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Modelo matemático para a predição das exigências de fósforo disponível e cálcio para codornas europeias de 16 a 36 dias de idade

Mathematical model for the prediction of available phosphorus and calcium requirements for European quails of 16-36 days old

Modelo matemático para la predicción de requerimientos de fósforo disponible y calcio para codornices europeas de 16 a 36 días de edad

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Caroliny Batista Lima Mariz
ORCID: https://orcid.org/0000-0002-3937-8823
Universidade Federal de Alagoas, Brasil
E-mail: cblzte@hotmail.com
Fernando Guilherme Perazzo Costa
ORCID: https://orcid.org/0000-0003-4075-1792
Universidade Federal da Paraíba, Brasil
E-mail: perazzo63@gmail.com
Danilo Vargas Gonçalves Vieira
ORCID: https://orcid.org/0000-0002-7407-9597
Universidade Federal do Tocantins, Brasil
E-mail: danilovargaszoo@hotmail.com
Matheus Ramalho de Lima
ORCID: https://orcid.org/0000-0002-9897-6209
Universidade Federal do Sul da Bahia, Brasil
E-mail: mrlmatheus@gmail.com
José Humberto Vilar da Silva
ORCID: https://orcid.org/0000-0001-8605-2829
Universidade Federal da Paraíba, Brasil
E-mail: vilardasiva@yahoo.com.br
José Jordão Filho
ORCID: https://orcid.org/0000-0003-3964-9301
Universidade Federal da Paraíba, Brasil
E-mail: jjordaofilho@yahoo.com.br

Danilo Teixeira Cavalcante
ORCID: https://orcid.org/0000-0001-8102-3738
Universidade Federal do Agreste Pernambuco, Brasil
E-mail: danilo.zootec@hotmail.com

Rannyelle Gomes Souza
ORCID: https://orcid.org/0000-0003-2717-0053
Universidade Federal do Tocantins, Brasil
E-mail: rannyellegomes@gmail.com

Venúcia de Diniella Santos Bourdon
ORCID: https://orcid.org/0000-0001-9240-7251
Universidade Federal do Tocantins, Brasil
E-mail: venuciabourdonzootecnia@gmail.com

Everton José do Nascimento Oliveira
ORCID: https://orcid.org/0000-0001-9045-4652
Universidade Federal do Tocantins, Brasil
E-mail: tobr27@yahoo.com.br

Anilma Sampaio Cardoso
ORCID: http://orcid.org/0000-0002-8494-2032
Universidade Federal do Sul da Bahia, Brasil
anilma5@hotmail.com

Mirian Lima Fernandes
ORCID: http://orcid.org/0000-0001-7618-0798
Universidade Estadual da Santa Cruz, Brasil
mirianlima.lima48@hotmail.com

Iva Carla de Barros Ayres
ORCID: http://orcid.org/0000-0003-4295-9108
Universidade Federal da Paraíba, Brasil
ivacarlabarros@gmail.com

Daniel Sales do Nascimento
ORCID: http://orcid.org/0000-0002-9688-4466
Universidade Federal do Sul da Bahia, Brasil
dan.sales26@gmail.com

Resumo

Foram utilizadas 724 codornas com peso inicial de 105,05 ± 1,40g para determinar as exigências nutricionais de cálcio e fósforo disponível para codornas europeias entre 16 e 36 dias de idade. Foram utilizadas 384 codornas para o experimento de exigência de mantença e 240 para o experimento de exigência em ganho e as 100 codornas restantes compuseram as aves do abate comparativo. Para determinar a exigência de mantença, os tratamentos experimentais consistiram em quatro níveis de oferta de ração (100, 75, 50 e 25% do *consumo ad libitum*) com quatro repetições e quatro codornas por unidade experimental para cada ambiente climático (18, 24 e 28ºC), sendo 192 codornas para cada nutriente em estudo. A exigência de ganho foi determinada a partir de 240 codornas, criadas e alimentadas *ad libitum*, sendo 120 codornas para cada nutriente estudado, ou seja, 30 codornas foram abatidas aos 21, 26, 31 e 36 dias de idade. Em conclusão. As equações de predição para estimar as exigências foram: 1) Pd (mg/codorna/dia) = Pd (mg/quail/day) = (27,029 + 1,5943 × T) × $kg^{0,75}$ + 12,24 × GP, em que Pd é a exigência de fósforo disponível, $kg^{0,75}$ é o peso metabólico (kg), GP é ganho de peso (g/codorna/dia). 2) Ca (mg/codorna/dia) = (158,93 – 5,187 × T) × $kg^{0,75}$ + 23,66 × GP, em que Ca é a exigência de cálcio, $kg^{0,75}$ é o peso metabólico (kg), GP é ganho de peso (g/codorna/dia)

Palavras-chave: Codornas para produção de carne; Exigência de ganho; Exigência de mantença; Nutrição mineral.

Abstract

Were used 724 quails, with initial weight of 105.05±1.40g to determine the model requirements for European quails 16-36 days old. Were used 384 quails for the maintenance requirement experiment and 240 for the gain requirement experiment and the remaining 100 quails composed the birds of the comparative slaughter. *Maintenance requirement:* the treatments consisted of four levels of feed offerings (100, 75, 50 and 25% of consumption ad libitum) with four pens and four quails per pen for each climatic environment (18, 24 and 28ºC), being 192 quails for each nutrient under study. *Gain requirement:* the requirements of the studied nutrients for gain were determined from 240 quails, created and fed ad libitum, being 120 quails for each nutrient studied, that is, 30 quails were slaughtered at 21, 26, 31 and 36 days of age. The quails of the reference slaughter comprise the same as the experiment for determining the maintenance requirement. In conclusion. The prediction equations for estimating the requirements were: 1) P_r (mg/quail/day) = (27.029 + 1.5943 × T) × $kg^{0.75}$ + 12.24 × WG, in which P_r is the phosphorus requirement, $kg^{0.75}$ is metabolic weight (kg), WG is weight gain (g/quail/day). 2) Ca (mg/quail/day) = (158.93 - 5.187 × T) × $kg^{0.75}$ + 23.66 × WG, in which Ca is the calcium requirement, $kg^{0.75}$ is metabolic weight (kg), WG is weight gain (g/quail/day), T is temperature.

Keywords: Gain requirement; Maintenance requirement; Meat quail; Mineral nutrition.

Resumen

Se utilizaron 724 codornices con un peso inicial de 105.05±1.40 g para determinar los requerimientos nutricionales de calcio y fósforo disponible para codornices europeas de 16 a 36 días. Se utilizaron 384 codornices para el experimento de requisitos de mantenimiento y 240 para el experimento de requisitos de ganancia y las 100 codornices restantes constituyeron las aves para el sacrificio comparativo. Para determinar el requerimiento de mantenimiento, los tratamientos experimentales consistieron en cuatro niveles de suministro de alimento (100, 75, 50 y 25% de consumo a voluntad) con cuatro réplicas y cuatro unidades experimentales de codornices para cada ambiente climático (18, 24 y 28ºC), con 192 codornices para cada nutriente en estudio. El requisito de ganancia se determinó a partir de 240 codornices criadas y alimentadas ad libitum, con 120 codornices por cada nutriente estudiado, es decir, 30 codornices fueron sacrificadas a los 21, 26, 31 y 36 días de edad. En conclusión. Las ecuaciones de predicción para estimar los requisitos fueron: 1) Pd (mg/codorniz/día) = (27.029 + 1.5943 × T) × $kg^{0.75}$ + 12.24 × GP, donde Pd es el requisito de fósforo, $kg^{0.75}$ es peso metabólico (kg), GP es ganancia de peso (g/codorniz/día). 2) Ca (mg/codorniz/día) = (158.93 - 5.187 × T) × $kg^{0.75}$ + 23.66 × GP, en el que Ca es el requerimiento de calcio, $kg^{0.75}$ es el peso metabólico (kg), GP es ganancia de peso (g/codorniz/día), T es la temperatura.

Palabras clave: Codornices para la producción de carne; Requisito de ganancia; Requisito de mantenimiento; Nutrición mineral.

1. Introduction

The difference in taxonomic classification confers the quails, to the detriment of broilers and laying hens, different growth curve and deposition of corporals components, that is, they have an earlier maturity rate (Neme et al., 2006; Dionello et al., 2008; Drumond et al., 2013; Mota et al., 2015, Demuner et al., 2017).

Japanese quails have a maturity rate of 0.0720 (Mota et al., 2015) and European quails of 0.0694 (Drumond et al., 2013), laying hens (Neme et al., 2006) and broilers (Silva et al., 2017), respectively of 0.0411 and 0.0373. Other differences: such as greater relative weight of the intestinal gastric tract (Marcato et al., 2010; Vasconcellos et al., 2014), lower relative weight of ovary and oviduct (Ferreira et al., 2014), and a higher relative egg weight (Vieira et al., 2012, Lima et al., 2014) in relation to commercial laying hens (Cardoso et al., 2014a, 2014b; Bezerra et al., 2015, Pastore et al., 2015). It is noteworthy that there are peculiarities between quail and other birds (laying hens and broilers) and between quail lineages, whether for laying and meat production, with which it is necessary to consider differences between nutritional requirements.

The dose-response method and the factorial method are methodologies used to determine the nutritional requirements of, laying hens, broilers, and quails. The latter fractionizes the requirements of the birds in maintenance, gain, and production (Longo et al., 2001; Sakomura et al., 2005) in relation to the first one that brings all this information into a single nutritional requirement value (Lima et al., 2014; Maurício et al., 2016).

There are several works that bring the requirements of laying quails in both methods (Silva et al., 2004a, 2004b; Filho et al., 2011a, 2011b; Vieira et al., 2020a; 2020b). However, for European quails, the data are scarce mainly in relation to the factorial method, and also, in mineral nutrition (Silva and Costa, 2009; Scherer et al., 2011; Vieira et al., 2012; Oliveira et al., 2015; Mariz et al., 2016; Perine et al., 2016).

In view of the above, the objective of this research was to carry out two mathematical models to predict the daily requirements of calcium and phosphorus for European quails from 16 to 36 days of age.

2. Materials and Methods

The projects had ethical approval from the Animal Use and Care Committee of the Federal University of Paraiba, Brazil, and were conducted at the Center for Humanities, Social and Agriculture Science, Campus III, located in the city of Bananeiras - PB.

Nine hundred European quails were purchased for the experiment, with one day old. The diet offered was formulated based (Table 1) the nutritional requirements of the European quails during their growth phase (Silva and Costa, 2009). The data collected in the room with 24ºC to determine the calcium requirements were not included due to laboratory problems.

Four hundred and twenty four European quails with aged 16 days, with initial weight of 105.05±1.40g, were used for estimating the phosphorous and calcium requirement for maintenance, at where 100 of these quails were used to compose the reference slaughter.

The remaining 384 quails were distributed in cages of galvanized wire (33x33x16cm), stored at three acclimatized chambers with specifics environmental temperatures (18, 24 and 28ºC). The treatments consisted of four levels of feed supply (100, 75, 50, and 25%) with four replicates and four quails per experimental unit, totaling 64 quails per temperature, 192 quails for each nutrient under study. The 100% level was determined by ad libitum feed intake, estimating the daily volume by weighing the leftovers. The levels 75, 50 and 25% were recalculated everyday based on the ad libitum treatment.

The maintenance requirements de calcium and phosphorus (mg/kg$^{0.75}$/quail/day) were determined by the linear relationship of nutrients retained in the empty carcass, and their ingestion, through the following model: Nutrient (retained) = a + b × Nutrient (ingested). The maintenance requirement will be given by the relation '*a/b*', extrapolating to zero retention (Sakomura and Rostagno, 2016). The parameter '*b*' represents the efficiency (*kg*) of calcium and phosphorus use by quails. The parameter '*a*' represents the endogenous loss of calcium and phosphorus.

Table 1. Feed, nutritional and energetic composition of the experimental diets[1]

Ingredient	Natural matter (%)
Corn	65.615
Soybean meal	29.624
Limestone	0.656
Dicalcium phosphate	1.050
DL-Methionine	0.264
Salt	0.441
Choline	0.050
Vitamin mix[2]	0.100
Mineral mix[3]	0.050
Antoxidant[4]	0.010
Inert [5]	2.140
Total	100.000
Calculated chemistry composition	
Crude protein (%)	19.00
ME (kcal/kg)	2,900
Calcium (%)	0.600
Available phosphorus (%)	0.300
Arginine (%)	1.249
Lysine (%)	0.987
Methionine (%)	0.565
Methionine + cystine (%)	0.880
Threonine (%)	0.743
Tryptophan (%)	0.232
Valine (%)	0.893
Sodium (%)	0.200
Potassium (%)	0.748
Chloride (%)	0.310

[1]Recommentations by Silva & Costa (2009); [2]Vitamin premix (concentration/kg of product): Vit.A - 15 million IU; Vit.D3 - 1,500,000 IU; Vit.E – 15,000 IU; Vit.B1 - 2.0 g; Vit.B2 - 4.0 g; Vit.B6 - 3.0 g; Vit.B12 - 0.015 g; Nicotinic acid - 25 g; Pantothenic acid - 10 g; Vit.K3 - 3.0 g, Folic acid - 1.0 g. [3]Mineral premix (concentration/kg of product): Mn - 60 g; Fe - 80 g; Zn - 50 g; Cu - 10 g; Co - 2 g; I - 1 g; Se - 250 mg; vehicle qs - 500 g. [4]Antioxidant BHT - 10 g. [5]Washed sand. Mineral and vitamin premix acquired with the company Guaraves®. Source: The author himself made the table.

The temperature effect on the phosphorus and calcium requirement for maintenance (P_m and Ca_m) was determined by linear regression as a function of temperature (18, 24, and 28ºC). After obtaining the maintenance requirement data for each nutrient at each temperature evaluated separated, these data were related to the respective temperatures understudy to obtain a linear equation of the maintenance data as a function of the temperatures, which was considered as the maintenance requirement.

The requirements of the studied nutrients for gain (mg/g) were determined from 240 quails, with initial weight of 105.05±1.40g, created and fed ad libitum and receiving the diets described in Table 1, being 120 quails for each studied nutrient. A sample of 30 quails were slaughtered at 21, 26, 31 and 36 days of age. The quails of the reference slaughter comprise

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the same as the experiment for determining the maintenance requirement. The net requirements for gain the studied nutrients were determined by the following equation: Nutrient (body) = a + b × FBW, where, FBW, is fasting body weight, and the parameter "*b*" was considered the net gain requirements. The dietary requirements of nutrients will be determined by dividing the net gain requirement by the efficiency of using them determined in the maintenance experiment (*b*/*kg*).

The slaughter was be by cervical displacement, avoiding the loss of blood and feathers to allow the evaluation of the nutrients deposited in the carcass after at the 12 hours solid-food fasting. The quails were kept whole and identified and stored in the freezer. The phosphorus, calcium, dry matter, ether extract and ash were conducted in the according to the methodology described by AOAC (1990). The metabolic weight (Kim, 1995) was estimated as follows $[(IW + FW) / 2]^{0.75}$ expressed in kg/quail, where IW is the initial weight and FW the final weight of the quails.

The errors were submitted to the Kolmogorov-Smirnov’s normality test ($\alpha = 0.01$). The homogeneity of variances was evaluated by the Levene’s test ($\alpha = 0.01$) and all variables showed normal distribution of errors and homoscedasticity (SAS, 9.0 - Proc GLM). Linear and exponential equations ($\alpha = 0.01$) were estimated (SAS, 9.0 - Proc NLin), and graphs were made using the Excel® 2019 software. All proposed models had a significant effect (T test, $\alpha = 0.01$) on the parameters of the equations 'β_0' and 'β_1', with a probability of $P < 0.01$.

3. Results

Table 2 shows that the European quails had reduction in the final body weight feed intake and thus the phosphorus feed intake, as the level of feed supply was reduced from 100 to 25%. The reduced levels of performance were expected, since the methodology employed in this study aims at reducing the feed intake by quails so that they would ingest nutrients below their maintenance levels. Feed intake ad libitum was not changed between the three temperatures (18, 24 and 28ºC) to which quail were submitted.

Table 2. Means of initial (IBW) and final (FBW) BW, weight gain (WG), feed intake (FI), phosphorus intake (P_{ingest}) on temperature and level of feed offered (NRO).

NRO (%)	IBW (g)	FBW (g)	WG (g/day)	FI (g/day)	P_{ingest} (mg/day)
Temperature 18ºC					
100	102.75	245.19	7.12	25.94	77.82
75	102.12	166.12	3.20	19.59	58.77
50	102.75	122.15	0.97	13.01	39.03
25	102.94	105.25	0.12	6.41	19.23
Temperature 24ºC					
100	103.12	230.34	6.36	25.52	76.56
75	104.81	188.36	4.18	19.02	57.06
50	103.81	135.58	1.59	12.87	38.61
25	103.12	110.75	0.38	6.41	19.23
Temperature 28ºC					
100	102.50	253.16	7.53	25.19	75.57
75	101.13	192.07	4.55	18.97	56.91
50	100.41	123.55	1.16	12.66	37.98
25	102.00	109.68	0.36	6.30	18.90

Source: The author himself made the table.

The weight gain was greater at 28°C, but not as much greater than in other studies that used the empirical method. Quails housed at 18ºC receiving 50 and 25% equivalent to the voluntary intake had the lowest absolute values of weight gain compared to other temperatures.

The chemical composition of the empty body in European quails aged between 16 and 36 d subjected to three temperatures are shown in Table 3 and Table 4. The levels of feed intake restriction and temperature affected the body composition of quails. It is observed that the average composition of dry matter, crude protein, fat and energy among the supply levels of feed intake showed similar behavior between temperatures.

The ash levels, unlike other nutrients, showed percentage increase. Possibly due to the supply levels of feed restriction and reduction of feed intake due to the environmental temperatures. Table 4 presents the mean levels of empty body weight and body phosphorus of European quail from 16 to 36 d of age, subjected to three environmental rearing temperatures and fed on 100, 75, 50, and 25 % of voluntary intake. Phosphorus levels in the empty body weight of European quails increased with temperature from 18 to 28°C, especially at levels of 100 and 75% feed supplied.

From feed intake (Table 2) and phosphorus retention in the empty body of quails (Table 4), regression equations were developed to estimate the daily phosphorus requirements for maintenance. The phosphorus requirement for maintenance based on the metabolic

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weight, the use efficiency for weight gain determined at 18, 24 and 28°C are shown in Table 5.

Table 3. Means of dry matter (DM), crude protein (CP), fat (F), crude energy (CE) and body ash (Ash) of European quails from 16 to 36 d of age subjected to different temperatures on the level of feed offered (NRO).

NRO (%)	DM (%)	CP (%)	F (%)	CE (kcal/kg)	Ash (%)
16 d					
	24.52	17.19	3.28	1.195	0.64
36 d					
Temperature 18ºC					
100	30.47	20.02	7.05	1.756	2.84
75	27.03	21.60	2.26	1.476	3.06
50	25.38	23.21	1.67	1.103	3.87
25	24.61	20.61	1.20	1.206	4.81
Temperature 24ºC					
100	30.18	17.49	8.96	1.784	2.82
75	26.52	18.34	2.48	1.307	3.26
50	25.33	19.05	1.98	1.227	4.44
25	24.51	18.62	1.22	1.056	4.44
Temperature 28ºC					
100	30.86	18.40	10.09	1.711	2.75
75	26.47	20.28	3.75	1.318	3.17
50	25.59	17.15	2.83	1.089	3.71
25	24.57	19.32	1.24	1.024	3.71

Source: The author himself made the table.

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Table 4. Average of empty body weight (EBW), phosphorus percentage (P) of body phosphorus (P_c) and retained phosphorus in carcass (P_{ret}) of European quails from 16 to 36 d of age subjected to different environmental temperatures on the diet level offered (NRO).

NRO (%)	EBW (g)	P (%)	P_c (mg)	P_{ret} (mg/day)
		16 d		
	93.15	0.84	782.46	---
		36 d		
		Temperature 18 ºC		
100	227.25	0.63	1,431.68	32.46
75	148.52	0.81	1,203.01	21.03
50	115.73	0.81	937.41	7.75
25	71.98	1.22	878.16	4.78
		Temperature 24 ºC		
100	213.85	0.82	1,753.57	48.56
75	166.52	0.90	1,498.68	35.81
50	110.82	1.00	1,108.20	16.29
25	86.86	0.96	833.86	2.57
		Temperature 28 ºC		
100	232.18	0.78	1,811.00	51.43
75	167.49	0.94	1,574.41	39.60
50	109.79	0.85	933.22	7.54
25	87.93	0.97	852.92	3.52

Source: The author himself made the table.

The estimation of the P_m maintenance requirements of the European quail's aged between 16-36 d: 56.36; 63.71 and 72.62 mg/kg$^{0.75}$/d at 18, 24 and 28ºC, respectively. It is observed in this table that the P_m requirement suffered direct interference of this environmental parameter on the nutritional requirements of quails. The utilization efficiency increased from 49 to 93% as the temperature rose from 18 to 28°C, respectively.

The lower phosphorus requirement at 18°C may have been due to the higher phosphorus intake at that temperature. It increased with temperature from 18 to 28ºC, according to the equation: $P_m = (27.029 + 1.5943 \times T) \times kg^{0.75}$ in wich kg = weight in kg and T = temperature in °C, indicating that maintenance phosphorus requirement increases 1.5943 mg/kg$^{0.75}$/day for each 1°C increase in temperature.

Table 6 shows the average levels of dry matter, crude protein, crude fat and ash in the empty body of the European quails depending on age. Table 7 presents the average weight of the empty body, the phosphorus percentage in the body weight in % and mean amounts of phosphorus present in the carcass of European quails (mg) depending on age.

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Table 5. Regression equations for retained (P_{ret}) versus ingested (P_{ing}) phosphorus, maintenance requirements (P_m) and use efficiencies (*kg*) of P to P_{gain} in European quails 16-36 d age submitted to different environmental temperatures (T, °C).

T (°C)	Equation	r^2	MW ($kg^{0.75}$)	P_m ($mg/kg^{0.75}/d$)	*kg* (%)
18	$P_{ret} = - 7.4577 + 0.4919 \times P_{ing}$	0.95	0.269	56.36	49
24	$P_{ret} = - 13.737 + 0.8261 \times P_{ing}$	0.99	0.261	63.71	83
28	$P_{ret} = - 18.504 + 0.9300 \times P_{ing}$	0.90	0.274	72.62	93
Mean			0.268	64.23	75

P_{ret} = phosphorus retained in the carcass; P_{ing} = Phosphorus intake, MW = metabolic weight $[(kg_{IBW} + kg_{FBW}) \div 2]^{0.75}$. IBW – Initial body weight; FBW – Final body weight. Source: The author himself made the table.

Table 6. Average chemical composition of the empty body of the European quails depending on age.

Age (d)	Body weight (%)	Water (%)	Protein (%)	Fat (%)	Ash (%)
16	24.52	75.48	17.19	3.18	3.28
21	27.11	72.89	19.20	3.34	3.14
26	29.17	70.83	20.85	4.06	3.47
31	29.09	70.91	19.55	4.94	3.14
36	30.47	69.33	19.66	8.08	2.93

Source: The author himself made the table.

Table 7. Means of empty body weight (EBWz), phosphorus on the body weight (P) and body phosphorus (Pc) of European quails depending on age

Age (d)	EBWz (g)	P (%)	P_c (mg)
16	93.15	0.83	773.15
21	132.20	0.90	1,189.80
26	157.40	0.82	1,290.68
31	200.60	0.84	1,685.04
36	230.03	0.91	2,093.27

EBWz = empty BW, P = phosphorus on body weight; P_c = amount of phosphorus in the carcass in mg. Source: The author himself made the table.

By establishing the ratio of phosphorus retained in the quail carcass as a function of body weight (Table 7), we can establish the net requirements for available phosphorus for weight gain (Table 8) in 9.18 mg/g. Using the average efficiency (75%) of using phosphorus for maintenance (Table 5) it was possible to calculate the dietary requirement of available phosphorus for weight gain (Table 8) at 12.24 mg/g.

Table 8. Regression equation of body phosphorus and body phosphorus depending on empty body weight (EBW_z), net gain requirement (NG_g), use efficiency (kg), and dietary requirement for gain (DR_g) in European quails from 16 - 36 d age.

Equation	r^2	NG_g (mg/g)	*kg* (%)	DR_g (mg/g)
$P_c = 87.867 + 9.1855 \times EBW_z$	0.98	9.18	75	12.24

Source: The author himself made the table.

The European quails had reduction in the final body weight, feed intake and thus the calcium intake, as the level of feed supply was reduced from 100 to 25% (Table 9).

Although quails have not changed the feed intake among temperatures, the weight gain was higher at 28°C, especially at 100 and 75% feed supply. Quails housed at 18ºC receiving 50% and 25% equivalent to the voluntary intake had the lowest absolute values of weight gain compared to other temperatures.

Table 9. Means of initial (IBW) and final (FBW) BW, feed intake (FI), calcium intake (Ca_{ingest}) on temperature and level of feed offered (NRO).

NRO (%)	IBW (g)	FBW (g)	WG (g/day)	FI (g/d)	Ca_{ingest} (mg/d)
Temperature 18ºC					
100	102.75	245.19	7.12	25.94	155.64
75	102.12	166.12	3.20	19.59	117.54
50	102.75	122.15	0.97	13.01	78.06
25	102.94	105.25	0.12	6.41	38.46
Temperature 28ºC					
100	102.50	253.16	7.53	25.19	151.14
75	101.13	192.07	4.55	18,97	113.82
50	100.41	123.55	1.16	12.66	75.96
25	102.00	109.68	0.36	6.30	37.80

Source: The author himself made the table.

The reduction in the diet supply decreased the amount of body weight, fat, protein and gross energy of the empty body of quails kept at 18 and 28ºC (Table 10). The fat content in the empty body of European quails were higher at 28ºC than those observed at 18°C in all levels of feed supply. However, this increase in carcass fat content had no interference with feed intake, since this feed intake was similar at both temperatures. The ash showed percentage increase under the influence of feed offered levels, and decrease due to rising temperatures (Table 11).

The highest ash concentration at the offered levels 50 and 25% can be explained by the lower feed intake and consequently calcium. Calcium levels in the empty body of

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European quails increased with temperature from 18 to 28°C, especially at levels of 100 and 75% feed supplied.

Table 10. Means of dry matter (DM), crude protein (CP), fat (F), crude energy (CE) and body ash (Ash) of European quails from 16 to 36 d of age subjected to different temperatures on the level of feed offered (NRO).

NRO (%)	DM[1] (%)	CP[2] (%)	F[3] (%)	CE[4] (kcal/kg)	Ash[5] (%)
16 d					
	24.52	17.19	3.28	1.195	0.64
36 d					
Temperature 18ºC					
100	30.47	20.02	7.05	1.756	2.84
75	27.03	21.60	2.26	1.476	3.06
50	25.38	23.21	1.67	1.103	3.87
25	24.61	20.61	1.20	1.206	4.81
Temperature 28ºC					
100	30.86	18.40	10.09	1.711	2.75
75	26.47	20.28	3.75	1.318	3.17
50	25.59	17.15	2.83	1.089	3.71
25	24.57	19.32	1.24	1.024	3.71

Source: The author himself made the table.

Table 11. Average of empty body weight (EBW), calcium percentage (Ca) of body calcium (Ca_c) and retained calcium in carcass (Ca_{ret}) of European quails from 16 to 36 d of age subjected to different environmental temperatures on the diet level offered (NRO).

NRO (%)	EBW (g)	Ca (%)	Ca_c (mg)	Ca_{ret} (mg/day)
16 d				
	93.15	0.64	596.16	---
36 d				
Temperature 18 ºC				
100	227.25	0.80	1,818.00	61.09
75	148.52	0.93	1,381.24	39.25
50	107.41	1.11	1,192.25	29.80
25	71.93	1.42	1,021.41	21.26
Temperature 28 ºC				
100	232.18	0.91	2,112.84	75.83
75	167.49	0.95	1,591.16	49.75
50	109.79	1.04	1,141.82	27.28
25	87.93	1.19	1,046.37	22.51

Source: The author himself made the table.

The estimation of the Ca_m (Table 12) maintenance requirements of the European quail's aged between 16-36 d: 65.56 and 13.69 mg/kg$^{0.75}$/d at 18 and 28ºC, respectively. It is observed in this table that the Ca_m requirement suffered direct interference of this environmental parameter on the nutritional requirements of quails. The utilization efficiency increased from 33 to 48% as the temperature rose from 18 to 28°C, respectively. The maintenance calcium requirement decreases with increases temperature from 18 to 28ºC, according to the equation: $Ca_m = (158.93 - 5.187 \times T) \times kg^{0.75}$ in wich kg = weight (kg) and T = temperature (°C), indicating that calcium requirement decreases 5.187 mg/kg$^{0.75}$/d for each 1°C increase in temperature.

Table 12. Regression equations for retained (Ca_{ret}) versus ingested (Ca_{ing}) calcium, maintenance requirements (Ca_m) and use efficiencies (kg) of Ca to Ca gain in European quails from 16-36 *d* of age submitted to different ambient temperatures (T, °C).

T (°C)	Equation	r^2	MW (kg$^{0.75}$)	Ca_m (mg/kg$^{0.75}$/d)	*kg* (%)
18	$Ca_{ret} = 5.8028 + 0.3290 \times Ca_{ing}$	0.94	0.269	65.56	33
28	$Ca_{ret} = - 1.8083 + 0.4822 \times Ca_{ing}$	0.93	0.274	13.69	48
Mean			0.272	39.63	41

Ca_{ret} = calcium retained in the carcass; Ca_{ing} = calcium intake, MW = metabolic weight $[(kg_{IBW} + kg_{FBW}) \div 2]^{0.75}$. IBW – Initial body weight; FBW – Final body weight. Source:The author himself made the table.

The increased body weight altered the chemical composition of quail carcass (Table 13). While the water percentage had continuous decrease, the protein percentage reduced only in the age group from 26 to 36 d, which probably were influenced by increased fat content of the empty body. Nevertheless, protein and body energy increased in absolute values with increasing empty body weight of quail aged from 16 to 36 d (Table 13).

Table 13. Mean chemical composition of the empty body of European quails depending on age.

Age (*d*)	BW (%)	Water (%)	Crude protein (%)	Fat (%)	Ash (%)
16	24.52	75.48	17.19	3.18	3.28
21	27.11	72.89	19.20	3.34	3.14
26	29.17	70.83	20.85	4.06	3.47
31	29.09	70.91	19.55	4.94	3.14
36	30.47	69.33	19.66	8.08	2.93

Source: The author himself made the table.

It is observed that with increasing age the mineral concentration increases in these quails carcass (Table 14).

Table 14. Mean empty body weight (EBW), calcium percentage (Ca) of body weight and body calcium (Ca_c) of European quails depending on age.

Age (*d*)	EBW (g)	Ca (%)	Ca_c (mg)
16	93.15	0.66	614.79
21	132.20	0.84	1,110.48
26	157.40	0.96	1,511.04
31	200.60	0.82	1,644.92
36	230.03	0.88	2,204.26

Source: The author himself made the table.

By establishing the ratio of calcium retained in the quail carcass as a function of body weight (Table 14), we can establish the net requirements for calcium for weight gain (Table 15) in 9.7 mg/g. Using the average efficiency (41%) of using calcium for maintenance (Table 12) it was possible to calculate the dietary requirement of calcium for weight gain (Table 15) at 23.66 mg/g.

Table 15. Regression equation of body calcium (Ca_c) depending on the empty body weight (EBW), net gain requirement (NG_g) use efficiency (*kg*) and dietary requirement for gain (DR_g) of calcium in European quails from 16-36 *d* of age.

Equation	r^2	NG_g (mg/g)	*kg* (%)	DR_g (mg/g)
$Ca_c = - 197.44 + 9.7036 \times EBW$	0.95	9.7	41	23.66

Source: The author himself made the table.

4. Discussion

It is observed that with the increase of age, the concentration of phosphorus was increasing in the carcass of these quails. The similarity in carcass proportions is a sign that the calcium does not interfere with phosphorus absorption and vice versa. Another factor that may have contributed was the rate of use efficiency between them, in addition to the water content reduction in the carcass depending on age, which makes higher the mineral concentration in the carcass.

The increase in body weight altered the carcass chemical composition of quails. While the water percentage had a continuous decrease, the protein percentage reduced only in the group aged 26 to 36 d, which was probably influenced by the increased fat content of the empty body. Nevertheless, protein and body energy increased in absolute values with increasing empty BW of quail aged from 16 to 36 d. The ash contents remained practically constant. Again, it can be explained by the productive genetic constitution of this genotype, since these animals are intended for meat production rather than eggs. The life stage should also interfere, once the routing of calcium and phosphorus absorbed is primarily designed for bone formation in the growth phase (Araujo et al., 2012).

The requirement and efficiency of phosphorus use was broadened as the environmental temperature increased from 18 to 28°C. There is enough scientific evidence to conclude that heat and cold are important agents of behavior modification and animal response (Donkoh and Atuahene, 1988; Oliveira et al., 2006). By approaching the thermoneutral zone, the animal reaches its maximum potential and body temperature is maintained with minimal use of thermoregulatory mechanisms (Silva et al., 1994). Probably, this effect occurred in this study, since the higher the temperature the higher the weight gain of quail, this one associated with a thermal condition conducive to animal performance. The increased demand and use efficiency of phosphorus follows the increase in weight gain of these quail, which was 245g at 18ºC, 230g at 24ºC and 253g at 28°C. This indicates that animals with greater weight gain need higher intakes of calcium and phosphorus for a proper bone formation.

This result does not provide a clear justification. Phosphorus is the mineral that accompanies the calcium metabolism, especially as regards the absorption and serum levels. Factors that could have interfered with this effect include the greater absorption of lipids, which did not happen, because the feed intake in different conditions remained constant.

The higher ash concentration in the restriction levels of 50 to 25% can be explained by the lower feed intake and consequently calcium and phosphorus intake. Sá et al. (2004), while studying the effect of calcium levels in the diet of broilers, found out that performance and bone ash content in these animals significantly reduced due to increased dietary calcium. According to Shafey and McDonald (1991), the excess of calcium and phosphorus in the diet may produce reduction in the bioavailability of these minerals by forming insoluble calcium phosphate in the digestive tract, thereby reducing the absorption of both elements.

The reduction of ash deposition in the carcass by temperature increase may have been influenced by the lower feed intake, since high temperatures affect the regulation of poultry metabolism, which makes the feed intake reduce to soften the heat effects by caloric increment generated during the process of digestion and absorption of nutrients, which therefore influences on the minerals availability (Araujo et al., 2007).

According to Barreto et al. (2007), quails are able to adapt to diets containing low calcium levels by increasing the intestinal absorption capacity. The efficient performance of parathyroid hormone (PTH) and ultimobrachial glands (calcitonin) allows an effective use of these minerals. The highest phosphorus concentration in the carcass of European quails may have been generated depending on the calcium, once phosphorus follows its metabolism, especially with regard to absorption rate and serum levels. About the weight gain at 28°C, this result indicates that the temperature of 18°C is below the temperature for comfort zone, making quails use part of lipids, carbohydrates and proteins (amino acids) contained in the diet for its maintenance and not for weight gain (Lilja et al., 1985).

The non-influence in feed intake ad libitum, for it did not change, in three temperatures in this study confirm the hypothesis of Macleod and Dabhuta (1997), when infer that the same way as in broilers, the European quails can keep feed intake under conditions of high temperature due to the ease of metabolic heat loss, as they have a more favorable surface: body volume ratio due to its larger size.

The reduced levels of performance were expected, since the methodology employed in this study aims at reducing the feed intake by quails so that they ingest nutrients below their maintenance levels.

Reductions in the contents of crude protein and crude energy and final BW, using a similar methodology in Japanese quails, were also observed by Silva et al., (2004b) from 15 to 32 d of age, Vieira et al. (2020a; 2020b) from 1 to 15 d and, Filho et al. (2011b) using in Japanese and European quails.

Feed intake at home was not changed between the two temperatures (18 and 28 ºC) to which poultry were submitted, confirming the hypothesis of Macleod and Dabhuta (1997), who infer that the same way as in broilers. The European quails can keep feed intake under conditions of high temperature due to the ease of loss of metabolic heat, as they have a more favorable surface: body volume ratio due to its larger size. In relation about the feed intake among temperatures, the results showed in the Table 2 can to indicate that the temperature of 18°C is below the temperature for comfort zone, making quails use part of lipids, carbohydrates and proteins (amino acids) contained in the diet for its maintenance and not for weight gain (Lilja et al., 1985).

The trend of increasing in the protein percentage in the empty body of European quails fed on 25% feed compared with those of ad libitum feed intake at 28°C may be indicative of preferential use of fat and not body protein as energy source for metabolism. This effect can be clearly observed through reduced empty body fat of quails from 10.09 to 1.24%, namely a decrease of nine points compared to treatments ad libitum (100%) and 25% feed supply.

According to Furlan et al. (2001), broilers kept at warm and thermoneutral room temperature have higher amounts of abdominal fat when compared to broilers kept at temperatures below the optimum, since the temperature can affect body fat deposition. Howlider and Rose (1987) argue that broilers show 0.81% increase in abdominal fat for every centigrade degree increase in temperature. Geraert et al. (1996) who observed more fat deposition in poultry kept at high temperature conditions (32°C) found similar results.

About the ash percentage, showed in the Table 3, Anderson et al. (1984) studying the effect of calcium levels in the diet of broilers found that the performance and bone ash content in these animals significantly reduced due to increased dietary calcium from 0.9 to 1.5%. According to Shafey and McDonald (1991), the excess of calcium and phosphorus in the feed can generate reduced availability of minerals by forming insoluble calcium phosphate in the digestive tract, thereby reducing their absorption.

It is observed in this table that the Ca_m requirement was different among temperatures. This indicates that the temperature has direct effect on the nutrient requirement for maintenance. The efficiency of using calcium for gain increased 45.45% doubled when the temperature was raised from 18 to 28°C. The reason why the calcium use efficiency remained low at 18°C may have been due to the low production of the PTH hormone by poultry preventing calcium from being absorbed in good quantities by the intestines.

The data relating to European quails show that while it is preached that temperature of thermal comfort for these animals is around 20ºC, this can be considered a lower critical temperature, since performance achieved was different from those observed in other treatments. The fact that body fat has been lower in these temperatures (18ºC) may also be indicative of this hypothermic condition that quails were submitted, which made part of this element of body energy reserve was diverted to heat production, since that there was no difference in feed intake between temperatures.

The low calcium use efficiency may have contributed to the greater mobilization of its bone reserves to increase their blood concentration, which resulted in increased demand. This similar situation was reversed at 28ºC so that the requirement decreased to 13.64 $mg/kg^{0.75}/d$ and the efficiency increased to 48%, even poultry ingesting the same feed amount that the previous temperature. It is clear that for quails at this life stage, this temperature condition is closer to the thermal comfort. Increased efficiency may have occurred due to the increased release of hormones responsible for calcium absorption due to a framework of serum deficiency of this mineral that must have been installed.

The lower calcium retention may be associated with the tested rearing thermal zone, this being probably less critical. In critical zones of temperature, poultry begin to make use of mechanisms that help maintain their body temperature. A lower percentage of body fat at 18ºC explains the occurrence of this fact. According to Abreu and Abreu (2003), the distancing of temperature from values near the thermoneutral region of animals unbalances the thermodynamic mechanism that poultry have to protect themselves from climate extremes leading to wasted energy. And according to Fraser et al. (1975), the animal is under stress when adjustments are needed in its physiology or behavior to adapt to the adverse aspects arising from the management or the environment in which it is inserted to.

According to Macari (2002), in order chemical reactions of the animal may occur constantly, several factors must be kept in narrow bounds of variation so that cellular integrity is maintained and its function preserved. Given what was observed in this study, European quails between 16 and 36 d of age showed comfort zone with higher temperatures. It is evident in this work that the metabolism of European quail behaves different from the Japanese quail; it makes them exhibit different behaviors under similar rearing conditions. Genotypic and productive features of both species evidently generate these differences, since one was selected for increased meat production and the other for higher egg production.

The ash content remained practically constant. Sá et al., (2004) studying the calcium nutritional requirement for broiler chickens in growing and finishing phases observed little variation in bone ash content in grams and percentage as the poultry received between 0.66 and 1.41% calcium in the diet.

5. Conclusion

In conclusion, the prediction equations for estimating the requirements were: Pd (mg/quail/day) = $(27.029 + 1.5943 \times T) \times kg^{0.75} + 12.24 \times WG$, in which Pd is the available phosphorus requirement, $kg^{0.75}$ is metabolic weight (kg), WG is weight gain (g/quail/day), T is temperature. Ca (mg/quail/day) = $(158.93 - 5.187 \times T) \times kg^{0.75} + 23.66 \times WG$, in which Ca is the calcium requirement, $kg^{0.75}$ is metabolic weight (kg), WG is weight gain (g/quail/day), T is temperature.

New research seeks to be carried out with the determination of the nutritional requirements of quails. Genetic progress is dynamic, as is the need to constantly review nutritional requirements.

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References

Abreu, V. M. N., & Abreu, P. G. (2011). The challenges of animal environment on the poultry systems in Brazil. *Brazilian Journal of Animal Science*, 40(supl. Especial), 1-14. Retrieved from https://www.alice.cnptia.embrapa.br/bitstream/doc/901939/1/osdesafiosdaambienciasobreossistemas.pdf

AOAC. (Association of Official Analytical Chemists). Official methods of analysis. (15a. ed.). Washington: AOAC, 1990.

Barreto, S. L. T., Pereira, C. A., Umigi, R. T., Rocha, T. C., Araujo, M. S., Silva, C. S., & Filho, R. A T. (2007). Determination of nutritional calcium requirement of Japanese quails in the initial production phase. *Brazilian Journal of Animal Science*, 36(1), 68-78. DOI: 10.1590/S1516-35982007000100009

Bezerra, R. M., Costa, F. G. P., Givisiez, P. E. N., Goulart, C. C., Santos, R. A., & Lima, M. R. (2015). Glutamic acid supplementation on low protein diets for laying hens. *Acta Scientiarum. Animal Sciences.* 37(2), 129-134. DOI: 10.4025/actascianimsci.v37i2.25911

Cardoso, A. S., Costa, F. G. P., Lima M. R., Nogueira, E. T., Santos, C. S., Sousa, R. B., Lima, R. C., & Vieira, D. V. G. (2014a). Nutritional requirement of digestible Threonine for white egg layers of 60 to 76 weeks of age. *Journal Applied Poultry Research*, 23(4), 724-728. DOI: 10.3382/japr.2014-01011

Cardoso, A. S., Costa, F. G. P., Silva, J. H. V., Saraiva, E. P., Nogueira, E. T., Santos, C. S., Lima, M. R., & Vieira, D. V. G. (2014b). Nutritional requirement of digestible tryptophan for white-egg layers of 60 to 76 weeks of age. *Journal Applied Poultry Research*, 23(4), 729-734. DOI: 10.3382/japr.2014-01012

Carvalho Filho, D. U., Figueiredo, A. V., Lopes, J. B., Almendra, S. N. O., Costa, E. M. S., Gomes, P. E. B., & Merval, R. R. (2015). Diets with phytase for broilers housed in environments with different air-conditioning systems. *Brazilian Journal of Veterinary Science*, 22(3-4), 180-187. DOI: 10.4322/rbcv.2016.011

Demuner, L., Suckeveris, D., Muñoz, J., Caetano, V., Filho, D., & Faria, D. (2017). Adjustment of growth models in broiler chickens. *Pesquisa Agropecuária Brasileira*, 52(12), 1241-1252. DOI: 10.1590/s0100-204x2017001200013.

Dionello, N. J. L., Macari, M., Ferro, J. A., Rutz, F., Ferro, M. I. T & Furlan, L. R. (2002). Physiological responses associated with thermotolerance in broiler chicks of two strains by exposure to high temperatures. *Brazilian Journal of Animal Science*, 31(1), 79-85. DOI: 10.1590/S1516-35982002000100009

Drumond, E. S. C., Gonçalves, F. M., & Veloso, R. C. (2013). Growth curve for quails. *Rural Science*, 43(10), 1872-1877. DOI: 10.1590/S0103-84782013001000023

Ferreira, F., Corrêa, G. S. S., Corrêa, A. B., Silva, M. A., Felipe, V. P. S., Wenceslau, R. R., Freitas, L. S., Santos, G. G., Godinho, R. M., Climaco, W. L. S., Dalsecco, L. S., & Caramori Júnior, J. G. (2014). Carcass traits of EV1 quail strain fed different methionine + cystine level diet. *Brazilian Archive of Veterinary Medicine and Zootechnics*, 66(6), 1855-1864. DOI: 10.1590/1678-6283.

Filho, J. J., Silva, J. H. V., Costa, F. G. P., Albino, L. F. T., Melo, T. S., Lacerda, P. B., Dantas, G. M., & Soares, R. P. (2012). Requirement for maintenance and gain of crude protein for two genotypes of growing quails. *Brazilian Journal of Animal Science*, 41(9), 2048-2054. DOI: 10.1590/S1516-35982012000900012

Filho, J. J., Silva, J. H. V., Costa, F. G. P., Sakomura, N. K., Silva, C. T., Chagas, N. A. (2011a). Prediction equations to estimate the demand of energy and crude protein for maintenance, gain and egg production for laying Japanese quails. *Revista Brasileira de Zootecnia*, 40(11), 2423-2430. DOI: 10.1590/S1516-35982011001100020

Filho, J. J., Silva, J. H. V., Costa, F. G. P., Sakomura, N. K., Silva, C. T., & Chagas, N. A. (2011a). Prediction equations to estimate the demand of energy and crude protein for maintenance, gain and egg production for laying Japanese quails. *Brazilian Journal of Animal Science*, 40(11), 2423-2430. DOI: 10.1590/S1516-35982011001100020

Filho, J. J., Silva, J. H. V., Silva, C. T., Costa, F. G. P., Sousa, J. M. B., Givisiez, P. E. N. (2011b). Energy requirement for maintenance and gain for two genotypes of quails housed in different breeding rearing systems. *Revista Brasileira de Zootecnia*, 40(11), 2415-2422. DOI: 10.1590/S1516-35982011001100019

Filho, J. J., Silva, J. H. V., Silva, C. T., Costa, F. G. P., Sousa, J. M. B., & Givisiez, P. E. N. (2011b). Energy requirement for maintenance and gain for two genotypes of quails housed in different breeding rearing systems. *Brazilian Journal of Animal Science*, 40(11), 2415-2422. DOI: 10.1590/S1516-35982011001100019

Fraser, D., Ritchie, J. S., & Fraser, A. F. (1975). The term" stress" in a veterinary context. *The British Veterinary Journal*, 131(6), 653-662. DOI: 10.1016/S0007-1935(17)35136-9

Lilja, C., Sperber, I., & Marks, H. L. (1985). Postnatal growth and organ development in Japanese quail selected for high growth rate. *Growth*, 49(1), 51-62. Retrieved from https://pubmed.ncbi.nlm.nih.gov/4007580/

Lima, R. C., Costa, F. G. P., Goulart, C. C., Cavalcante, L. E., Freitas, E. R., Silva, J. H. V., Dantas, L. S., & Rodrigues, V. P. (2014). Nutritional requirement of crude protein for Japanese quail (Coturnix japonica) in the production phase. *Brazilian Archive of Veterinary Medicine and Zootechnics*, 66(4), 1234-1242. DOI: 10.1590/1678-6414

Longo, F. A., Sakomura, N. K., Figueiredo, A. N., Rabello, C. B. V & Ferraudo, A. S. (2001). Prediction Equations for Protein Requirements on Broilers. *Revista Brasileira de Zootecnia*, 30(5), 1521-1530. DOI: 10.1590/S1516-35982006000100015

Macari, M., Furlan, R. L., & Gonzales, E. (2002). *Fisiologia aviária aplicada a frangos de corte.* 2ª ed. Campinas: FACTA.

MacLeod, M. G., & Dabhuta, L.A. (1997). Diet selection by Japanese quail (Coturnix japonica) in relation to ambient temperature and metabolic rate. *British Poultry Science*, 38(5), 586-589. DOI: 10.1080/00071669708418040

Marcato, I. S. M., Sakomura, I. N. K., Fernandes, J. B. K., Siqueira, J. C., Dourado, L. R. B., & Freitas, E. R. (2010). Growth and nutrients deposition on organs of two commercial strains of broiler chickens. *Brazilian Journal of Animal Science*, 39(5), 1082-1091. DOI: 10.1590/S1516-35982010000500019

Mariz, C. B. L., Silva, J. H. V., Jordão Filho, J., Lima, M. R., & Costa, F. G. P. (2016). P and Ca requirements for Japanese quail. *Journal of Animal Physiology and Animal Nutrition*, 101(2), 389-400. DOI: 10.1111/jpn.12446

Maurício, T. V., Vargas Junior, J. G, Souza, M. F., Barboza, W. A., Nunes, L. C., Soares, R. T. N., & Nascimento, H. S. (2016). Digestible arginine levels in diets for Japanese quails. *Semina Agrarian Sciences*, 37(4 – supplement 1), 2453-2462. DOI: 10.5433/1679-0359.2016v37n4Supl1p2453

Mota, L. F. M., Alcântara, D. C., Abreu, L. R. A., Costa, L. S., Pires, A. V., Bonafé, C. M., Silva, M. A., & Pinheiro, S. R. F. (2015). Growth comparison of different genetic groups using nonlinear models. *Brazilian Archive of Veterinary Medicine and Zootechnics*, 67(5), 1372-1380. DOI: 10.1590/1678-4162-7534

Neme, R., Sakomura, N. K., Fukayama, E. H., Freitas, E. T., Fialho, F. B., Resende, K. T., & Fernandes, J. B. K. (2006). Growth curves and deposition of body components in pullets of different strains. *Brazilian Journal of Animal Science*, 35(3 - supplement), 1091-1100. DOI: 10.1590/S1516-35982006000400021

Oliveira, R. G., Pinheiro, S. R. F., Goulart, K. B., Pires, A. V., Figueiredo, F. C., & Cordido, K. A. A. T. (2015). Available phosphorus in starter diets for meat-type quail. *Ciencia e Investigación Agraria*, 42(1), 19-25. DOI: 10.4067/S0718-16202015000100002

Pastore, S. M., Gomes, P. C., Barreto, S. L. T., Viana, G. S., Silva, E. A., Almeida, R. L., Barbosa, L. V. B., & Oliveira, W. P. (2015). Nutritional requirement of digestible lysine for white-egg laying hens in production. *Rural Science*, 45(8), 1496-1502. DOI: 10.1590/0103-8478cr20140661

Perine, T. P., Marcato, S. M., Furlan, A. C., Grieser, D. O., Zancanela, V., Stanquevis, C. E., Benites, M. I., & Euzébio, T. C. (2016). Calcium requirement and vitamin D supplementation in meat-type quail at second stage of growth. *Brazilian Journal of Animal Science*, 45(11), 655-660. DOI: 10.1590/s1806-92902016001100003

Sakomura, N. K., & Rostagno H. S, editors. (2016). *Research Methods in Monogastric Nutrition*. Second ed. Jaboticabal: FUNEP.

Sakomura, N. K., Basaglia, R., C. M. L & Fernandes, J. B. K. (2005). Modelling protein utilization in laying hens. *Brazilian Journal of Animal Science*. 31(6), 2247-2254 DOI: 10.1590/S1516-35982005000200027

Scherer, C., Furlan, A. C., Martins, E. N., Scapinello, C., & Ton, A. P. S. (2011). Metabolizable energy requirements of meat quail from 1 to 14 days of age. *Brazilian Journal of Animal Science*, 40(11), 2496-2501. DOI: 10.1590/S1516-35982011001100030.

Silva, J. H. V., & Costa, F. G. P. (2009). *Nutritional requirement table for quails - Food composition and productive management*. 2nd ed. Bananeiras.

Silva, J. H. V., Filho, J. J., Costa, F. G. P., Lacerda, P. B. L., Vieira, D. V. G., & Lima, M. R. (2012). Nutritional requirements of quails. *Brazilian Journal of Animal Health and Production*. 13(3), 775-790. DOI: 10.1590/S1519-99402012000300016

Silva, R. M., Furlan, A. C., Ton, A. P. S., Martins, E. M., Scherer, C., & Murakami, A. E. (2009). Calcium and phosphorus requirements of finishing meat quail. *Brazilian Journal of Animal Science*, 38(8), 1509-1517. DOI: 10.1590/S1516-35982009000800015.

Silva, M. T. P., Veloso, R. C., Pires, A. V., Torres Filho, R. A., Pinheiro, S. R. F., Winkelstroter, L. K., Barros, F. J. M., & Senna, J. A. B. (2017). Performance and carcass traits of three commercial broiler genotypes fed different diets. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, 69(5), 1311-1318. DOI: 10.1590/1678-4162-8241

Vasconcelos, R. C., Pires, A. V., Lima, H. J. D., Ballotin, L. M. V., Veloso, R. C., Drumond, E. S. C., & Gonçalves, F. M. (2014). Meat quails carcass characteristics fed with different protein and energy levels. *Brazilian Journal of Health and Animal Production*, 15(4), 1017-1026. DOI: 10.1590/S1519-99402014000400007

Vieira, D. V. G., Barreto, S. L. T., Valeriano, M. H., Jesus, L. F. D., Silva, L. F. F., Mencalha, R., Barbosa, K. S., Mendes, R. K. V., Cassuce, M. R., & Melo, T. S. (2012). Requirements for calcium and phosphorus available for Japanese quail of the 26 to 38 weeks of age. *Brazilian Journal of Animal Health and Production*. 13(1), 204-213. DOI: 10.1590/S1519-99402012000100018

Vieira, D. V. G. V., Oliveira, E. J. N., Souza, R. G., Bourdon, V. D. S., Oliveira, T. R., Silva, K. E. C., Cruz, J. S., Stivanin, T. E., Souza, T. A., Nascimento, C., Rodrigues, K. F., Vaz, R. G. M. V., Lima, M. R., Cavalcante, D. T., & Costa, F. G. P. (2020a). Mathematical models to predict Japanese quail crude protein requirements from 01 to 35 days old. *Research, Society and Development*, 9(8), 1-21. DOI: 10.33448/rsd-v9i8.6160

Vieira, D. V. G. V., Oliveira, E. J. N., Souza, R. G., Bourdon, V. D. S., Oliveira, T. R., Silva, K. E. C., Cruz, J. S., Stivanin, T. E., Souza, T. A., Nascimento, C., Rodrigues, K. F., Vaz, R. G. M. V., Lima, M. R., Cavalcante, D. T., & Costa, F. G. P. (2020b). Mathematical models to predict the energy requirements of Japanese quails from 01-35 days age. *Research, Society and Development*, 9(8), 1-21. DOI: 10.33448/rsd-v9i8.6544

Percentage of contribution of each author in the manuscript

Caroliny Batista Lima Mariz – 20%

Fernando Guilherme Perazzo Costa – 8%

José Humberto Vilar da Silva – 8%

José Jordão Filho – 10%

Matheus Ramalho de Lima – 10%

Danilo Vargas Gonçalves Vieira – 15%

Danilo Teixeira Cavalcante – 6%

Rannyelle Gomes Souza – 3%

Venúcia de Diniella Santos Bourdon – 3%

Everton José do Nascimento Oliveira – 3%

Anilma Sampaio Cardoso – 5%

Mirian Lima Fernandes – 3%

Iva Carla de Barros Ayres – 3%

Daniel Sales do Nascimento – 3%