Revista Brasileira de Zootecnia
© 2011 Sociedade Brasileira de Zootecnia
ISSN 1806-9290
www.sbz.org.br

R. Bras. Zootec., v.40, n.3, p.587-592, 2011

Available phosphorus levels in diets for 30 to 60 kg female pigs selected for meat deposition by maintaining calcium and available phosphorus ratio

Alysson Saraiva[1], Juarez Lopes Donzele[2], Rita Flávia Miranda de Oliveira[2], Márvio Lobão Teixeira de Abreu[3], Francisco Carlos de Oliveira Silva[4], Rafael Alves Vianna[5], Anderson Lazarini Lima[1]

[1] *Doutorando em Zootencia – DZO/UFV.*
[2] *DZO/UFV.*
[3] *DZO/UFPI.*
[4] *EPAMIG.*
[5] *Estudante de graduação em Zootecnia – DZO/UFV.*

ABSTRACT - With the objective to evaluate levels of available phosphorus (aP) in diets for pigs selected for meat deposition by maintaining the calcium and available phosphorus ratio, it was used 50 commercial hybrid female pigs with initial weight of 30.32 ± 0.29 kg, distributed in a complete randomized experimental design, with five treatments, five replicates, and two animals per experimental unit. Treatments were composed of a corn-soybean meal basal diet and four diets obtained by supplementation of basal diet with dicalcium phosphate, resulting in diets with 0.144; 0.224; 0.304; 0.384 and 0.464% of aP. Calcium levels were adjusted by varying the quantities of limestone in the diets. There was no effect of aP on both daily feed intake and feed conversion. Levels of aP affected daily weight gain which increased quadratically up to the estimated level of 0.372%. There was no effect of aP on quantity of phosphorus in the bones. The quantity of calcium in the bones and percentage of ash in the bones were influenced in an increasing linear way by the aP in the rations. The best result of weight gain of swine females, from 30 to 60 kg, genetically selected for meat deposition, is provided by the level of available phosphorus of 0.372%, which corresponds to a relationship with calcium of 2.06:1 and to a daily intake of 8.20 g of available phosphorus.

Key Words: growth phase, phosphorus, performance, requirement

Níveis de fósforo disponível em rações para fêmeas suínas dos 30 aos 60 kg selecionadas para deposição de carne mantendo-se a relação entre o cálcio e o fósforo disponível

RESUMO - Com o objetivo de avaliar níveis de fósforo disponível (Pd) em rações para suínos selecionados para deposição de carne, mantendo-se a relação entre o cálcio e o fósforo disponível, foram utilizadas 50 fêmeas suínas, híbridas comerciais, com peso inicial de 30,32 ± 0,29 kg, distribuídas em delineamento experimental inteiramente casualizado, com cinco tratamentos, cinco repetições e dois animais por unidade experimental. Os tratamentos foram constituídos por uma ração basal formulada a base de milho e farelo de soja e quatro rações obtidas pela suplementação da ração basal com fosfato bicálcico resultando em rações com 0,144; 0,224; 0,304; 0,384 e 0,464% de Pd. Os níveis de cálcio foram ajustados variando-se a quantidade de calcário das rações. Não houve efeito dos níveis de Pd das rações sobre o consumo de ração diário e sobre a conversão alimentar. Os níveis de Pd influenciaram o ganho de peso diário que aumentou de forma quadrática até o nível estimado de 0,372%. Não houve efeito dos níveis de Pd sobre a quantidade de fósforo nos ossos. A quantidade de cálcio nos ossos e a porcentagem de cinza óssea foram influenciadas de forma linear crescente pelos níveis de Pd das rações. O melhor resultado de ganho de peso de fêmeas suínas, dos 30 aos 60 kg, selecionadas geneticamente para deposição de carne, é proporcionado pelo nível de fósforo disponível de 0,372%, correspondente a uma relação com o cálcio de 2,06:1 e a um consumo diário de 8,20 g de fósforo disponível.

Palavras-chave: desempenho, exigência, fase de crescimento, fósforo

Introduction

Obtaining satisfactory production rates as well as welfare of pigs depends on adequate energy and nutrient supply, and among these nutrients phosphorus has deserved special attention.

Phosphorus is a critical element for body protein accretion because of its involvement in the energy

Received October 29, 2009 and accepted August 27, 2010.
Corresponding author: alysson_zoo@yahoo.com.br

metabolism, synthesis of nucleic acids, and structure of cell membranes. Muscle tissue contains great amounts of phosphorus compared to fat (Stahly et al., 2000). As a consequence, it is hypothesized that the available phosphorus requirement by pigs increases with the increase in their genetic capacity for muscle deposition. Thus, the continuous genetic selection of new pig strains with high lean gains warrants greater attention from nutritionists, making necessary a constant reassessment of their available phosphorus requirements, since the nutrient needs vary with the genetic potential for lean gain of pigs.

Despite these considerations, few studies have been carried out recently to investigate the available phosphorus requirements of modern pig strains. In the past, phosphorus requirements of pigs were based mainly on performance and bone mineralization (breaking strength and ash content). However, maximization of bone development based on breaking strength seems not to be necessary, particularly in pigs for meat production inasmuch as the amount of phosphorus required for maximum bone strength is higher than that required for meat production (Crenshaw et al., 1986). Still regarding to bone strength, significant variations occur between the levels of phosphorus required for maximum bone strength reported in the literature. Such variations can be attributed to different types of instruments used for determining the physical properties of bone, type of bone used, procedures adopted in the preparation of bones, moisture content in bones and its position on the equipment (Crenshaw et al., 1981).

Phosphorus and calcium metabolism are closely associated, and the excess of dietary calcium can result in lower weight gains and feed efficiency of pigs because of insoluble complexes of calcium phosphate formation in the small intestine (Rao et al., 2003). On the other hand, it seems that the negative effects of dietary calcium excess in the diet may not occur if the level of dietary phosphorus is greater than that required for maximum performance (Cromwell et al., 1970). Thus, it is possible that the available phosphorus requirement of pigs will change depending on the calcium concentration in the diet.

This study was conducted to evaluate the effects of available phosphorus levels in diets for 30 to 60 kg female pigs selected for meat deposition, maintaining calcium and available phosphorus ratio.

Material and Methods

The experiment was conducted at the Setor de Suinocultura in Departamento de Zootecnia, Universidade Federal de Viçosa (UFV), Viçosa, Minas Gerais, Brazil.

Fifty commercial hybrid female pigs with initial body weight of 30.32 ± 0.29 kg were used. Pigs were allotted in a completely randomized block design with five treatments, five replicates, and two pigs per experimental unity which was represented by the pen. Pigs were housed in pens with semi-automatic feeders, drinkers, and concrete floor. The thermal environment inside the facility was monitored daily (8:00), using minimum and maximum thermometer placed in an empty pen in the middle of the building at half height of the body of pigs.

Experimental diets (Table 1) were corn-soybean meal based supplemented with minerals and vitamins to meet the requirements for this animal category defined by Rostagno et al. (2005) for all nutrients, except calcium and phosphorus. The treatments which consisted of different available phosphorus levels (aP) included a basal diet and four diets supplemented with dicalcium phosphate, varying the amounts of limestone and sand, resulting in diets with 0.144, 0.224, 0.304, 0.384, and 0.464% aP. Calcium levels were adjusted varying the amount of limestone and sand in order to maintain calcium and aP ratios close to the value of 2.1 (Saraiva et al., 2009a).

Pigs were fed *ad libitum* and water was provided throughout the experimental period (30 days). Daily feed waste was manually collected and weighed at the same time and animals were weighed at the beginning and at the end of the experimental period to calculate average daily feed intake (ADFI), average daily gain (ADG), feed conversion (F:G), and phosphorus intake.

At the end of the experiment, only one pig per pen with body weight closest to 60 kg after eighteen hours of fasting was stunned and immediately exsanguinated to collect the front foot from the right side. The collected paws were placed in aluminum container and boiled in water to soften the skin and muscle around bones to remove the third metacarpals.

Metacarpals were dissected and dried at 65°C in a drying oven for 72 hours. The dried bones were crushed and defatted by a petroleum ether procedure using Soxhlet equipment, placed again in a 65°C drying oven for 24 hours and then were ground.

The diets levels of calcium and phosphorus and the concentrations of calcium, phosphorus, and ash in the bones were realized by Rodes Química Cajati LTDA (Cajati, SP, Brazil).

Performance and bone parameters data were analyzed using the procedures for analysis of variance and regression contained in the System for Statistical and Genetics Analysis (SAEG), developed at the Federal University of Viçosa (UFV, 2000), version 9.0. For all statistical procedures, it was adopted 0.05 as the critical probability level for the type I error.

Table 1 - Composition and nutritional values of experimental diets

Ingredient	Dietary aP levels (%)				
	0.144	0.224	0.304	0.384	0.464
Corn	55.498	55.498	55.498	55.498	55.498
Soybean meal	39.485	39.485	39.485	39.485	39.485
Soybean oil	1.483	1.483	1.483	1.483	1.483
Dicalcium phosphate	0.000	0.433	0.866	1.298	1.730
Limestone	0.304	0.436	0.572	0.704	0.841
Washed sand	2.330	1.765	1.196	0.632	0.063
Salt	0.415	0.415	0.415	0.415	0.415
DL-methionine	0.025	0.025	0.025	0.025	0.025
Mineral premix[1]	0.200	0.200	0.200	0.200	0.200
Vitamin premix[2]	0.200	0.200	0.200	0.200	0.200
Growth promoter	0.050	0.050	0.050	0.050	0.050
BHT (butylhydroxytoluene)	0.010	0.010	0.010	0.010	0.010
Nutrional calculated composition					
Metabolizable energy (kgcal/kg)	3230	3230	3230	3230	3230
Crude protein (%)[4]	22.51	22.51	22.51	22.51	22.51
Digestible lysine (%)[4]	1.100	1.100	1.100	1.100	1.100
Digestible Met + Cys (%)[4]	0.660	0.660	0.660	0.660	0.660
Sodium (%)	0.180	0.180	0.180	0.180	0.180
Calcium (%)	0.227	0.385	0.543	0.700	0.858
Calcium analyzed (%)	0.320	0.470	0.610	0.750	0.940
Total phosphorus analyzed (%)	0.430	0.510	0.590	0.670	0.750
Available phosphorus (%)	0.144	0.224	0.304	0.384	0.464

[1] Provided per kg of product: A vitamin - 3,000,000 IU; D3 vitamin - 1,200,000 UI; E vitamin - 7,500 mg; K vitamin - 1,250 mg; B12 vitamin - 7,000 mg; B_2 vitamin - 2,300 mg; biotin - 50 mg; calcium pantothenate - 6,000 mg; niacin - 10,000 mg; growth promoter - 50 g; antioxidant - 5,000 mg; B_1 vitamin - 500 mg; B6 vitamin - 1,000 mg; folic acid - 150 mg; vehicle q.s.p. - 1,000 g.
[2] Provided per kg of product: iron - 45,000 mg; copper - 37,000 mg; manganese - 25,000 mg; zinc - 35,000 mg; cobalt - 300 mg; iodine - 800 mg; selenium - 120 mg; vehicle q.s.p. 1,000 g.
[3] Provided per kg of product: tylosin - 400,000 mg.
[4] Values estimated based on the digestibility coefficients of amino acids of ingredients, according to Rostagno et al. (2005).

Results and Discussion

During the experimental period, the minimum and maximum temperatures inside the facility were 20.2 ± 1.4 and 24.1 ± 1.8ºC, respectively. Considering that the ideal range of temperature for growing pigs suggested by Coffey et al. (2000) is between 16.0 and 24.0°C, it can be concluded based on the temperature variation in the current study that pigs were not subjected to heat stress.

There was no effect (P>0.05) of aP on average daily feed intake (ADFI) of pigs (Table 2). Similar results were obtained by Hastad et al. (2004) and Saraiva et al. (2009a) who working with growing pigs also found no significant effect of dietary aP in ADFI.

On the other hand, Eeckhout et al. (1995) and Saraiva et al. (2009b) assessing different dietary aP levels for 37 to 61 kg and 15 to 30 kg pigs, respectively, verified that voluntary feed intake of pigs increased linearly with increasing aP in the diets. Unlike, Ketaren et al. (1992), Ekpe (2002), and Arouca et al.(2010) working with growing pigs fed different dietary aP, found that the ADFi of the animals showed a quadratic behavior up to the maximum estimated levels of 0.300, 0.350, and 0.430% aP.

Table 2 - Performance and bone parameters of female pigs from 30 to 60 kg fed different dietary available phosphorus

Item	Dietary available Phosphorus, %					CV, %
	0.144	0.224	0.304	0.384	0.464	
Final body weight, kg	57.66	59.33	60.30	62.31	60.14	-
Feed intake, g/d	2057	2249	2216	2221	2281	5.95
Available phosphorus intake, g/d[1]	2.96	5.04	6.74	8.53	10.58	5.57
Weight gain, g/d[3]	909	967	997	1072	994	4.41
Feed conversion	2.26	2.33	2.22	2.07	2.31	4.33
Bone phosphorus, g/kg	82.35	81.40	83.78	83.72	86.86	4.68
Bone calcium, g/kg[2]	163.25	164.60	170.40	164.17	179.80	4.64
Bone ash, %[1]	49.30	48.48	49.02	50.54	51.80	3.19
Bone Ca:P ratio[4]	1.98	2.02	2.03	1.96	2.07	-

[1,2] Linear effect (P<0.01) and (P<0.05), respectively.
[3] Quadratic effect (P<0.01).
[4] Calculated calcium:phosphorus ratio in metacarpals.

Although in this study the dietary aP did not influence feed intake of pigs, the animals fed diets with the lowest aP (0.144%) showed in numerical value a reduction of 8.24% on voluntary feed intake compared to the ADFI of animals in the other treatments. Similarly, Saraiva et al. (2009b) evaluating six levels of aP in diets for 15 to 30 kg pigs, found a significant reduction in ADFI of pigs fed diets with the lowest level of aP.

It can be inferred from these results that dietary aP below 0.224% can compromise the voluntary feed intake of growing pigs. This proposition is consistent with the results of Reinhart and Mahan (1986) who working with growing pigs found that low phosphorus diets reduced voluntary feed intake.

Dietary aP influenced (P<0.01) available phosphorus intake which increased linearly according to the equation: $\hat{Y} = -0.3380 + 23.4049aP$ ($r^2 = 0.99$). Because feed intake of pigs did not vary among treatments, it can be concluded that the variation on consumption of aP occurred as a direct proportion to its concentration in the diets.

There was an effect (P<0.01) of aP on average daily gain (ADG), which increased quadratically up to 0.372% aP maximum response (Figure 1), corresponding to a daily intake of 8.20 g aP.

The results of ADG obtained in this study confirm those of Saraiva et al. (2009a) who studying the effects of available phosphorus in diets for 30 to 60 kg female pigs genetically selected for meat deposition reported an increase in average daily gain of pigs up to 0.349% aP, corresponding to a daily intake estimated of 7.45 g. These authors highlighted that the lower weight gain observed in the animals fed diets with the lower phosphorus levels may have been caused by the high calcium and phosphorus ratio (Ca:P) in the diets (2.04, 1.65, and 1.39). According to the NRC (1998), the ideal Ca:P in corn-soybean meal based diets should be between 1.1:1 and 1.25:1.

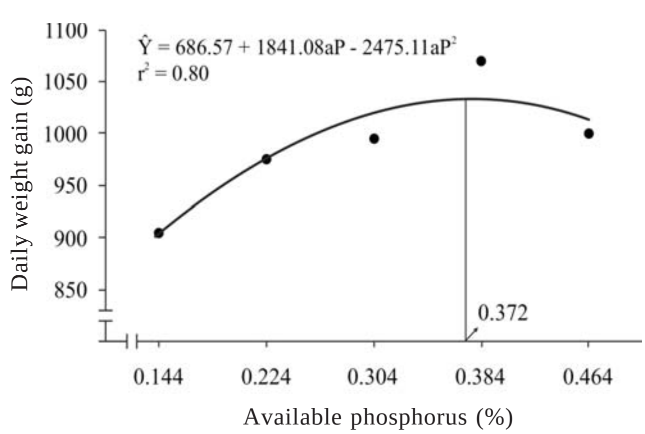

Figure 1 - Effect of available phosphorus levels on average daily weight gain of 30 to 60 kg female pigs.

Variation in ADG of growing pigs related to dietary aP was also observed by Stahly et al. (2000), Ekpe et al. (2002) and Arouca et al. (2010) who found the greatest responses at the levels of 0.40, 0.35, and 0.42% aP.

The divergence of results found among studies may be related, among other factors, to differences of genetic potential for muscle deposition of pigs. According to Stahly (2000), muscle has greater phosphorus contents than the adipose tissue, so the increase in aP requirement of pigs selected for high lean gain can be explained by the increased demand of phosphorus for protein synthesis. Several authors, Fandrejewski & Rymarz (1986), Hendricks et al. (1993), and Mahan (2006) found that pigs from lines with different genetic merit for lean deposition may have differences in their mineral requirements.

Assessing the effects of high Ca:P (1.2:1, 1.6:1, and 2.0:1), with two levels of dietary phosphorus (0.360 and 0.435%), and phytase supplementation in piglets, Qian et al. (1996) found that the ADG and feed efficiency decreased linearly as Ca:P ratio increased in the diets. The authors associated the lower performance to a possible negative effect of calcium excess on phosphorus absorption in the small intestine of pigs as a result of insoluble complexes formation, especially when the dietary phosphorus is below the required by the pigs. In a study with pigs from 23 to 54 kg, Liu et al. (2000) found that the apparent phosphorus absorption in the small intestine increased linearly as the Ca:P ratio decreased from 1.5:1 to 1.0:1.

However, Cromwell et al. (1970) stated that the negative effects of dietary calcium excess may not occur if phosphorus concentration in the diet is greater than the required for optimal performance. Based on these considerations, it can be assumed that dietary calcium above the needs of pigs can result in an increase of available phosphorus requirement to not compromise the performance. Considering the results of this study and those obtained by Saraiva et al. (2009a) who assessed similar levels of aP for pigs within the same weight range and genetic pattern, it can be concluded that the lower weight gain of pigs fed diets with the lower aP concentration (0.144, 0.224 and 0.304%) reported by Saraiva et al. (2009a) was a result of dietary aP deficiency. Thus, according to the results obtained in both studies, the calcium level recommended by Rostagno et al. (2005) for this animal category is suitable as it did not interfere with the aP requirement of pigs for the best ADG. However, it was shown that the aP of 0.230 and 0.332% recommended by the NRC (1998) and Rostagno et al. (2005), respectively, may not meet the requirements of growing pigs of the current genotypes.

Feed conversion (F:G) was not influenced (P>0.05) by the dietary aP (Table 2). Similar results were obtained by

Stahly & Cook (1996) and Kegley et al. (2001) who also verified no effect of aP on F:G of piglets at 6 to 31 and 6 to 18 kg, respectively.

On the other hand, Arouca et al. (2010) and Saraiva et al. (2009a) in studies with pigs at 30 to 60 kg, reported positive effects of dietary aP on F:G of pigs which increased up to estimated levels of 0.390 and 0.345% aP, respectively.

Even though there was no significant variation on F:G among treatments, it was observed that the concentration of 0.384% aP provided, in terms of absolute value, the best response of F:G which was 6.8 to 11.2% lower compared to the F:G of pigs in the other treatments. This result is an indicative that a variation in weight gain composition of pigs among the experimental treatments might have occurred; so pigs fed diets up to 0.384% aP had higher protein accretion rate rather than fat deposition. Increase in body fat content in pigs feeding diets with low aP was reported by Stahly et al. (2001). According to Krick et al. (1992), an increase in weight gain of pigs associated with improvements in feed conversion can be explained mainly by the increase in protein deposition.

In a study with growing pigs, Cromwell et al. (1970) found that pigs fed diets containing low levels of phosphorus presented carcasses with significantly higher fat content, lower loin eye area and ham yield when compared with animals fed diets with high phosphorus concentration.

Increasing dietary aP did not influence ($P>0.05$) the amount of phosphorus in the bones (BP) (Table 2). In agreement with this result, Gomes et al. (1989a,b), when assessing the influence of dietary aP in performance and bone parameters of 31 to 62 kg and 62 to 93 kg pigs also did not observe any variation in phosphorus in the bones. However, Saraiva et al. (2009a) observed a linear increase in phosphorus in the bones of growing pigs, with increasing aP in the diets.

Although there was no variation in phosphorus in the bones in the treatments in this study, it was found a 5.5% increase ($P=0.055$) in the absolute value of BP between the lowest and the highest dietary aP concentrations (0.144 × 0.464%).

The quantity of calcium in bones (BCa) was influenced ($P<0.05$) by the dietary aP and increased linearly according to the equation: $\hat{Y} = 155.447 + 43.6098aP$ ($r^2 = 0.60$) (Table 2). Similarly, Viana (2008) and Saraiva et al. (2009b) found an increase in BCa of pigs from 15 to 30 kg with the increase of aP in the diets.

By contrast, Saraiva et al. (2009a) reported no effect of aP on the amount of calcium in the bones of female pigs during the growth phase. The difference of BCa responses observed among the studies may have occurred as a consequence of the calcium concentration in the diets which varied in this study, but were constant (0.730%) in the one by Saraiva et al. (2009a).

Studying the metabolism of calcium and phosphorus in pigs, Fernandez (1995) found that the deposition of these minerals in the bones tended to be constant and close to 2:1, regardless of their levels in the diet (Table 2). However, at low levels of dietary calcium bone resorption increases in order to maintain this ratio resulting consequently in a decrease of bone mineral content.

Considering the results of our study, in which the maximum variation in the calculated ratio between calcium and phosphorus (Ca × P) deposited in the bones corresponded to 19.6 × 2.07, it can be inferred that the deposition of these minerals in the bones seems to be interdependent and tend to maintain a close proportionality of deposition.

The percentage of bone ash (BA) was influenced ($P<0.01$) by the levels of dietary available phosphorus increasing linearly according to the equation: $\hat{Y} = 46.9539 + 9.31656\, aP$ ($r^2 = 0.72$) (Table 2). Significant variation in the percentage of CO of growing pigs due to dietary phosphorus was also observed by Eeckhout et al. (1995), Ekpe et al. (2002) and Saraiva et al. (2009a).

However, this result is different from those obtained by Viana (2008) and Saraiva et al. (2009b), who investigating the effects of aP levels on bone parameters of 15 to 30 kg piglets, observed no effect on BA percentage.

The inconsistency of results regarding the concentration of ash in the bones of pigs observed among studies may be related to the type of bones used in the assessment. In a study by Cromwell et al. (1970), it was found that the reduction of dietary phosphorus from 0.50 to 0.38% caused a 22% reduction in BA content of the turbinate bone against a reduction of only 6.0% in the metacarpal of growing pigs.

In a more recent study, Hastad et al. (2004) found that the effect of dietary available phosphorus levels on the percentage of BA of growing pigs, also varied depending on the type of bone assessed. As the BA content of the fourth metatarsal, fifth, sixth, and seventh ribs increased linearly, the BA concentration of the third metatarsal did not change when the level of phosphorus in the diets was increased.

Conclusions

The greatest weight gain for 30 to 60 kg female pigs selected for meat deposition is obtained at 0.372% of available phosphorus, corresponding to a calcium and phosphorus ratio of 2.06:1, and to an intake of 8.20 g/day of available phosphorus.

References

AROUCA, C.L.C.; FONTES, D.O.; SILVA, F.C.O. et al. Níveis de fósforo disponível para suínos machos castrados dos 60 aos 95 kg. **Revista Brasileira de Zootecnia**, v.39, p.2646-2655, 2010.

COFFEY, R.D.; PARKER, G.R.; LAURENT, K.M. **Feeding growing-finishing pigs to maximize lean grow rate**. University of Kentucky: College of Agriculture, 2000. Disponível em: <http://www.animalgenome.org/edu/PIH/prod_grow_finish.pdf>. Acesso em: 14/5/2007.

CRENSHAW, T.D. Reliability of dietary Ca and P levels and bone mineral content as a predictors of bone mechanical properties at various time periods of growing swine. **Journal of Nutrition**, v.116, p.2155, 1986.

CRENSHAW, T.D.; PEO, E.R.; LEWIS, A.J. et al. Bone strength as a trait for assessing mineralization in swine: a critical review of techniques involved. **Journal of Animal Science**, v.53, p.827, 1981.

CROMWELL, G.L.; HAYS, V.W.; CHANEY, C.H. et al. Effects of dietary phosphorus and calcium levels on performance, bone mineralization and carcass characteristics of swine. **Journal of Animal Science**, v.30, p.519, 1970.

EECKHOUT, W.; PAEPE, M.; WARNANTS, N. et al. An estimation of the minimal P requirements for growing-finishing pigs, as influenced by the Ca level on the diet. **Animal Feed Science and Technology**, v.52, p.29-40, 1995.

EKPE, E.D.; ZIJLSTRA, R.T.; PATIENCE, J.F. Digestible phosphorus requirement of grower pigs. **Canadian Journal of Animal Science**, v.82, p.541-549, 2002.

FANDREJEWSKI, H.; RYMARZ, A. Effect of feeding level on Ca, P, K and Na content in bodies of growing boars and gilts. **Livestock Production Science**, v.14, p.211-215, 1986.

FRIENSEN, K.G.; NELSSEN, J.L.; GOODBAND, R.D. et al. Influence of dietary lysine on growth and carcass composition of high-lean-growth gilts fed from 34 to 72 kilograms. **Journal of Animal Science**, v.72, n.7, p.1761-1770, 1994.

GOMES, P.C.; ROSTAGNO, H.S.; FONSECA, J.B. et al. Exigência de fósforo total e disponível para suínos na fase de crescimento. **Revista da Sociedade Brasileira de Zootecnia**, v.18, n.3, p.233-239, 1989a.

GOMES, P.C.; ROSTAGNO, H.S.; FONSECA, J.B. et al. Exigência de fósforo total e disponível para suínos na fase de terminação. **Revista da Sociedade Brasileira de Zootecnia**, v.18, n.3, p.241-247, 1989b.

HASTAD, C.W.; DRITZ, S.S.; TOKACH, M.D. et al. Phosphorus requirements of growing-finishing pigs reared in a commercial environment. **Journal of Animal Science,** v.82, p.2945-2952, 2004.

HENDRIKS, W.H.; MOUGHAN P.J. Whole-body mineral composition of entire male and female pigs depositing protein at maximal rates. **Livestock Production Science,** v.33, p.161-170, 1993.

HUERTAS, C.A.P. **Exigências nutricionais de fósforo em porcas nas fases de gestação e lactação**. 1992. 160f. Tese (Doutorado em Zootecnia) - Universidade Federal de Viçosa, Viçosa, MG.

KETAREN, P.P.; BATTERHAM, E.S.; WHITE, E. Phosphorus studies in pigs. 1. Available phosphorus requirements of grower/finisher pigs. **British Journal of Nutrition**, v.70, p.249-268, 1992.

KRICK, B.J.; BOYD, R.D. Influence of genotype and sex on the response of growing pigs to recombinant porcine somatotropin. **Journal of Animal Science**, v.70, p.3024-3034, 1992.

LIPTRAP, D.O.; MILLER, D.E.; ULLREY, K.K. et al. Calcium level for developing boars and gilts. **Journal of Animal Science**, v.31, p.540, 1970.

LIU, J.; BOLLINGER, D.W.; LEDOUX, D.R. et al. Effects of dietary calcium:phosphorus ratios on apparent absorption of calcium and phosphorus in small intestine, cecum and colon of pigs. **Journal of Animal Science**, v.78, p.106-109, 2000.

MAHAN, D. [2006] **Necessidades de minerales em cerdos selecionados por um alto contenido em magro y cerdas de alta productividad**. FEDNA. Disponível em: <http://www.etsia.upm.es/fedna/capitulos/06CAP_VIII.pdf>. Acesso em: 18/5/2007.

NATIONAL RESEARCH COUNCIL – NRC. **Nutrient requirements of swine**. 9.ed. Washington: National Academy of Science, 1998. 189p.

NATIONAL RESEARCH COUNCIL – NRC. **Requirements of swine**. 10.ed. Washington: 1998. 189p.

QIAN, H.; KORNEGAY, E.T.; CORNER, E.D. Adverse effects of wide calcium:phosphorus rations on supplemental phytase efficacyfor wealing pigs fed two phosphorus levels. **Journal of Animal Science**, v.74, p.1288-1297, 1996.

RAO, S.V.R.; PANDA, A.K.; RAJU, M.V.L.N. et al. Requirement of calcium for commercial broilers and white leghorn layers at low dietary phosphorus levels. **Animal Feed Science and Technology**, v.106, p.199-208, 2003.

REINHARD, G.A.; MAHAN, D.C. Effect of various calcium:phosphorus ratios at low and high dietary phosphorus for starter, grower and finishing swine. **Journal of Animal Science**, v.63, p.457-466, 1986.

ROSTAGNO, H.S.; ALBINO, L.F.T.; DONZELE, J.L. et al. **Tabelas brasileiras para aves e suínos**: composição de alimentos e exigências nutricionais. 2.ed. Viçosa, MG: UFV, Imprensa Universitária, 2005. 186p.

SARAIVA, A.; DONZELE, J.L.; ABREU, M.L.T. et al. Available phosphorus levels in diets for swine from 15 to 30 kg genetically selected for meat deposition. **Revista Brasileira de Zootecnia**, v.38, n.2, p.307-303, 2009b.

SARAIVA, A.; DONZELE, J.L.; OLIVEIRA, R.F.M. et al. Níveis de fósforo disponível em rações para leitoas de alto potencial genético para deposição de carne dos 30 aos 60 kg. **Revista Brasileira de Zootecnia.**, v.38, n.7, p.1279-1285, 2009a.

STAHLY, T.S.; CROMWELL, G.L.; TERHUNE, D. Responses of high, medium and low lean growth genotypes to dietary amino acid regimen. **Journal of Animal Science**, v.69, p.364, 1991 (suppl. 1).

STAHLY, T.S.; LUTZ, T.R.; CLAYTON, R.D. [2000]. Dietary available phosphorus needs of high lean pigs fed from 9 to 119 kg body weight. ASR-L655. Iowa State University. **Swine Research Report**. Disponível em: <http://www.ipic.iastate.edu/reports/00swinereports/asl-655.pdf>. Acesso em: 20/6/2007.

WISEMAN, T.G.; MAHAN, D.C.; PETERS, J.C. et al. Tissue weights and body composition of two genetics lines of barrows and gilts from twenty to one hundred twenty-five kilograms of body weight. **Journal of Animal Science**, v.85, p.1825-1835, 2007.

UNDERWOOD, E.J.; SUTTLE, N.F. **The mineral nutrition of Livestock**. 3.ed. New York: CABI Publishing, 1999. 598p.

UNIVERSIDADE FEDERAL DE VIÇOSA - UFV. **SAEG - Sistemas de Análises Estatísticas e Genéticas**. (Versão 9). Viçosa, MG, 2000. 301p.

VIANA, J.M. **Biodisponibilidade de fósforo em fosfatos e níveis s de fósforo disponível para suínos na fase inicial**. 2008. 49f. Dissertação (Mestrado em Zootecnia) - Universidade Federal de Viçosa, Viçosa, MG.