



Revista Brasileira de Ciência Avícola

ISSN: 1516-635X

revista@facta.org.br

Fundação APINCO de Ciência e  
Tecnologia Avícolas  
Brasil

Ribeiro, CLN; Barreto, SLT; Reis, RS; Muniz, JCL; Viana, GS; Ribeiro Junior, V;  
Mendonça, MO; Ferreira, RC; DeGroot, AA

The Effect of Calcium and Available Phosphorus Levels on Performance, Egg Quality and  
Bone Characteristics of Japanese Quails at End of the Egg-Production Phase

Revista Brasileira de Ciência Avícola, vol. 18, julio-septiembre, 2016, pp. 33-39

Fundação APINCO de Ciência e Tecnologia Avícolas  
Campinas, Brasil

Available in: <http://www.redalyc.org/articulo.oa?id=179746973006>

- How to cite
- Complete issue
- More information about this article
- Journal's homepage in redalyc.org

redalyc.org

Scientific Information System

Network of Scientific Journals from Latin America, the Caribbean, Spain and Portugal

Non-profit academic project, developed under the open access initiative



#### ■ Author(s)

Ribeiro CLN<sup>I</sup>  
Barreto SLT<sup>II</sup>  
Reis RS<sup>I</sup>  
Muniz JCL<sup>I</sup>  
Viana GS<sup>I</sup>  
Ribeiro Junior V<sup>III</sup>  
Mendonça MO<sup>I</sup>  
Ferreira RC<sup>I</sup>  
DeGroot AA<sup>III</sup>

<sup>I</sup> Doctorate Program, DZO/UFV.

<sup>II</sup> Federal University of Viçosa, Department of Animal Science, Av PH Rolfs S/N, Viçosa 36570-000, MG, Brazil.

<sup>III</sup> University of Illinois at Urbana-Champaign, Department of Animal Sciences, 1207 W. Gregory Dr, Urbana, Illinois 61801, United States of America.

#### ■ Mail Address

Corresponding author e-mail address  
Cleverson Luís Nascimento Ribeiro  
Rua Francisco Machado, n° 207, CEP:  
36570-000. Viçosa, MG, Brazil  
Email: [cleverson.ribeiro@ufv.br](mailto:cleverson.ribeiro@ufv.br)

#### ■ Keywords

*Coturnix*, bone development, dicalcium phosphate, eggshell, bone mineral deposition.

## The Effect of Calcium and Available Phosphorus Levels on Performance, Egg Quality and Bone Characteristics of Japanese Quails at End of the Egg-Production Phase

### ABSTRACT

Calcium (Ca) and available phosphorus (avP) requirements for egg production are different between the beginning and the end of the egg-production cycle. The objective of this study was to estimate the Ca and avP requirements of Japanese quails at end of the production phase. In total, 256 Japanese quails with 48 weeks of age were randomly distributed in 2 x 2 factorial arrangement consisting of two Ca levels (29 and 38 g/kg) and two avP levels (1.5 and 3.0 g/kg), totaling four treatments with eight replicates of eight hens each. The variables evaluated were feed intake (FI); egg production (EP); marketable egg production (MEP); egg weight (EW); egg mass (EM); feed conversion ratio per egg mass (FCRM); feed conversion ratio per dozen eggs (FCRD); livability (L); yolk weight (YW), albumen weight (AW), eggshell weight (SW); yolk percentage (YP), albumen percentage (AP), eggshell percentage (SP), specific egg weight (SEW); bone calcium percentage (BCa), bone phosphorus percentage (BP), bone ash weight (Bash) and bone ash percentage (PBash). There was no interaction between Ca and avP levels for any of the evaluated parameters, except for SEW. Quail performance was not influenced by the treatments, except for MEP. Bone characteristics were not influenced by the tested dietary Ca and avP levels. However, SW and SP increased and AP decreased as dietary Ca level increased. The dietary supplementation of 38 g Ca/kg and 3.0 g avP/kg may increase marketable egg production and the egg quality of Japanese quails at end of the production cycle.

### INTRODUCTION

The knowledge of calcium (Ca) and available phosphorus (avP) requirements are important for older laying quails because they require more minerals than younger birds for bone and egg mineral deposition (Costa *et al.*, 2010b). Dietary Ca supplementation is required during the egg production to improve Ca deposition on eggshell, and also it is an important mineral for quail bone development (Garcia *et al.*, 2000). Phosphorus is also an important nutrient of quail diets because it is a component of the bone matrix and influences calcium bone deposition (Scott *et al.*, 1982). Those nutrients work together during the absorption, metabolism, and excretion (Salter *et al.* 1931). According to Furtado (1991), the best level of phosphorus (P) absorption occurs when dietary Ca level are appropriate according to the adequate Ca: avP ratio. Excessive Ca levels may reduce P absorption by producing an insoluble complex with myo-inositol and trace elements in the intestinal lumen. Therefore, a perfect balance between Ca and avP levels in quail diets are required.

Currently, Ca and avP requirements for Japanese quails can be obtained from published nutritional tables (NRC, 1994; Rostagno *et al.*, 2011) as well as from published studies (Costa *et al.*, 2007; Vieira



et al., 2012; Aguda et al., 2013). However, these requirements were obtained in studies evaluating quails at the beginning of the egg-production phase and during the peak of egg production (Costa et al. 2011). Also, there are few studies about Ca and avP requirements for Japanese quails at end of production phase (Costa et al., 2010a; Costa et al., 2010b).

Costa et al. (2010a) determined a requirement of 22 g Ca/kg of egg production in Japanese quails immediately after the peak of egg production. However, those authors recommend a higher dietary Ca level (38 g/kg) for maximum eggshell thickness and eggshell percentage. In another study, Costa et al. (2010b) estimated a dietary Ca level of 35 g/kg for Japanese quails at end of the egg-production cycle. However, because this result was estimated by a linear regression equation, it is not possible to estimate the maximum Ca recommendation.

The Ca and avP requirement data on the current Brazilian nutritional tables for poultry (Rostagno et al., 2011; Costa & Silva, 2009) were not estimated using hens during the final production phase, and therefore do not allow determining these recommendations for this production phase.

Therefore, the goal of this study was to identify a possible interaction between dietary Ca and P levels and to evaluate the effects of these levels on the performance, egg quality and bone characteristics of Japanese quails at end of the egg-production phase.

## MATERIAL AND METHODS

The study was carried out at Poultry Farm of the Animal Science Department of the University of Viçosa, state of Minas Gerais, Brazil. The experimental procedures (Process Number 16/2015) complied with the ethical principles for animal research established by the Brazilian Committee for Animal Experimentation and current Brazilian legislation (Brasil, 2008).

Two hundred and fifty-six Japanese quails (*Coturnix coturnix japonica*), with 48 weeks of age and initial body weight of 187 g ( $\pm 0.006$ ), were evaluated during an experimental period of 63 days. Birds were distributed according to a completely randomized design in a 2 x 2 factorial arrangement. Treatments consisted of two Ca levels (29 g/kg and 38 g/kg) and two avP levels (1.5 g/kg and 3.0 g/kg), with eight replicates of eight birds each. Each experimental unit consisted of a cage with eight birds housed at a density of 106 cm<sup>2</sup>/bird. Birds were offered feed and water *ad libitum*. A 16-h light:8-h dark lighting program was adopted, according to the recommendations of Albino & Barreto (2003).

Thermometers were distributed inside the poultry house to measure maximum and minimum environmental temperatures. The maximum and minimum temperatures observed were  $26.1 \pm 0.7$  °C and  $14.0 \pm 1.9$  °C, respectively. Air relative humidity was  $84.1 \pm 2.8\%$  in the morning and  $65.7 \pm 5.2\%$  in the evening.

A control diet based on corn and soybean meal (193 g/kg crude protein and 2,800 kcal/kg of AMEn) was formulated to meet the quails' requirements according to NRC (1994). Digestible amino acid requirements were supplied using the digestible lysine:amino acid ratios described by Pinto et al. (2003), Umigi et al. (2008), Pinheiro et al. (2008), and Reis et al. (2011), because the recommendations are expressed on total amino acids in the NRC table (1994). The ingredients and the calculated nutritional composition of the experimental diets are shown in Table 1.

**Table 1** – Ingredients and calculated nutritional composition of experimental diets (g/kg as fed)

Ingredients	Available phosphorus levels (g/kg)			
	1.5		3.0	
	Calcium levels (g/kg)			
	29	38	29	38
Corn	574.3	525.6	574.3	525.6
Soybean meal (45% CP)	321.8	330.7	321.9	330.7
Soybean oil	12.8	29.2	12.8	29.2
Limestone	71.5	94.8	66.3	89.6
Dicalcium phosphate	2.49	2.62	10.6	10.7
Salt	3.20	3.22	3.20	3.22
L- lysine (79%)	2.27	2.11	2.27	2.11
DL-methionine (99%)	4.01	4.08	4.01	4.08
Choline chloride (60%)	1.00	1.00	1.00	1.00
Mineral premix <sup>1</sup>	0.50	0.50	0.50	0.50
Vitamin premix <sup>2</sup>	1.00	1.00	1.00	1.00
Antioxidant <sup>3</sup>	0.10	0.10	0.10	0.10
Inert material <sup>4</sup>	5.00	5.00	2.07	2.07
Calculated composition				
Metabolizable energy (kcal/kg)	2,800	2,800	2,800	2,800
Crude protein (g/kg)	193	193	193	193
Digestible lysine (g/kg)	11.2	11.2	11.2	11.2
Digestible methionine + cystine (g/kg)	9.41	9.41	9.41	9.41
Digestible threonine (g/kg)	6.16	6.16	6.16	6.16
Digestible tryptophan (g/kg)	2.35	2.35	2.35	2.35
Available phosphorus (g/kg)	1.5	1.5	3.0	3.0
Total calcium (g/kg)	29	38	29	38
Ca: avP ratio	19	25	10	13
Total sodium (g/kg)	1.45	1.45	1.45	1.45

<sup>1</sup> Composition/kg of product. Mn - 160g; Fe - 100g; Zn - 100g; Cu - 20g; Co - 2g; I - 2g; vehicle q.s.p.- 1,000 g;

<sup>2</sup> Composition/kg of product. Vit. A - 12,000,000 IU; Vit D<sub>3</sub> - 3,600,000 IU; Vit. E - 3,500 IU; Vit B<sub>1</sub> - 2,500 mg; Vit B<sub>2</sub> - 8,000 mg; Vit B<sub>6</sub> - 5,000 mg; Pantothenic acid - 12,000 mg; biotin - 200 mg; Vit. K - 3,000 mg; folic acid - 1,500 mg; nicotinic acid - 40,000 mg; Vit. B<sub>12</sub> - 20,000 mg; selenium - 150 mg; vehicle q.s.p. - 1,000g;

<sup>3</sup> Butylated hydroxy toluene, BHT (99%). <sup>4</sup>Washed sand.



The performance parameters evaluated on this study were feed intake (FI, g/bird/day); egg production (EP, g/kg); marketable egg production (MEP, g/kg), calculated as total number of intact eggs/total number of eggs produced  $\times$  100; egg weight (EW, g); egg mass (EM, g/bird/day); feed conversion ratio per egg mass (FCRM, kg of diet/kg of eggs) and per dozen eggs (FCRD, kg of diet/egg dz); livability (L, %), calculated as total number of live birds – total number of dead birds/total number of live birds  $\times$  100.

The following egg quality parameters were evaluated: yolk weight (YW, g); albumen weight (AW, g); eggshell weight (EW, g); yolk percentage (YP, %), albumen percentage (AP, %), eggshell percentage (ESP, %), specific egg weight (SEW, g/cm<sup>3</sup>).

The bone characteristics calcium percentage (BCa, %), phosphorus percentage (BP, %), ash weight (Bashw, g), and ash percentage (PBash, %) were evaluated according to methodology described by Sakomura & Rostagno (2007).

Four eggs per experimental unit were randomly collected on days 19, 20, 21, 40, 41, 42, 61, 62, and 63 of the experimental period (63 days) to determine the weight of egg components. Eggs were individually weighed on 0.001-g precision scale. After weighing, eggs were identified and broken. The yolk of each egg was weighed, and the eggshell was washed and dried to determine its weight. Albumen weight was calculated by difference between egg weight, yolk weight, and eggshell weight.

Specific egg weight was determined by immersion in a series of sodium chloride solutions with increasing density, ranging from 1.055 to 1.09 g/cm<sup>3</sup> in 0.005 g/cm<sup>3</sup> intervals, according to Archimedes Principle), as described by Thompson & Hamilton (1982) and Yannakopoulos & Tserveni-Gousi (1986).

At the end of the trial, 96 hens were euthanized to collect the left tibia and left femur to estimate tibia Ca (%), tibia P (%), and tibia ash percentage (%) and weight (g). The analyses were performed according to the methodology described by Silva & Queiroz (2002), at the Animal Nutrition Laboratory of Department of Animal Science, Federal University of Viçosa, Minas Gerais, Brazil.

The main effects of the study were four treatments. The statistical model used was:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}, \text{ where:}$$

$Y_{ijk}$  is the observation k of the  $i^{\text{th}}$  Ca level within the  $j^{\text{th}}$  avP level;

$\mu$  is the overall mean;

$\alpha_i$  is the effect of the  $i^{\text{th}}$  dietary Ca level;

$\beta_j$  is the effect of the  $j^{\text{th}}$  avP level;

$(\alpha\beta)_{ij}$  is the interaction of the  $i^{\text{th}}$  Ca level i with the  $j^{\text{th}}$  avP level;

$\varepsilon_{ijk}$  is the residual random error.

All data were analyzed using the GLM procedure of SAS statistical package (SAS Institute, 2004) and means were compared by the test of Tukey at 5% probability level. When there was no interaction between Ca and avP levels, the treatments were studied independently.

## RESULTS AND DISCUSSION

There was no effect of the different Ca levels ( $p > 0.05$ ) on hen performance (Table 2). However, the interaction between Ca and avP levels influenced ( $p < 0.05$ ) SEW, with the best result observed with the combination of 38 g/kg Ca with 3.0 g/kg avP (Table 4). There were no significant differences among treatments when the high dietary Ca level (38 g/kg) was fed in combination with the two avP levels evaluated (1.5 g/kg and 3.0 g/kg).

Performance traits were not influenced by the evaluated dietary avP levels, irrespective of Ca levels, except for MEP. The high dietary avP level increased MEP (2.4%) compared to the low dietary avP level. Recent studies have shown avP levels did not influence the egg production of laying quails (Pedroso *et al.*, 1999; Costa *et al.*, 2011).

Studies have shown FI is not influenced by dietary Ca levels (Pedroso *et al.*, 1999; Barreto *et al.*, 2007) nor by dietary avP levels (Costa *et al.*, 2011). In the present study, dietary Ca and avP levels did not stimulate nor inhibit FI, and neither induced excess or deficiency of these minerals in the diets. Therefore, the evaluated levels and interactions between these minerals may have influenced the experimental results. Phosphorus metabolism is directly related to dietary Ca levels, and it influences bone eggshell Ca deposition in laying Japanese quails and chickens (Costa *et al.*, 2007; Almeida *et al.*, 2009; Vieira *et al.*, 2012).

The evaluated dietary Ca levels influenced ( $p < 0.05$ ) ESW, ESP, and AP. The best ESW and SP results were obtained when hens were fed diets with 38 g Ca/kg. Eggshell weight increased ( $p < 0.05$ ) by 4.5% in birds fed the diets with 38 g Ca/kg compared with those fed 29 g Ca/kg. Also, ESP increased ( $p < 0.05$ ) by 4.1% when the highest Ca level was fed. On the other hand, AP decreased ( $p < 0.05$ ) by 1.4% when birds were fed diets with 38 g/kg Ca compared with the lower dietary Ca level (29 g/kg).



**Table 2** – Performance parameters of Japanese quails fed diets with different calcium (Ca) and available phosphorus (avP) levels during 48-57 weeks of age

Factors		Variables <sup>1</sup>							
Ca	avP	FI (g/bird/day)	EP (g/kg)	MEP (g/kg)	EW (g)	EM (g/bird/day)	FCRM (kg/kg)	FCRD (kg/dz)	L (%)
29	1.5	25.6	716.9	949.3	11.68	8.36	3.08	0.43	92.8
	3.0	25.8	770.6	970.3	11.86	9.15	2.86	0.41	94.6
38	1.5	25.7	773.7	955.1	11.59	8.99	2.90	0.40	89.3
	3.0	26.3	804.8	980.4	11.92	9.60	2.75	0.39	89.3
Mean									
Ca	29	25.7	743.8	959.8	11.8	8.76	2.97	0.42	93.7
	38	26.0	789.3	967.8	11.7	9.29	2.83	0.40	89.3
avP	1.5	25.6	745.3	952.2 b	11.6	8.68	2.99	0.42	91.1
	3.0	26.1	787.7	975.4 a	11.9	9.37	2.81	0.40	91.9
p value									
Ca		0.453	0.125	0.404	0.900	0.170	0.148	0.077	0.235
avP		0.343	0.151	0.020	0.094	0.079	0.061	0.170	0.810
Ca x avP		0.650	0.697	0.821	0.630	0.813	0.689	0.484	0.810
SEM <sup>2</sup>		1.223	8.126	2.625	0.424	1.080	0.268	0.033	10.467

<sup>a, b</sup>Means followed by different letters in the same column are significantly different by Tukey's test at 5% probability level ( $p < 0.05$ ).

<sup>1</sup>Feed intake (FI), egg production (EP), marketable egg production (MEP), egg weight (EW), egg mass (EM), feed conversion ratio per egg mass (FCRM), feed conversion ratio per egg dozen (FCRD) and livability (L).

<sup>2</sup>Standard error of the mean.

The influence of dietary Ca levels on ESW, ESP, AP, and SEW supports the dietary requirement of 38 g Ca/kg proposed by Costa *et al.* (2010b) to improve eggshell thickness and eggshell percentage in Japanese quails. According to Scherer (2004), calcium utilization mainly depends on animal species and age. Endogenous calcium is primarily utilized for eggshell formation in laying birds. In addition, daily eggshell calcium deposition represents 10% (2.0 g) of total stored calcium in the body of quails (Miller, 1967). The

present study confirms the importance dietary Ca for egg quality, as demonstrated by the ESW, ESP and SEW results. According to Pedroso *et al.* (1999), supplying adequate calcium levels during the egg-production phase may allow maintaining eggshell quality throughout the productive life of Japanese quails.

The effect of dietary Ca levels on AP was different from those on ESW and ESP. Albumen percentage decreased when the diet contained 38 g Ca/kg (Table 3). High Ca levels may increase blood alkalinity by

**Table 3** – Egg quality traits of Japanese quails fed diets with different calcium (Ca) and available phosphorus (avP) levels during 48-57 weeks of age.

Factors		Variables <sup>1</sup>						
Ca	avP	YW (g)	AW (g)	ESW (g)	YP (%)	AP (%)	ESP (%)	SEW (g/cm <sup>3</sup> )
29	1.5	3.47	7.26	0.87	29.79	62.72	7.49	1.073
	3.0	3.53	7.41	0.89	29.85	62.65	7.50	1.072
38	1.5	3.57	7.14	0.90	30.80	61.44	7.75	1.073
	3.0	3.57	7.39	0.93	30.02	62.13	7.85	1.073
Mean								
Ca	29	3.50	7.34	0.88 b	29.82	62.68 a	7.49 b	1.072
	38	3.57	7.26	0.92 a	30.41	61.79 b	7.80 a	1.073
avP	1.5	3.52	7.20	0.86 b	30.30	62.08	7.62	1.073
	3.0	3.55	7.40	0.91 a	29.93	62.39	7.68	1.072
p value								
Ca		0.075	0.535	0.003	0.067	0.010	0.001	0.004
aP		0.441	0.098	0.046	0.250	0.358	0.517	0.178
Ca x avP		0.424	0.684	0.498	0.183	0.257	0.620	0.013
SEM <sup>2</sup>		0.1058	0.3348	0.0336	0.8736	0.9258	0.2445	0.0009

<sup>a, b</sup>Means followed by different letters in the same column are significantly different by Tukey's test at 5% probability level ( $p < 0.05$ ).

<sup>1</sup>Yolk weight (YW), albumen weight (AW), eggshell weight (ESW), yolk percentage (YP), albumen percentage (AP), eggshell percentage (ESP), specific egg weight (SEW).

<sup>2</sup>Standard error of the mean





interfering with the acid-base balance (Salter *et al.*, 1931). The maintenance of the blood acid-base balance is physiologically and biochemically important, because cell enzyme activity, electrolyte exchange, and the maintenance of body protein structure are affected by small changes in blood pH (Macari *et al.*, 2002). The albumen is composed of 13.5% proteins (FAO, 2010), out of which albumins account for 70% (Ramos, 2008). Serum calcium can be found in the albumen attached to albumin (Vieites *et al.*, 2004). Increasing blood pH may theoretically reduce the blood ionized calcium pool by increasing the concentration of calcium that is bound to protein (Allen & Somjen, 1983), and therefore, reduce the availability of proteins to synthesize the egg albumen.

Egg quality traits were not influenced by dietary avP levels, except for ESW, which increased by 5.8% in birds fed diets with high dietary avP level compared to the low dietary avP level. Eggshell percentage was not affected by dietary avP levels ( $p > 0.05$ ).

**Table 4** – Effect of the interaction between dietary calcium (Ca) and available phosphorus (avP) levels on specific egg weight (SEW)

SEW (g/cm <sup>3</sup> )				
Factors <sup>1</sup>	Ca (g/kg)		Mean	
	29	38		
avP (g/kg)	1.5	1.073 Aa	1.073 Aa	1.072
	3.0	1.072 Bb	1.073 Aa	1.072
Mean	1.072	1.072	SEM <sup>2</sup> = 0.0009	

<sup>1</sup>Means followed by different uppercase letters in the same column and by different lowercase letters in the same row are significantly different by Tukey's test at 5% probability level ( $p < 0.05$ ).

<sup>2</sup>Standard error of the mean

There was no statistical effect of treatments on bone characteristics ( $p > 0.05$ ), which results are shown in Table 5. The effects of dietary Ca and avP levels on the bone matrix are less evident at the end of the egg-production phase than in the beginning probably due reduced intestinal absorption and bone mobilization of these minerals at this age (Costa *et al.*, 2010b). Dietary avP levels did not influence ( $p > 0.05$ ) bone characteristics.

Some studies have shown that higher eggshell weight and specific egg weight positively influence total intact egg production (Costa *et al.*, 2010a; Costa *et al.*, 2011; Vieira *et al.*, 2012). MEP is the ratio between total number of intact eggs and total egg production; therefore, the higher total intact egg production, the higher the MEP.

The results of the present study indicate that Japanese quails require higher Ca levels than laying chickens at end of production phase. Previous studies have also shown that Japanese quails need higher Ca levels at end of the egg-production phase because quails present faster deterioration of performance and egg quality compared with chickens (Almeida Paz *et al.*, 2009; Pedroso *et al.*, 1999). Costa *et al.* (2010b) reported that the dietary level of 35 g Ca/kg promoted good performance and egg quality in Japanese quails at the end of the egg-production phase.

The dietary avP level of 3.0 g/kg improved marketable egg production and eggshell weight. Additionally, the best egg quality results were obtained with the combination of high dietary Ca level with

**Table 5** – Bone characteristics of Japanese quails fed diets with different calcium (Ca) and available phosphorus (avP) levels during 48-57 weeks of age

Factors		Variables <sup>1</sup>			
Ca	avP	BCa (%)	BP (%)	BashW (g)	PBash (%)
29	1.5	38.6	22.0	0.885	62.4
	3.0	37.9	20.9	0.885	61.9
38	1.5	39.1	22.2	0.903	64.0
	3.0	37.6	22.2	0.902	63.7
Mean					
Ca	29	38.3	21.4	0.885	62.1
	38	38.4	22.2	0.902	63.8
avP	1.5	38.9	22.1	0.894	63.2
	3.0	37.8	21.5	0.894	62.8
p value					
Ca		0.957	0.247	0.308	0.138
avP		0.383	0.363	0.975	0.726
Ca x avP		0.773	0.358	0.975	0.930
SEM <sup>2</sup>		2.792	1.335	0.036	2.447

<sup>a,b</sup>Means followed by different letters in the same column are significantly different by Tukey's test at 5% probability level ( $p < 0.05$ ).

<sup>1</sup>Bone calcium percentage (BCa), bone phosphorus percentage (BP), bone ash weight (BashW) and bone ash percentage (PBash).

<sup>2</sup>Standard error of the means.



high dietary avP. This indicates that when dietary avP levels are increased, Ca levels must be proportionally increased in order to maintain good performance and egg quality.

## CONCLUSIONS

The dietary available phosphorus level of 3.0g/kg increases marketable egg production, and high dietary calcium and available phosphorus levels improve the egg quality of Japanese quails at end of the egg-production phase.

The supplementation of 38 g Ca/kg (998 mg Ca/bird/day) and 3.0 g avP/kg (78 mg avP/bird/day) to the diet of Japanese quails at the end of the egg-production phase is recommended.

## ACKNOWLEDGEMENTS

We thank the Universidade Federal de Viçosa (UFV) for the use of facilities and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, Brazil) for first author's grant.

## REFERENCES

- Aguda AY, Sekoni AA, Omage JJ, Bulus ED. Calcium and available phosphorus requirement of growing Japanese quail birds (*Coturnix coturnix japonica*) in Nigeria. *Advances in Agriculture, Sciences and Engineering* 2013;3:1176 - 1183.
- Albino LFT, Barreto SLT. Criação de codornas para produção de ovos e carne. Viçosa (MG): Aprenda Fácil; 2003.
- Allen BW, GG. Somjen, The influence of pH on [Ca<sup>2+</sup>] in circulating blood. *Federation Proceedings* 1983;42:296.
- Almeida Paz ICL, Mendes AA, Balog AA, Komiyama CM, Takahashi SE, Almeida ICL, et al. Calcium effect in bone and egg quality of the hens. *Revista Archivos de Zootecnia* 2009;58(222):173-183.
- Araújo WAG, Albino LFT. Comercial incubation [Incubação comercial]. In: Araújo WAG. Importância de qualidade da casca do ovo em matriz pesada. Viçosa: UFV; 2011. p.130.
- Baião NC, Lúcio CG. Nutrição de matrizes pesadas. In: Macari M, Mendes AA. Manejo de matrizes de corte. Campinas: Fundação APINCO de Ciência e Tecnologia Avícolas; 2005. p.197-212.
- Barreto SLT, Pereira CA, Umigi RT, Rocha TC, Araujo MS, Silva CS, et al. Determinação da exigência nutricional de cálcio de codornas japonesas na fase inicial do ciclo de produção. *Revista Brasileira de Zootecnia* 2007;36:68-78.
- Brasil. Lei 11.794 de 08 de Outubro de 2008. Regulamento o inciso VII do §1º do art. 225 da Constituição Federal, estabelecendo procedimentos para o uso científico de animais. Presidência da República. Casa Civil. Subchefia para Assuntos Jurídicos. Brasília; 2008.
- Costa CHR, Barreto SLT, Umigi RT, Lima HJD, Araújo MS, Medina P. Balanço de cálcio e fósforo e estudo dos níveis desses minerais em dietas para codornas japonesas (45 a 57 semanas de idade). *Revista Brasileira de Zootecnia* 2010a;39(8):1748-1755.
- Costa CHR, Barreto SLT, Gomes PC, Maia GVC, Lipari CA, Hosoda LH. Teores de cálcio em dietas para codornas japonesas no terço final de postura (45 a 57 semanas de idade). *Arquivo Brasileiro de Medicina Veterinária e Zootecnia* 2010b;62(5):1225-1231.
- Costa CHR, Barreto SLT, Moura WCO, Reis RS, Leite CDS, Maia GVC. Níveis de fósforo e cálcio em dietas para codornas japonesas em postura. *Revista Brasileira de Zootecnia* 2007;36(6):2037-2046.
- Costa CHR, Barreto SLT, Gomes PC, Hosoda LH, Lipari CA, Lima, HJD. Níveis de fósforo disponível em dietas para codornas japonesas de 45 a 57 semanas de idade. *Revista Brasileira de Zootecnia* 2011;40(10):2152-2160.
- FAO. Agribusiness handbook - poultry meat & eggs. 2010 [cited 2015 Abr 21]. Available from: <http://www.fao.org/docrep/012/al175e/al175e.pdf>.
- Furtado MAO. Determinação da biodisponibilidade de fósforo em suplementos de fósforo para aves e suínos [dissertation]. Belo Horizonte (MG): Universidade Federal de Minas Gerais; 1991.
- Garcia J, Murakami AE, Martins EN, Furlan AC. Exigências Nutricionais de Cálcio e Fósforo para Codornas Japonesas (*Coturnix coturnix japonica*) em Postura. *Acta Scientiarum* 2000;22(3):733-739.
- Gilbert AB, Peddie J, Mitchell GG, Teague PW. The egg laying response of the domestic hen to variation in dietary calcium. *British Poultry Science* 1981;22:537-548.
- Macari M, Furlan RL, Gonzalez E. Fisiologia aviária aplicada a frangos de corte. Jaboticabal: Unesp; 2002.
- Mazzuco H, Kunz A, de Paiva DP, Jaenisch FRF, Palhares JCP, de Abreu, PG, et al. Boas práticas de produção na postura comercial [CT n° 49]. Concórdia: Embrapa Suínos e Aves; 2006.
- Miller BF. Calcium and phosphorus in the diet of coturnix quail. *Poultry Science* 1967;46(3):686-692.
- National Research Council. Nutrient requirements of poultry. 9th ed. Washington (DC): National Academy of Sciences; 1994.
- Pedroso AA, Moraes VMB, Arik J, Kronka SN. Níveis de cálcio e fósforo na ração sobre o desempenho e qualidade dos ovos de codornas japonesas. *Ars Veterinaria* 1999;15(2):135-139.
- Pinheiro SR, Barreto SLT, Albino LFT. Efeito dos níveis de triptofano digestível em dietas para codornas japonesas em postura. *Revista Brasileira de Zootecnia* 2008;37(6):1012-1016.
- Pinto R, Ferreira AS, Donzele JL. Exigência de lisina para codornas japonesas em postura. *Revista Brasileira de Zootecnia* 2003;32(5):1182-1189.
- Ramos BFS. Gema de ovo composição em aminos biogênicas e influência da gema na fração volátil de creme de pasteleiro [dissertation]. Porto (POR): Faculdade de Farmácia da Universidade do Porto; 2008.
- Reis RS, Barreto SLT, Gomes PC. Relationship of methionine plus cystine with lysine in diets for laying Japanese quails. *Revista Brasileira de Zootecnia* 2011;40:1031-1037.
- Rostagno HS, Albino LFT, Donzele JL, Gomes PC, Oliveira RF, Lopes DC, et al. Tabelas brasileiras para aves e suínos. Composição de alimentos e exigências nutricionais. 3rd ed. Viçosa: UFV; 2005.
- SAS Institute. SAS/STAT 9.1 user's guide. Cary; 2004.
- Salter WT, Fulton C, Angier F. Studies in calcium and phosphorus metabolism. *The Journal of Nutrition* 1931;1(4):1-13.
- Sakomura NK, Rostagno HS. Métodos de pesquisa em nutrição de monogástricos. Jaboticabal: Funep; 2007.



Scott ML, Holm ER, Reynolds RE. A study of the phosphorus requirements of young bobwhite quail. *Poultry Science* 1958;37:1425-1428.

Scott ML, Nesheim MC, Young RJ. Nutrition of the chicken. 3rd edition. New York: ML Scott and Associates; 1982.

Scherer C. Avaliação dos teores de cálcio para poedeiras semi pesadas durante a fase de pré-postura. *Anais da Conferência Apinco de Ciência e Tecnologia Avícola*; 2004; Santos, São Paulo. Brasil. p. 98.

Silva DJ, Queiroz AC. Análise de alimentos (métodos químicos e biológicos). 3<sup>rd</sup> ed. Viçosa: Imprensa Universitária; 2002.

Thompson R, Hamilton RMG. Comparison of precision and accuracy of the flotation and Archimedes' methods for measuring the specific gravity of eggs. *Poultry Science* 1982;60:2388-2394.

Umigi RT, Barreto SLT, Mesquita Filho RM. Exigência de treonina digestível para codorna japonesa em postura [abstract]. Brasília: Sociedade Brasileira de Zootecnia; 2008.

Vieira DVG, Barreto SLT, Valeriano MH, Jesus LFD, Silva LFF, Mencalha R, et al. Exigências de cálcio e de fósforo disponível para codornas japonesas de 26 a 38 semanas de idade. *Revista Brasileira de Saúde e Produção Animal* 2012;13(1):204-213.

Vieites FM, Moraes GHK, Albino LFT, Rostagno HS, Donzele JL, Vargas Junior JG, et al. Balanço eletrolítico e níveis de proteína bruta sobre o desempenho de pintos de corte de 1 a 21 dias de idade. *Revista Brasileira de Zootecnia* 2004;33(2):2076-2085.

Yannakopoulos AL, Tserveni-Gousi AS. Quality characteristics of quail eggs. *British Poultry Science* 1986;27:171-176.



