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Available phosphorus levels for 95 to 120 kg barrows genetically selected for lean gain[1]

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ABSTRACT - With the objective of evaluating available phosphorus (aP) levels in diets for barrows selected for lean meat deposition, eighty commercial hybrid pigs with initial weight of 94.05±1.05 kg were used in this experiment. Pigs were allotted in a completely randomized block design, with five treatments (0.092, 0.156, 0.220, 0,284, and 0.348% of aP), eight replicates and two pigs per experimental unit. The average daily weight gain of pigs increased and the feed conversion improved quadratically with increasing aP in the diets up to the estimated levels of 0.21 and 0.20%, respectively. There was no effect of the dietary aP on average daily feed intake. However, aP intake, bone strength and concentration of phosphorus in the bones increased linearly with increasing aP in the diets. The levels of aP did not affect carcass traits; however, the alkaline phosphatase activity was improved and the values of serum inorganic phosphorus increased quadratically up to the estimated levels of 0.26 and 0.27% of aP, respectively. The available phosphorus levels of 0.21, 0.27, and 0.35%, corresponding to daily aP intakes of 6.34, 8.13, and 10.44 g result, respectively, in greatest performance, blood and bone parameters of 95 to 120 kg barrows selected for lean gain.

Key Words: carcass, finishing, minerals, nutrition, performance

Introduction

Formulation of diets using adequate proportions of nutrients, in addition to improving the efficiency of weight gain and feed conversion at different rearing phases can also reduce the cost of pig production. Along with better adjusted diets, it has been found that genetic selection by enhancing the potential for lean tissue accretion of pigs, and the improvements in the conditions of production with proper adjustment of feeders in order to reduce waste can also improve the utilization of feed and reduce the excretion of nutrients to the environment.

It has been verified that there is nowadays a trend towards slaughtering of pigs at higher weights, approximately 120 kg. However, the nutritional requirements are not the same for all categories of pigs and may vary depending on genetic, sex, temperature, health, density, age and body weight (NRC, 1998).

Thus, pigs with different genetic potential for lean gain may have different nutritional requirements, especially minerals (Hendricks & Moughan, 1993). Therefore, animals of superior genetic groups for lean tissue accretion may have their phosphorus requirements increased due to the change in the ratio of soft and skeletal tissues.

Phosphorus requirements of pigs have usually been established through the evaluation of performance, mainly based on growth rate and feed efficiency, not considering parameters such as bone mineralization, shear strength (NRC, 1998), content of inorganic phosphorus in serum, and activities of enzymes involved in the formation of bone tissue, such as alkaline phosphatase.

As phosphorus is involved in different vital metabolic functions, it is essential that its level in the diet be adequate, not only to meet the requirements for maximum performance. In addition to rapid and efficient growth, proper development of bones, teeth and enhancement of enzymes activities is necessary. Therefore, the objective of this study was to assess levels of available phosphorus for 95 to 120 kg barrows genetically selected for lean gain.

Material and Methods

The experiment was conducted at the state-owned company Empresa de Pesquisa Agropecuária de Minas

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Gerais - EPAMIG (Experimental Pig Farm Vale do Piranga, Oratórios, Minas Gerais, Brasil), from November to January, 2008.

Eighty commercial hybrid castrated male pigs (Agroceres Pic), selected for high lean meat deposition, with initial weight 94.05±1.05 kg were used. Pigs were allotted in a completely randomized block design, with five available phosphorus levels (aP), eight replicates, and two pigs per experimental unit (pen). Their initial body weight was considered the criterion in formation of the blocks.

The experimental diets were prepared from a basal diet with no dicalcium phosphate, consisting of corn and soybean meal and supplemented with minerals, vitamins, and amino acids to meet the minimum nutritional recommendations suggested by Rostagno et al. (2005) for all nutrients, except aP.

The diets corresponding to the experimental treatments were obtained by supplementing the basal diet with four levels of dicalcium phosphate (0.350, 0.695, 1.040, and 1.386%) in replacement of kaolin and limestone, resulting in five experimental diets with 0.092, 0.156 , 0.220, 0.284 and 0.348% aP (Table 1).

Pigs were housed in pens (1.87 m^2/pig) with concrete floor, provided with semi-automatic feeders and drinkers, located in a facility, covered with asbestos tiles. A digital thermohygrometer was placed inside the facility, with sensors located at one meter in height and at the height of pigs for daily monitoring of temperature and relative humidity during the experimental period.

The experimental diets and water were provided *ad libitum* throughout the experimental period. Experimental diets and leftovers were weighed periodically, and pigs were weighed individually at the beginning, at 21 days, and at the end of the experimental period, when they reached 118.96±4.32 kg. Average daily gain (ADG), feed conversion (FC), average daily feed intake (ADFI), and daily available phosphorus intake (aPI) were determined.

At 21 days of the experiment, all pigs were fasted for 12 hours, followed by 1 hour of feeding *ad libitum*. Then the pigs were fasted again with no access to water for four hours following blood sampling by puncturing the orbital venous plexus. Blood samples were kept at rest for one hour at room temperature for clotting and clot retraction, and then centrifuged at 3,500 rpm for 10 minutes to separate the

Table 1 - Composition and nutritional values of experimental diets

Ingredient	Available phosphorus levels, %				
	0.092	0.156	0.220	0.284	0.348
Corn	80.750	80.750	80.750	80.750	80.750
Soybean meal	15.080	15.080	15.080	15.080	15.080
Soybean oil	0.900	0.900	0.900	0.900	0.900
Ducalcium phosphate	—	0.350	0.695	1.040	1.386
Limestone	0.980	0.752	0.530	0.305	0.084
Kaolim	1.360	1.238	1.115	0.995	0.870
Salt	0.300	0.300	0.300	0.300	0.300
Vitamin premix[1]	0.200	0.200	0.200	0.200	0.200
Mineral premix[2]	0.100	0.100	0.100	0.100	0.100
Antibiotic[3]	0.020	0.020	0.020	0.020	0.020
Growth promoter[4]	0.150	0.150	0.150	0.150	0.150
L-lysine HCl – 78.4%	0.150	0.150	0.150	0.150	0.150
Antioxidant[5]	0.010	0.010	0.010	0.010	0.010
Total	100.0	100.0	100.0	100.0	100.0
Nutritional calculated value[6]					
Metabolizable energy, kcal/kg	3.237	3.237	3.237	3.237	3.237
Crude protein, %	13.96	13.96	13.96	13.96	13.96
Digestible lysine, %	0.750	0.750	0.750	0.750	0.750
Digestible met + cys, %	0.484	0.484	0.484	0.484	0.484
Digestible threonine, %	0.575	0.575	0.575	0.575	0.575
Sodium, %	0.169	0.169	0.169	0.169	0.169
Calcium, %	0.453	0.453	0.453	0.453	0.453
Total phosphorus, %	0.276	0.341	0.405	0.469	0.533
Available phosphorus, %	0.092	0.156	0.220	0.264	0.348

[1] Provided per kg of product: folic acid - 116.55 mg; pantothenic acid - 2,333.50 mg; antioxidant - 1,500 mg; biotin - 5.28 mg; niacin - 5,600 mg; pyridoxine - 175 mg; riboflavin - 933.30 mg; selenium - 105 mg; thiamine - 175 mg; vitamin A - 1,225,000 IU; vitamin B12 - 6,825 mcg; vitamin D3 - 315,000 IU; vitamin E - 1,400 mg; vitamin K3 - 700 mg.
[2] Provided per kg of product: Ca - 98,800 mg; Co - 185 mg; Cu - 15,750 mg; Fe - 26,250 mg; I - 1,470 mg; Mn - 41,850 mg; Zn - 77,999 mg.
[3] Ciprofloxacin.
[4] Zinc bacitracin.
[5] Oxinil (Provided per kg of product: citric acid - 40,000 mg; BHT - 100,000 mg; etoxiquin - 40,000 mg)
[6] According to Rostagno et al. (2005).

serum, which was stored in a refrigerator. Cooled serum was then sent to the Laboratory of Clinical Pathology of the Veterinary School of UFMG for analysis of alkaline phosphatase activity (APA) and phosphorus in serum.

The analyses to determine APA and serum phosphorus (Synermed®[1]) were performed by means of kits using "Cobas Mira" which is equipped with spectrophotometer, according to methodology described by Bowers Jr. & McComb (1966).

On the first and last days of the experimental period, after weighing the pigs, *in vivo* measurements of carcass traits using a portable ultrasound (PigLog-105®, v.3.1) were taken.

The pigs were restrained and the readings were obtained from the left side of the animals, where the following items were determined: backfat thickness (BT-P1) measured 6.0 cm from the lumbar midline and 6.5 cm from the last rib in the caudal direction, backfat thickness (P2), obtained 6.0 cm from the lumbar midline and 6.5 cm from the last rib in the cranial direction, where the loin depth (LD) was also obtained; percentage of lean meat estimated from backfat thickness (P1) and loin depth (LD), and the rate of daily lean gain was obtained by dividing the difference between the estimated percentage of lean meat on the last day and the percentage of meat lean estimated on the first day by the number of days of the experiment.

At the end of the experiment, pigs were weighed and fasted for 15 hours, then weighed again and sent to a commercial slaughterhouse. The animals were electrically stunned followed by exsanguination, subjected to carcass traits evaluation, and the front foot of the right side of each carcass was removed in accordance with the procedures adopted by the slaughterhouse.

The carcasses were individually evaluated with the aid of skin fold caliper Stork-SKF (model S-87), using the computerized system "Fat-o-Meater Fom". The caliper was introduced at the height of the third thoracic vertebra, surpassing the layer of fat and the *longissimus dorsi*. The data obtained were hot carcass weight, carcass backfat thickness, *longissimus dorsi* depth, lean percentage and amount of lean meat.

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. The metacarpals were used for measurements of bone strength and analysis of ash, calcium, and phosphorus. The metacarpal bones were oven-dried (65 °C, 72 hours) and then subjected to a breaking bending force (shear failure), indicator of bone strength, which was performed at the Laboratory of Building Materials in Department of Civil Engineering of Universidade Federal de Viçosa.

For analyses of calcium, phosphorus and ash the metacarpals were defatted in Soxhlet extractor and again brought to ventilated oven at 65 °C for a period of 24 hours and afterward ground in a ball-type mill. The samples were burned in an oven at 600 °C for determination of ash and then the levels of calcium and phosphorus were analyzed in the Laboratory of Animal Nutrition Agroceres in Rio Claro - São Paulo.

Performance data, blood and bone parameters, ultrasonic measurements in vivo and carcass traits were submitted to ANOVA using the statistical computer package SAEG (Sistema para Análises Estatísticas, version 9.0). The greatest available phosphorus levels were obtained by linear and quadratic regression analysis and/or discontinuous model "Linear Response Plateau" (LRP) according to the best fit obtained for each variable, taking into account the animal biological behavior.

Results and Discussion

The average minimum and maximum temperatures observed were, respectively, 20.23±1.75ºC and 32.48±2.52 ºC at one meter in height and 21.32±1.74 ºC and 29.51±3.49 ºC at the height of the pigs body, while the average minimum and maximum relative humidity were 37.38±10.79% and 79.00±5.86%. According to Coffey et al. (2000), for 68 kg pigs to be slaughtered, the optimal thermal zone is between 10.0 and 23.9 °C. Thus it can be inferred that the pigs were probably exposed to some periods of heat stress during the experiment, which may have affected their performance.

There was a quadratic effect ($P<0.05$) of aP levels on the average daily gain (ADG), which improved up to 0.21% aP, corresponding to daily intake of 6.35 g aP (Table 2 and Figure 1). Similarly, Stahly et al. (2000) observed a quadratic increase on ADG of pigs with high potential for lean gain, from 92 to 119 kg, when assessing aP levels between 0.082 and 0.297%.

On the other hand, Carter & Cromwell (1998a) found a linear effect of dietary aP levels (0.07 to 0.81%) on ADG of barrows from 72 to 114 kg, while O'Quinn et al. (1997) and Hastad et al. (2004) found no effect of phosphorus on ADG of barrows and gilts, respectively, from 80 to 118 kg and from 88 to 109 kg.

The average weight gain obtained in this study (973 g/day) was lower than the 1028 g/day, obtained by Carter and

[1] *SYNERMED® laboratory routes for alkaline phosphatase and serum phosphorus analysis, Westfield, IN, USA (SYNERMED® do Brasil, São Paulo, SP).*

Table 2 - Performance and daily available phosphorus intake (aPI) of 95 to 120 kg barrows

Item	Available phosphorus levels, %					CV, %
	0.092	0.156	0.220	0.284	0.348	
Weight gain, g/day[1]	944	1001	1045	951	925	12.33
Feed intake, g/day	2858	2960	2941	2866	3003	10.75
Feed conversion[2]	3.05	2.97	2.82	3.04	3.26	7.21
aPI, g/day[3]	2.62	4.61	6.47	8.10	10.40	13.10

[1, 2] Quadratic (P<0.05) and (P<0.01), respectively.
[3] Linear (P<0.01).

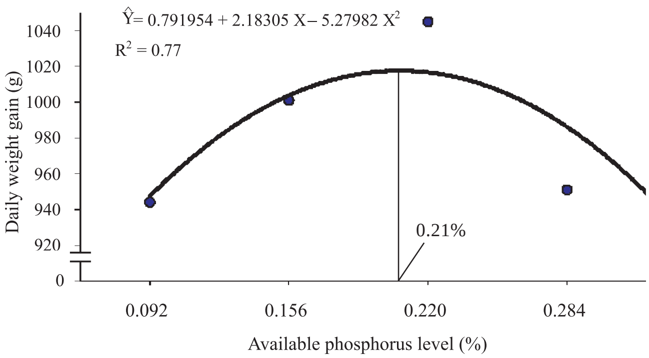

Figure 1 - Effect of available phosphorus levels on average daily gain of 95 to 120 kg barrows.

Cromwell (1998a) for late finishing barrows (72 to 114 kg). It is important to highlight that the high Ca:total phosphorus (Ca:P) ratio of 1.64:1, as well as the low ones of 0.98:1 and 0.85:1 in the diets with, respectively, lower (0.092%) and higher (0.284 and 0.348%) levels of available phosphorus resulted in the lowest weight gains of pigs. Gomes et al. (1989) also found the weight gain of finishing pigs was negatively influenced when pigs were fed diets with low or high levels of phosphorus. An inadequate dietary Ca:P ratio can reduce the absorption of phosphorus and/or calcium resulting in low rates of weight gain (NRC, 1998; Liu et al., 2000). Rostagno et al. (2005) suggested that the Ca:P ratio in practical diets for pigs showed stay between 1:13 and 1.20:1.

There was no effect (P>0.10) of aP levels on average daily feed intake (ADFI) of pigs. Similar results were obtained by O'Quinn et al. (1997), Carter & Cromwell (1998a), and Hastad et al. (2004). On the other hand, Stahly et al. (2000) found a quadratic effect of aP levels on the ADFI of pigs in the late finishing phase (92 to119 kg).

The ADFI of 2926 g/day obtained in this study was lower than the 2999 g/day obtained by Stahly et al. (2000), and the value of 3100 g/day suggested by Rostagno et al. (2005), for barrows with high genetic potential (100 to 120 kg). Thus, one can deduce that the thermal stress to which the pigs were subjected during the experimental period of this study probably negatively affected their voluntary feed intake. According to Ekpe et al. (2002), the temperature can also alter the feed intake and the potential for lean meat accretion, and consequently the amount of phosphorus required by pigs.

There was a quadratic effect (P<0.01) of aP levels on feed conversion (FC), which increased up to the estimated level of 0.20%, corresponding to an intake of 6.05 g/day of aP (Figure 2). Similar results were found by O'Quinn et al. (1997) and Stahly et al. (2000), who reported a quadratic effect of aP (0.10 to 0.19%) on the feed efficiency of late finishing pigs. However, Hastad et al. (2004) found no significant effect of the treatments on feed efficiency, while Carter & Cromwell (1998a) observed a linear increase.

The level of 0.20% aP that resulted in the greatest feed conversion in this study was approximately 30% higher than the recommended by NRC (1998) for barrows from 80 to 120 kg (0.15% aP) and Stahly et al. (2000), who estimated the requirement of aP for barrows and gilts at 0.16%. On the other hand, was 18.4% lower than the 0.245% aP recommended by Rostagno et al. (2005) for barrows with superior performance, from 100 to 120 kg, and similar to the levels of 0.19 and 0.21% recommended by Hastad et al. (2004) and Agroceres-Pic (2007), respectively.

The results of ADG and FC obtained in this study corroborate the reports of Arouca et al. (2010), that pigs with high potential for lean tissue deposition require greater amount of phosphorus in the diet to express their productive

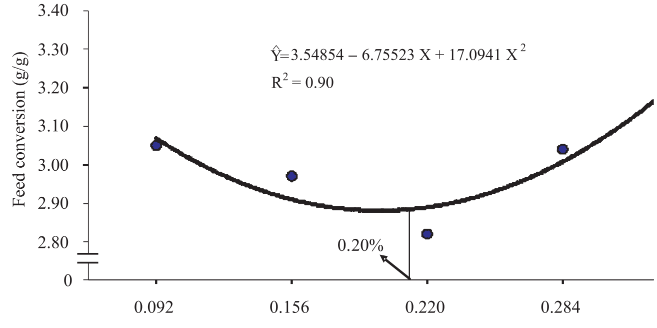

Figure 2 - Effect of available phosphorus levels on feed conversion of 95 to 120 kg barrows.

efficiency. According to Wiseman et al. (2007), pigs genetically selected for high lean deposition have higher content of lean and bone tissues compared with low genetic potential pigs, which may explain the greater demand for aP.

The Ca:aP ratio of 2.2:1 obtained in this study at the level of phosphorus that resulted in the best feed conversion ratio of 3:1 was lower than recommended by the NRC (1998). However, it was similar to the 2:1 obtained by Stahly et al. (2000) and higher than 1.85:1 recommended by Rostagno et al. (2005). Thus, one can deduce that the value of 0.15% aP established by NRC (1998) may not meet the requirements of pigs with high potential for lean gain during the late finishing phase.

The aP intake (aPI) increased linearly ($P<0.01$) with increasing the levels of aP in the diets, according to the equation $\hat{Y} = 0.0987888 + 29.7390X$ ($r^2=1.00$). This confirms the reports of Stahly et al. (2000), who observed a linear effect of phosphorus on the daily intake of aP in pigs from 92 to 119 kg, and the results of Hastad et al. (2004), who verified a linear effect on aPI of gilts reared in a commercial environment, from 88 to 109 kg. As no significant variation was observed on the ADG pigs, it can be inferred that the linear increase of aP intake was due to increased levels of aP in the diets.

There was a quadratic effect ($P<0.05$) of aP levels on the value of serum alkaline phosphatase (APA), which improved up to the estimated level of 0.26% aP, corresponding to an intake of 7.83 g/day aP (Table 3 and Figure 3). Koch & Mahan (1986), when assessing the effects of different Ca:P ratios and the effects of low levels of P in diets for 65 to 95 kg pigs, observed linear decrease in the APA at 21 days and at the end of the experimental period (35 days) by increasing dietary phosphorus.

Similarly, Nimmo et al. (1980) observed a decrease of APA due to the increased levels of calcium and phosphorus in the diets of 21 to 100 kg boars from two genetic groups. However, Nimmo et al. (1981) found no significant effect of calcium and phosphorus in the diet on the APA of crossbred gilts from 7 to 93 kg.

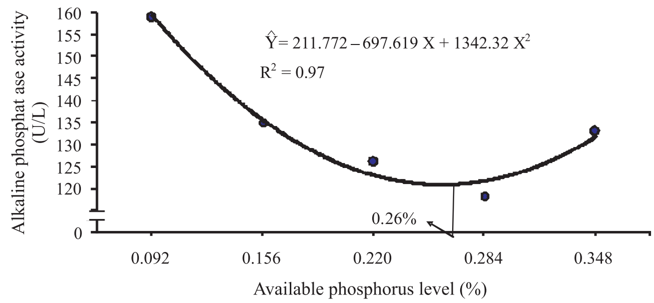

Figure 3 - Effect of available phosphorus levels on phosphatase alkaline activity of 95 to 120 kg barrows.

The estimated level of 0.26% aP which resulted in the lowest value of APA was higher than that estimated for better FC (0.20% aP). Based on this result, one can conclude that the aP level required to optimize APA is higher than that required for maximum performance of pigs in late finishing phase, although the enzyme activity decreases with the age of the pigs (Santos, 1983).

According to Koch & Mahan (1986), the APA decreased with the increase of phosphorus in the diet of finishing pigs, but the magnitude of decline was lower than in growing pigs. The smaller magnitude of the APA decline observed in the initial and growing phases compared with the finishing phase may be a consequence of the decline in bone growth and osteoblast activity with increasing age. Thus, one can infer that APA may be one more variable to be used to evaluate the effects of dietary phosphorus in pigs with high rates of bone growth and osteoblastic activity.

The levels of aP affected ($P<0.01$) the values of inorganic phosphorus in serum quadratically (Figure 4), which increased up to 0.27%, corresponding to a daily intake of 8.13 g aP. Koch & Mahan (1986) observed a linear increase of inorganic phosphorus in serum at 21 days and at the end of the experiment (35 days) due to the increase in the concentration of phosphorus in diets for pigs from 65 and 95 kg.

Similarly, Nimmo et al. (1981) observed an increase in serum inorganic phosphorus by increasing the levels of

Table 3 - Alkaline phosphatase activity (APA) and phosphorus concentration in the serum of 95 to 120 kg barrows according to the available phosphorus in the diet

Item	Available phosphorus levels, %					CV, %
	0.092	0.156	0.220	0.284	0.348	
APA, U/L[1]	159	135	126	118	133	30.48
Serum phosphorus, μg/dL[2]	7.99	9.10	9.53	9.36	9.53	6.59
Bone strenght, N/m[3]	941.8	1,016	1,013	1,037	1,322	20.00
Bone phosphorus, %[3]	56.65	56.95	57.87	57.37	58.02	3.63
Bone calcium, %[1]	9.64	9.93	10.11	9.76	9.80	1.63

[1, 2] Quadratic ($P\leq0.05$) and ($P\leq0.01$), respectively.
[3] Linear ($P\leq0.01$).

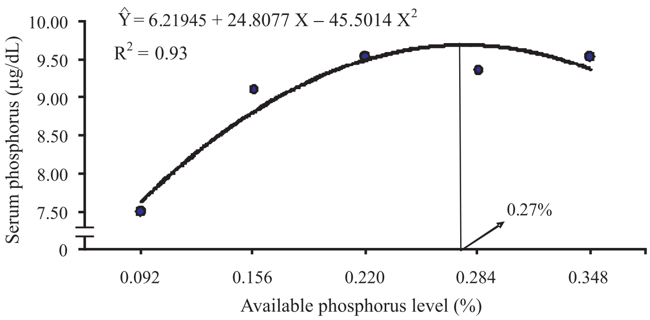

Figure 4 - Effect of available phosphorus levels on the serum concentration of phosphorus of 95 to 120 kg barrows.

calcium and phosphorus in the diets. Kornegay & Thomas (1981) reported an increase in serum inorganic phosphorus due to the increase of P in the diet as well as an increased level of serum inorganic phosphorus in pigs with fast growth rate compared with those with low growth rates, when evaluating different levels of calcium and phosphorus and growth rates of castrated male pigs and gilts, from 50 to 107 kg.

Reinhart & Mahan (1986) also observed a linear increase in serum inorganic phosphorus at the end of a 42-day experimental period by increasing the concentration of phosphorus in the diet and a linear decrease in serum phosphorus content by increasing the dietary Ca:P ratio for 54 to 86 kg barrows and gilts. On the other hand, Nimmo et al. (1980) found no effect of dietary Ca and P on the values of inorganic phosphorus in the serum of two genetic groups of 21 to 100 kg boars.

The estimated level of 0.27% aP that resulted in the greatest value of inorganic phosphorus in serum was higher than that estimated for better FC (0.20% aP). Thus, one can deduce that the aP level required to maximize the serum inorganic phosphorus is higher than that required for better feed conversion.

The inorganic phosphorus in serum may be a variable to assess dietary levels of aP in pigs during the late finishing phase, due to the response behavior associated with the high coefficient of correlation. Similarly, Ekpe et al. (2002) also suggested the values of inorganic phosphorus in plasma as a possible parameter to determine phosphorus requirement of pigs by resulting in a similar requirement to that estimated from the values of phosphorus retained.

The bone breaking strength was influenced ($P<0.05$) by the levels of aP increasing linearly according to the equation: $\hat{Y} = 790.737 + 1285.85X$ ($r^2 = 0.69$). Carter & Cromwell (1998a) and Saraiva et al. (2009) also observed a linear effect of increasing dietary phosphorus on bone breaking strength when evaluating, respectively, total phosphorus and aP levels from 0.35 to 0.65% and 0.115 to 0.435% for 79 to 109 kg and 30 to 60 kg pigs

In this study, the level of aP that resulted in maximum ADG of pigs was estimated at 0.21%, while bone strength continued to increase linearly with increasing levels of aP. These results corroborate the reports of Crenshaw (1986) and Saraiva et al. (2009), that phosphorus requirements for maximum weight gain and feed efficiency of growing pigs at levels below those required to maximize bone strength.

There was effect ($P<0.01$) of the aP levels on bone phosphorus, which increased linearly according to the equation: $\hat{Y} = 56.2676 + 5.00661X$ ($r^2 = 0.82$) by increasing the levels of aP in the diet. Similarly, Saraiva et al. (2009) also verified a linear increase in the amount of phosphorus in the bones of pigs from 30 to 60 kg. However, Gomes et al. (1989) reported no difference of the levels of aP in the amount of phosphorus in the bones of pigs from 62 to 93 kg.

The percentage of calcium in the bones increased ($P<0.01$) quadratically with increasing aP in the diet up to 0.23%, corresponding to a daily intake of 6.76 g aP (Figure 5). On the other hand, Saraiva et al. (2009) verified no effect of the levels of aP on the concentration of calcium in the bones of pigs during the initial phase of growth.

Based on reports of Mahan et al. (1980), that bone mineralization does not increase linearly with increasing phosphorus in the diet, it can be inferred by the results of bone strength and phosphorus and calcium concentration in the bones of this study that the highest aP level assessed (0.348%) was not sufficient to promote maximum bone mineralization in pigs from 95 to 120 kg, probably because the diets with the highest levels of aP (0.284 and 0.348%) compromised calcium absorption.

The levels of aP in the diets did not affect ($P>0.10$) backfat thickness at P1 and P2, loin depth, lean meat percentage and the rate of daily lean gain obtained in vivo (Table 4) . Similar results were obtained by Traylor et al.

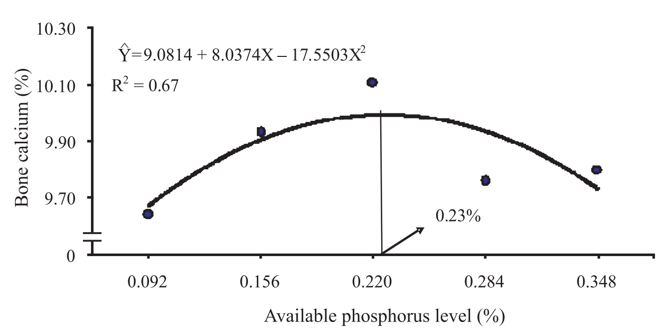

Figure 5 - Effect of available phosphorus levels on concentration of bone calcium of 95 to 120 kg barrows.

(2005), who also found no effect of different levels and sources of phosphorus on the backfat thickness, loin depth, and loin eye area obtained by real time ultrasound, and on the percentage of lean meat and daily gain of lean meat, estimated from equations in 105 kg pigs.

The average lean meat percentage (53.6%) obtained in this study was higher than the results obtained by O'Quinn et al. (1997) and Traylor et al. (2005), who reported values of 49.7 and 52.7% of lean meat percentage, respectively.

The average rate of daily lean gain obtained in our study (460 g/day) was higher than observed by O'Quinn et al. (1997) and Traylor et al. (2005), which were 317 and 316 g/day, respectively. That value was also higher than 350 g/day suggested by the NRC (1998) for 20 to 120 kg pigs with high rates of lean growth.

Phosphorus is essential for the synthesis of body protein, nucleic acid and it participates as a component of the cell membrane phospholipids and also in the energy metabolism through ATP production (Stahly, 2007). When compared, the phosphorus concentration in muscle tissue is significantly higher than that of adipose tissue. Thus, the increases observed in the aP requirements of pigs with high genetic potential for lean deposition may be a consequence of the increasing demand of phosphorus for muscle protein synthesis.

There was no effect (P>0.10) of the aP in the diet on carcass yield or backfat thickness taken in the slaughterhouse (Table 5). Likewise, Ketaren et al. (1993) also found no effect of phosphorus levels on the backfat thickness of barrows and gilts from 50 to 90 kg. Similarly, O'Quinn et al. (1997) and Carter & Cromwell (1998b) verified no effect of phosphorus levels on backfat thickness measured at the 10th rib of barrows and gilts from 80 to 118 kg and 72 to 114 kg, respectively.

On the other hand, Cromwell et al. (1970), assessing phosphorus levels in diets for 18 to 93 kg pigs verified that pigs fed the diet containing the lowest concentration of phosphorus had the highest value of backfat thickness.

There was no effect (P>0.10) of dietary aP levels on loin depth. Similarly, Stockland & Blaylock (1973), Weeden et al. (1993), O'Quinn et al. (1997), and Carter & Cromwell (1998b) found no effect of phosphorus on loin eye area. However, Cromwell et al. (1970) reported an increase in loin eye area by increasing the level of phosphorus in the diet of pigs from 18 to 93 kg.

The aP levels did not influence (P>0.10) the amount and percentage of lean meat. O'Quinn et al. (1997) also found no effect of aP in the diet on the daily gain of lean meat. According to Stahly (2007), the optimal level of aP on a diet for pigs, for a given weight, seems to be that which maximizes the rate and efficiency of protein deposition but maintains the stock of phosphorus in bones. An inadequate intake of phosphorus slows body weight gain, decreases the efficiency of feed utilization, and increases the body content of tissues poor in phosphorus (adipose tissue, for example). By consuming inadequate amounts of phosphorus in the diet, pigs with high potential for lean gain will mobilize phosphorus from the bones and to some extent, from the muscles, although not enough for optimal performance.

Table 4 - In vivo carcass traits and daily rate of lean meat deposition (DRLMD) of 95 to 120 kg barrows according to the available phosphorus in the diet

Item	Available phosphorus levels, %					CV, %
	0.092	0.156	0.220	0.284	0.348	
Backfat thickness at P_1, mm	16.27	17.21	16.50	15.46	17.07	18.52
Backfat thickness at P_2, mm*	12.67	12.71	13.00	12.54	14.07	13.94
Loin depth, mm	49.67	49.43	52.75	50.69	48.93	9.71
Lean meat, %*	53.67	53.05	53.89	54.28	53.13	3.05
DRLMD, g/day	433	450	492	478	448	21.98

* Values adjusted by the same variables measured at the beginning of the experiment.

Table 5 - Carcass traits of 95 to 120 kg barrows according to the available phosphorus in the diet

Item	Available phosphorus levels, %					CV, %
	0.092	0.156	0.220	0.284	0.348	
Carcass yield, %	73.06	73.69	74.46	73.52	74.20	4.43
Backfat thickness, mm	14.33	14.52	15.78	14.03	15.89	2.13
Loin detph, mm	61.03	59.97	62.23	58.77	61.94	20.20
Lean meat, kg	47.57	48.10	48.75	47.99	47.95	8.29
Lean meat, %	56.48	56.18	55.72	56.31	55.59	5.26

Conclusions

The greatest results of performance, blood and bone parameters of 95 to 120 kg barrows genetically selected for lean gain are obtained at 0.21, 0.27, and 0.35% available phosphorus in the diet, corresponding to intakes of 6.34, 8.13, and 10.44 g/day of available phosphorus.

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