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RESEARCH PAPER

Different sources of evaluation and calcium levels in diets for pigs of 21 to 63 days of age

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Abstract

One experiment was conducted to evaluate different sources and levels of dietary calcium in relation to performance, fecal score and bone deposition of piglets. We used 126 pigs, barrows and gilts with high genetic potential, selected for lean gain, distributed in a randomized block randomized in a 4x2 factorial arrangement (four levels of calcium x two sources of calcium). The treatments consisted of four levels of calcium (0.600, 0.675, 0.750 and 0.825) applied to each source of calcium used (limestone and calcium lactate). There was no interaction between the levels and sources of calcium tested for any of the performance parameters, fecal score and bone deposition evaluated. The sources of calcium did not influence the performance parameters, fecal score on the tenth day and bone deposition of piglets. The calcium lactate improved fecal score evaluated on the fifth day. Calcium levels had a quadratic effect the daily feed intake (ADFI) and average daily gain (ADG) of piglets from 21 to 35 days. However, there was no effect of calcium levels in relation to feed conversion (FC), fecal score and bone deposition of animals in the same period. There was no influence of calcium levels on the ADG, FC, fecal score and bone deposition of piglets from 21 to 63 days. However, there was a linear effect of calcium on the ADFI. Thus, calcium lactate provides improvement in fecal score on the fifth day of piglets; however, the other parameters of performance, fecal score on the tenth day and bone deposition were equivalent to limestone. The estimated level of 0.703% calcium corresponding to an intake of 2.61 g calcium/ day provides the best results from daily gain for pigs from 21 to 35 days. The estimated level of 0.600% calcium corresponding to an intake of 4.88 g calcium / day meets the requirements of pigs from 21 to 63 days for the best results for performance, fecal score and bone deposition.

Keywords: bone deposition, mineral, performance requirement, nutrition

Introduction

Calcium is a very important mineral that plays a role in the development and maintenance of the skeletal system and also performs many other physiological functions. Piglets have a particularly high growth rate requiring adequate calcium supplementation to promote bone development and support whole-body metabolism (Hanzlik et al., 2005).

Calcium concentrations are of paramount importance when evaluating the potential of a source as a dietary supplement. Calcite limestone is the most widely used calcium source as a nutritional supplement, due to its high calcium content (about 37.7%), bone meal (about 12%) has a lower calcium content than limestone. of calcium, and in the same range fit other calcium salts such as: calcite citrate, calcium gluconate, calcium lactate and calcium acetate around 10-25% calcium (Malde et al., 2010).

However, limestone is known to have a high acid-binding capacity (Lawlor et al., 2005) and, as a result of this binding, thus raising the pH in the proximal portion of the intestine. Thus, the supply of calcium in the form of limestone will tend to increase the pH of the digesta throughout the intestine (Selle et al., 2009). Additional effect may occur from the interaction between calcium and microminerals precipitating the latter (Shafey, et al., 1991).

In general, organic acids or their salts aim to reduce gastric pH, resulting in improved nutrient digestion and decreased bacterial concentration (Gottlob, et al., 2009). Hanzlik et al. (2005) reported that calcium citrate (calcium salt) is a good source of calcium, with comparable bioavailability to calcium carbonate for weaned piglets.

Thus, calcium lactate, within this context, can contribute as a valuable source of calcium without negatively affecting the buffer capacity of the feed and favoring the beneficial intestinal microbiota. There is evidence that lactose promotes calcium absorption by interacting with absorptive cells in the intestine by increasing permeability to calcium ions (Allen, 1982).

In this sense, the present work was carried out with the objective of evaluating levels and sources of calcium (limestone and calcium lactate) in rations for pigs from 21 to 63 days, based on performance, fecal score and bone deposition of the animals.

Materials and Method

The experiment was carried out at the Pig Farming Sector of the Animal Science Department at the Federal University of Viçosa, Minas Gerais.

The experiment was carried out with authorization from the Ethics Committee of the Animal Science Department of the Federal University of Viçosa (process n°66/2014) and the care and use of the pigs were carried out in accordance with the rules for the use of animals in experiments.

A total of 168 pigs were used, 88 males and 80 females, commercial hybrids, with high genetic potential for meat deposition on the carcass. Piglets weaned at 21 days of age and with an average weight of 6.08 ± 0.33 kg were distributed in a randomized block experimental design, in a 2 x 4 factorial arrangement – two calcium sources (calcitic limestone and calcium lactate) and four levels of calcium (0.600; 0.675; 0.750 and 0.825%), seven replicates and three animals per cage, which was considered the experimental unit. In the formation of blocks, the initial weight of the animals was taken into account.

The animals were housed in suspended cages, with slatted floors, equipped with semi-automatic feeders and pacifier-type drinkers, located in masonry rooms, with concrete floors and covered with ceramic tiles. The environmental conditions inside the rooms were recorded daily by a minimum and maximum (7h), black globe and dry bulb and wet bulb thermometer (7, 12 and 17 h) kept in an empty cage in the center of the room. half height of the animals' body. The recorded values were later converted into the globe temperature and humidity index (GTI), according to Buffington et al. (1981), to characterize the thermal environment in which the animals were kept.

The basal experimental diets (Table 1) were formulated based on corn and soybean meal and supplemented with minerals and vitamins, to meet the requirements of the animals, according to Rostagno et al. (2017), except for calcium. The treatments consist of two basal diets with calcitic limestone and calcium lactate (calcium level of 0.600%) and another six other diets provided by supplementing the basal diets with calcitic limestone or calcium lactate, replacing washed sand, in diets experimental with levels of 0.675; 0.750 and 0.825% of Ca.

In all rations, the relationships between essential amino acids and digestible lysine were verified, in order to ensure that no amino acid was limiting. In the evaluation of amino acid relationships, those recommended by Rostagno et al. (2017) on the ideal protein for growing animals.

During the entire experimental period, which lasted 42 days, feed and water were freely supplied to the animals.

Feed, leftovers and waste were periodically weighed and the animals weighed at the beginning of the experimental period, at 14 days and at the end of the experimental period (42 days), to determine the average daily feed intake (ADFI), the average daily weight gain (ADG) and feed conversion (FC).

Table 1: Ingredient composition of the basal diets

Ingredients (g/kg)	Phase, days					
	21 - 35		36 - 49		50 - 63	
	Calcium source					
	Calcitic limestone	Calcium lactate	Calcitic limestone	Calcium lactate	Calcitic limestone	Calcium lactate
Corn	450.64	450.64	540.88	540,88	546.71	546.71
Soybean meal	140.00	140.00	190.00	190,00	348.50	348.50
Soy oil	0.00	0.00	0.00	0.00	45.30	45.30
Lactose	132.80	132.80	69.50	69,50	0.00	0.00
Micronized Soybeans	93.94	93.94	90.00	90,00	0.00	0.00
Skimmed milk powder.	60.00	60.00	25.00	25,00	0.00	0.00
Blood plasma	40.00	40.00	20.00	20,00	0.00	0.00
Dicalcium phosphate	9.90	9.90	12.60	12,60	15.36	15.36
Sugar	15.00	15.00	0.00	0.00	0.00	0.00
calcitic limestone	3.85	0.00	3.80	0.00	3,22	0.00
calcium lactate	0.00	11.30	0.00	10.88	0.00	9.51
Inert	25.00	17.55	24.45	17.45	24,37	18.08
Salt	1.07	1.07	2.48	2.48	5.09	5.09
Aminogut	8.00	8.00	6.00	6.00	0.00	0.00
L-lysine, 78%	4.40	4.40	4.50	4.50	3.42	3.42
DL-methionine, 99%	3.16	3.16	2.42	2.42	1.24	1.24
L-Threonine, 98.5%	2.07	2.07	1.80	1.80	1.19	1.19
L-Valine, 96.5%	1.19	1.19	0.83	0.83	0.00	0.00
L-Tryptophan, 99%	0.28	0.28	0.16	0.16	0.00	0.00
L-Isoleucine, 99%	0.70	0.70	0.08	0.08	0.00	0.00
Vitamin Premix[1]	1.50	1.50	1.50	1.50	1.50	1.50
Mineral Premix[2]	1.00	1.00	1.00	1.00	1.00	1.00
butyric acid	1.50	1.50	1.50	1.50	1.50	1.50
Growth Promoter[3]	1.50	1.50	1.50	1.50	1.50	1.50
Zinc oxide	2.50	2.50	0.00	0.00	0.00	0.00
Antioxidant	0.00	0.00	0.00	0.00	0.10	0.10
Total	1,000	1,000	1,000	1,000	1,000	1,000
Calculated composition						
ME, kcal/kg	3,453	3,453	3,328	3,328	3,328	3,328
Crude protein, g/kg	211.98	211.98	207.34	207.34	208.00	208.00
Digestible lysine, g/kg	14.50	14.50	13.50	13.50	12.5	12.5
Digestible met+cys, g/kg	8.10	8.10	7.60	7.60	7.00	7.00
Digestible threonine, g/kg	9.20	9.20	8.50	8.50	7.90	7.90
Digestible tryptophan, g/kg	2.50	2.50	2.30	2.30	2.25	2.25
Digestible isoleucina, g/kg	8.00	8.00	7.43	7.43	7.92	7.92
Digestible valine, g/kg	10.00	10.00	9.30	9.30	8.6	8.6
Lactose, g/kg	120.00	120.00	60.00	60.00	0.00	0.00
Calcium, g/kg	6.00	6.00	6.00	6.00	6.00	6.00
Available phosphorus, g/kg	4.10	4.10	4.10	4.10	4.10	4.10
Sodium, g/kg	2.30	2.30	2.30	2.30	2.20	2.20

[1]Content/kg of product: vitamin A (10,000,000 IU), vitamin D3 (2,000,000 IU), vitamin E (40,000 IU), vitamin K3 (2,000 mg), vitamin B12 (20,000 mg), vitamin B2 (6,000 mg), biotin (200 mg), niacin (30 g), pantothenic acid (16 g), antioxidant (100 mg), B1 (1,500 mg), vitamin B6 (2,000 mg), folic acid (600 mg) and vehicle eq. (1,000 g). [2]Content/kg of product: iron (100,000 mg), copper (10,000 mg), manganese (40,000 mg), zinc (100,000 mg), cobalt (1,000 mg), iodine (1,500 mg), calcium (160.68 g) and vehicle qsp (1,000 g). [3]Active ingredient: Colistin sulfate. [4]washed sand

To study the effect of sources and levels of calcium in the feed on fecal consistency, it was measured on the fifth and tenth days at 9:00 and 17:00 hours by a macroscopic score for each cage, which corresponded to the experimental unit (Ball and Aherne, 1982). Score 1 corresponded to normal consistency stools, score 2 to soft stools, score 3 to watery stools and score 4 to bloody stools.

At the end of the experimental period, after fasting for 24 hours, one animal from each experimental unit with a weight closer to the average was slaughtered by bleeding to collect the right forepaw. The collected paws were placed in an aluminum container containing water and boiled for 25 minutes, aiming at softening the skin and the flesh surrounding the bones to remove the third metacarpal bone. The metacarpus of each slaughtered animal was kept in a ventilated oven at 65°C for 72 hours.

The bones were broken and degreased in a Soxhlet extractor and taken again to a ventilated oven at 105ºC for 24 hours and then ground in a ball mill.

The determination of the calcium and phosphorus contents of the calcium, phosphorus and ash concentrations in the bones was carried out at the Laboratory of the Federal University of Viçosa.

The cage was considered the experimental unit for analysis of performance variables (average daily feed intake, average daily weight gain and feed conversion) and fecal score. Only one animal from each repetition was considered the experimental unit in the statistical analysis of bone parameters (calcium, phosphorus and bone ash).

The data obtained were subjected to analysis of variance using the general linear model (GLM) procedure, using the SAS statistical program (2001). The effects included in the model were calcium source, calcium level and the interaction between calcium source and calcium level. Any differences between the means for the calcium source factor were compared using the F test. Calcium levels were submitted to linear and/or quadratic regression analysis depending on the best fit of the model to the variables.

Results and discussion

During the experimental period, maximum and minimum temperatures and air inside the experimental room remained at 28.90 ± 0.35; 26.90 ± 0.90 and 27.5 ± 1.02°C, respectively. The relative humidity and the globe temperature and humidity index (GTI) calculated in the period were, respectively, 69 ± 10.1% and 74.7 ± 1.32. With reference to the report by Coffey et al. (2000) that the optimal ideal temperature for piglets for the initial growth phase is in the range of 18 to 28°C and that of Alebrante et al. (2011), that the ITGU of 76.3 represents comfort for pigs from 15 to 30 kg, it can be inferred, based on the variation in temperature during the experimental period, that the animals were not subjected to heat stress.

Table 2: Initial and final weights, weight gains, feed intakes and feed conversions of pigs as a function of calcium levels and calcium sources (calcitic lime and calcium lactate) of the experimental feeds

Sources of calcium	Average	calcium levels (%)				P-value			CV, %
		0.600	0.675	0.750	0.825	Levels	Sources	Interaction L x S	
				Starting weight, kg					
Calcitic limestone	6.14	6.08	6.06	6.09	6.08	0.411	0.929	0.996	0.869
Calcium lactate	6.08								
				Final weight 28 days old, kg					
Calcitic limestone	9.97	9.88	10.20	10.09	9.78	0.076	0.883	0.505	6.531
Calcium lactate	10.00								
				Daily feed consumption, g²					
Calcitic limestone	358	344	372	361	341	0.065	0.642	0.872	13.567
Calcium lactate	351								
				Daily weight gain, g/g²					
Calcitic limestone	278	271	296	286	264	0.069	0.913	0.478	16.847
Calcium lactate	280								
				Food conversion (g/g)					
Calcitic limestone	1.31	1.28	1.28	1.29	1.30	0.964	0.284	0.383	11.976
Calcium lactate	1.26								
				Final weight 63 days old, kg					
Calcitic limestone	27.77	27.81	28.23	27.74	27.34	0.336	0.975	0.685	4.582
Calcium lactate	27.79								
				Daily feed consumption, g¹					
Calcitic limestone	829	834	841	820	790	0.007	0.390	0.338	5.558
Calcium lactate	814								
				Daily weight gain, g					
Calcitic limestone	517	517	528	516	499	0,173	0.787	0.533	6.611
Calcium lactate	513								
				Food conversion, g/g					
Calcitic limestone	1,61	1.61	1.60	1.59	1.59	0.896	0.549	0.393	5.473
Calcium lactate	1,59								

[1]Linear effect ($P<0.05$); Daily feed consumption: $\hat{Y} = -204.0X + 966.60$, $r^2=0.76$.
[2]Quadratic effect ($P<0.07$); Daily feed consumption: $\hat{Y} = -2177.78X^2 + 3075.33X - 715.50$, $r^2=0.91$; Daily weight gain: $\hat{Y} = -2088.89X^2 + 2935.33X - 737.05$, $r^2 = 0.96$.

There was no interaction (P>0.05) between calcium levels and sources for any of the performance variables, fecal score and bone deposition evaluated: final weight, daily feed intake (ADFI), daily weight gain (ADG), feed conversion (FC), bone calcium deposition, bone phosphorus deposition and bone ash deposition. Similar results were obtained by Jiang et al. (2013), evaluating the performance of piglets from 7 to 18 kg with diets containing different levels of calcium (0.37; 0.50; 0.60; 0.70; 0.80; 0.90; 1.00 and 1.10%) and calcium sources (calcium carbonate and calcium citrate) also did not observe interaction between the factors for the variables final weight, daily feed intake daily weight gain, feed conversion and fecal score.

When the two sources of calcium were evaluated, there was also no significant difference (P>0.05) on any of the performance variables evaluated for the periods from 21 to 35 and 21 to 63 days final weight, daily feed intake daily weight gain and feed conversion. These results are consistent with those obtained by Jiang et al. (2013), who, evaluating calcium sources (calcium carbonate and calcium citrate) also did not observe a significant difference for the performance variables and plasma calcium concentration.

According to reports by Gottlob et al. (2006) using calcium salts in simple corn and soybean meal based diets seems to be more effective than a complex diet. In the present study, the protein sources in the feed were not only based on soy bean, but also soy protein concentrate, skimmed milk powder and blood plasma. In addition, supplementation with lactose in the feed would generate lactic acid, which could facilitate limestone absorption, a fact also observed by Jiang et al. (2013) who found that lactose improves calcium carbonate absorption.

During the period from 21 to 35 days, there was an effect (P<0.07) of calcium concentrations on the performance variables daily feed intake and daily weight gain, which increased quadratically, according to the following equations $\hat{Y} = -2177.78X^2 + 3075.33X - 715.50$, $r^2=0.91$ and $\hat{Y} = -2088.89X^2 + 2935.33X - 737.05$, $r^2 = 0.96$, respectively (Figures 1 and 2). However, Jiang, et al. (2013) observed a quadratic response of calcium levels up to the estimated level of 0.60% for piglets from 7 to 18 kg. These same authors found no significant difference in calcium levels in relation to the animals' ADFI.

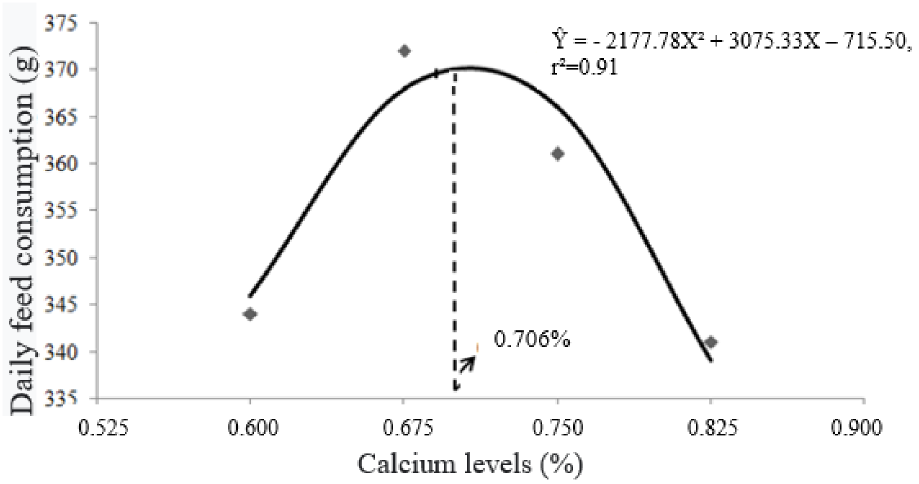

Figure 1: Effect of calcium levels in the diet on the daily feed intake of pigs from 21 to 35 days of age

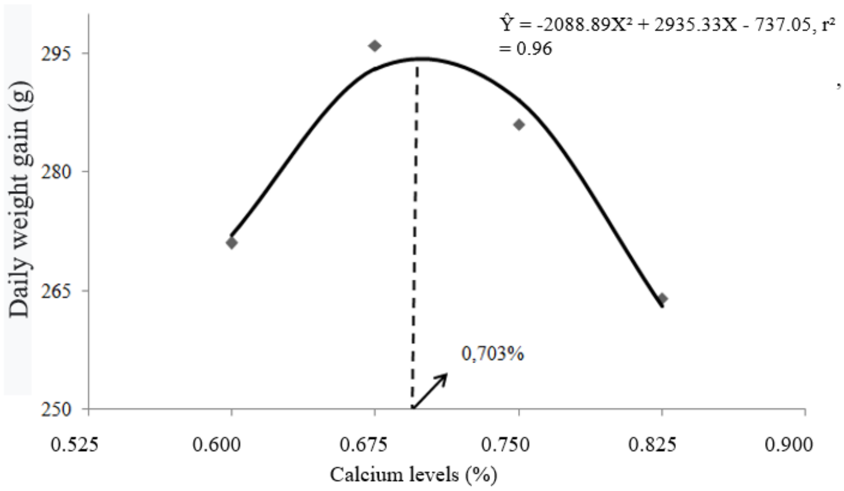

Figure 2: Effect of calcium levels in the diet on daily weight gain in pigs from 21 to 35 days of age

In contrast, Han & Thacker (2006) evaluating calcium concentrations (0.83; 0.91; 1.01 and 1.13%) and with two levels of total phosphorus (0.61 and 0.63), they did not observe effect of calcium levels on the ADFI and ADG of the animals. However, these authors evaluated levels higher than those found in the present study.

Létourneau-Montminy et al. (2010) studying two calcium levels (1.42 and 0.67%) with the same calcium: phosphorus ratio for piglets in the initial growth stage, they did not verify the effect of calcium levels on the ADFI and ADG of the animals. Calcium levels did not influence (P>0.10) the feed conversion of animals (Table 4). Lack of effect of feed calcium levels on the AC of early growing pigs was also observed by (Létourneau-Montminy et al., 2010; Nedeva et al., 2010).

In contrast, Kornegay et al. (1994) and Jiang, et al. (2013) verified the influence of calcium concentrations on the AC of post-weaning piglets. With the ADG results in this study, it can be inferred that the calcium level of 0.703% is relatively low compared to the level of 0.825% recommended by Rostagno et al. (2011) for piglets from 5.5 to 9 kg as the requirements for maximum animal performance. According to this reasoning, it can be inferred that the excellent performance of these animals in the present study, combined with complex experimental rations, may have influenced the reduction of calcium requirement by these animals.

When evaluated from 21 to 63 days, there was no difference (P>0.10) of calcium levels on the ADG and FC of the animals. These results are consistent with those of Nedeva et al. (2010) who, evaluating two levels of available phosphorus (0.35% and 0.80%) and calcium (0.71% and 1.22%) in feed for piglets from 9 to 30 kg, did not observe any effect of the levels of calcium on the ADG and FC.

Manh et al. (1982) working with calcium levels (0.50 to 1.30%) in diets for piglets from 7 to 20 kg, also did not observe significant difference in levels in relation to ADG and ADFI in pigs. However, these researchers observed worsening feed conversion as the calcium concentration increased.

There was a linear descending effect (P<0.05) of calcium levels on the ADFI of animals, according to the equation: $\hat{Y} = -204.0X + 966.60$, $r^2=0.76$. With these results, it can be inferred that high calcium levels can compromise voluntary feed intake for pigs in the initial growth phase.

According to these researchers Pallauf & Huter (1993) and Lawlor et al. (2006) when piglets were fed with a high content of calcium or phosphorus, the animal's feed intake was depressed. However, Lawlor et al. (2006) observed that when pigs were fed diets with a high calcium content with fumaric acid, there was an increase in the animals' voluntary intake. The performance results verified in the present work were similar to those reported by Zimmerman et al. (1963), Miller et al.(1962) and Jiang et al. (2013) who found that the calcium level of 0.60% meets the requirement for piglets in the initial growth stage.

However, Pallauf & Huter, (1993) reported that the high level of dietary calcium resulted in less weight gain and worse feed efficiency in the animals. Since calcium is known to have a high acid-binding capacity (Lawlor et al., 2005), thus, the pH in the proximal portion of the intestine is increased. Thus, the supply in high concentrations will tend to increase the pH of the digesta throughout the intestine (Selle et al., 2009). As a result of this pH change, less calcium is solubilized and some may even be precipitated (Schedl et al. 1968).

This fact was not observed in the present study, as the experimental rations contained butyric acid and lactose, which probably favored the reduction of stomach pH in the animals, even when they ingested high concentrations of calcium, based on performance and bone deposition.

Table 3: Fecal scores and bone deposition of pigs as a function of calcium levels and calcium sources (calcitic limestone and calcium lactate) of the experimental diets

Sources of calcium	Averages	Calcium Levels (%)				< P-value			CV, %
		0.600	0.675	0.750	0.825	Levels	Sources	Interaction L x S	
				Fecal score 5th day					
Calcitic limestone	2.5A	2.4	2.4	2.1	2.4	0.753	0.034	0.751	31.506
Calcium lactate	2.1B								
				Fecal score 10th day					
Calcitic limestone	1.7	1.7	1.7	1.5	1.6	0.406	0.366	0.313	35.258
Calcium lactate	1.6								
				Calcium deposition in bone, g					
Calcitic limestone	165	165	168	165	170	0.275	0.221	0.714	4.153
Calcium lactate	168								
				Phosphorus deposition in bone, g					
Calcitic limestone	89	90	88	90	91	0.250	0.321	0.951	3.212
Calcium lactate	90								
				Ash deposition on bone, g					
Calcitic limestone	487	489	482	490	490	0.544	0.685	0.673	3.059
Calcium lactate	489								

[1]Different letters differ (P<0.05) by the F test.

This variation can be influenced by several factors such as the bioavailability of calcium in the sources (Underwood & Suttle, 1999), differences in the calcium and phosphorus ratio (Crenshaw, 2001), weight range (Rostagno et al., 2011), genetic capacity from lean meat deposition (Manhan et al., 2008) and immune stress (Lawlor, et al., 2006).

When the two sources of calcium were analyzed, there was a significant difference (P<0.05) of the sources in relation to the fecal score on the fifth experimental day of the piglets, the animals that consumed calcium lactate showed greater consistency of feces than those that did they ingested calcitic limestone.

Organic acid (calcium lactate) can favor a rapid drop in gastric pH after feeding, thus preventing the establishment and multiplication of microorganisms that cause diarrhea (Bolduan et al., 1988). However, there was no effect (P>0.10) of the sources on the fecal score on the tenth day. A fact also analyzed by Jiang et al. (2013) who found no difference in the fecal score of animals that consumed calcium carbonate and calcium citrate.

Calcium levels did not influence (P<0.10) the fecal score on the fifth or tenth day. In contrast, Jiang et al. (2013) observed a higher incidence of diarrhea in animals that consumed a higher concentration of calcium (0.90-1.10%) in the diet of those that consumed higher levels.

There was no effect (P>0.05) of calcium sources on the bone deposition parameters of piglets. Jiang et al. (2013) did not observe differences in plasma calcium concentration between different sources of calcium (calcium citrate and calcitic limestone). There was no influence (P>0.05) of calcium levels on the bone deposition parameters of the animals.

On the other hand, Létourneau-Montminy et al. (2010), studying two calcium levels (1.42 and 0.67%) with the calcium: phosphorus ratio even for growths, who found a higher concentration of calcium deposition in bone and bone ash in animals that consumed rations with a higher concentration of calcium in the feed

According to some researchers such as Koch et al. (1984), Reinhart & Mahan (1986) and Pointillart et al. (1989), the increase in the concentration of calcium in the diet reduces the absorption of phosphorus, which results in a decrease in bone growth and calcification.

The different calcium concentrations in the present study did not modify the bone deposition of the animals, and the excellent feed intake of the animals compensated for the low calcium concentration in the feed (0.600%). Létourneau- Montminy et al. (2010) demonstrated that the increase in bone remodeling in pigs fed diets with low calcium concentration was sufficient to deposit calcium in the bone, being equivalent to that of animals fed diets with high calcium concentration. These observations indicate that pigs are able to regulate bone turnover in response to the absence of calcium (Létourneau-Montminy et al., 2010).

Conclusions

Calcium lactate provided an improvement in the fecal score on the 5th experimental day of the piglets, however, in the other performance parameters and bone deposition the results were equivalent to calcitic limestone. The estimated 0.703% calcium level corresponding to an estimated consumption of 2.61g calcium/day provides the best daily weight gain results for pigs from 21 to 35 days. The estimated level of 0.600% calcium corresponding to an estimated consumption of 4.88g calcium/day meets the requirements of swine from 21 to 63 days for the best performance results, fecal score and bone deposition.

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