

## Lysine supplementation in late gestation of gilts: effects on piglet birth weight, and gestational and lactational performance

### Suplementação de lisina no terço final da gestação de leitões: efeitos no peso ao nascimento de leitões e no desempenho gestacional e lactacional

Diogo Magnabosco<sup>I</sup> Thomas Bierhals<sup>I</sup> Renato Rosa Ribeiro<sup>I</sup> Henrique Scherer Cemin<sup>I</sup>  
Jamil Elias Ghiggi Faccin<sup>I</sup> Mari Lourdes Bernardi<sup>II</sup>  
Ivo Wentz<sup>I</sup> Fernando Pandolfo Bortolozzo<sup>I\*</sup>

#### ABSTRACT

Lysine requirements for gain in maternal body reserves and piglet birth weight, during pregnancy, in contemporary prolific genotypes, are not well established. This study aimed to evaluate the effect of dietary lysine in late pregnancy on piglet birth weight, and on the gestational and lactational performance of gilts. Pregnant gilts were uniformly distributed into two groups and received, from 85 to 110 days of gestation, either of two lysine levels in their diet: Control group - 28g lysine/day (n=136), and Lysine group - 35g lysine/day (n=141). There were no effects ( $P>0.10$ ) of supplemental lysine on body weight and backfat (BF) gain of females or on piglet birth weight. Gilts supplemented with lysine tended to have a lower percentage of stillbirths ( $P=0.077$ ), reduced within-litter birth weight variation ( $P=0.094$ ) and a lower percentage of piglets weighing less than 1100g ( $P=0.082$ ) than in the Control group. During lactation, the performance of sows and litters was also evaluated in a subgroup of sows (n=26/group). There were no differences between the Control and Lysine groups ( $P>0.10$ ) in voluntary feed intake, body reserve losses (weight and BF), weaning-to-estrus interval of the sows, and litter weaning weight. In conclusion, an increase in lysine (from 28 to 35g/day) in late gestation of gilts (85 to 110 days) tends to reduce the rate of stillbirths and to improve the uniformity of litter weight at birth, but does not affect the performance of females until farrowing or during subsequent lactation.

**Key words:** lysine, pregnancy, piglets, birth weight.

#### RESUMO

As exigências de lisina durante a gestação, para o ganho de reservas corporais maternas e peso ao nascer dos leitões, não estão bem estabelecidas nos genótipos contemporâneos prolíficos. Este estudo objetivou avaliar o efeito da suplementação de lisina no terço final da gestação, sobre o peso ao nascer dos

leitões e o desempenho gestacional e lactacional de leitões. Leitões prenhes foram uniformemente distribuídas em dois grupos que receberam, dos 85 aos 110 dias de gestação, diferentes níveis de lisina na dieta: Grupo Controle - 28g lisina/dia (n=136), e Grupo Lisina - 35g lisina/dia (n=141). Não houve efeito ( $P>0,10$ ) da suplementação de lisina no ganho de peso e espessura de toucinho (ET) das fêmeas e no peso dos leitões ao nascer. Leitões suplementadas com lisina tenderam a ter menor percentagem de natimortos ( $P=0,077$ ), menor variação de peso dentro da leitegada ( $P=0,094$ ) e menor percentagem de leitões pesando menos que 1100g ( $P=0,082$ ), em comparação ao grupo controle. Durante a lactação, o desempenho das fêmeas e das leitegadas foi avaliado em um subgrupo de fêmeas (n=26/grupo). Não houve diferença entre os grupos Controle e Lisina ( $P>0,10$ ) no consumo voluntário de ração, perdas de reservas corporais (peso e ET), intervalo desmame-estro das fêmeas e peso da leitegada ao desmame. Em conclusão, um incremento de lisina (de 28 para 35g dia<sup>-1</sup>) no terço final da gestação de leitões (85 até 110 dias) tende a reduzir o número de natimortos e aumentar a uniformidade do peso dos leitões ao nascer, mas não afeta o desempenho das fêmeas até o parto ou na fase lactacional subsequente.

**Palavras-chave:** lisina, gestação, leitões, peso ao nascer.

#### INTRODUCTION

An increase in litter size has marked the evolution of swine genetics in the last ten years, with a remarkable increase in the number of piglets born (11.2 vs. 12.8 piglets), most evident (12.1 vs. 14.2 piglets) in farms considered the 10% most productive (PIGCHAMP 1998, 2009). The competition for the

<sup>I</sup> Setor de Suínos, Faculdade de Veterinária, Universidade Federal do Rio Grande do Sul (UFRGS), Av. Bento Gonçalves 9090, CEP 91540-000 Porto Alegre, RS, Brasil. E-mail: fpbortol@ufrgs.br. \*Autor para correspondência.

<sup>II</sup> Departamento de Zootecnia, Faculdade de Agronomia, UFRGS, Porto Alegre, RS, Brasil.

uterine space in hyperprolific sows may restrict the potential of piglet development, contributing to the reduction of birth weight commonly observed in larger litters (QUINIOU et al., 2002; TOWN et al., 2004).

Most studies which have been performed to establish nutritional requirements during pregnancy have been based on the physiological needs and responses of growing animals, with few studies conducted using adult pigs (CLOSE et al., 1985; NOBLET et al., 1990; DOURMAD & ETIENNE, 2002). The levels of lysine suggested by the NRC (1998) for pregnant females are being questioned because they are no longer considered sufficient to meet the demands of contemporary prolific high-lean-type females (BALL et al., 2008; SAMUEL et al., 2008; YANG et al., 2009).

Lysine is the first limiting amino acid in corn and soybean based diets, and is a key element for protein deposition in maternal and fetal tissues (KIM et al., 2009). Nevertheless, recommendations for daily amino acid intake (NRC, 1998) are constant, not taking into account changes in amino acid or protein deposition in maternal and fetal tissues throughout gestation (WU et al., 1999; MCPHERSON et al., 2004; JI et al., 2005).

A few studies have focused on the influence of relatively high lysine levels during late gestation (CERISUELO et al., 2009; YANG et al., 2009). Although lysine levels higher than those previously suggested (NRC, 1998; DOURMAD et al., 2008) are not yet recommended for use on a commercial scale, they are already being used in late gestation under practical conditions on some Brazilian pig farms. The aim of this study was to evaluate the effect of dietary lysine in late gestation on the birth weight of piglets, as well as on the gestational and lactational performance of swine females.

## MATERIAL AND METHODS

The study was conducted on a pig farm with 5,330 sows, located in Midwest Santa Catarina State, in southern Brazil, between January and April, corresponding to Summer and early Autumn in the southern hemisphere. Pregnant gilts (DB-DanBred®; Landrace x Large White crossbred), which had been mated at an average of  $226.7 \pm 0.7$  days of age, were selected at 85 days of gestation. Gilts were inseminated with pooled semen doses containing 3 billion sperm cells diluted in BTS® extender (Beltsville Thawing Solution - MINITUB®, Minitub GmbH, Tiefenbach, Germany) and stored at 15-18°C.

The selected females had no locomotor problems or previous reproductive failures, such as return to estrus or abortion.

During pregnancy, gilts remained in individual crates (0.6x2.5m) with a partially slatted concrete floor, and were automatically fed twice a day (7:00 and 13:00h) with a corn soybean diet (3,064kcal ME kg<sup>-1</sup>, 16.0% CP and 0.84% lysine). They received 1.8-2.2kg feed day<sup>-1</sup> from the time of mating to 50 days of gestation, and 2.4-2.8kg feed day<sup>-1</sup> from 51 to 84 days, according to their body condition score (YOUNG et al., 2004), which was evaluated at mating, and again at 30 and 60 days of gestation. From the beginning of the experimental phase (85 days of gestation) until transfer to the farrowing house (110 days of gestation), all pregnant gilts received 3.3kg feed day<sup>-1</sup>. After being transferred to farrowing rooms, females were fed 3.3kg feed day<sup>-1</sup> of a lactation diet (3,273kcal ME kg<sup>-1</sup>, 20.0% CP and 1.38% Lysine), offered twice a day (7:00 and 13:00h) with a gradual reduction in the quantity provided, from 3.3kg (5 days before the expected farrowing) to 1kg (1 day before the expected farrowing). During lactation, automatic feeders allowed sows to have free access to feed (*ad libitum*). Water supply was always provided *ad libitum*. The nutritional composition of the diets is shown in table 1.

At 85 days of pregnancy, females were weighed and backfat thickness (BF) was measured at the level of the last rib, approximately 6.5cm from the midline, by A-mode ultrasonography (Renco Lean Meter®, Renco Corporation, Minneapolis, USA). Body condition score (BCS) was evaluated with a scale ranging from 1 to 5 (YOUNG et al., 2004).

Pregnant gilts were distributed uniformly into two groups, based on age at first mating, in addition to body weight (BW), BCS and BF at 85 days of gestation. Two lysine levels in the diet were tested: Control group - 3.3kg of feed per day with 0.84% lysine, corresponding to a daily consumption of 28g lysine, and Lysine group - 3.3kg of feed per day with 0.84% lysine, and a 'top dressing' supplementation of 7g lysine, which corresponded to a daily consumption of 35g lysine. Supplemental lysine was provided once per day (from 85 to 110 days of gestation) as 25g of a corn-based pre-gelatinized premix containing 7g lysine (L-Lysine 99% AJINOMOTO®, Valparaíso, SP, Brazil), within the drops of the individual feeding system, in addition to the daily ration offered to the females.

Weight and BF were measured at the time of transfer to farrowing rooms. Piglets born alive and stillborn were both counted and individually weighed

Table 1 - Composition of the experimental diets (as-fed basis).

Ingredient, %	Gestation	Lactation
Corn, 8% CP	71.64	48.66
Soybean meal, 46% CP	22.30	32.60
Sugar	-	5.00
Dicalcium phosphate, 19% P	3.06	1.93
Limestone, 37% Ca	-	0.69
Salt	0.60	0.35
Soybean oil	-	1.00
Energy concentrate*	-	7.50
Vitamin/mineral premix**	2.40	1.55
Sodium bicarbonate	-	0.40
L-Lysine 99%	-	0.20
Tylosin 25%	-	0.02
Mycotoxin Adsorbent	-	0.10
-----Chemical composition-----		
ME, kcal/kg	3064	3273
Crude Protein, %	16.00	20.00
Crude Fibre, %	2.81	3.36
Lysine, %***	0.84	1.38
Calcium, %	1.45	1.00
Total phosphorus, %	0.88	0.68

\*Energy concentrate composed of Extruded Soybean Meal, Sugar, Cracker Meal, flavor additive and antioxidant additive.

\*\*Provided, per kilogram of feed: 10,000UI of vitamin A; 2,000UI of vitamin D3; 30mg of vitamin E; 3mg of vitamin K3; 2mg of vitamin B1; 3.5mg of vitamin B2; 3mg of vitamin B6; 0.015mg of vitamin B12; 250mg of colin; 25mg of niacin; 14mg of pantothenic acid; 1.6mg of folic acid; 0.15mg of biotin; 80mg of iron; 70mg of manganese; 150mg of zinc; 15mg of copper; 1mg of iodine and 0.3mg of selenium.

\*\*\*Considering total amino acids.

within 12h after birth. Mummified fetuses were also counted, and included in the total number of piglets born.

Lactational performance was evaluated in 52 sows in two uniform groups, formed by taking into account their BW at 85 days of gestation and the number of piglets born. The sows had at least 13 functional teats, and received 13 piglets whose birth weight was similar between the Control and Lysine groups. During lactation (18 days), the same diet (Table 1) was provided to sows of both groups and no feed was offered to the piglets. Feed refusal was collected daily (at 2:00 PM) and weighed in order to calculate the actual average daily feed intake. The litter was weighed at cross-fostering day and again at weaning.

Within 24h after farrowing and at weaning, BW and BF of sows were measured. Weaning-to-estrus interval (WEI) was recorded after estrus detection being performed twice a day using the standing reflex in response to the back pressure test, in the presence of a sexually mature boar.

#### Statistical analysis

All statistical analyses were performed with Statistical Analysis System, version 9.1.3 (SAS,

2005). Overall, differences with a P value of 5% were considered significant, and P values between 5% and 10% were considered as trends. For variables concerning piglets, the experimental unit was the litter. The following variables were analyzed with the GLM procedure and means were compared with t test: BW and BF of sows at farrowing, BW and BF gain from 85 to 110 days of gestation, number of piglets born, piglet birth weight, coefficient of within-litter birth weight variation, changes in BW and BF of sows during lactation, feed intake by sows during lactation, litter weight at weaning, number of weaned piglets and WEI. Data concerning the percentages of stillborn piglets, mummified fetuses, piglets weighing <1100g and survival until weaning were analyzed using the NPAR1WAY procedure, and groups were compared with the Wilcoxon test.

#### RESULTS

Of 298 sows initially selected, twenty one were excluded, twelve of them because it was not possible to weigh their piglets at birth, eight for death and one for abortion. At 85 days of gestation, females weighed on average  $188.9 \pm 0.5$ kg, without difference

between groups ( $P>0.10$ ). At 85 days of gestation, BF was different ( $P=0.053$ ) between Control and Lysine groups ( $15.6\pm 0.2$  and  $15.1\pm 0.2$ , respectively). The average number of total piglets born was  $14.1\pm 0.2$ , without difference ( $P>0.10$ ) between groups.

There was no effect ( $P>0.10$ ) of supplemental lysine on BW and BF gain of females (Table 2). Piglet birth weight was similar between groups ( $P>0.10$ ). Percentage of stillbirths ( $P=0.077$ ), percentage of piglets weighing less than 1100g ( $P=0.082$ ) and within-litter birth weight variation ( $P=0.094$ ) tended to be reduced in Lysine than in Control group (Table 2).

In sows evaluated during lactation ( $n=52$ ), there were no differences between the Control and Lysine groups ( $P>0.10$ ) in voluntary feed intake (4.8 vs. 4.7kg), BW loss (4.2 vs. 4.5%), BF loss (2.1 vs.

1.9mm), WEI (7.8 vs. 8.4 days), number of weaned piglets (12.5 vs. 12.5 piglets), litter weaning weight (61.3 vs. 61.2kg), and pre-weaning survival (overall, minimum, median and maximum values were 77%, 92% and 100%, respectively).

## DISCUSSION

The effect of lysine levels on the performance of pregnant females is still controversial, as there have been some reports showing that gestational lysine level does not affect body weight gain (COOPER et al., 2001), whereas an increase from 18 to 24g (YANG et al., 2009) has been reported to result in increased weight gain by sows during pregnancy. Productivity and metabolic characteristics of sows have changed over the last decade (YANG

Table 2 - Weight and backfat gain, performance at farrowing and characteristics related to piglets' birth weight according to lysine supplementation from 85 to 110 days of gestation (means  $\pm$  SEM).

Variables	Control 28g lysine (n=136)	Lysine 35g lysine (n=141)	P value
Body weight at 110d, kg	216.9 $\pm$ 0.87	216.0 $\pm$ 0.85	0.440
Body weight gain 85-110d, kg	27.5 $\pm$ 0.59	26.7 $\pm$ 0.58	0.366
Backfat thickness at 110d, mm	16.7 $\pm$ 0.21	16.1 $\pm$ 0.20	0.064
Backfat gain 85-110d, mm	1.05 $\pm$ 0.15	1.04 $\pm$ 0.15	0.965
Total born piglets, n	14.1 $\pm$ 0.24	14.1 $\pm$ 0.23	0.959
Piglets born alive, n	12.9 $\pm$ 0.22	13.0 $\pm$ 0.22	0.853
Stillborn piglets <sup>a</sup> , %	4.8 (0 - 36.4)	3.7 (0 - 33.3)	0.077
Mummified fetuses <sup>a</sup> , %	3.0 (0 - 35.7)	3.9 (0 - 31.2)	0.384
Piglet birth weight, g	1309.3 $\pm$ 13.73	1323.5 $\pm$ 13.48	0.461
Within-litter piglet birth weight CV, %	19.4 $\pm$ 0.52	18.2 $\pm$ 0.51	0.094
Piglets weighing <1100 g <sup>a</sup> , %	24.5 (25.0 - 85.7)	21.1 (15.4 - 100.0)	0.082

SEM = standard error of mean; CV= coefficient of variation.

<sup>a</sup> Values correspond to mean (median and maximum).

Data analyzed using the NPAR1WAY procedure of SAS.

et al., 2009); the nutritional requirements of pregnant and lactating sows are being reviewed, and past recommendations of NRC (1998) are being questioned (BALL et al., 2008; SAMUEL et al., 2008; YANG et al., 2009). New nutritional requirements are being proposed for contemporary prolific genotypes, since their requirements for maintenance, for example, exceed by 30% (SAMUEL et al., 2008) the levels recommended (NRC, 1998). In the present study, the increase from 28 to 35g of lysine, offered from 85 to 110 days of gestation, did not affect BW or BF gain of females, suggesting that 28g were sufficient to meet the demands for maternal growth. At farrowing, females weighed on average 190kg, completely satisfying the target of 180kg established for the first farrowing (WILLIAMS et al., 2005).

The reduction of the within-litter birth weight variation is especially important for highly modern prolific sows. Nevertheless, CAMPOS et al. (2012) have well documented the inconsistency about the positive effect of extra nutrition during late gestation on birth weight. There was an expectation that the lysine levels required would be higher for prolific females, and that lysine supplementation would increase the birth weight of piglets. Nevertheless, the likely beneficial effect of increasing the gestational lysine level on birth weight was not observed in this study. An increased birth weight has been reported when lysine levels were increased from 18 to 24g (YANG et al., 2009) or from ~19g to ~28g (CERISUELO et al., 2009), in gilts farrowing approximately 10 and 13 piglets, respectively. In our study, lysine supplementation late in gestation tended to reduce stillbirths, decrease the number of light piglets and minimize the within-litter CV of birth weight. However, the observed effects were marginal, suggesting that the amount of lysine used in the control group (28g) was close to that needed to meet the demands of fetal growth in prolific sows. The marginal effect observed could also be related to an inefficient use of supplemented lysine, because the females were fed once a day. Synthetic amino acids added in a single meal are absorbed more rapidly than those linked to proteins, and may be oxidized very quickly (YEN et al., 2004).

The reduced percentage of piglets with birth weight <1100g probably explains the lower rate of stillbirths observed in females supplemented with lysine. Piglets weighing less than 1100g represented approximately one quarter of the piglets born, being close to the percentages reported by WU et al. (2006). A reduced number of light piglets may represent an advantage for postnatal growth performance, because a low birth weight has been associated with lower

survival (QUINIOU et al., 2002) and lower weight gain (KING et al., 2006). The birth weight of the piglets (on average 1316g) can be considered low if compared with the weight close to 1500g reported in other studies (MILLER et al., 2000; CERISUELO et al., 2009). However, in those studies females of several parities were used and average numbers of total piglets born were only 11.1 (MILLER et al., 2000) and 12.7 (CERISUELO et al., 2009). The reduced birth weight observed in the present study is probably explained by the fact that gilts had a higher number of piglets born (on average 14.1 piglets), since litter size is negatively associated with birth weight (QUINIOU et al., 2002; TOWN et al., 2004).

The lysine level offered during late gestation did not affect body reserve losses of the sows during lactation, consistent with previous reports (COOPER et al., 2001; YANG et al., 2009). Similarly, postnatal growth of piglets was not affected by gestational lysine supplementation, in agreement with CERISUELO et al. (2009). Although sows lost on average less than 5% of BW and WEI was not affected by gestational lysine levels, the overall WEI of 8.1 days can be considered long, because it could negatively affect subsequent reproductive performance (POLEZE et al., 2007). The extended WEI may be related to a low feed intake by the sows, which consumed on average 4.7kg of feed per day. This relatively low amount of consumed feed may be related to the fact that the lactation period occurred during the hot season, which can be associated with a reduction in feed intake. The amount of consumed feed was insufficient to avoid losses of body reserves during lactation, confirming that requirements for maintenance and milk production of primiparous are often not fulfilled by nutrients supplied through feed (QUESNEL et al., 2007).

## CONCLUSION

Stillbirth, birth of light piglets (<1100g), and the within-litter coefficient of variation in birth weight are slightly reduced by the increase in lysine (from 28 to 35g day<sup>-1</sup>) offered from 85 to 110 days of gestation in gilts. In the conditions of the present study, the performance of the females until farrowing and during subsequent lactation is not affected by gestational lysine levels.

## BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

Process n. 18326.

## REFERENCES

- BALL, R.O. et al. Nutrient requirements of prolific sows. **Advances in Pork Production**, v.19, p.223-236, 2008.
- CAMPOS, P.H.R.F. et al. Effects of sow nutrition during gestation on within-litter birth weight variation: a review. **Animal**, v.6, p.797-806, 2012. Available from: <<http://journals.cambridge.org/ANM>>. Accessed: Jul. 11, 2011. doi:10.1017/S1751731111002242.
- CERISUELO, A. et al. Increased sow nutrition during mid gestation affects muscle fiber development and meat quality, with no consequences on growth performance. **Journal of Animal Science**, v.87, p.729-739, 2009. Available from: <<http://jas.fass.org/cgi/content/full/87/2/729>>. Accessed: Apr. 22, 2010. doi:10.2527/jas.2007-0677.
- CLOSE, W.H. et al. Studies on the energy metabolism of the pregnant sow. The partition and utilization of metabolizable energy intake in pregnant and non-pregnant animals. **British Journal of Nutrition**, v.53, p.267-279, 1985. Available from: <[dx.doi.org/10.1079/BJN19850034](http://dx.doi.org/10.1079/BJN19850034)>. Accessed: Aug. 05, 2009. doi:10.1079/BJN19850034.
- COOPER, D.R. et al. Effect of energy and lysine intake in gestation on sow performance. **Journal of Animal Science**, v.79, p.2367-2377, 2001. Available from: <<http://www.journalofanimalscience.org/content/79/9/2367>>. Accessed: Jul. 22, 2009.
- DOURMAD, J.Y.; ÉTIENNE, M. Dietary lysine and threonine requirements of the pregnant sow estimated by nitrogen balance. **Journal of Animal Science**, v.80, p.2144-2150, 2002. Available from: <<http://jas.fass.org/cgi/content/full/80/8/2144>>. Accessed: Aug. 5, 2009.
- DOURMAD, J.Y. et al. InraPorc: a model and decision support tool for the nutrition of sows. **Animal Feed Science and Technology**, v.143, p.372-386, 2008. Available from: <<http://www.sciencedirect.com>>. Accessed: May 11, 2012. doi:10.1016/j.anifeeds.2007.05.019.
- JI, F. et al. Changes in weight and composition in various tissues of pregnant gilts and their nutritional implications. **Journal of Animal Science**, v.83, p.366-375, 2005. Available from: <<http://jas.fass.org/cgi/content/full/83/2/366>>. Accessed: Apr. 26, 2010.
- KIM, S.W. et al. Ideal amino acid balance for sows during gestation and lactation. **Journal of Animal Science**, v.87, E123-E132, 2009. Available from: <[http://jas.fass.org/cgi/content/full/87/14\\_suppl/E123](http://jas.fass.org/cgi/content/full/87/14_suppl/E123)>. Accessed: Dec. 6, 2010. doi:10.2527/jas.2008-1452.
- KING, R.H. et al. The response of sows to increased nutrient intake during mid to late gestation. **Australian Journal of Agricultural Research**, v.57, p.33-39, 2006. Available from: <<http://publish.csiro.au/journals/ajar>>. Accessed: Dec. 9, 2010. doi:10.1071/AR05195-0004-9409/06/010033.
- MCPHERSON, R.L. et al. Growth and compositional changes of fetal tissues in pigs. **Journal of Animal Science**, v.82, p.2534-2540, 2004. Available from: <<http://jas.fass.org/cgi/content/full/82/9/2534>>. Accessed: Jan. 21, 2011.
- MILLER, H.M. et al. Increasing food intake in late gestation improved sow condition throughout lactation but did not affect piglet viability or growth rate. **Animal Science**, v.71, p.141-148, 2000. Available from: <<http://bsas.org.uk>>. Accessed: Jul. 24, 2009. doi:1357-7298/00/96820141\$20-00.
- NRC (National Research Council). **Nutrient requirements of swine**. 10.ed. Washington: National Academy, 1998. 210 p.
- NOBLET, J. et al. Energy utilization in pregnant and lactating sows: modeling of energy requirements. **Journal of Animal Science**, v.68, p.562-572, 1990. Available from: <<http://jas.fass.org>> Accessed: Aug. 12, 2009.
- PIGCHAMP. **Breeding herd summary**. USA, 1998. Available from: <<http://www.pigchamp.com/1998Datashare.html>>. Accessed: Nov. 19, 2010.
- PIGCHAMP. **Pigchamp Benchmarking**. Canada, 2009. Available from: <[http://www.pigchamp.com/summary\\_archives.html](http://www.pigchamp.com/summary_archives.html)>. Accessed: Nov. 19, 2010.
- POLEZE, E. et al. Consequences of variation in weaning-to-estrus interval on reproductive performance of swine females. **Livestock Science**, v.103, p.123-130, 2006. Available from: <<http://dx.doi.org/10.1016/j.livsci.2006.02.007>>. Accessed: Jan. 25, 2011. doi:10.1016/j.livsci.2006.02.007.
- QUESNEL, H. et al. Influence of litter size on metabolic status and reproductive axis in primiparous sows. **Journal of Animal Science**, v.85, p.118-128, 2007. Available from: <<http://www.animal-science.org/content/85/1/118.short>> Accessed: Jul. 10, 2009. doi:10.2527/jas.2006-158.
- QUINIOU, N. et al. Variation of piglets birth weight and consequences on subsequent performance. **Livestock Production Science**, v.78, p.63-70, 2002. Available from: <[http://dx.doi.org/10.1016/S0301-6226\(02\)00181-1](http://dx.doi.org/10.1016/S0301-6226(02)00181-1)>. Accessed: Jul. 10, 2009. doi:10.1016/S0301-6226(02)00181-1.
- SAMUEL, R.S. et al. Dietary lysine requirement for maintenance is 49 mg/kg<sup>0.75</sup> in a population of modern, high productivity sows. **Advances in Pork Production**, v.19, Abstract #1, 2008.
- SAS. **SAS/STAT® 9.3 User's Guide**. Cary, NC: SAS Institute Inc., 2005. 8621 p.
- TOWN, S. et al. Number of conceptuses in utero affects porcine foetal muscle development. **Reproduction**, v.128, p.443-454, 2004. Available from: <<http://www.reproduction-online.org>>. Accessed: Apr. 22, 2010. doi:10.1530/rep.1.00069.
- WILLIAMS, N.H. et al. Non-negotiables in gilt development. **Advances in Pork Production**, v.16, p.281-289, 2005.
- WU, G. et al. Amino acid composition of the fetal pig. **Journal of Nutrition**, v.129, p.1031-1038, 1999. Available from: <<http://jn.nutrition.org/content/129/5/1031.full.pdf+html>>. Accessed: Apr. 22, 2010.
- WU, G. et al. Intrauterine growth retardation: implications for the animal sciences. **Journal of Animal Science**, v.84, p.2316-2337, 2006. Available from: <<http://jas.fass.org/cgi/content/full/84/9/2316>>. Accessed: Dec. 22, 2010. doi:10.2527/jas.2006-156.
- YANG, Y.X. et al. Effects of lysine intake during late gestation and lactation on blood metabolites, hormones, milk

composition and reproductive performance in primiparous and multiparous sows. **Animal Reproduction Science**, v.112, p.199-214, 2009. Available from: <<http://dx.doi.org/10.1016/j.anireprosci.2008.04.031>>. Accessed: Sept. 11, 2010. doi:10.1016/j.anireprosci.2008.04.031.

YEN, J.T. et al. Difference in rates of net portal absorption between crystalline and protein-bound lysine and threonine in

growing pigs fed once daily. **Journal of Animal Science**, v.82, p.1079-1090, 2004. Available from: <<http://jas.fass.org/cgi/content/full/82/4/1079>>. Accessed: Oct. 15, 2010.

YOUNG, M.G. et al. Comparison of three methods of feeding sows in gestation and the subsequent effects on lactation performance. **Journal of Animal Science**, v.82, p.3058-3070, 2004. Available from: <<http://jas.fass.org/cgi/content/full/82/10/3058>>. Accessed: