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NONRUMINANTS NUTRITION

Digestible lysine requirement for European laying quail

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ABSTRACT. The experiment was carried out to evaluate the productive performance of European quails (*Coturnix coturnix*) in the production phase, fed with diets containing different levels of digestible lysine. A total of 175 female quails, aged 65 days, were randomly distributed in a completely randomized design with five treatments and five replicates per treatment. The animals were housed in 25 metal cages, and each cage represented an experimental parcel, with seven birds per parcel. The birds were fed the experimental rations containing 1.177, 1.217, 1.317, 1.417, and 1.517% digestible lysine. The parameters evaluated were: laying rate, mass of eggs produced, feed intake in the period, lysine intake, feed conversion per dozen and per mass. Significant differences were observed for posture rate with quadratic behavior, which indicated higher production for the level of 1.23% of digestible lysine. There was an increasing linear behavior for the feed and lysine intake, and for conversion feed per dozen and by mass, we observed quadratic behaviors. This indicates better feed conversion index when the optimal inclusion level was 1.33% and 1.404% of digestible lysine in the diet, respectively. The requirement of digestible lysine in diets for European quails is 1.404%, which corresponds to a daily intake of 421.20 milligrams of digestible lysine.

Keywords: feed intake; nutrition; amino acids.

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Introduction

The creation of quail for production of meat and eggs has presented an expressive growth in Brazil, since it represents a good alternative to obtain products of high nutritional quality for population (Drumond et al., 2013; Fernandez et al., 2018). The rapid development of quail farming is reinforced by the greater participation of large poultry companies, which improve management techniques and invest in modern installations, allowing housing an increasing number of birds in the same shed (Lucena, Holanda, Holanda, & Anjos, 2019). In 2016, the number of quail in Brazil, regardless of the type of creation (meat or egg production), was 15.1 million birds distributed in various regions of the country. This fact coincides with the emergence of great automated creations and new forms of commercialization of quail's egg and meat (Fernandez et al., 2018; Silva et al., 2009).

Studies involving nutrition have become even more important, because in addition to the high costs of feed formulation for Japanese (*Coturnix japonica*) and European quails (*Coturnix coturnix*), tables of nutritional requirements are normally used in this process (Rostagno et al., 2017). According to Silva et al. (2009), European quails require more amino acids for growing than Japanese quails. Moreover, Jordão Filho et al. (2011) showed that European quails require more energy for weight gain than Japanese quails; however, the quantification of these differences is widely variable. The introduction of digestible lysine in order to maximize weight gain in European quails has been studied, as reported by Ton et al. (2011), who verified an optimal level of 1.52% of digestible lysine in their study, while Barreto et al. (2006) verified an optimal level of 1.20%.

Several authors performed studies evaluating the introduction of digestible lysine for eggs production in diet for European and Japanese quails. Della-Flora, Germano, Bavaresco, Lacerda, and Dionello (2012) verified an optimal lysine level of 1.1137% for European quail. For Japanese quail, Lima et al. (2016) verified the optimal level with the supply of 1.18% of lysine in the diet; Nery, Castro, and Novoa (2015) with 1.08%; and Costa et al. (2008) when providing 1.03% of digestible lysine.

The production of carcasses with higher yields of meat increases the interest of researchers for works that aim to gain more meat, regardless the condition of egg production, both in quantity as well as in larger size. This may reflect on the improvement of productivity of breeding stock eggs, which will produce quails that will be raised exclusively for slaughter. The objective of this study was to evaluate the performance of European quails fed with different levels of digestible lysine.

Material and methods

The experiment was conducted from August to December 2017 in the experimental poultry's sector of the Universidade Federal Rural do Pernambuco, located at latitude 08° 04 '03 "S and longitude 34° 55' 00" W, with elevation of 4m, with mean temperature and air humidity of 29.12°C and 39.30%, respectively.

A total of 175 female quails of the European lineage (*Coturnix coturnix*) at 65 days of age were used. They were distributed in a completely randomized design, with five treatments and five replications per treatment, which resulted in 25 metal cages, with each cage representing an experimental plot, with seven birds per plot. The cages were equipped with a nipple-style water fountain and gutter-type feeder, with a collection spout and egg picking. Water and feed were provided *ad libitum*.

The treatments consisted of five increasing levels of digestible lysine (1.117, 1.217, 1.317, 1.417 and 1.517%) in the diet. The rations were formulated in accordance with the recommendations of Rostagno et al. (2017), with 23% of crude protein and apparent metabolizable energy of 2900 kcal kg^{-1}. The ingredients and composition of the experimental diets are shown in Table 1.

Table 1. Ingredients and composition of diets with different levels of digestible lysine for European quails in laying phase.

	Levels of digestible lysine, %				
Ingredients, kg	1.117	1.217	1.317	1.417	1.517
Corn	43.366	43.366	43.366	43.366	43.366
Soybean meal	40.200	40.200	40.200	40.200	40.200
Dicalcium phosphate	1.590	1.590	1.590	1.590	1.590
Limestone	7.480	7.480	7.480	7.480	7.480
Salt	0.424	0.424	0.424	0.424	0.424
DL-methionine, 98%	0.160	0.160	0.160	0.160	0.160
L-lysine HCl, 79%	0.000	0.100	0.200	0.300	0.400
Soy oil	5.310	5.400	5.450	5.550	5.600
Starch	1.270	1.170	1.070	0.970	0.870
Vitamin and mineral premix	0.200	0.200	0.200	0.200	0.200
Total	100	100	100	100	100
Calculated composition of diets					
Starch (%)	32.336	32.280	32.250	32.140	32.130
Digestible arginine (%)	1.444	1.443	1.440	1.450	1.450
Calcium (%)	3.394	3.394	3.390	3.390	3.390
Chlorine (%)	0.042	0.042	0.040	0.040	0.040
Metabolizable energy (kcal kg^{-1})	2.900	2.900	2.900	2.900	2.900
Digestible Phenylalanine (%)	1.018	1.018	1.018	1.018	1.018
Phenylalanine+Digestible Tyrosine(%)	1.715	1.714	1.710	1.713	1.714
Crude fiber (%)	2.932	2.931	2.931	2.931	2.931
Phosphorus available (%)	0.401	0.401	0.401	0.401	0.401
Lard (%)	2.248	2.245	2.240	2.240	2.250
Digestible histidine (%)	0.551	0.551	0.551	0.551	0.551
Digestible isoleucine (%)	0.885	0.885	0.890	0.890	0.890
Digestible leucine (%)	1.719	1.718	1.720	1.720	1.720
Digestible lysine (%)	1.117	1.217	1.317	1.417	1.517
Digestible methionine (%)	0.461	0.461	0.461	0.460	0.460
Methionine + disgestible cystine (%)	0.590	0.590	0.590	0.590	0.590
potassium (%)	0.858	0.858	0.858	0.858	0.858
Crude protein (%)	21.830	21.830	21.830	21.830	21.830
Sodium (%)	0.230	0.230	0.230	0.230	0.230
Digestible threonine (%)	0.749	0.749	0.749	0.749	0.749
Digestible Tryptophan (%)	0.251	0.251	0.251	0.251	0.251

Vitamin and mineral premix by kg of feed: vit. A 3,750,000 UI; vit. D3, 750,000 UI; vit. E 7,500 mg; vit K3 1,000 mg; vit. B1, 750 mg; vit. B2 1,500 mg; vit. B6 1,500 mg; vit. B12 7,500mcg; vit. C 12,500mg, biotin 30mg, niacin 10,000mg, folic acid 375; pantothenic acid 3,750mg; hill 10,000mg, methionine 400,000 mg, selenium 45mg; iodine 175 mg; iron 12,525 mg; copper 2,500 mg; manganese 19,500 mg; zinc 13,750 mg; prom. Prod 15,000mg, coccidiostat 10,000 mg, antioxidant (BHT) 500 mg.

The maximum and minimum temperatures and relative air humidity in the experimental period were measured daily, at 9:00 am and 4:00 p.m., by digital thermohygrometers distributed in the experimental shed. From the sixty-fifth day of life, the birds were submitted to a 17-hour light program, which was controlled by automatic watch (timer).

The following parameters were tracked up and recorded in control archives, separated by treatment and their respective repetitions: the supply and leftover rations, in order to measure feed intake, the average egg production per bird/day (%) in each treatment, feed intake (g/bird/day), egg mass (g of egg/bird/day) and feed conversion per dozen (g of feed/dozen of egg), and feed conversion by mass (g of feed/dozen of egg)

The eggs collection was performed for 84 days, with tree cycles of 28 days. The eggs were collected daily by morning and in the afternoon, and the average egg production was obtained by dividing the total of produced eggs (whole eggs, broken, cracked and deformed) by the number of viable birds in each plot.

$$\%\text{posture} = \frac{\text{total eggs produced}}{\text{number of viable birds in each plot}}$$

The feed conversion by mass (FC/M) was obtained by dividing the total feed intake by weight of the eggs produced, being expressed in grams of feed per gram of egg produced.

$$\text{FC/M} = \frac{\text{total feed intake}}{\text{weight of the eggs produced}}$$

The feed conversion per dozen of eggs (FC/Dozen) was obtained by means of the product between the average feed intake and dozens of eggs produced.

$$\text{FC/Dozen} = \frac{\text{total feed intake}}{\text{number of dozen eggs produced}}$$

The feed intake (FI) was obtained by daily sum of the difference between total ration in the plot and the leftovers of plot ration.

The lysine intake (LI) in the treatment was obtained by the following expression:

$$\text{LI} = \%\ \text{lysine} * \text{FI}$$

The effects of digestible lysine levels in the diets were evaluated by analysis of variance, set at 5% probability. When statistical differences were observed, we used Tukey test at 5% probability. The linear and quadratic regression analysis were performed as described below:

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i \text{ and}$$

$$Y_i = \beta_0 + \beta_1 X_i + \beta_2 {X_i}^2 + \varepsilon_i$$

where, Y_i is the i-th value of the evaluated response variable, $X_i$is the i-th digestible lysine value received by plot and ε_i is random error associated at the model, which presents normal distribution of mean 0 and constant variance σ^2. β_0, β_1 e β_2 are the parameters associated at the model (Lucena et al., 2019).

The models were evaluated by the following criteria: coefficient of determination of model (R^2), Akaike's information criterion (AIC), and by the sum of the squared residuals (SSR) (Lucena et al., 2019).

Since $\hat{Y}_i$ is the value of i-th variable analyzed after fitting of model, then the sum of squared residuals is defined by the following expression:

$$\text{SSR} = \sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2$$

The coefficient of determination of the model (R^2) is expressed by:

$$R^2 = 1 - \frac{\sum_{i=1}^{n} \left(Y_i - \hat{Y}_i\right)^2}{\sum_{i=1}^{n} (Y_i - \bar{Y})^2}$$

The Akaike's information criterion (AIC) is given by:

$$\text{AIC} = -2\ln L\left(x \backslash \hat{\theta}\right) + 2p$$

where, $L(x \backslash \hat{\theta})$ is the maximum likelihood function, defined as the product of density function, p is the number of model parameters and $\bar{Y}$ is the mean of variable in the analysis (Y_i). All analyzes were performed using R-project 2.13.1 software (Lucena et al., 2019).

Results and discussion

Table 2 shows that the percentage of posture was higher when the quails were fed digestible lysine levels of 1.1317 (79.71%) and 1.417% (80.14%), respectively. The lowest production occurred when the level 1.517% (70.11%) was introduced in their diet. Feed intake was higher among quails fed with the maximum lysine level (1073.14), whereas the lowest intake was observed in the lower level of lysine added to the diet (926.62). The highest mean feed conversion per dozen of eggs was observed for quails fed with the highest level of lysine (500.14), and the lowest for the level of 1.317% (447.95). The same occurred for feed conversion by mass. The egg mass in the period did not present difference ($p > 0.05$), which indicates that there was no relationship with the increase of lysine levels in the diet of European quails (Table 2).

The percentage of posture behaved in a quadratic manner, with the maximum production of 77.79% when the percentage of lysine included in the diet reached the optimum level of 1.233%, as determined by the equation $\hat{Y} = -51.1X^2 + 126.1X$, which presents power of explanation of 99.78%, SSR = 38.65 and AIC = 30.41 (Table 3).

These results corroborate with those observed by Della-Flora et al. (2012), who observed, for European quails, a percentage of laying of 86.65% for an optimal lysine level of 1.1137%, when using the quadratic regression model. Through the use of quadratic regression model, several authors explained the percentage of posture in Japanese quails with variable explanatory power, such as 75.0%, as observed by Lima et al. (2016) with the supply of 1.18% lysine in the diet; 92.4% by Nery et al. (2015) with 1.08% of lysine; and up to 96.0%, as obtained by Costa et al. (2008) when they provided 1.03% of digestible lysine in Japanese quail diets.

There was a difference between the means for feed intake ($p < 0.05$) with an increasing linear behavior, which indicated an increase of 76.68 grams per bird for each 0.1% increase in lysine level, as determined by the equation $\hat{Y} = 766.85X$ with $R^2 = 99.55\%$, SSR = 23.39 and AIC = 60.43. In a study with European quails, Della-Flora et al. (2012), when using the quadratic model with explanatory power of 99.94%, observed a value of 47.19 grams in feed intake when using an optimum lysine level of 1.07%, whereas Ton et al. (2011) using the linear model with a precision power of 96%, verified an optimal level of digestible lysine of 0.92%. In contrast, Barreto et al. (2006) found no difference in feed intake in relation to the different levels of digestible lysine. For Japanese quails, Costa et al. (2008) verified, through a linear model with precision of 60%, that with each increase of 0.1% of lysine, an increase of 0.5g in the feed intake occurred. Ribeiro et al. (2013), Nery et al. (2015) and Lima et al. (2016) did not verify relationship between feed intake and digestible levels of lysine for Japanese quail.

Table 2. Means of posture percentage, egg mass, feed intake, lysine intake, feed conversion per dozen eggs produced, and feed conversion by egg mass produced.

Variables	Levels of digestible lysine (%)					p-value
	1.117	1.217	1.317	1.417	1.517	
Posture percentage	75.48 b	76.54 b	79.71 a	80.14 a	70.11 c	0.03
Egg mass	2095.60 a	2228.40 a	1829.20 a	2391.60 a	2293.20 a	0.09
Feed intake	926.62 d	1020.1 c	1027.42 c	1037.14 b	1073.14 a	0.02
Lysine intake	10.34 e	12.40 d	13.52 c	14.70 b	16.28 a	0.02
FC/Dozen	479.28 b	463.06 b	447.95 c	449.35 c	500.14 a	0.03
FC/M	3.24 a	3.18 b	3.05 c	2.98 c	3.32 a	0.04

Means values followed by different lower letters in row indicate difference between the means by Tukey test at 5%.

Table 3. Estimation of parameters and adequacy criteria of models.

Models	Equation	Adequacy criteria of models		
		R^2	SSR	AIC
Egg number	$\hat{Y} = -28.53X^2 + 70.45X$	99.79	11.42	24.32
Posture percentage	$\hat{Y} = -51.1X^2 + 126.1X$	99.78	38.65	30.41
Feed intake	$\hat{Y} = 766.85X$	99.55	23.39	60.43
Lysine intake	$\hat{Y} = 10.256X$	99.81	1.80	13.08
FC/Dozen	$\hat{Y} = -240.43X^2 + 675.46X$	99.76	26.81	51.61
FC/M	$\hat{Y} = -1.8X^2 + 4.8X$	99.77	0.11	1.24

R^2 (coefficients of determination); SSR (sum squared of residuals); AIC (Akaike information criteria).

These results show that European quails require higher consumption levels and, consequently, nutrients for body maintenance and maximization of production due to their physical characteristics. This shows that, as the animals increase their feed intake, consequently, they increase the intake of nutrients contained in the diet. Thus, each increase of lysine that occurs in each treatment implies in an increasing intake of lysine, without interference from physiological consumption controls, because the increase in ingested lysine will promote an increase in production, as observed for both egg production and laying rate. These findings positively impact in the feed conversion index.

The same behavior was observed for the intake of lysine per bird ($p < 0.05$), indicating an increase of 10.256 grams of lysine per bird for each 0.1% increase in the lysine level, as determined by equation $\hat{Y} = 10.256X$ with $R^2 = 99.81\%$, SSR=1.8 and AIC=13.08. Similar results were reported by Ton et al. (2011), Ribeiro et al. (2013), Nery et al. (2015) and Lima et al. (2016), who found, for Japanese quail, a linear behavior with precision of 99%, 100%, 98% and 98%, respectively.

There was a difference of feed conversion per dozen between the digestible lysine levels ($p < 0.05$), with a quadratic behavior yielding the best conversion index of 474.41g of feed per dozen eggs produced, when the optimal level of lysine inclusion in the diet was 1.404%, as determined by equation $\hat{Y} = -240.43X^2 + 675.46X$ with $R^2 = 99.76\%$, SSR = 26.81 and AIC = 51.61. Della-Flora et al. (2012) working with European quails, did not find differences between the levels of digestible lysine. The same was reported by Costa et al. (2008) and Nery et al. (2015) for Japanese quails. Nevertheless, when working with Japanese quails, Lima et al. (2016) verified, through the linear model with a precision of 99%, that at each increment of 0.1% of lysine there was an increase of 13.5 g in feed conversion per dozen. Ribeiro et al. (2013) verified a quadratic effect with explanatory power of 91%, for an optimal lysine level of 1.121%, which reflected in a feed conversion per dozen of 9.16g.

Similar behavior was observed for feed conversion by mass ($p < 0.05$), with the birds reaching the best mass feed conversion of eggs in the period, which corresponded to 3.2g of feed to one gram of egg produced when the level of inclusion of lysine in the diet reached the optimum of 1.33%, as determined by the equation $\hat{Y} = -1.8X^2 + 4.8X$ with R^2=99.77%, SSR=0.11 and AIC=1.24. Ton et al. (2011) verified linear behavior with 93% of precision power for feed conversion in European quail. Barreto et al. (2006) and Della-Flora et al. (2012) found, in European quails, that there was no difference in feed conversion per mass in relation to the different levels of digestible lysine, and the same was found by Costa et al. (2008), Ribeiro et al. (2013) and Nery et al. (2015) for Japanese quails.

This increase in the requirement of lysine by birds, when compared to the results observed by these authors, might be due to a higher age and to the egg production phase of those animals, which implies in an increase of nutritional contribution for the organism maintenance and growth of ovarian follicles.

Conclusion

The requirement of digestible lysine in diets for European quails (*Coturnix coturnix*) in the production stage is 1.404%, which corresponds to a daily intake of 421.20 milligrams of digestible lysine.

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