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RESEARCH PAPER

Available phosphorus in starter diets for meat-type quail

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Abstract

R.G. Oliveira, S.R.F. Pinheiro, K.B. Goulart, A.V. Pires, F.C. Figueiredo and K.A.A. Torres-Cordido. 2015. Available phosphorus in starter diets for meat-type quail. *Cien. Inv. Agr. 42(1): 19-25*. Phosphorus is an important mineral for optimum growth and bone mineralization and is considered the third most expensive nutrient in diets for nonruminants. An experiment was conducted to evaluate the available phosphorus requirements (AP) for meat-type quail in the starter phase (1 to 21 days old). One-day-old, unsexed European quail (375) from the LF1 lineage were used for the study and were housed in pens. The experiment had a completely randomized design, with five treatments (0.13, 0.23, 0.33, 0.43 and 0.53% of AP), each of which included five replicates in 15 birds. Feed intake, weight gain, feed conversion ratio, and the tibial deposition of phosphorus, calcium, and ash were assessed. The AP levels influenced all studied variables. We calculated that levels of 0.381% AP or 0.12% AP megacalorie of metabolizable energy (% AP/Mcal ME) were best for bone quality related to high tibial ash deposition.

Key words: Calcium, bone growth, calcium/phosphorus ratio, quail.

Introduction

The Brazilian quail production is growing rapidly. The Brazilian Institute of Geography and Statistics (IBGE) recorded annual increases of 19.8% between 2009 and 2011 (Quintslr and Bolliger, 2012). According to the Brazilian Association of Animal Protein (ABPA), 5.56 million quail were slaughtered in 2013, which corresponded

to 74.13% of the national production of nonconventional types of poultry (*i.e.*, not broilers and turkeys) (ABPA, 2014). However, the national production of specific lineages of meat-type quail is in development; therefore, research is required to optimize the genetic potential of the lineages (Barbieri *et al.*, 2015). According to Teixeira *et al.* (2013a), it is necessary to establish meat-type quail breeding programs, to understand quail nutritional needs, and to development feeding programs aimed at improving the performance and carcass yield.

Among the macrominerals that are provided in poultry feed, both phosphorus and calcium are important because of their contributions to optimal growth rates and bone mineralization. According to Underwood and Suttle (1999), phosphorus is the second-most abundant mineral in the composition of animal tissue, with 80% of phosphorus found in the bones and teeth and the remainder distributed among other tissues and fluids. Furthermore, phosphorus is essential for the formation of molecules, such as phospholipids in cell membranes, and the nucleic acids that are involved in the maintenance of osmotic and electrolytic balance. It is also essential for the use and transfer of energy, the transport of fats and the synthesis of amino acids and proteins, and it participates in the control of appetite and feed efficiency (Runho *et al.*, 2001).

The sources of phosphorus are considered one of the most expensive ingredients in diets, following only energy and protein. This mineral is currently being researched because of its economical and physiological importance and its impact on the environment. Thus, much research has focused on decreasing phosphorus excretion in birds without compromising animal performance. However, the nutritional requirements of phosphorus that are used in the formulation of diets for meat-type quail have been extrapolated from studies in laying quail (Lima *et al.*, 2009). Given the importance of phosphorus in animal feed, we conducted this research to evaluate the nutritional requirements of AP to obtain the optimal productive performance and mineral deposition in the bones of starter phase (from 1 to 21 days old) meat-type quail of the LF1 lineage.

Materials and methods

Birds and experimental design

The experiment was conducted in the Animal Science Department of the Federal University of Vales of Jequitinhonha and Mucuri (UFVJM)

in Diamantina-Minas Gerais, Brazil, in 2010. Three hundred seventy-five 1-day-old, unsexed, LF1 meat-type quail (*Coturnix coturnix coturnix*) from the Quail Breeding Program at the UFVJM were used in the study. The experiment had a completely randomized design with five levels of AP (0.13, 0.23, 0.33, 0.43 or 0.53%) in the diet and five replicates with 15 quail each. The birds were reared in 1.00×0.70 m pens that were placed on a litter floor (wood shavings, approximately 5 cm deep), and each pen had a manual feeder with cup drinkers and a gas brooder. Only natural light was used, and no specific light program was followed. The maximum and minimum environmental temperatures were registered with thermometers that were placed at different sites in the room.

Treatments

The quail were fed experimental diets, which consisted of corn and soybean meal, and these diets were formulated according to nutritional requirements, except for the AP (Table 1), and in agreement with the composition of ingredients in Rostagno *et al.* (2005). Quail were fed *ad libitum* throughout the experimental period.

Performance and bone quality

Performance variables such as feed intake (g), weight gain (g) and feed conversion ratio (feed intake/weight gain) were determined. The rates of mortality were used as a factor of feed intake correction. The tibial percentage of calcium, phosphorus and ash were considered variables of bone quality. At 21 days, three quail from each replicate were fasted for five hours and then killed by cervical dislocation. The two tibias of each bird were dissected and boiled in distilled water for five minutes. Fibula and cartilage were also removed. The tibias were identified with aluminum plates, immersed in petroleum ether for 48 hours, and dried in an oven with forced ventilation at 60 °C for 48 h. Then, the bones were ground up in a

Table 1. Percentage composition and calculated analysis of experimental starter diets for meat-type quail (1 to 21 days old).

Treatments	Available phosphorus (%)				
	0.13	0.23	0.33	0.43	0.53
Ingredients					
Yellow corn	51.115	51.115	51.115	51.115	51.115
Soybean meal (45%)	43.168	43.168	43.168	43.168	43.168
Soybean oil	2.101	2.101	2.101	2.101	2.101
Salt	0.330	0.330	0.330	0.330	0.330
L-lysine HCl	0.119	0.119	0.119	0.119	0.119
DL-methionine	0.171	0.171	0.171	0.171	0.171
Trace mineral and vitamins premix ¹	0.200	0.200	0.200	0.200	0.200
Calcium phosphate	0.062	0.603	1.145	1.684	2.224
Limestone	1.734	1.385	1.035	0.686	0.338
Inert ²	1.000	0.810	0.617	0.425	0.234
Total	100.00	100.00	100.00	100.00	100.00
Composition calculated					
Metabolizable energy (kcal kg ⁻¹)	2.900	2.900	2.900	2.900	2.900
Crude protein (%)	24.00	24.00	24.00	24.00	24.00
Available phosphorus (%)	0.130	0.230	0.330	0.430	0.530
Total phosphorus (%)	0.382	0.482	0.582	0.682	0.782
Calcium (%)	0.800	0.800	0.800	0.800	0.800
Sodium (%)	0.150	0.150	0.150	0.150	0.150
Digestible methionine (%)	0.500	0.500	0.500	0.500	0.500
Digestible methionine + cystine (%)	0.808	0.808	0.808	0.808	0.808
Digestible lysine (%)	1.300	1.300	1.300	1.300	1.300
Digestible threonine (%)	0.877	0.877	0.877	0.877	0.877
Digestible tryptophan (%)	0.274	0.274	0.274	0.274	0.274

¹Provided per kg product: vitamin A 1700 UI; vitamin B1 250 mg; vitamin B12 2500 mg; vitamin B2 1000 mg; vitamin B6 500 mg; vitamin D3 375,000 UI; vitamin E 3000 UI; vitamin K3 400 mg; folic acid 175 mg; pantothenic acid 2500 mg; biotin 3.75 mg; choline 37.5 g; niacin 7500 mg; bacitracin zinc 13.75 g; salinomycin 16.5 g; BHT 1000 mg; Cu 2500 mg; Fe 12.5 g; I 212.5 mg; Mn 17.5 g; Se 75 mg; Zn 15 g.

²Clean sand.

ball mill. The analyses were made in the Animal Nutrition Laboratory at the Animal Science Department of the UFVJM according to the methods of Silva and Queiroz (2002), and the results were expressed as defatted dry matter.

Statistical analysis

The data from the performance variables and bone composition were submitted to ANOVA after assumptions were met. The AP levels were unfolded

in linear and quadratic effects regression analysis. An estimate of the AP levels was obtained using the “Linear Response Plateau” (LRP) and/or quadratic models. To check the fit of the models, the sum of the squares of the deviations, the significance of the F test and the determination coefficients were considered. To avoid the occurrence of high (overestimated) and low (underestimated) levels, where an adjustment of both models was possible, the optimal level was estimated by the first intersection of the quadratic equation with the plateau of the LRP, as described by Sakomura

and Rostagno (2007). Statistical analyses were performed using the computer program SAEG (Sistema para Análises Estatísticas e Genéticas, Fundação Arthur Bernardes, Universidade Federal de Viçosa-MG, 2004), and significance was observed at the level of 5% ($P \leq 0.05$).

Results and discussion

The feed intake (FI) was affected ($P \leq 0.01$) by the AP levels (Table 2). The settings for the linear ($FI = 187.45 + 132.02AP$, $R^2 = 0.64$), quadratic ($FI = 125.914 + 588.865AP - 692.19AP^2$, $R^2 = 0.88$) and LRP functions ($FI = 246.90 + 366.10(0.288 - AP)$, $R^2 = 0.94$) were verified. The estimates from the LRP and quadratic functions were 0.288% and 0.425% of AP, respectively. The value from the intersection of the quadratic and LRP functions was 0.347% AP in the experimental diet or 0.12% AP/Mcal ME. Phosphorus is an element of adenosine triphosphate (ATP), a molecule that stores energy in the phosphate bonds for several biological processes. Thus, a diet deficient in phosphorus impairs ATP formation and leads to disturbances in the metabolism of energy and, consequently, to weight loss and a reduction in production (McDowell, 1992; Pinheiro *et al.*, 2011). In this experiment, the lowest feed intake and weight gain were obtained at the 0.13% AP level; thus, this level led to a nutritional deficiency of phosphorus in the meat-type quail (*C. coturnix coturnix*) lineage LF1. In contrast, we observed

that high levels of AP inclusion (0.53%) led to a discrete decline in feed intake. Similarly, Teixeira *et al.* (2013b) observed that 0.5% AP inclusion led to a lower feed intake than did 0.4% AP inclusion in broilers' diets (22 to 42 days old). However, Fassani *et al.* (2007) verified that meat-type quail had a higher feed intake when they were fed with 0.48% (0.165%/Mcal ME) of AP in the diet until 21 days of age, but that value was estimated using a quadratic model, which often overestimates the nutrients (Sakomura and Rostagno, 2007). Meanwhile, Mello *et al.* (2012) demonstrated the importance of maintaining the Ca:AP relationship. They evaluated the AP needs for growing broilers when the Ca:AP relationship was constant and observed that feed intake was not affected by the AP levels. The settings for the LRP ($P \leq 0.01$) and quadratic ($P \leq 0.05$) models that were used to test the weight gain (WG) results were also verified. The estimates of AP obtained were 0.229%, using the LRP model with the equation $WG = 110.80 - 138.30(0.229 - AP)$, $R^2 = 0.73$, and 0.374%, using the quadratic model with the equation $WG = 80,176 + 176.99AP - 236.75 AP^2$, $R^2 = 0.60$. The optimal level of AP for maximum weight gain was estimated by the intersection of the quadratic equation and the plateau of LRP and was 0.272% AP, which corresponded to 0.094% AP/Mcal ME. The lowest AP level in the experimental diet (0.13%, deficient in phosphorus) led to a smaller weight gain compared with the estimated levels, which could also be justified by the lower feed intake that was observed.

Table 2. Feed intake (FI), weight gain (WG), feed:gain ratio (FC) (1 to 21 days), tibial calcium (TCa), tibial phosphorus (TP) and tibial ash (TAs) in meat-type quail (21 days old) fed experimental starter diets with different levels of available phosphorus.

Variable	Available phosphorus (%)					CV ¹ (%)	Pr. ²
	0.13	0.23	0.33	0.43	0.53		
FI (g Bird ⁻¹)	189	225	254	236	248	5.23	0.01
WG (g Bird ⁻¹)	97	111	116	105	110	8.29	0.04
FC	1.942	2.035	2.194	2.253	2.268	8.43	0.04
TCa (%)	34.727	38.923	40.527	46.124	54.834	15.72	0.01
TP (%)	16.275	26.440	23.586	30.105	31.225	15.64	0.01
TAs (%)	20.334	28.811	30.234	28.927	28.073	10.33	0.01

¹CV = Coefficient of variation; ²Pr. = Probability.

After assessing the phosphorus requirement for broilers in the initial phase, Runho *et al.* (2001) reported that a diet deficient in phosphorus caused a severe reduction in the synthesis and release of growth hormone and thyroid hormones, primarily T3, and that, consequently, the birds showed lower feed intake and lower weight gain. In contrast, Silva *et al.* (2009) and Furlan *et al.* (2009) estimated that 0.41% AP was required to maximize the weight gain of meat-type quail at 14 days old, which was higher than the levels observed in this study. This divergence between our results and those of other authors may be due to differences in the age and genetic lineage, considering that there are many genetically different quail being marketed in Brazil; we used LF1 quail, which is a specific lineage. The heritability of phosphorus utilization is significant in Japanese quail, similar to that in broilers (Beck *et al.*, 2014). Therefore, research is necessary to determine the specific nutritional requirements of each lineage.

The results of the feed conversion (FC), which was adjusted ($P \leq 0.01$) according to the increasing linear equations ($FC = 1.85 + 0.868AP$, $R^2 = 0.92$) and LRP ($FC = 2261 - 1259 (AP - 0.391)$, $R^2 = 0.99$), were verified. However, the levels of AP required to maximize feed conversion, as provided by these settings, could not be verified and were thus not suitable for recommendation.

The relationship between all of the bone variables and the phosphorus levels increased linearly ($P \leq 0.01$). An increase in calcium deposition in the tibia (TCa) that was proportional to the increasing levels of available phosphorus was observed according to the following equation: $TCa = 27.379 + 47.416AP$ ($R^2 = 0.93$). This result was in agreement with that of Silva *et al.* (2009), who increased the phosphorus content in the diets of 14-day-old meat-type quail and observed a linear increase in the deposition of calcium and phosphorus. This response would be justified because the absorption of phosphorus depends

on the absorption of calcium. In the bird's starter phase, the bone tissue formation rate is faster than it is in other phases, and the deposition of calcium and phosphorus in the tibia is also greater (Pinheiro *et al.*, 2011).

Increasing levels of phosphorus in the diets provided a greater deposition of phosphorus in the tibia (TP) ($P \leq 0.01$), according to the following equation: $TP = 15,599 + 30.893AP$ ($R^2 = 0.78$). Brugalli *et al.* (1999) verified an increased content of phosphorus in the bones and bone ash of broilers that were fed with increasing levels of available phosphorus in the diet.

The ash content in the tibia (TAs) of quail increased in both the linear form ($TAs = 22.129 + 15.594AP$, $R^2 = 0.39$) and quadratic form ($TAs = 8.546 + 116.438AP - 152.794AP^2$, $R^2 = 0.91$) and was estimated to reach a maximum at the level of 0.381% AP or 0.13% AP/Mcal ME. A similar result was observed by Silva *et al.* (2009), who reported that the best response in optimal bone density was obtained with 0.41% AP, which corresponded to 0.14% AP/Mcal ME, in the diets of meat-type quail up to 14 days of age. Yan *et al.* (2003) estimated a level of 0.31% AP for the increased deposition in bone ash in broilers at 49 days of age, and they recommended this level as a good strategy for feeding chickens to provide the optimal deposition in bone ash and a decreased excretion of phosphorus in the manure, thereby reducing environmental pollution.

The dietary AP levels required to maximize bird performance are lower than those required to promote good bone quality in the starter phase of broilers (Brugalli *et al.*, 1999; Runho *et al.*, 2001). The results obtained in this work suggest that the above concept can also be applied when recommendations are made for feeding meat-type quail. However, we acknowledge that the AP levels were more important in ensuring the quality of bone formation than a greater weight was during the quail starter

phase. From this point of view, we recommend a level of 0.381% or 0.12% AP/Mcal ME for better bone quality, which will maximize ash deposition in the tibia of meat-type quail that are 1 to 21 days old.

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Resumen

R.G. Oliveira, S.R.F. Pinheiro, K.B. Goulart, A.V. Pires, F.C. Figueiredo y K.A.A. Torres-Cordido. 2015. Fósforo disponible en dietas para codornices de engorde en la fase inicial de cría. Cien. Inv. Agr. 42(1): 19-25. El fósforo es un mineral importante por ser necesario para la óptima tasa de crecimiento y para la mineralización ósea, siendo considerado como el tercer nutriente más caro en los concentrados para no rumiantes. Fue conducido un experimento para evaluar las exigencias de fósforo disponible (Pd) para codornices de engorde en la fase inicial de cría (1 a 21 días de edad). Se utilizaron 375 codornices europeas, linaje LF1, no sexadas, instaladas en compartimientos. El delineamiento experimental utilizado fue enteramente al azar, siendo los tratamientos constituidos por cinco niveles de Pd (0,13; 0,23; 0,33; 0,43 y 0,53%) cada tratamiento contó con cinco repeticiones de 15 aves por repetición. Se evaluó el consumo de concentrado, la ganancia de peso, la conversión alimenticia y la deposición de fósforo, calcio y cenizas en las tibias. Se observó que los niveles de Pd estudiados influenciaron todas las variables analizadas. Fue calculado el nivel de 0,381% de Pd o 0,12% de Pd/Megacaloría de Energía Metabolizable para obtener la mejor calidad ósea, porque permite maximizar la deposición de cenizas en la tibia de las codornices de engorde.

Palabras clave: Calcio, codornices, crecimiento óseo, relación calcio/fósforo.

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