents the increment in protein deposition per unit of increment in metabolizable energy intake (MEI) at restricted intakes (ΔPD/ΔMEI g/MJ). Both variables are influenced by genotype andendocrine status, so the optimal protein/energy ratio may be different for breeds with dissimilar genetic potential for PD.

Dietary protein in our experiments have been formulated always following the "ideal protein concept" (i. e., the perfect balance of essential amino acids needed for maintenance and productive functions, BSAS, 2003; NRC, 2012). All the pigs used in the experimental designs have been pure Iberian from the *Silvela* strain provided by a single producer (Sánchez Romero Carvajal Jabugo, S.A, Spain). The method used for quantifying body PD along all the experiments shown has been the comparative slaughter technique.

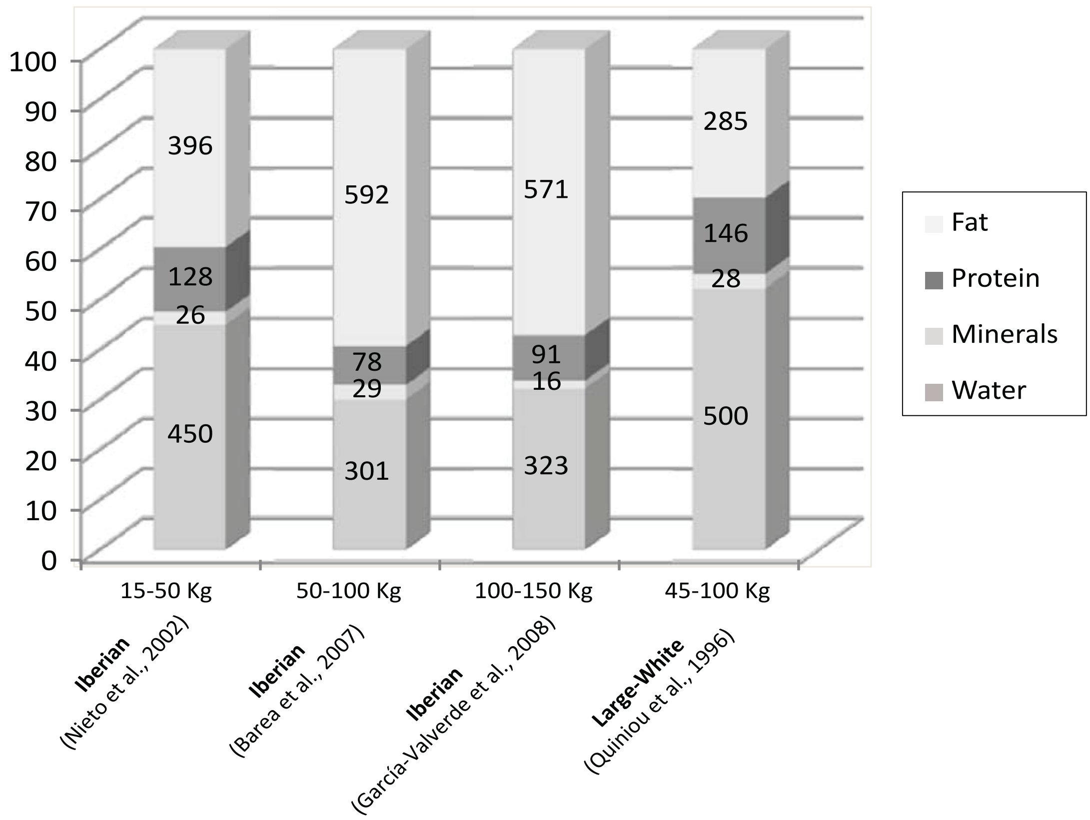

Figure 1. Body-weight gain composition of growing Iberian and conventional-type pigs.

Results and discussion

In studies with growing pigs, performed in the BW range of 15 to 50 kg BW, 6 dietary protein and 3 feeding levels were allocated into a factorial arrangement (6 × 3) with 4 pigs per treatment combination. Protein levels used were: 101, 129, 156, 175, 192 y 223 g crude protein (CP)/kg dry matter (DM), and feeding levels 0.95, 0.80 and 0.60 of *ad libitum* intake (*Nieto et al., 2002*). Experimental diets were prepared by diluting a diet of highprotein content (based on barley and soya bean meal) with a protein-free mixture base on maize starch.

Therefore,dietary protein/energy ratiowas progressively reduced without changing protein amino acid profile. Average digestible energy content was 15.2 MJ/DM. Best performance was obtained in pigs fed 129 gCP/DM diet at 0.95 × *ad libitum,* reaching 559 g average daily gain (ADG) and 74 g protein deposited/day (*Pmax*). This figure is considerably lower to those described for conventional or lean pigs which can attain values of 170 g/d or even above for this BW range. This dietary treatment provides 8.49 g CP/MJ ME, equivalent to 6.87 g digestible protein /MJ ME. The marginal efficiency of protein deposition was 2.81g/MJ.

In growing-fattening Iberian pigs (50-100 kg BW) an experiment according to a factorial arrangement (4 dietary protein × 3 feeding levels) with 6 or 7 pigs per treatment combination was carried out. Dietary treatments were obtained in a similar manner as previously described resulting in four diets containing 70, 95, 120 and145 gCP/kg DM (*Barea et al., 2007*). Feeding levels were the same as in growing pig experiments. In this case PD showed a trend to increase with decreasing dietary CP until 95 g/kg DM. With this dietary regime pigs also grew faster (854 g/d). *Pmax* reached 71g/d with pigs consuming this treatment at 0.95 × *ad libitum*. In energy terms, this diet provides6.60 g CP/MJ ME or 5.20 g digestible protein/MJ ME. The capacity for PD was considerably reduced compared with growing pigs as shown by the lower marginal efficiency of protein deposition obtained,1.43 g/MJ.

For conventional pigs of similar BW ranges, the National Research Council (*NRC, 2012*) recommends protein intakes 35 and 50% above those found to fit Iberian pig requirements. Clearly, if Iberian pig feeding programmes would follow these guidelines, the oversupply of protein would impact negatively in animal growth, lean tissue deposition, farm economy and environmental pollution.

Following similar procedures, growth, carcass and PD parameters were studied in finishing Iberian pigs (100-150kg BW, *García-Valverde et al., 2008*). For practical reasons, dietary protein level was fixed at the same value found optimal for 50-100 BW growing-fattening pigs (i. e.,95 g/kg DM) and the feeding level adjusted either at 0.95 or 0.70 × *ad libitum*, with 6 pigs allocated to each. Daily protein gain was not modified by feeding level and averaged 80 g/d (very close to previous observations in growing and fattening pigs). It is noticeable than in restrictedly fed pigs lean content/kg carcass gain was increased. Therefore, a degree of feed restriction may result in an improvement in carcass quality and deserves attention in the feeding management of the finishing Iberian pig reared indoors.

The potential for protein deposition in the pig decreases as the animal approaches maturity (*van Lunen & Cole, 1996*) and protein needs change accordingly. For this reason, optimum protein levels during post-weaning were further investigated, as the potential for lean tissue deposition could differ from the observed in growing pigs from 15 to 50 kg BW. With this aim, an experiment to investigate protein requirement from 10 to 25kg BW was designed including 4 protein concentrations (201, 176, 149 y 123 g CP/kg DM) and 2 levels of feeding (0.95 or 0.70 × *ad libitum*) with 6 or 7 piglets per combination of treatments (*Conde-Aguilera et al., 2011*).Orthogonal polynomial contrast analysis revealed a significant linear effect of protein level upon body protein retention, suggesting that maximum PD was not achieved (no significant quadratic effect was observed). On the other hand, mean treatment comparison showed that pigs consuming the higher protein concentration diets -210 and176 gCP/kg DM-showed similar PD which suggests that the aforementioned PD values could be close to *Pmax* for this growing phase. The maximal values for ADG, and PD were obtained in piglets fed the greatest CP diet at 0.95 × ad libitum, 416 and 60 g/d, respectively. This treatment provides 11.0 g digestible protein (0.77 g digestible lysine)/MJ ME. The marginal efficiency of body PD (ΔPD:ΔME) obtained with diets supplying 210 and176 gCP/kg DM, 4.39 g/MJ of ME, indicates greater efficiency of PD when compared with previously determined values in growing and growing-fattening pigs (2.81 and 1.34 g/MJ, respectively).

For all previously described studies, dietary protein was formulated following the optimum AA pattern – in terms of g AA/kg CP – established for conventional growing pigs (*NRC, 2012; BSAS, 2003*). Nevertheless, it remained questionable if this protein profile would be the more adequate for the growth of these obese pigs. Therefore a study was designed with the aim of determining the optimum Lys proportion of dietary protein for Iberian piglets by analyzing responses in growth, carcass nutrient deposition and plasma metabolites (*Nieto et al., 2015*). Six diets containing increasing Lys concentrations at a constant dietary CP content (165 ± 0.7 g/kg DM) were prepared by adding L-Lys HCl at the expense of corn starch, providing Lys:CP ratios of 43, 47, 52, 57, 64 and 72 g/kg. Ten piglets were allocated to each treatment. Carcass PD increased linearly and quadratically on increasing dietary Lys, reaching maximum values (39.3–40.2 g /d) with diets providing 57, 64 and 72 g Lys/kg CP. The first derivative of the quadratic function relating carcass PD and dietary Lys content gave a value of 63.7 g Lys/kg CP. Plasmaurea concentration tended to decrease on increasing Lys concentration and, both the broken- line and quadratic approach gave an estimate for Lys requirements of61.2 g Lys/kg dietary CP. However, our preferred estimate, based on carcass PD – the more reliable measure of metabolic Lysutilization – is 63.7 g Lys/kg CP, somewhat below the established for conventional piglets.

In another set of experiments was investigated the likely causes for the slow growth rate of the Iberian suckling piglet compared with lean and conventional pig types (*Aguinaga et al., 2011*). The starting hypothesis was that these lower rates of growth could be caused either by an insufficient milk nutrient supply (related to less milk intake or less nutrient concentration in the Iberian sow milk compared with leaner sows´milk) or by a decreased milk nutrient utilization efficiency. The lactation period was extended up to 34 days. Mean birth weight was 1.4 kg. The average growth rate over lactation was 168 g/d, and mean milk intake during this period 863 g/pig per day, comparable to values described for conventional piglets (*ARC, 1981*) if appropriate corrections for Iberian litter size are applied (6 piglets/litter). Moreover, the composition of Iberian sow's milk showed little differences compared to milk from other porcine breeds (*Klobasa et al., 1987*). When weight gain was related to energy intake from milk we obtained the equation: ADG (g/d) = 0.0148 milk gross energy intake (KJ/d). The slope of this equation indicates that for each MJ increment in energy intake, the growth of the Iberian suckling piglet increases by 41.8 g. In energy terms, this figure implies 24 kJ per gram of weight gain, a value 30% greater compared with similar estimations in leaner suckling piglets (18.4 MJ, *Noblet et al., 1998*). Mean values for body protein, fat and energy retention over the lactation period were 27.4 g, 22.7 g and 1615 KJ, respectively. The efficiency for protein retention was 0.59, meanwhile in lean pigs has been described as 0.85 or even higher (*Noblet & Etienne, 1986*). The conclusion from these experiments was that the lower growth rate observed in Iberian compared with conventional suckling piglets seems to be related to a lower efficiency of utilization of milk nutrients and not to a decreased nutrient intake. In further experiments with suckling piglets provided with creep feed during lactation a similar figure for whole-body PD was obtained (*Castellano et al., 2014*) suggesting that *Pmax* for this growing period is close to 27.4 g/d.

The graphic evolution of the maximum capacity of the Iberian pig for PD (*Pmax*) during growth is represented in Figure 2. According to the previously discussed results, *Pmax* increases rapidly during the earlier phases of growth (*Conde-Aguilera et al., 2011, Nieto et al., 2002*) to reach a plateau thereafter. The inflexion point corresponds to 32.5 kg BW, mid-point of the study performed with growing pigs from 15 to 50 kg BW (*Nieto et al., 2002*). Beyond this point, *Pmax* is maintained at an average value of 75 g/d. The equation that best fits this model is: $Pmax = 77.5 \pm 2.86 - 218 \pm 26.2 \times 1 / BW_{(mean)}$.

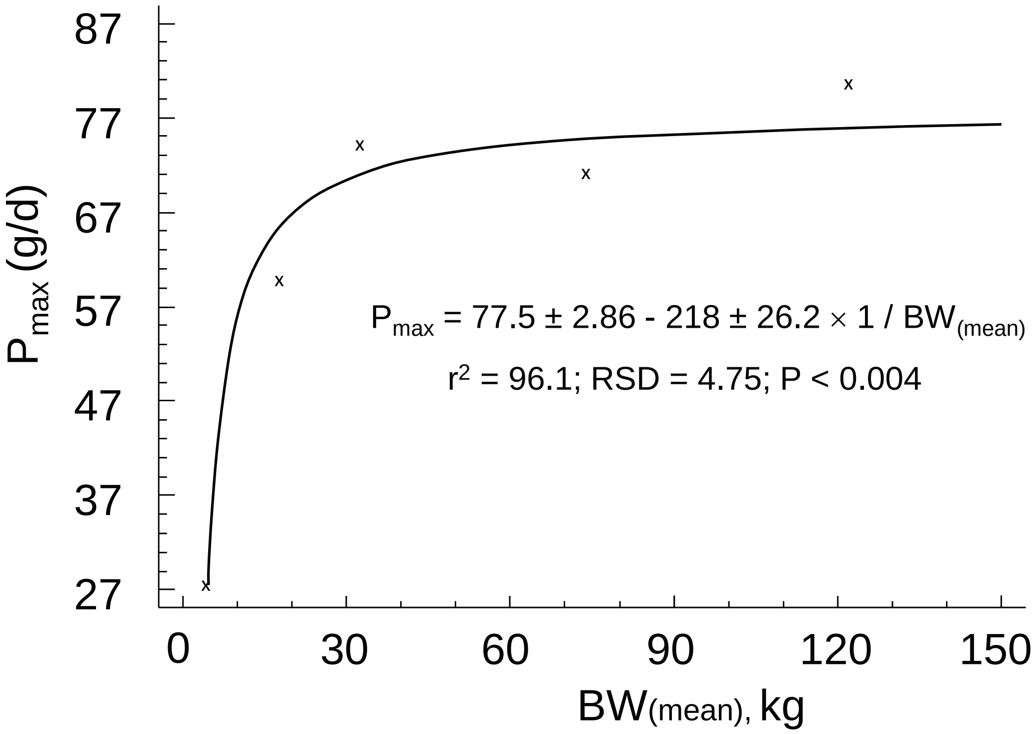

Figure 2. Evolution of maximum capacity for body protein deposition in the Iberian pig

During the previous discussion, we have already mentioned that the marginal efficiency of protein deposition, i. e., the response in PD to changes in energy intake, which is estimated as the slope of the linear relationship between PD and MEI, undergo considerable changes along the Iberian pig productive cycle. In this sense, the slope achieved a value of 4.39 g/MJ EM in post-weaned piglets from 15 to 25 kg BW (*Conde-Aguilera et al., 2011*) decreased to 2.81 g/MJ EM in growing pigs from 15 to 50 kg (*Nieto et al., 2002*), and decreased further to 1.34 g/MJ EM in growing-fattening pigs from 50 to 100 kg PV (*Barea et al., 2007*). This means that the growing phase of the pig has a determinant influence upon the effect of energy intake over the process of body protein deposition. For the last finishing period (100-150 kg BW) we have assumed that ΔPD/ΔME approaches zero, similar to what have been described in conventional pig genotypes. Overall, our results show that when the Iberian pig is fed under dietary regimes with optimum or sub-optimum protein/energy ratio, the relationship between PD and MEI decreased as the pig increases BW (age), following a curvilinear patter described by the equation:

$\Delta PD/\Delta EM = 10.6 \pm 0.46 - 2.20 \pm 0,117 \times \ln BW\ (_{mean})$; $r^2 = 99.4$; RSD = 0.173; P < 0.003

These findings are in the line of those described for conventional pig genotypes by *Black et al. (1986)* and *Bikker (1994)*, who also observed decreases in the marginal efficiency for protein deposition as the pig increases in BW.

Finally, in Figure 3 there is a summary of the productive performance parameters observed in the Iberian pig from the post-weaning to the finishing period, along with the protein recommended intakes for each growth period. These recommendations could be useful for the nutrition of other autochthonous pig breeds whose protein requirements are completely unknown.

Body weight range	10-25 kg	25-50 kg	50-100 kg	100-150 kg
Performance parameters				
Maximum protein deposition capacity (P_{max}), g/d	60	74	71	80
Average daily gain, g/d	416	559	854	679-917
Δ protein deposition / Δ energy intake, g/MJ ME	4.39	2.81	1.43	≈ 0
Recommendations				
Crude protein (ideal) / Dry matter, g/kg	201	129	95	95
Ap. digestible protein (ideal) / ME, g/MJ	11.0	6.86	5.20	4.84
Ap. digestible lysine / ME, g/MJ	0.77	0.54	0.36	0.34

Figure 3.Recommended protein intakes for the Iberian pig during different growth phases.

Conclusion

The overall analysis of the results presented in this review underline the loss of efficiency that undergo the PD process as the pig advances in BW and age. This is reflected in the considerable decrease in the marginal efficiency of PD from the early stages of growth, expressed by a curvilinear function. The decrease in this parameter is more noticeable in the Iberian pig that, therefore, does not follow the growth models developed for conventional or lean pig types. These, and other findings, fully support the use of dietary regimes of lower protein concentration adjusted to the particular needs of the growth period under consideration, as protein needs suffer a dynamic change along the productive life of the animal. There are several advantages associated to this practice; one of them is the environmental benefit derived from the lesser nitrogenous wastes produced, as all the protein (nitrogen) provided in oversupply will be finally catabolized and excreted; on the other hand, protein reduction in feeds could imply also an economic benefit for the producer as usually protein is one of the most expensive feed ingredients. There are also animal health and welfare considerations as protein excess can cause digestive problems in weaning piglets, and also can be deleterious for Ca metabolism according to our last findings in this area (Nieto et al., unpublished).

Acknowledgment

Supported by Spanish Ministry of Economy and Competiveness (MINECO) grants No. AGL2011-25360 and AGL2008-0255, and Junta de Andalucía, grants No. AGR-395 and AGR-5886. We are also very grateful to Sánchez Romero CarvajalJabugo S.A. (El Puerto de Santa María, Cádiz, Spain) for providing the experimental animals.

Proteini u ishrani autohtone iberijske svinje

J. F. Aguilera, L. Lara, M.A. Aguinaga, R. Barea, J. A. Conde-Aguilera, R. García-Valverde, P. Palma-Granados, R. Nieto

Rezime

Tačnu procenu uslova potreba životinje je od izuzetnog značaja za uravnoteženu ishranu domaćih životinja. U ovom pregledu se opisuju rezultati niza eksperimenata naše istraživačke grupe, obavljenih tokom poslednjih godina, u cilju procene korišćenje proteina u ishrani iberijske svinje tokom različitih faza njenog proizvodnog ciklusa. Studije koje se bave ishranom i tretmanima/dozama koje uključuju nekoliko izoenergetskih tretmana koji se razlikuju u koncentraciji proteina - sa sličnim aminokiselinskim profilom koji prati koncept idealnog proteina - zajedno sa komparativnim studijama rasta i metabolizma sa konvencionalnim rasama su izvršene. Naša zapažanja pokazuju da je kapacitet ove rase za deponovanje proteina prilično ograničen u poređenju sa konvencionalnim ili mesnatim rasama u sličnim fazama rasta. Oni takođe ukazuju na potrebu za smanjenje koncentracije proteina u ishrani iberijske svinja u skladu sa metaboličkim profilom ove autohtone rase svinja. Mi rezimiramo sve informacije

prikupljene tokom poslednjih petnaest godina i dajemo preporuke o nivou i sastavu proteina u ishrani za čiste rase životinja tokom različitih faza rasta. Adekvatno upravljanje ishranom, naročito u odredbama koje se odnose na protein, poboljšava efikasnost korišćenja proteina u ishrani i dovodi do relevantnih ekonomskih, socijalnih prednosti i za životnu sredinu i za dobrobit životinja.

References

AGRICULTURAL RESEARCH COUNCIL (1981): The nutrient requirements of pigs. Slough: Commonwealth Agricultural Bureau.

AGUINAGA, M. A., GÓMEZ-CARBALLAR, F., NIETO, R., AGUILERA, J. F. (2011): Production and composition of the Iberian sow milk and utilisation of milk nutrients by the suckling Iberian piglet.Animal 5, 1390-1397.

BAREA, R., NIETO, R., AGUILERA, J.F. (2007): Effects of the dietary protein content and the feeding level on protein and energy metabolism of Iberian pigs growing from 50 to 100 kg. Animal 1, 357-365.

BIKKER, P. (1994): Protein and lipid accretion in body components of growing pigs: Effects of body weight and nutrient intake. Ph.D. Thesis, Wageningen Agricultural University, the Netherlands.

BLACK, J. L., CAMPBELL, R. G., WILLIAMS, I. H., JAMES, K. J, DAVIES, G. T. (1986): Simulation of energy and amino acid utilization in the pig. Research and Development in Agriculture 3,121-145.

BRITISH SOCIETY OF ANIMAL SCIENCE (BSAS) (2003): Nutrient requirement standards for pigs. British Society of Animal Science, Penicuik, UK.

CAMPBELL, R. G., TAVERNER, M.R., CURIC, D.M. (1984). Effect of feeding level and dietary protein content on the growth, body composition and rate of protein deposition in pigs growing from 45 to 90 kg. Animal Production, 38, 233-240.

CAMPBELL, R.G., TAVERNER, M.R. (1988): Genotype and sex effects on the relationship between energy intake and protein deposition in growing pigs. Journal of Animal Science, 66, 676-686.

CASTELLANO, R., AGUINAGA, M.A., NIETO, R., AGUILERA, J.F., HARO, A., SEIQUER, I. (2014): Effects of intermittent suckling on body composition of Iberian suckling piglets weaned at 35-d of age. Animal, 8, 714-720.

CONDE-AGUILERA, J.A., AGUINAGA, M.A., AGUILERA, J.F., NIETO, R. (2011): Nutrient and energy retention in weaned Iberian piglets fed diets with different protein concentrations. Journal of Animal Science 89, 754-763.

GARCÍA-VALVERDE, R., BAREA, R., LARA, L., NIETO, R., AGUILERA, J.F. (2008): The effects of feeding level upon protein and fat deposition in Iberian heavy pigs. Livestock Science 114, 263-273.

KLOBASA, F., WERHAHN E., BUTLER J.E. (1987): Composition of sow milk during lactation. Journal of Animal Science 64, 1458-1466.

KYRIAZAKIS, I., EMMANS, G.C. (1992): The effects of varying both energy and protein intake on the growth and body composition of pigs. 2. The effects of varying both energy and protein intake. British Journal of Nutrition, 68, 615-625.

NATIONAL RESEARCH COUNCIL (2012): Nutrient Requirement of Swine. 11th rev. ed. National Academic Press, Washington, DC.

NIETO, R., MIRANDA, A., GARCÍA, MA, 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. British Journal of Nutrition 88, 39-49.

NIETO, R., L. LARA, R. BAREA, R. GARCÍA-VALVERDE, J. A. CONDE-AGUILERA, J. F. AGUILERA (2012): Response analysis of the Iberian pig growing from birth to 150 kg body weight to changes in protein and energy supply. J. Anim. Sci. , 90, 3809-3820.

NIETO, R. BAREA, R., LARA. L., PALMA-GRANADOS, P., AGUILERA, J.F. (2015): Lysine requirement relative to total dietary protein for optimum performance and carcass protein deposition of Iberian piglets. Animal Feed Science and Technology, 206, 48-56.

NOBLET J., ETIENNE, M. (1986): Effect of energy level in lactating sows on yield and composition of milk and nutrient balance of piglets. Journal of Animal Science 63, 1888-1896.

NOBLET, J., ETIENNE, M., DOURMAND, J.Y. (1998): Energetic efficiency of milk production. In The lactating sow (eds MWA. Verstegen, PJ Moughan and JW Scharama), pp.113-130. WageningenPers, Wageningen, The Netherlands.

RIVERA-FERRE, M.G., AGUILERA, J.F., NIETO, R. (2005): Muscle fractional protein synthesis is higher in Iberian than in Landrace growing pigs fed adequate or lysine-deficient diets. Journal of Nutrition 135, 469-478.

RIVERA-FERRE, M.G., AGUILERA, J.F., NIETO, R. (2006): Differences in whole-body protein turnover between Iberian and Landrace pigs fed adequate or lysine-deficient diets. Journal of Animal Science 84, 3346-3355.

VAN LUNEN, T.A. COLE, D.J. (1996): Energy-amino acid interactions in modern pig genotypes. Pages 233-234 in Recent Advances in Animal Nutrition. Garnsworthy P.C., Wiseman J. and W. Haresign, ed. Nottinghan University Press, UK.