Archivos de Zootecnia
Journal website: https://www.uco.es/ucopress/az/index.php/az/
PROCEEDINGS IX Simposio Internacional sobre el Cerdo Mediterráneo

Nutritional basis for protein feeding of pure Iberian pigs

Nieto, R.[1@], Aguinaga, M. A.[1], Lara, L.[1], Barea, R.[2], García-Valverde, R.[3], Palma-Granados, P.[1], Conde-Aguilera, J.A.[4] and Aguilera, J.F.[1]

[1]Department of Physiology and Biochemistry of Animal Nutrition, Estación Experimental del Zaidín, Consejo Superior de Investigaciones Científicas (CSIC), Granada, Spain.
[2]Novus International, Milan, Italy.
[3]Centro de Investigación y Calidad Agroalimentaria del Valle de los Pedroches, CICAP, Pozoblanco, Córdoba, Spain.
[4]INRA UMR PEGASE 3550 Saint-Gilles, France.

Additional keywords

Amino acids.
Dietary protein.
Efficiency.
Performance.
Protein deposition.

SUMMARY

Along this review we describe the results from a series of experiments performed to assess the utilization of dietary protein by the Iberian pig throughout different stages of its productive cycle. Nutritional dose-response studies involving several isoenergetic treatments differing in protein concentration -all with similar amino acid 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 breeds at similar stages of growth, and suggest the need for reducing the concentration of protein in the diet of the Iberian pig to comply with its metabolic profile. Basic comparative studies have brought to light information to help us explaining some of the metabolic peculiarities of this autochthonous breed of pigs, like the low capacity to accrete protein and lean tissue. We summarise all the information gathered in several experiments and provide recommendations on the concentration and composition of dietary protein in the diet for purebred animals during different phases of growth. 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.

Palabras clave adicionales

Aminoácidos.
Proteína dietética.
Eficiencia.
Índices productivos.
Deposición de proteína.

Bases nutricionales para la alimentación proteica del cerdo Ibérico puro

RESUMEN

En este trabajo de revisión describimos los resultados obtenidos en una serie de experimentos realizados con el objetivo de evaluar la utilización de la proteína dietética por el cerdo Ibérico en distintas fases de su ciclo productivo. Se describen ensayos nutricionales basados en diseños dosis/respuesta, en los que se han empleado tratamientos isoenergéticos con distinta concentración de proteína –con idéntica composición en aminoácidos siguiendo el concepto de proteína ideal-, así como ensayos ensayos metabólicos comparativos con razas porcinas magras. Los resultados obtenidos indican que la capacidad de la raza Ibérica para depositar proteína corporal es limitada en comparación con la descrita para razas porcinas convencionales en etapas similares de crecimiento. Asimismo, sugieren la necesidad de utilizar dietas con concentración de proteína sensiblemente inferior a la utilizada para razas convencionales, de acuerdo a esta limitación metabólica del animal. Estudios de carácter básico han puesto de manifiesto algunas peculiaridades metabólicas que dan lugar a un crecimiento limitado en proteína y tejido magro. Resumimos la información obtenida en varios experimentos y aportamos recomendaciones sobre la concentración y composición de la proteína en las dietas destinadas a la alimentación del cerdo Ibérico puro, en distintas fases de su ciclo productivo. Un adecuado manejo nutricional, particularmente el aporte proteico, mejora la eficiencia de utilización de este nutriente y da lugar a beneficios de carácter ambiental, económico y de bienestar animal.

Information

Cronología del artículo.
Recibido/Received: 18.08.2016
Aceptado/Accepted: 07.01.2017
On-line: 15.07.2017
Correspondencia a los autores/Contact e-mail:
rosa.nieto@eez.csic.es

INTRODUCTION

The scientific literature available shows that in the growing pig protein deposition (PD) 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 & Emmans, 1992). One of the metabolic singularities of the pure Iberian pig is its low genetic capacity for lean tissue deposition. 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 (Nieto et al. 2002; Barea et al. 2007; García-Valverde et al. 2008,

Conde-Aguilera et al. 2011). In a comparative study with Iberian and Landrace gilts of approximately 25 kg BW, nitrogen retention and efficiency of N retention was significantly lower in Iberian gilts, particularly those fed the higher protein content diet (120 vs 160 g crude protein/kg, 12.0 MJ EM/kg; Rivera-Ferre et al. 2006). We aimed at identifying the primary causes that limit PD in the Iberian breed. In this sense, we measured (by the flooding-dose procedure and stable isotopic techniques) protein synthesis rates in different muscles and viscera of Iberian and Landrace gilts (Rivera-Ferre et al. 2005). Surprisingly, for all the muscles studied synthesis rates were 25-30% higher in the Iberian pigs despite muscles relative weights (g/kg BW) were 20-30% lower. This information suggests that in Iberian pig muscles, both protein synthesis and degradation are comparatively higher than in the conventional breed, leading to reduced protein accretion (g/d) and less body protein mass in the former. The higher relative weights of viscera (Rivera-Ferre et al. 2005) joined to higher muscle protein turnover rates, makes Iberian less efficient in the use of dietary protein and energy than lean pigs. Consequently, the energy cost of PD should be higher in the native breed as both processes require considerable amounts of energy. We have confirmed this hypothesis in later studies (Barea et al. 2007; Conde-Aguilera et al. 2011; Nieto et al. 2012). This particular metabolic profile demands a feeding system adapted to the actual metabolic needs of these animals.

MATERIALS AND METHODS

The way of assessing protein requirement in the Iberian pig has been the direct method, i.e., by analysing animal growth and protein-deposition responses to variable protein intakes. The determination of protein accretion rates have been performed by the comparative slaughter technique **(Figure 1)**. By these procedures, both the pig maximal capacity to accrete protein (Pmax, g/d) and the response in PD to changes in energy intake –the marginal efficiency of protein deposition- can be determined. This last concept represents the increment in PD per unit of increment in metabolizable energy intake (MEI) at restricted intakes (ΔPD/ΔMEI g/MJ). Both variables are influenced by genotype and endocrine status, therefore the optimal protein/energy dietary ratio may be different for breeds with dissimilar genetic potential for PD.

All the pigs used in the experiment designs have been pure Iberian from the Silvela strain provided by a single producer (Sánchez Romero Carvajal Jabugo, S.A, Spain). For all the experiments we have followed the "ideal protein concept" (i. e., the perfect balance of essential amino acids needed for maintenance and productive functions, BSAS, 2003; NRC, 2012) for formulation of dietary protein.

RESULTS AND DISCUSSION

In growing pigs of 15 to 50 kg BW, a study was performed with 6 dietary protein and 3 feeding levels allocated in a factorial arrangement of treatments (6 × 3), with 4 pigs per combination. Protein levels used ranged from 101 to 223 g crude protein (CP)/kg dry matter (DM), and feeding levels were 0.95, 0.80 and 0.60 of *ad libitum* intake (Nieto et al. 2002). Experimental diets were prepared by diluting a high-protein diet based on barley and soya bean meal, with a protein-free mixture based on maize starch. Therefore, protein amino acid profile was maintained constant in all experimental diets. Best performance was obtained in pigs fed 129 g CP/DM diet at 0.95 × *ad libitum*, reaching 559 g average daily gain (ADG) and 74 g protein deposited/day (Pmax), considerably lower to those described for conventional or lean pigs, which can attain values up to 170 g/d or even above for this BW range. This dietary treatment provides 8.49 g CP/MJ ME, equiva-

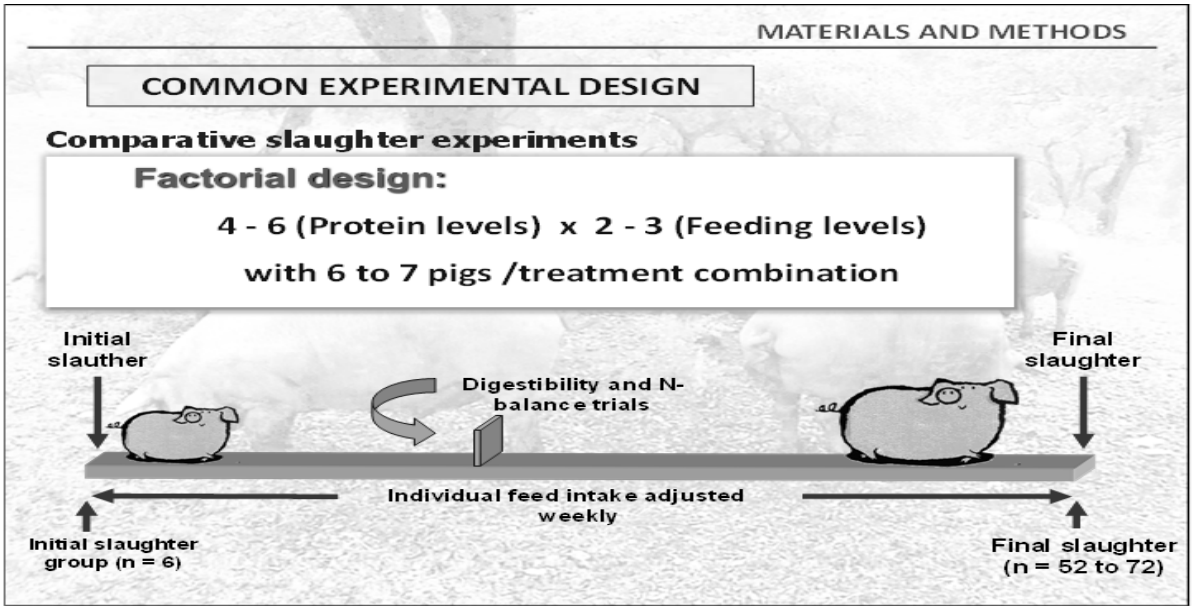

Figure 1. Common scheme of comparative slaughter experiments used in the determination of protein requirements of Iberian pigs (Esquema general de los experimentos de sacrificio comparado realizados para determinar las necesidades proteicas del cerdo Ibérico)

lent to 6.87 g digestible protein /MJ ME. The marginal efficiency of PD obtained 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 to 145 g CP/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 71 g/d with pigs consuming this treatment at 0.95 × ad libitum. In energy terms, this diet provides 6.60 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 PD obtained, 1.43 g/MJ.

The National Research Council (NRC, 2012) recommends protein intakes 35 and 50% above those found to fit Iberian pig requirements. If Iberian pig feeding programs would follow these guidelines, the oversupply of protein would impact negatively in lean tissue growth, farm economy and environmental pollution.

Growth, carcass and PD parameters were also studied in finishing Iberian pigs (100-150 kg BW, García-Valverde et al. 2008). 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 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).

Optimum protein levels during post-weaning were further investigated, as the potential for lean tissue decreases as the animal ages (van Lunen & Cole, 1996). An experiment to investigate protein requirement from 10 to 25 kg BW pigs was designed including 4 protein concentrations (201 to 123 g CP/kg DM) and 2 levels of feeding (0.95 or 0.70 × ad libitum), with 6-7 piglets per combination of treatments (Conde-Aguilera et al. 2011). The maximal values for ADG, and PD were obtained in piglets fed the higher 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 was 4.39 g/MJ of ME, considerably greater than in older pigs.

For all previous 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 **(Figure 2**; Nieto et al. 2015**)**. Six diets containing increasing Lys concentrations at a constant dietary CP content 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 reached maximum values (39.3–40.2 g /d) with diets providing 57 to 72 g Lys/kg CP. Estimations based on this parameter gave a value of 63.7 g Lys/kg CP as optimum to maximize carcass lean growth, which is somewhat below the established for conventional piglets (74 g Lys/kg CP, NRC, 2012) .

Estimation of optimum Lys/CP ratio for Iberian pigs according to three response criteria

Variable	Linear model (broken-line)	Quadratic model (1st derivative max/min)
ADG, g/d	71.0 (474)	71.0
Carcass protein retention, g/d	58.6 (39.9)	63.7
Plasma urea, mg/ 100 mL	61.2 (21.03)	61.2

Figure 2. Estimation of the optimum Lys content of dietary protein for Iberian piglets with growth, carcass protein retention and plasmatic urea as response criteria. In parentheses the value for each variable used as response criteria (Estimación del contenido de Lys óptimo en la proteína de la dieta de lechones Ibéricos en los que se ha utilizado como criterio respuesta el crecimiento, la retención de proteína en la canal, y la concentración de urea plasmática. Entre paréntesis, el valor utilizado para cada variable utilizada como criterio respuesta)

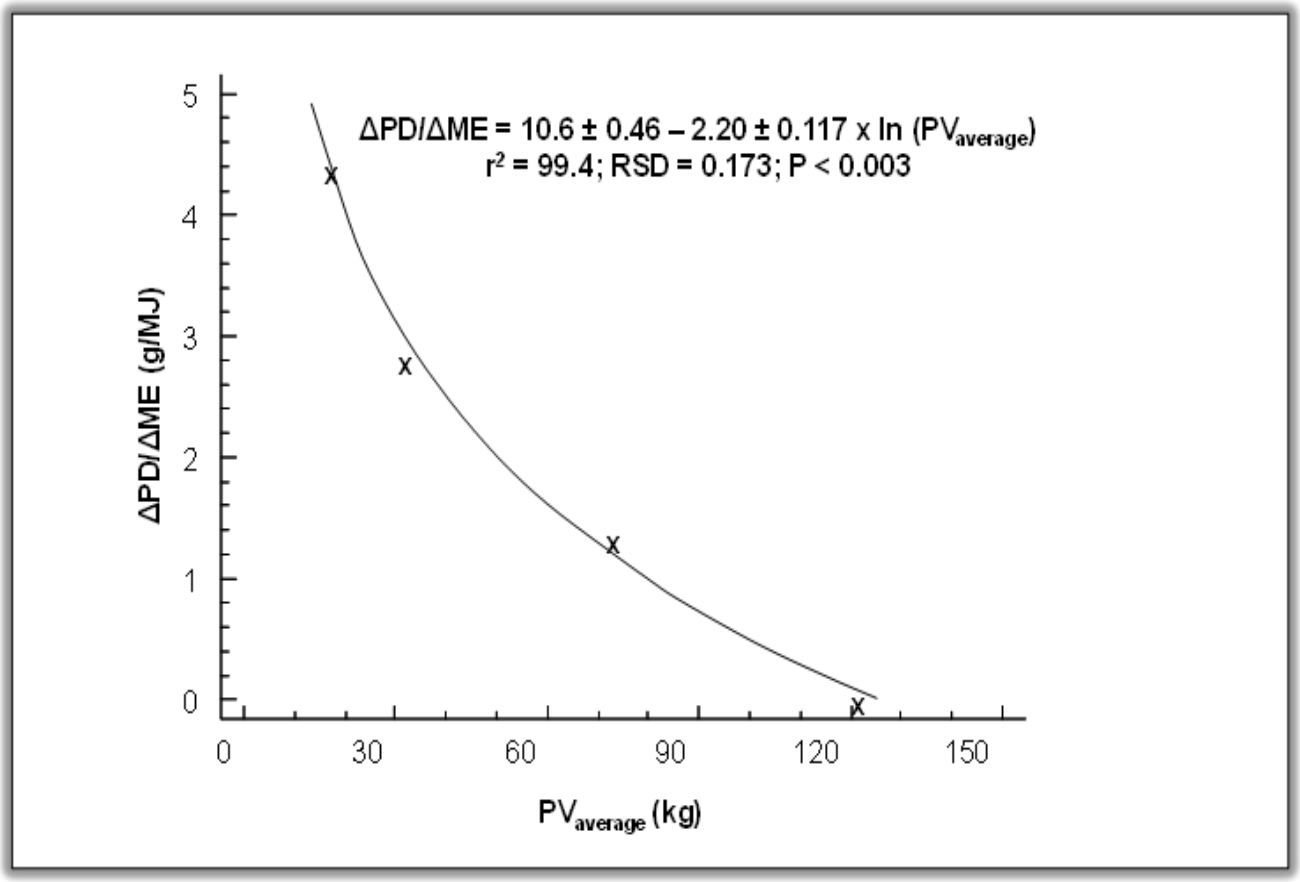

Figure 3. Evolution of the marginal efficiency of protein deposition in the Iberian pig along its productive cycle
(Evolución de la eficiencia marginal de retención proteica en el cerdo Ibérico a lo largo de su ciclo productivo)

The possible causes for the slow growth rate of Iberian suckling piglets compared with conventional pig genotypes was assessed in a study conducted by Aguinaga et al. (2011a). The initial hypothesis was that the 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 and mean birth weight observed was 1.4 kg. The average piglet 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 main nutrient composition of Iberian sow's milk showed little differences compared to milk from other porcine breeds (Klobasa et al. 1987). The results obtained indicate 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 than similar estimations in leaner suckling piglets (18.4 MJ, Noblet et al. 1998). Mean values for whole-body protein and fat retention over lactation period were 27.4 and 22.7 g/d, respectively. The efficiency for protein retention was 0.59, whereas in lean pigs it 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 linked to a lower efficiency of utilization of milk nutrients. Additionally, the comparison of the amino acid profile of the Iberian sow´s milk protein vs. carcass protein of piglets reveals possible limitation in availability for some amino acids (Aguinaga et al. 2011b) which could add to explain the low efficiency of use of milk protein during lactation in Iberian piglets.

From the results described we can suggest that the evolution of the maximum capacity of the Iberian pig for PD (Pmax) during growth would follow this pattern: 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 33 kg BW, mid-point of the study performed with growing pigs from 15 to 50 kg BW (Nieto et al. 2002), beyond which Pmax is maintained at an average value of 75 g/d.

Concerning the marginal efficiency of protein deposition, i. e., the response in PD to changes in energy intake, estimated as the slope of the linear relationship between PD and ME intake, this parameter undergoes considerable changes along the Iberian pig productive cycle **(Figure 3)**. 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. These findings are in the line of those described for conventional pig genotypes (Black et al. 1986; Bikker, 1994).

The results presented 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 genotypes. 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. There are several advantages associated to this practice: the environmental benefit derived from the lesser nitrogenous wastes produced, the economic benefit for producers as usually protein is one of the most expensive feed ingredients, and additionally animal health and welfare considerations as protein excess can cause digestive problems in weaning piglets and other metabolic disorders.

ACKNOWLEDGEMENTS

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 Carvajal Jabugo S.A. (El Puerto de Santa María, Cádiz, Spain) for providing the experimental animals.

BIBLIOGRAPHY

Agricultural Research Council, 1981, 'The nutrient requirements of pigs', Slough: Commonwealth Agricultural Bureau.

Aguinaga, MA, Gómez-Carballar, F, Nieto, R, & Aguilera JF 2011a, 'Production and composition of the Iberian sow milk and utilisation of milk nutrients by the suckling Iberian piglet', *Animal,* vol 5, pp.1390-97.

Aguinaga, MA, Gómez-Carballar, F, Nieto, R, & Aguilera JF 2011b, 'Utilization of amino acids by the suckling Iberian piglet', *Journal of Animal Physiology and Animal Nutrition*, vol 95, pp. 771-80.

Barea, R, Nieto R, & Aguilera JF 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*, vol 1, pp. 357-65.

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, JL, Campbell, RG, Williams IH, James KJ & Davis GT 1986, 'Simulation of energy and amino acid utilization in the pig', *Research and Development in Agriculture*, vol 3, pp.121-45.

British Society of Animal Science (BSAS) 2003, 'Nutrient requirement standards for pigs', British Society of Animal Science, Penicuik, UK.

Campbell, RG, & Taverner, MR 1988, 'Genotype and sex effects on the relationship between energy intake and protein deposition in growing pigs', *Journal of Animal Science*, vol 66, pp. 676-86.

Campbell, RG, Taverner, MR, & Curic, DM 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*, vol 38, pp. 233-40.

Conde-Aguilera, JA, Aguinaga, MA, Aguilera, JF, & Nieto, R 2011, 'Nutrient and energy retention in weaned Iberian piglets fed diets with different protein concentrations', *Journal of Animal Science*, vol 89, pp.754-63.

García-Valverde, R, Barea, R, Lara, L, Nieto, R, & Aguilera JF 2008, 'The effects of feeding level upon protein and fat deposition in Iberian heavy pigs', *Livestock Science*, vol 114, pp.263-73

Klobasa, F, Werhahn, E, & Butler JE 1987, 'Composition of sow milk during lactation', *Journal of Animal Science*, vol 64, pp.1458-66.

Kyriazakis, I, & Emmans, GC 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*, vol 68, pp. 615-25

National Research Council 2012, 'Nutrient Requirement of Swine', 11th rev. ed. National Academic Press, Washington, DC.

Nieto, R, Lara, L, Barea, R, García-Valverde, R, Conde-Aguilera, JA, & Aguilera JF 2012, 'Response analysis of the Iberian pig growing from birth to 150 kg body weight to changes in protein and energy supply', *Journal of Animal Science*, vol 90, pp. 3809-20.

Nieto, R, Barea, R, Lara, L, Palma-Granados, P, & Aguilera JF 2015, 'Lysine requirement relative to total dietary protein for optimum performance and carcass protein deposition of Iberian piglets', *Animal Feed Science and Technology*, vol 206, pp.48-56.

Nieto, R, Miranda, A, García, MA, & Aguilera, JF 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*, vol 88, pp. 39-49.

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*, vol 47, pp. 634-38.

Noblet, J, Etienne, M, & Dourmand, JY 1998, 'Energetic efficiency of milk production', In The lactating sow (eds MWA. Verstegen, PJ Moughan and JW Scharama), pp.113-130. Wageningen Pers, Wageningen, The Netherlands.

Rivera-Ferre, MB, Aguilera, JF, & 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*, vol 135, pp.469-78.

Rivera-Ferre, MB, Aguilera, JF, & Nieto, R 2006, 'Differences in whole-body protein turnover between Iberian and Landrace pigs fed adequate or lysine-deficient diets', *Journal of Animal Science*, vol 84, pp. 3346-55.

Van Lunen, TA, & Cole, DJ 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.