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

R. Bras. Zootec., v.40, n.12, p.2725-2731, 2011

Available phosphorus for 15- to 30-kg pigs kept in hot environment[1]

Leandro Alebrante[2], Juarez Lopes Donzele[2], Rita Flavia Miranda de Oliveira[2], Alysson Saraiva[2], Simoni Eliza Facioni Guimarães[2], Aloízio Soares Ferreira[2], Francisco Carlos de Oliveira Silva[3], Márvio Lobão Teixeira de Abreu[4]

[1] Project funded by Pronex/Fapemig/INCT.
[2] DZO, UFV.
[3] EPAMIG.
[4] UFPI.

ABSTRACT - This experiment was conducted to determine the requirement of available phosphorus (aP) for pigs kept in hot environment. Seventy-two pigs (36 castrated males and 36 females) with initial weight of 15.10±0.31 kg were allotted in a completely randomized block design with six treatments (0.107, 0.214, 0.321, 0.428, 0.535, and 0.642% of aP), six replicates and two pigs (1 castrated male and 1 female) per experimental unit. Pigs were kept in a hot environment with temperature of 34.1±0.8 ºC. The levels of aP influenced the daily weight gain, which increased quadratically up to the estimated level of 0.477%, and feed conversion, which improved quadratically up to the estimated level of 0.457%. The levels of aP also influenced the content of phosphorus in the bone, which increased quadratically up to the estimated level of 0.529%. The available phosphorus requirement of 15- to 30-kg pigs kept in a hot environment, for the best results of daily weight gain, feed conversion and bone parameters are 0.477, 0.457, and 0.529%, corresponding to the estimated daily available phosphorus intakes of 4.75; 4.55 and 5.27 g, respectively.

Key Words: genotype, minerals, requirement, swine, temperature

Introduction

The performance of pigs is influenced, among other factors, by the thermal environment in which they are reared. The poor performance observed in heat-stressed pigs is due to the reduction in feed intake that becomes lower with the rise of the air temperature (Christon, 1988).

From a nutritional point of view, inadequate feed intake results in inadequate intake of nutrients by the pig, having a direct impact on the rate and chemical composition of body gain (Quiniou et al., 2000). In this sense, identifying the need for nutrients in hot condition will enable to formulate diets that provide the adequate amount of nutrients consistent with the feed intake capacity of pigs in this environmental condition.

A nutrient whose requirement was found to be different in pigs with high genetic potential is phosphorus (Saraiva et al., 2009). Phosphorus is an abundant mineral in the animal body, and the bone tissue has the most of it (80.0%). The other 20.0% is found distributed among the soft tissues and body fluids where it performs many essential bodily functions (Underwood & Suttle, 1999). However, few studies have been conducted to determine the available phosphorus requirement of the current genotype of pigs when kept in hot environments.

Thus, an experiment was conducted with the objective to determine the available phosphorus requirement of 15- to 30- kg pigs kept in hot environment.

Material and Methods

The experiment was conducted from January to March of 2008. Seventy-two pigs (36 castrated males and 36 females) with initial weight of 15.10±0.31 kg were allotted in a completely randomized block design with six treatments (0.107, 0.214, 0.321, 0.428, 0.535, and 0.642% of aP), six replicates and two pigs (1 castrated male and 1 female) per experimental unit. The experimental unit was represented by the pen. Body weight and kinship of pigs were used as criteria in the blocks formation.

Pigs were housed in suspended metal cages, with wired mash floor and sides, equipped with semi-automatic feeders and nipple drinkers, located in rooms with controlled air temperature. The room temperature was kept constant at 34 ºC.

The thermal environment in the room was monitored three times a day (7:00 a.m., 12:00 a.m. and 5:00 p.m.) using a set of thermometers (maximum and minimum, dry and wet bulb and black globe) placed in an empty cage in the middle of the room, and at half the height of the body of the pigs.

Received September 17, 2010 and accepted April 13, 2011.
Corresponding author: lacamargors@hotmail.com

These data were then converted into the black globe humidity index (BGHI), according to Buffington et al. (1981).

Experimental diets (Table 1) were corn/soybean-based meal supplemented with minerals, vitamins and industrial amino acids to meet the requirements of piglets in the initial growth phase (15 to 30 kg), as defined by Rostagno et al. (2005) for all nutrients, except phosphorus. The aP levels were obtained through the inclusion of dicalcium phosphate in place of kaolin, resulting in diets with 0.107, 0.214, 0.321, 0.428, 0.535 and 0.642% aP. Industrial amino acids were added to the diets to keep the relationship between digestible lysine and the other digestible amino acids according to the ideal protein concept for this animal category recommended by Rostagno et al. (2005).

Feed and water were provided *ad libitum* throughout the experimental period. Experimental diets, daily feed waste and leftovers were weighted daily, and pigs were weighed at the beginning and end of the experimental period (25 days) for calculation of the average daily feed and phosphorus intakes, average daily gain and feed conversion.

On the first day of the experimental period, each piglet received 0.5 mL of a commercial antihelmintic ivermectin (1%) injected subcutaneously.

Pigs remained on trial until they reached an average of 29.09±1.93 kg and then fasted for a period of 24 hours. After fasting, one pig from each experimental unit with a final body weight closest to 30 kg was stunned and immediately exsanguinated. Carcasses were then opened and eviscerated.

An additional group of five pigs weighing 15.55±0.75 kg was euthanized, following the same procedure as the experimental animals to determine the carcass composition at the beginning of the experiment.

Eviscerated carcasses with no blood were divided longitudinally and the left side of each carcass (including head and feet) was crushed for 15 minutes by a 30HP, 1775 rpm commercial cutter. Afterwards, crushed and homogenized samples were taken and stored at -12 °C.

Samples were thawed at room temperature for a period of 24 hours and then oven-dried at 65 °C for 72 hours. Because of the high fat concentration, samples were defatted by a petroleum ether procedure using Soxhlet equipment for 4

Table 1 - Composition and nutritional values of experimental diets

Ingredient	Available phosphorus level (%)					
	0.107	0.214	0.321	0.428	0.535	0.642
Corn	62.011	62.011	62.011	62.011	62.011	62.011
Soybean meal 45%	32.000	32.000	32.000	32.000	32.000	32.000
Soybean oil	1.810	1.810	1.810	1.810	1.810	1.810
Dicalcium phosphate	-	0.577	1.156	1.734	2.312	2.891
Limestone	1.837	1.467	1.098	0.730	0.360	-
Kaolin	1.200	0.993	0.783	0.573	0.365	0.146
Salt	0.456	0.456	0.456	0.456	0.456	0.456
Vitamin premix[1]	0.100	0.100	0.100	0.100	0.100	0.100
Mineral premix[2]	0.050	0.050	0.050	0.050	0.050	0.050
Growth promoter[3]	0.075	0.075	0.075	0.075	0.075	0.075
Growth promoter[3]	0.030	0.030	0.030	0.030	0.030	0.030
L-Lysine HCl	0.282	0.282	0.282	0.282	0.282	0.282
DL-methionine	0.073	0.073	0.073	0.073	0.073	0.073
L-threonine	0.066	0.066	0.066	0.066	0.066	0.066
Antioxidant[4]	0.010	0.010	0.010	0.010	0.010	0.010
Nutritional calculated composition						
ME (kcal/kg)	3250	3250	3250	3250	3250	3250
Crude protein (%)[5]	19.981	19.981	19.981	19.981	19.981	19.981
Digestible lysine (%)[5]	1.146	1.146	1.146	1.146	1.146	1.146
Digestible met + cist (%)[5]	0.641	0.641	0.641	0.641	0.641	0.641
Digestible threonine (%)[5]	0.721	0.721	0.721	0.721	0.721	0.721
Calcium (%)	0.800	0.800	0.800	0.800	0.800	0.800
Total P analyzed (%)	0.344	0.440	0.546	0.690	0.782	0.821
Available P (%)	0.107	0.214	0.321	0.428	0.535	0.642

[1] Provided per kg of product: vitamin A – 8,000,000 IU; vitamin D3 – 2,000,000 IU; vitamin E – 10,000 mg; vitamin K3 – 1,500 mg; vitamin B12 – 20,000 mg; vitamin B2 – 5,000 mg; biotin – 50 mg; calcium pantothenate – 12,000 mg; niacin – 25,000 mg; antioxidant – 30,000 mg; vitamin B1– 1,500 g; vitamin B6 – 2,000 mg; folic acid – 800 mg; selenium – 320 mg; vehicle q.s.p. – 1000 g.
[2] Provided per kg of product: iron – 100,000 mg; copper – 30,000 mg; manganese – 70,000 mg; zinc – 160,000 mg; iodine – 1,900 mg; and vehicle q.s.p. – 1000 g.
[3] Provided per kg of product: colistin – 80,000 mg; and tylosin – 400,000 mg.
[4] Butylhydroxitoluene.
[5] Values estimated based on the digestibility coefficients of amino acids of ingredients, according to Rostagno et al. (2005).

hours. Dried and defatted samples were ground and packed into identified glass jars for further laboratory analysis. The water and fat removed during sample preparation were considered for correction of the values for the subsequent analysis, according to the technique described by Donzele et al. (1992).

The chemical analyses of protein and lipid from the carcass samples were performed at the Laboratório de Nutrição Animal of the Departamento de Zootecnia in the Universidade Federal de Viçosa, according to the techniques described by Silva (1990).

The deposition of protein and fat in the carcass was measured by comparative criteria between the carcasses of the first group of animals with body weight of 15.55±0.75 kg and the second group of animals, according to the methodology proposed by Donzele et al. (1992).

The front foot from the right side of each carcass was collected, placed in an aluminum container with water and boiled to soften the skin and muscle around the bones for removal of the third metacarpal.

Metacarpals were dissected and oven-dried at 65 °C for 72 hours. Dried bones were then crushed and defatted following a petroleum ether procedure using Soxhlet equipment for 3 hours. After, they were taken to the ventilated oven at 65 °C for a period of 24 hours and then ground in a ball mill.

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

The statistical analysis of the performance data, bone parameters and daily carcass protein and fat deposition was performed using the procedures for analysis of variance and regression contained in the System for Statistical and Genetics Analysis (UFV, 2000), version 8.0.

The requirement of aP was obtained based on the results of daily weight gain, feed conversion, bone parameters and daily deposition of protein and fat in the carcass using linear, quadratic or linear response plateau models, according to the best model adjustment for each variable.

Results and Discussion

During the experimental period, the temperature in the room was kept at 34.1±0.8 °C, the relative humidity at 70.1±8.1% and the black globe temperature at 35.2±0.7 °C with calculated black globe humidity index (BGHI) value of 86.7±1.14. It can be inferred, based on the values of mean air temperature (34.1 ºC) and BGHI (86.7), that pigs were exposed to heat stress considering that the thermoneutral range for this animal category is 18 to 28 ºC (Coffey et al. 2000) and that a BGHI value above 80.0 (Campos et al. 2008) characterizes an environment of heat stress.

The levels of aP did not influence (P>0.05) the average daily feed intake (ADFI) of pigs (Table 2). Taking as reference the results obtained by Saraiva et al. (2009), who verified significant variation in the ADFI by increasing aP in diets for pigs from the same genetic and weight range kept on thermoneutral environment (19.5 and 28.3 °C), one can deduce that the thermal environment to which pigs are exposed influences the pattern of feed consumption concerning the levels of aP in the diet. Probably, this altered response to feed intake between the thermal environments is related to the fact that pigs exposed to high ambient temperatures have a significant reduction in voluntary feed intake, regardless of their nutritional levels (Collin et al., 2001).

The daily available phosphorus intake increased (P<0.01) linearly by increasing aP level in the diets (Table 2),

Table 2 - Performance, bone parameters and daily carcass protein and fat deposition of pigs fed different levels of available phosphorus (aP)

Item	Available phosphorus level (%)						CV (%)
	0.107	0.214	0.321	0.428	0.535	0.642	
Feed intake (g/day)	937	962	1006	1073	957	1043	9.25
aP intake (g/day)[1]	1.00	2.06	3.23	4.59	5.12	6.70	9.10
Weight gain (g/day)[2]	465	531	574	641	551	594	8.97
Feed conversion (g/g)[2]	2.01	1.81	1.75	1.68	1.74	1.76	5.17
Bone phosphorus (g/kg)[2]	78.73	83.15	88.97	90.32	91.32	90.25	2.12
Bone calcium (g/kg)[1]	162.50	176.67	178.33	180.33	184.00	183.50	5.20
Bone ash (%)[1]	45.78	47.69	50.63	50.72	50.66	50.45	2.44
Carcass deposition							
Protein (g/day)	72.40	72.84	77.66	82.62	67.20	81.07	12.15
Fat (g/day)	61.26	59.23	61.54	67.36	69.72	58.73	19.04

[1] Linear effect (P<0.01).
[2] Quadratic effect (P<0.01).

according to the equation: $\hat{Y} = -0.13 + 10.40Pd$ ($r^2 = 0.99$). As there was no significant variation in voluntary feed intake, one can assume that the increase in the daily aP intake occurred due to the concentration of this mineral in the diet. Assessing aP levels in diets of castrated males and females pigs from 9 to 37 kg and 15 to 30 kg, Stahly et al. (2000) and Saraiva et al. (2009) also found a linear increase in the daily available phosphorus intake by increasing dietary aP.

There was effect (P<0.01) of aP on the average daily gain (ADG) of pigs (Table 2), which increased quadratically up to the estimated level of 0.477% (Figure 1). This result is consistent with those reported by Stahly et al. (2000) who verified positive effect of the aP levels in the diet on the growth rate of castrated male and females pigs from 9 to 37 kg up to the estimated level of 0.480%. In studies conducted with barrows and barrows and gilts up to 30 kg Stahly & Cook (1997) and Saraiva et al. (2009), respectively, also observed improvement in pigs weight gain by increasing the level of aP in the diet, although the greatest results between the studies were obtained at 0.500 and 0.509% of aP, respectively. Positive responses of ADG of pigs as a consequence of increasing dietary aP may be related to increases in the synthesis and formation of bone and muscle tissues, since low phosphorus availability in the diet can limit the formation of these tissues (Stahly, 2007) which have priority for development in the early stage of pigs growth (Shields Junior et al., 1983).

The inconsistency of results between studies regarding the values of aP that provided the greatest results ADG may be related to factors such as genetic potential of pigs for growth and the thermal environment. Assessing available phosphorus levels in diets for pigs with different growth potential from 28 to 42 days old, Hittmeier et al. (2006) found that the pigs' genetic potential interact with the aP content of the diet resulting in weight gains that are genotype specific. As for the effect of the thermal environment, Manno et al. (2005) found that pigs genetically similar and fed the same diet from 15 to 30 kg showed a decrease of 28.2% in the ADG when kept in a high temperature environment (34.2 °C), compared with the thermoneutral environment (22.7 °C).

Feed conversion (FC) of pigs was influenced (P<0.01) by the levels of aP in the diet (Table 2) increasing up to 0.457% aP (Figure 2). In a study with pigs in the initial phase of growth, Saraiva et al. (2009) found effect of the aP in the diet on the FC that improved quadratically up to the estimated level of 0.477% aP. However, the result of FC obtained in this study differs from that found by Kegley et al. (2001), who observed no variation in the FC of 6- to 17-kg piglets by increasing aP in the diet. As improvement in FC is usually related to the possible change in the composition of weight gain of pigs with increase in the proportion of protein (Marinho et al., 2007) and considering that quantitatively the muscle constitutes the second largest reserves of organic phosphorus (Stahly, 2007), one can assume that the variation in the genetic of pigs for meat deposition capacity justifies the difference seen in the results between studies.

Based on aP daily intakes of 4.75 and 4.55 g, corresponding to the estimated levels of 0.477 and 0.457% aP in the diet that provided the greatest results of ADG and FC in this study, respectively, it can be verified that the values of 3.74 and 4.40 g/day of aP recommended, respectively, by the NRC (1998) and Rostagno et al. (2005), may not be sufficient to meet the requirement of the current pig genotypes in the initial phase of growth (15 to 30 kg), kept in hot environment.

The amount of phosphorus deposited in the bones (BP) was influenced (P<0.01) by the aP levels (Table 2), which increased quadratically up to the estimated level of 0.529%

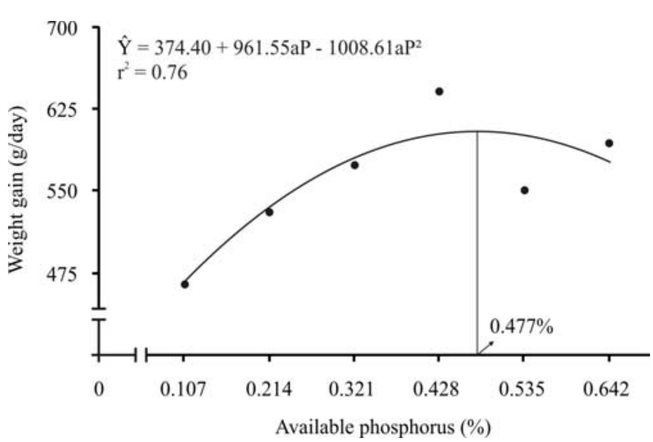

Figure 1 - Effect of available phosphorus levels on the weight gain of 15- to 30-kg pigs kept in hot environment.

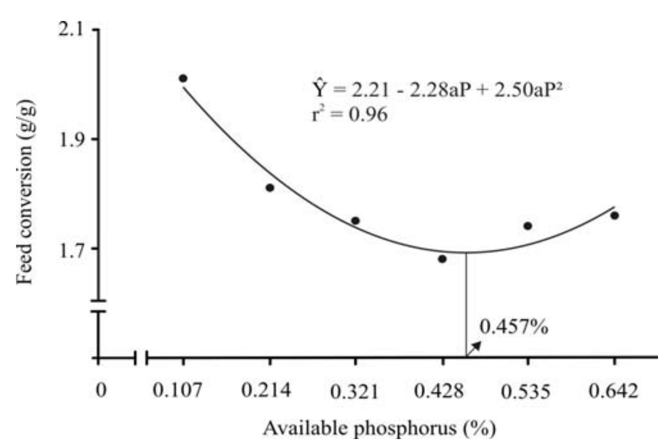

Figure 2 - Effect of available phosphorus levels on feed conversion of 15- to 30-kg pigs kept in hot environment.

aP in the diet (Figure 3). Studying the influence of dietary aP on the BP content of pigs from the same genetic and weight range of this study, but kept in a thermoneutral environment (24.5 ºC), Alebrante et al. (2011) also observed that the amount of BP increased up to the level of 0.525% aP.

Based on these results, we can infer that regardless of the thermal environment to which pigs are exposed, bone mineralization constitutes a priority of the metabolic use of phosphorus.

There was effect (P<0.01) of aP on the amount of calcium in the bones (BCa) (Table 2), which increased linearly according to the equation: $\hat{Y} = 164.66 + 34.44Pd$ ($r^2 = 0.73$). Significant increase in the concentration of BCa in castrated male and female piglets from 15 to 30 kg by increasing aP in the diet was also observed by Saraiva et al. (2009), up to the level of 0.619%.

Analyzing the metabolism of calcium and phosphorus in growing pigs, Fernández (1995) found that the calcium:phosphorus ratio (Ca:P) in the bone was maintained close to 2:1, irrespective to the amount of phosphorus consumed by the pigs. Consistent with this finding, it was observed in this study that although the Ca:P varied from 7.47 to 1.24, the calculated ratio between these minerals in the bones ranged only between 2.00 and 2.12. Thus, one can conclude that there is a proportionality of calcium and phosphorus deposited in the bone which does not seem to change with the level of these minerals in the diet.

It was verified in this study that the estimated aP levels of 0.529 to 0.642% which provided the highest values of phosphorus and calcium, respectively, in the bone were consistently above those that resulted in greatest response of weight gain (0.477%) and feed conversion (0.457%). Similarly, Kornegay et al. (1981), Mahan (1982) and Combs et al. (1991) also found that the greater bone mineralization occurred at dietary phosphorus levels above those required to maximize performance of pigs. These results are consistent with the NRC (1998) recommendations, which state that phosphorus requirement for maximum bone development is approximately 0.1% higher than the requirement for maximum weight gain.

The percentage of bone ash (BA) increased (P<0.01) linearly by increasing aP in the diets (Table 2). However, the Linear Response Plateau model provided the best fit to the data, estimating at 0.328% the level of aP from which BA remained on a plateau (Figure 4). This result is consistent with those obtained by O'Quinn et al. (1997), Spencer et al. (2000) and Hastad et al. (2004), who also found increase in the percentage of BA due to the increasing levels of aP in the diets of pigs at different stages of production.

Despite the similarity of results observed between studies concerning the positive effects of dietary available phosphorus in the concentration of bone ash in pigs, studies conducted by Ketaren et al. (1993) suggested that the bone analyzed is considered a factor that can lead to different responses to the phosphorus levels studied. These authors observed that levels of phosphorus in the diet that did not alter the percentage of ash in the metatarsal bone resulted, however, in significant variation in ash content of radius and femur bones.

The levels of aP did not influence (P>0.05) daily protein (DPD) or fat (DFD) deposition in the carcass (Table 2). These results differed from those obtained by Frederick & Stahly (1998), who studying levels of aP for pigs in the early stages of growth observed increase in the DPD and reduction in DFD as a result of the increase in the dietary aP.

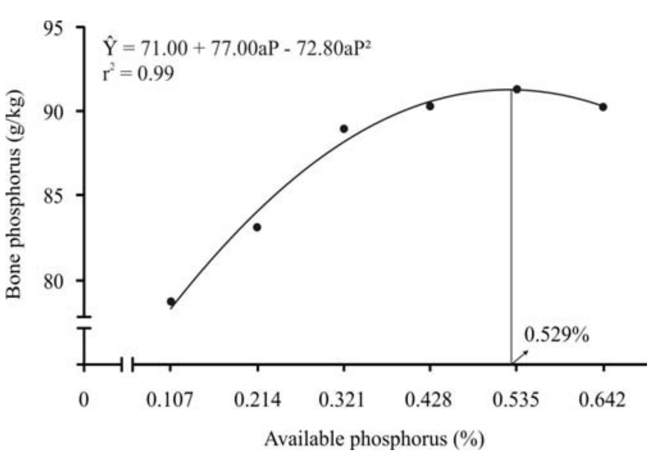

Figure 3 - Effect of available phosphorus levels on the amount of phosphorus in the bones of 15- to 30-kg pigs kept in hot environment.

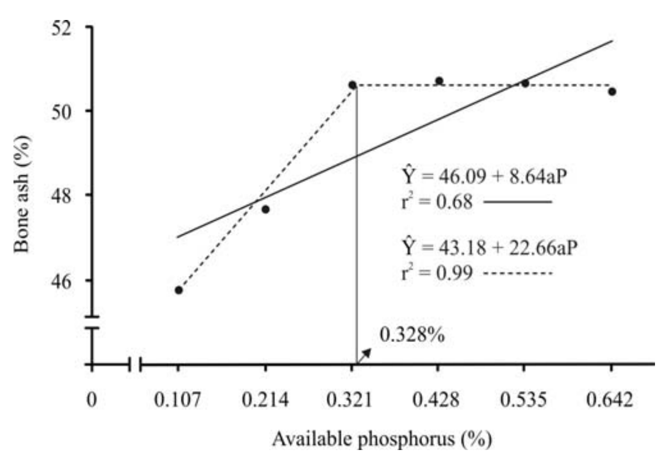

Figure 4 - Effect of available phosphorus levels on the bone ash content of 15- to 30-kg pigs kept in hot environment.

Although no significant change occurred, there was a 14.1% increase in the DPD between the levels of 0.107 and 0.428% aP. This result is consistent with the improvements observed in feed conversion between these levels of aP, since the deposition of protein in the carcass of pigs is a major factor that may explain the result of increased weight gain associated with improvement in feed conversion (Marinho et al., 2007).

Conclusions

The available phosphorus requirement of 15- to 30-kg pigs kept in hot environment for greatest results of daily weight gain, feed conversion and bone parameters are 0.477, 0.457, and 0.529%, respectively, corresponding to the estimated daily consumptions of 4.75, 4.55 and 5.27 g available phosphorus and to the calcium:available phosphorus ratios of 1.68:1, 1.75:1, and 1.51:1.

References

ALEBRANTE, L.; DONZELE, J.L.; OLIVEIRA, R.F.M. Available phosphorus levels in diets for pigs with high genetic potential for lean meat deposition kept in thermoneutral environment from 15 to 30 kg. **Revista Brasileira de Zootecnia**, v.40, n.2, p.323-330, 2011.

BUFFINGTON, D.E.; COLAZZO-AROCHO, A.; CANTON, G.H. et al. Black globe humidity index (BGHI) as comfort equation for dairy cows. **Transactions of the ASAE**, v.24, p.711-714, 1981.

CAMPOS, J.A.; TINÔCO, I.F.F.; BAÊTA, F.C. et al. Ambiente térmico e desempenho de suínos em dois modelos de maternidade e creche. **Revista Ceres**, v.55, n.3, p.187-193, 2008.

CHRISTON, R. The effect of tropical ambient temperature on growth and metabolism in pigs. **Journal of Animal Science,** v.66, p.3112-3123, 1988.

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. Available at: <http://www.animalgenome.org/edu/PIH/prod_grow_finish.pdf> Accessed on: May 14, 2007.

COLLIN, A.; VAN MILGEN, J.; DUBOIS, S. et al. Effect of high temperature on feeding behavior and heat production in group-housed young pigs. **British Journal of Nutrition**, v.86, p.63-70, 2001.

COMBS, N.R.; KORNEGAY, E.T.; LINDEMANN, M.D. et al. Calcium and phosphorus requirement of swine from weaning to market weight: II. Development of response curves for bone criteria and comparison of bending and shear bone testing. **Journal of Animal Science**, v.69, p.682-693, 1991.

DONZELE, J.L.; COSTA, P.M.A.; ROSTAGNO, H.S. et al. Efeito dos níveis de lisina na composição da carcaça de suínos de 5 a 15 kg. **Revista da Sociedade Brasileira de Zootecnia**, v.21, p.1091-1099, 1992.

FERNÁNDEZ, J.A. Calcium and phosphorus metabolism in growing pigs. II. Simultaneous radio-calcium and radio-phosphorus kinetics. **Livestock Production Science**, v.41, p.243-254, 1995.

FREDERICK B.R.; STAHLY, T.S. Dietary available phosphorus needs of high lean pigs. ISU Swine report research. Iowa State University Extention, 1998. Available at: <http://www.extension.iastate.edu/Pages/ansci/swinereports/asl-1563.pdf>. Accessed on: Aug. 2, 2009.

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

HITTMEIER, L.J.; GRAPES, L.; LENSING, R.L. et al. Genetic background influences metabolic response to dietary phosphorus restriction. **Journal of Nutritional Biochemistry**, v.17, p.385-395, 2006.

KEGLEY, E.B.; SPEARS, J.W.; AUMAN, S.K. Dietary phosphorus and an inflammatory challenge affect performance and immune function of wealing pigs. **Journal of Animal Science**, v.79, p.413-419, 2001.

KETAREN, P.P.; BATTERHAM, E.S.; WHITE, E. Phosphorus studies in pig. Available phosphorus requirements of grower/finisher pigs. **British Journal of Nutrition**, v.70, p.249-268, 1993.

KORNEGAY, E.T.; THOMAS, H.R.; BAKER, J.L. Phosphorus in swine. IV. Influence of dietary calcium and phosphorus and protein levels on feedlot performance, serum minerals, bone development and soundness scores in boars. **Journal of Animal Science**, v.52, p.1070-1084, 1981.

MAHAN, D.C. Dietary calcium and phosphorus levels for weanling swine. **Journal of Animal Science**, v.54, p.559-564, 1982.

MANNO, M.C.; OLIVEIRA, R.F.M.; DONZELE, J.L. et al. Efeito da temperatura ambiente sobre o desempenho de suínos dos 15 aos 30 kg. **Revista Brasileira de Zootecnia**, v.34, n.6, p.1963-1970, 2005.

MARINHO, P.C.; FONTES, D.O.; SILVA, F.C.O. et al. Efeito da ractopamina e de métodos de formulação de dietas sobre o desempenho e as características de carcaça de suínos machos castrados em terminação. **Revista Brasileira de Zootecnia**, v.36, p.1061-1068, 2007 (supl.).

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

O'QUINN, P.R.; KNABE, D.A.; GREGG, E.J. Digestible phosphorus needs of terminal-cross growing-finishing pigs. **Journal of Animal Science**, v.75, p.1308-1318, 1997.

QUINIOU, N.; DUBOIS, S.; NOBLET, J. Voluntary feed intake and feeding behaviour of group-housed growing pigs are affected by ambient temperature and body weight **Livestock Production Science,** v.63, p.245-253, 2000.

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.; OLIVEIRA, R.F.M. 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.307-313, 2009.

SHIELDS JUNIOR, R.G.; MAHAN, D.C.; GRAHAM, P.L. Changes in swine body composition from birth to 145 kg. **Journal of Animal Science**, v.57, p.43-54, 1983.

SILVA, D.J. **Análise de alimentos**: métodos químicos e biológicos. Viçosa, MG: Universidade Federal de Viçosa, 1990. 166p.

SPENCER, J.D.; ALLEE, G.L.; SAUBER, T.E. Phosphorus bioavailability and digestibility of normal and genetically modified low-phytate corn for pigs. **Journal of Animal Science**, v.78, p.675-681, 2000.

STAHLY, T.S. Nutrient needs for high lean pigs. Manitoba agriculture, food and rural initiatives. 2007. Available at: <http://www.gov.mb.ca/agriculture/livestock/pork/swine/bab10s13.html> Accessed on: June 1, 2007.

STAHLY, T.S.; COOK. D.R. **Dietary available phosphorus needs of pigs from 13 to 70 pounds body weight**. ISU Swine report research. Iowa State University Extention, 1997. Available at: <http://www.extension.iastate.edu/Pages/ansci/swinereports/asl-1477.pdf>. Accessed on: Aug. 2, 2009.

STAHLY, T.S.; LUTZ, T.R.; CLAYTON, R.D. **Dietary available phosphorus needs of high lean pigs fed from 9 to 119 kg body weight**. ISU Swine report research. Iowa State University Extention, 2000. Available at: <http://www.ipic.iastate.edu/reports/00swinereports/asl-655.pdf>. Accessed on: Aug. 2, 2009.

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

UNIVERSIDADE FEDERAL DE VIÇOSA – UFV. **Sistemas de Análises Estatísticas e Genéticas – SAEG**. Versão 8.0. Viçosa, MG, 2000. 142p.