ANIMAL SCIENCE (ZOOTECNIA)

Revista Brasileira de Ciências Agrárias
ISSN (on line) 1981-0997
v.17, n.3, e1558, 2022
Recife, PE, UFRPE. www.agraria.pro.br
DOI: 10.5039/agraria.v17i3a1558 - Protocol 1558
Subm. 27/10/2021 • App. 22/06/2022 • Pub. 29/08/2022

Performance and egg production of European quails fed with increasing levels of apparent metabolizable energy

Glayciane Costa Gois[1], Maylane Rayane Brito dos Santos[1], Débora Cristine de Oliveira Carvalho[1]*, Mário Adriano Ávila Queiroz[1], René Geraldo Cordeiro Silva Junior[1], Macio Fabrício Santos Leite[1]

[1] Universidade Federal do Vale do São Francisco, Petrolina, PE, Brasil. E-mail: glayciane_gois@yahoo.com.br; maylane.brito@gmail.com; debora.carvalho@univasf.edu.br; mario.queiroz@univasf.edu.br; rene.cordeiro@univasf.edu.br; maciozootecnia.granja@gmail.com

ABSTRACT: This study aimed to evaluate the performance and egg production of European quails fed diets with different levels of apparent metabolizable energy. One hundred and twenty European quails (*Coturnix coturnix coturnix*) with 129 days of age and average body weight of 289.04 g were used. The experiment lasted 56 days, divided into 2 cycles of 28 days (first cycle: 129 to 156 days; second cycle: 157 to 185 days). A completely randomized experimental design was adopted, with five treatments (apparent metabolizable energy (AME) levels - 2,700, 2,800, 2,900, 3,000, and 3,100 kcal kg^{-1} of AME) formulated with a ratio of apparent metabolizable energy and crude protein (AME:CP) of 122.73, 127.27, 131.82, 136.36, and 140.91, respectively, with four replications for treatments. Increasing AME reduced feed intake, egg production and albumen proportion during the first cycle ($p < 0.05$), in contrast to feed conversion per dozen eggs, and yolk proportion increased ($p < 0.05$). For the second cycle, egg production was reduced with increasing AME levels ($p < 0.05$). The better AME level for European quails was 2,700 kcal kg^{-1} of AME for a diet with 22% CP (AME:CP 122.73), obtaining the better performance (feed intake, egg production and feed conversion per dozen eggs) of quails from 129 to 185 days and egg production from 157 to 185 days. The inclusion of 3,000 kcal kg^{-1} of AME in the diets provided eggs with a higher proportion of yolk and a lower proportion of albumen.

Key words: albumen; *Coturnix coturnix coturnix*; egg components; intake

Desempenho e produção de ovos de codornas europeias alimentadas com níveis crescentes de energia metabolizável aparente

RESUMO: Objetivou-se avaliar o desempenho e produção dos ovos de codornas europeias alimentadas com dietas com diferentes níveis de energia metabolizável aparente. Foram utilizadas 120 codornas europeias (*Coturnix coturnix coturnix*) fêmeas com 129 dias de idade e peso corporal médio de 289,04 g. O experimento teve duração de 56 dias, dividido em 2 ciclos de 28 dias (primeiro ciclo: 129 a 156 dias; segundo ciclo: 157 a 185 dias). Adotou-se um delineamento experimental inteiramente casualizado, com cinco tratamentos (níveis de energia metabolizável aparente (EMA) - 2.700, 2.800, 2.900, 3.000 e 3.100 kcal kg^{-1} de EMA) formulados com relação de energia metabolizável aparente e proteína bruta (EMA:PB) de 122,73, 127,27, 131,82, 136,36 e 140,91 respectivamente, com quatro repetições por tratamento. O aumento da EMA reduziu o consumo de ração, produção de ovos e proporção de albúmen durante o primeiro ciclo ($p < 0,05$), em contrapartida a conversão alimentar por dúzia de ovos, e a proporção de gema aumentaram ($p < 0,05$). Para o segundo ciclo, a produção de ovos foi reduzida com o aumento dos níveis de EMA ($p < 0,05$). O melhor nível de EMA para codornas europeias foi de 2.700 kcal kg^{-1} de EMA para uma dieta com 22% de PB (EMA:PB 122,73), obtendo o melhor desempenho (consumo de ração, produção de ovos e conversão alimentar por dúzia de ovos) das aves dos 129 aos 185 dias e produção de ovos dos 157 aos 185 dias. A inclusão de 3.000 kcal kg^{-1} de EMA nas dietas proporcionou ovos com maior proporção de gema e menor proporção de albúmen.

Palavras-chave: albúmen; *Coturnix coturnix coturnix*; componentes do ovo; consumo

* Débora Cristine Oliveira Carvalho - E-mail: debora.carvalho@univasf.edu.br (Corresponding author)
Associate Editor: Edney Silva

Introduction

The growing production demand in the area of coturniculture is accompanied by the need for knowledge of the nutritional management of quails. This practice has often been based on breeders experience, due to the scarce research conducted in Brazil on nutritional requirements for quails, especially for European quails (Muniz et al., 2016; 2018).

Energy is the main nutritional component of diets for layers. Birds meet their energy needs by oxidizing carbohydrates, fats, proteins, and fiber in the diet. Energy is necessary for the maintenance of vital body functions, such as movement, regulation of body temperature, and synthesis of organic tissues. In addition, energy can also be stored or directed to production functions, such as egg production (Granghelli et al., 2019).

There are several factors that justify the use of lipid sources in quail feed. These include improved feed digestibility, reduced wastage, reduced gastrointestinal tract passage rate, and low caloric increment, as well as providing essential fatty acids (EFA) and fat-soluble vitamins (A, D, E, and K) (Alagawany et al., 2020). Although the effects of dietary energy content on broiler performance are well elucidated, studies determining the best levels of apparent metabolizable energy to be offered to European quails conducted in the Northeast region of Brazil are scarce (Jordão Filho et al., 2011).

The amount of energy in the diet influences feed consumption, and can interfere with egg production and egg constituents, and consumption is also influenced by factors such as body weight, ambient temperature, photoperiod, among others (Severo et al., 2020; Santana et al., 2021). When there is an increase in the energy level of the feed, voluntary consumption decreases, reducing egg production (Silva et al., 2003). Therefore, the nutrient requirements of poultry should be expressed in relation to their energy content by correlating them with protein and amino acid requirements.

Data found in the literature indicate that the AME:CP ratio for best performance of laying quails are 125 to 150:1, as a basis for calculating AME, CP and other nutrients (Moura et al., 2008). Therefore, studies are needed to obtain more consistent data for better adjustment in the formulation of rations for European quails. Thus, it was hypothesized that increasing the level of apparent metabolizable energy of diets for European quails without protein correction affects feed intake and consequently other production parameters, including egg constituents.

Thus, the objective was to evaluate the performance parameters and egg constituents of European quails fed diets with different energy levels.

Materials and Methods

Experiment site

The experiment was conducted at the aviculture house belonging to the Centro de Ciências Agrárias of the Universidade Federal do Vale do São Francisco (CCA/UNIVASF), Petrolina, Pernambuco, Brazil (latitude 9° 19’ 28” S, longitude 40° 33’ 34” W, and 393 m altitude). The climate is of the hot semi-arid type, with a rainy season (BSh), with average annual precipitation of 376 mm.

Animals and accommodation

The study was evaluated and approved by the Comitê de Ética no Uso de Animais (CEUA) of the Universidade Federal do Vale do São Francisco (UNIVASF), protocol number 0002/100614.

For the experiment, 120 female European quails (*Coturnix coturnix coturnix*) at 129 days of age with an average initial body weight of 289.04 g were used. The experimental period lasted 56 days divided into 2 experimental cycles of 28 days. The first cycle corresponded to the period from 129 to 156 days and the second cycle from 157 to 185 days.

The birds were raised in metal frame cages, equipped with feeders and drinkers. During the entire experimental period, maximum and minimum temperatures and relative humidity were recorded daily, at 8:00 am and 5:00 pm (Table 1), using digital thermo-hygrometers (Incoterm, São Paulo, SP, Brazil).

Table 1. Minimum (TMin, °C) and maximum (TMmax, °C) temperatures and relative humidity during the first and second experimental cycles.

Cycles	Hours	Temperatures (°C)		Relative humidity (%)
		TMin	TMax	
1st	8:00 am	22.50	27.07	60.82
	5:00 pm	26.85	30.41	39.26
2nd	8:00 am	21.41	26.43	52.89
	5:00 pm	26.63	30.15	30.35

Treatments and experimental diets

An entirely randomized experimental design was adopted, with five treatments and four repetitions, with five birds per experimental unit. The treatments consisted of diets with increasing levels of apparent metabolizable energy, namely: 2,700, 2,800, 2,900, 3,000, and 3,100 kcal kg^{-1} of AME, the apparent metabolizable energy:protein ratio (AME:CP) being 122.73, 127.27, 131.82, 136.36, and 140,91, respectively. The diets were formulated to be isoproteic based on the nutritional requirements for European quails described by Silva (2009) and were composed of corn meal, soybean meal, cottonseed oil, being differentiated as to diet energy levels (Table 2).

Samples of the experimental diets, corn meal and soybean meal were collected for the determination of the contents of (DM; method 967.03), mineral matter (MM; method 942.05), organic matter (OM; 100 - MM), crude protein (CP; method 981.10) and ether extract (EE; method 920.29) using the procedures described by the Association of Official Analytical Chemists (AOAC, 2016) and crude fiber (CF) according to the methodology of Silva & Queiroz (2006) (Table 3).

Table 2. Percentage and chemical composition of the experimental diets.

Ingredients (% natural matter)	Levels of apparent metabolizable energy (kcal kg^{-1})				
	2,700	2,800	2,900	3,000	3,100
Corn meal	45.95	43.51	41.74	40.77	41.24
Soybean meal	39.34	39.81	40.29	38.64	36.20
Cottonseed oil	2.65	4.61	6.58	8.55	10.52
Limestone	7.90	7.90	7.88	7.88	7.87
Bicalcium phosphate	1.28	1.29	1.30	1.31	1.31
Salt	0.53	0.52	0.53	0.53	0.53
Vitamin mineral blend	2.00	2.00	2.00	2.00	2.00
Choline chloride	0.15	0.15	0.15	0.15	0.15
D-Methionine	0.13	0.13	0.13	0.13	0.14
L-Lysine	0.08	0.07	0.06	0.05	0.04
Calculated chemical composition[2]					
Protein (%)	22.00	22.00	22.00	22.00	22.00
Apparent metabolizable energy (kcal kg^{-1})	2,700	2,800	2,900	3,000	3,100
Calcium (%)	3.50	3.50	3.50	3.50	3.50
Total phosphorus (%)	0.57	0.56	0.56	0.56	0.56
Available phosphorus (%)	0.35	0.35	0.35	0.35	0.35
Digestible methionine (%)	0.42	0.42	0.42	0.42	0.42
Methionine + Cystine (%)	0.72	0.72	0.72	0.72	0.72
Digestible lysine (%)	1.15	1.15	1.15	1.15	1.15
Sodium (%)	0.23	0.23	0.23	0.23	0.23

[1] Nutrient levels kg^{-1}: Vitamin A (min) 3,750.00 UI; Vitamin D3 (min) 1,200 UI; Vitamin E (min) 50.00 UI; Vitamin K3 (min) 0.94 mg; niacin (min) 15.00 mg; pantothenic acid (min) 200.00 mg; Vitamin B1 (min) 0.91 mg; Vitamin B2 (min) 10.00 mg; Vitamin B6 (min) 1.50 mg; Vitamin B12 (min) 10.00 mcg; pantothenic acid 5.00 mg; Iron (min) 50.00 mg; Copper (min) 5.00 mg; Zinc (min) 35.00 mg; Manganese (min) 40.00 mg; Iodine (min) 1.0 mg; Selenium (min) 0.15 mg.
[2] Composition calculated according to Silva (2009).

Table 3. Chemical composition of the experimental diets and ingredients.

Items	Levels of apparent metabolizable energy (kcal kg^{-1})					SM	CM
	2,700	2,800	2,900	3,000	3,100		
Dry matter (% NM)	92.27	92.48	92.47	92.60	92.69	91.82	90.40
Mineral matter (% DM)	13.27	13.25	13.42	13.17	13.47	6.58	1.45
Organic matter (% DM)	86.73	86.75	86.58	86.83	86.53	93.42	98.55
Crude protein (% DM)	22.15	22.20	22.22	22.23	22.24	45.00	8.00
Crude fiber (% DM)	5.54	5.57	5.52	5.58	5.61	6.03	1.73
Ether extract (% DM)	5.96	8.22	8.72	7.00	7.38	0.83	3.76

SM - Soybean meal; CM - Corn meal; NM - Natural matter; DM - Dry matter.

Daily managements

Feed and water were provided at will during the two experimental cycles. Lighting programming equipment was installed in the shed, providing a total of 16 hours of light every day, 13 hours of natural lighting from the sun, and 3 hours of artificial lighting (incandescent bulbs).

Feed consumption

During the two experimental cycles the feed was weighed and distributed to each experimental unit. The leftovers from the feeders and containers were weighed every 28-day period. The feed intake (FI) in g bird^{-1} day^{-1}, was determined by the difference between the feed supplied and the leftovers. In the event of death, the feed calculation was corrected and the ratio of the number of birds remaining at the end of the experimental period to the total number of birds at the beginning was considered.

Eggs production

Eggs were collected daily at 8:00 am and 5:00 pm for egg production calculation. For the total number of eggs produced, per experimental unit, the sum of the number of eggs collected from each cage in each of the experimental cycles evaluated was made. Egg bird^{-1} day^{-1} percentages were calculated by dividing the total eggs produced by the number of birds in each experimental unit and the number of days multiplied by 100 (Carvalho et al., 2009), for each 28-day period.

Average weight and mass of eggs

The whole eggs produced in each experimental unit were individually weighed on an analytical balance (Tecnal, SHI-BL-3200H, Piracicaba, SP, Brazil) on the last three days of each experimental cycle. Egg mass was calculated (in g bird^{-1} day^{-1}) as the product of the percentage of eggs bird^{-1} day^{-1} and the average egg weight in each experimental unit (Carvalho et al., 2009) within each 28-day cycle.

Percentages of yolk, shell, and albumen

To obtain egg components, the yolk, albumen, and shell weights of three eggs from each experimental unit, randomly collected on the last three days of each 28-day period, were evaluated. After weighing, the eggs were identified and broken on a flat, smooth polyethylene surface and the yolks were separated from the albumen. The chalazas were carefully removed from the yolk, using tweezers. Before weighing, all yolks were wrapped in paper towels to remove adhered albumen. The shells were thoroughly washed and air dried for 24 hours and weighed. The percentages of shell, yolk and albumen were determined using Equations 1, 2 and 3 (Nemati et al., 2020):

$$\%\text{shell} = \left(\frac{\text{shell weight}}{\text{egg weight}}\right)\times 100 \quad (1)$$

$$\%\text{yolk} = \left(\frac{\text{yolk weight}}{\text{egg weight}}\right)\times 100 \quad (2)$$

$$\%\text{albumen} = 100 - \left(\%\text{shell} - \%\text{yolk}\right) \quad (3)$$

Feed conversion per egg mass and feed conversion per egg dozen

The feed conversion index per egg mass was calculated by the ratio between the amount of feed ingested by the quails (g) and the egg mass produced (g). The feed conversion index per dozen eggs was calculated by the ratio between the amount of feed ingested by the quails (g) and the dozen eggs produced (g dozen^{-1}) (Migliorini et al., 2019).

Statistical analysis

Data were analyzed using PROC GLM of the Statistical Analysis System University Software (SAS University) program by analysis of variance and regression at the 5% probability level. It was adopted as criteria for choosing the linear and quadratic regression models, the significance of the parameters estimated by the models and the values of the determination coefficients, according to the best fit obtained for each variable, considering the biological behavior of the quails. The statistical model used is expressed according to Equation 4:

$$Y = \mu + T_j + e_{ij} \quad (4)$$

where: μ = overall average; T_j = levels of apparent metabolizable energy; and, e_{ij} = residual error.

Results and Discussion

Quails seek to keep their energy intake constant, according to the energy level of the offered feed, so that their requirements for performing physiological functions are met (Muniz et al., 2018). In turn, high energy levels in the feed induce lower intake to avoid excess energy in the body (Kang et al., 2018). Corroborating the premise presented, the increase in the levels of apparent metabolizable energy in the diets tested in this study promoted a decrease ($p = 0.017$; Table 4) in the feed consumption of the quails during the first cycle (period 129 to 156 days), with a linear reduction. When the levels of 2,700 and 3,100 kcal kg^{-1} were compared, there was a 1.9 g reduction in feed intake. These results are in agreement with those reported by Muniz et al. (2016), who observed decreased feed intake with increasing level of apparent metabolizable energy (2,850-3,250 kcal kg^{-1}) in diets for quails.

According to Ribeiro et al. (2016), when quails are in an environment that provides them heat stress, probably the reduction in feed intake may be related to the adjustment in energy intake that the birds make according to the ambient temperature, seeking to reduce body heat production including the heat produced during the digestion process. Thus, the reduction in feed intake with increasing apparent metabolizable energy in the diets may have made less nutrients available for egg formation, which provided a reduction in egg production by quails during the first experimental cycle ($p < 0.001$; Table 4). There was a linear reduction, with a difference

Table 4. Average values of feed intake, production, mean weight and egg mass and feed conversion of European quails during the periods 129 to 156 days and 157 to 185 days as a function of the levels of apparent metabolizable energy (AME).

Variables	Levels of apparent metabolizable energy (kcal kg^{-1})					SEM	p-value	
	2,700	2,800	2,900	3,000	3,100		L	Q
			129 to 156 days					
Feed consumption (g)[1]	33.95	32.56	31.92	31.57	32.05	0.29	0.017	0.075
Eggs production (%)[2]	95.52	95.36	94.14	88.66	90.61	0.70	<0.001	0.987
Average egg weight (g)	14.19	14.58	14.60	14.57	14.26	0.11	0.880	0.168
Egg mass (g)	12.84	13.16	13.55	12.87	13.42	0.16	0.464	0.668
FC_1 (g g^{-1})	2.65	2.43	2.67	2.58	2.40	0.05	0.389	0.588
FC_2 (g dozen^{-1})[3]	0.40	0.43	0.47	0.45	0.47	0.01	0.010	0.294
			157 to 185 days					
Feed consumption (g)[1]	33.09	34.72	33.36	34.14	33.99	0.30	0.575	0.594
Eggs production (%)[2]	98.04	95.71	93.74	93.62	93.18	0.56	<0.001	0.142
Average egg weight (g)	14.48	14.59	14.46	14.80	14.34	0.11	0.923	0.515
Egg mass (g)	14.20	13.96	13.54	13.96	13.45	0.15	0.173	0.816
FC_1 (g g^{-1})	2.54	2.54	2.79	2.45	2.53	0.06	0.767	0.395
FC_2 (g dozen^{-1})[3]	0.47	0.44	0.46	0.42	0.49	0.01	0.825	0.388

FC_1 - feed conversion per gram of eggs (g g^{-1}); FC_2 - feed conversion per dozen eggs (g dozen^{-1}); SEM - standard error of the mean; L - linear effect; Q - quadratic effect; Equations: $y^1 = 46.27 - 0.005x$, $R^2 = 0.28$; $y^2 = 140.77 - 0.16x$, $R^2 = 0.58$; $y^3 = -0.05 + 0.0002x$, $R^2 = 0.33$, $y^4 = 129.08 - 0.01x$, $R^2 = 0.46$.

of 0.16% in egg production during the period 129 to 156 days, for each kcal increase in feed apparent metabolizable energy.

Although there was no effect of increasing levels of apparent metabolizable energy in the diets on feed intake of quails during the second experimental cycle (157 to 185 day period) ($p > 0.05$; Table 4), egg production was reduced as levels of apparent metabolizable energy in the feed were increased ($p < 0.001$; Table 4) with a 0.01% reduction in egg production for each kcal increase in feed apparent metabolizable energy.

The results of the present study differ from those obtained by Abeysekara & Atapattu (2016) who, when evaluating egg production of Japanese quails receiving 2,700 kcal kg^{-1} of AME and 20% crude protein (i.e., AME:CP ratio of 135:1) in the feed offered, observed increases in egg production. However, unlike these authors, in this study European quails were used and received a similar level of AME:CP ratio, i.e. 136.36:1 (3,000 kcal kg^{-1} of AME and 22% CP) in the feed offered.

According to Pinheiro et al. (2020), the energy level of the diet is not the only determining factor in egg production. Factors such as ingredient composition, nutrient content of the diet, environmental conditions (humidity and temperature), strain, and age of the birds can also influence egg production rate (Scappaticcio et al., 2021). Ribeiro et al. (2016) emphasize that European quails are more efficient at using energy for weight gain, so we can infer that the energy intake by the European quails in this experiment was aimed at increases in body weight gain, rather than in increases in egg production.

Unlike studies found in the literature (Granghelli et al., 2019; Pinheiro et al., 2020), the feed conversion rate per dozen eggs increased linearly ($p = 0.010$; Table 4) with increasing levels of apparent metabolizable energy in the diets during the 129- to 156-day period, with increases of 0.0002 g $dozen^{-1}$ occurring for each kcal increase in feed apparent metabolizable energy. In this period, the lowest levels of apparent metabolizable energy inclusion in the diets (2,700 kcal kg^{-1}) provided the highest feed intake, the highest egg production, and the best feed conversion per dozen eggs (0.40 g $dozen^{-1}$) (Table 4). For the second cycle (157 to 185-day period), although there was no effect of levels of apparent metabolizable energy for feed conversion per dozen eggs ($p > 0.05$; Table 4), quails receiving diets containing 3,000 kcal kg^{-1} obtained the best feed conversion per dozen eggs (0.42 g $dozen^{-1}$) relative to the other treatments.

According to Kang et al. (2018) diets with high apparent metabolizable energy content result in a better feed conversion rate per dozen eggs, a fact not observed in the present study. Possibly the cottonseed oil used in the composition of the diets limited feed intake, which may have influenced the utilization of nutrients such as protein, amino acids, and carbohydrate fractions of the diet and therefore reduced egg production, culminating in a worse feed conversion per dozen eggs for quails at 129 to 156 days of age, especially at the level of 3,100 kcal kg^{-1} of AME of feed, where the AME:CP ratio was 140.90:1.

There was no effect of increasing levels of apparent metabolizable energy on feed conversion per gram of eggs of European quails during the two experimental cycles ($p > 0.05$; Table 4). During the first cycle, quails receiving diets containing 3,100 kcal kg^{-1} showed better feed conversion per gram of eggs (2.40 g g^{-1}). For the second cycle, the 3,000 kcal cal^{-1} level provided the best feed conversion per gram of egg (2.45 g g^{-1}). Corroborating the present study Agboola et al. (2016) testing levels of apparent metabolizable energy between 3,000 and 3,200 kcal kg^{-1} in diets for Japanese quails, also found no significant effect of the levels for feed conversion per gram of egg, but observed that diets containing 3,000 kcal kg^{-1} of AME in their composition provided better feed conversion (3.72 g g^{-1}) for Japanese quails.

Because there was no significant effect of levels of apparent metabolizable energy on egg weight, no differences were found between treatments for egg mass produced by European quails during the two experimental cycles ($p > 0.05$; Table 4). The results found in the present work corroborate the findings of Kang et al. (2018) who, when testing levels of apparent metabolizable energy between 2,750 and 3,050 kcal kg^{-1} in diets for layers, also obtained no effect of treatments on the weight and mass of eggs analyzed.

Energy levels influenced egg components in terms of yolk and albumen percentages during the first experimental cycle (Table 5). The albumen proportion decreased linearly ($p = 0.028$; Table 5) while the yolk proportion increased ($p = 0.015$; Table 5). Similar results were found by Agboola et al. (2016) and by Abeysekara & Atapattu (2016) who observed that as levels of apparent metabolizable energy in quail diets increased, there was a reduction in the proportion of albumen and an increase in the proportion of yolk.

Table 5. Percentages of shell, albumen and yolk of eggs of European quails during the periods 129 to 156 days and 157 to 185 days as a function of the levels of apparent metabolizable energy (AME).

Variables	Levels of apparent metabolizable energy (kcal kg^{-1})					SEM	p-value	
	2,700	2,800	2,900	3,000	3,100		L	Q
129 to 156 days								
% Shell	8.87	8.98	8.93	9.15	8.97	0.08	0.566	0.696
% Albumen[1]	61.69	61.74	60.55	60.13	60.76	0.23	0.028	0.269
% Yolk[2]	29.44	29.28	30.52	30.73	30.27	0.19	0.015	0.242
157 to 185 days								
% Shell	7.95	7.81	8.17	8.46	8.10	0.08	0.051	0.358
% Albumen	61.15	61.15	60.79	60.02	60.42	0.30	0.274	0.888
% Yolk	30.90	31.04	31.04	31.52	31.48	0.27	0.458	0.963

SEM - standard error of the mean; L - linear effect; Q - quadratic effect; Equations: $y^1 = 71.05 – 0.003x$, $R^2 = 0.24$; $y^2 = 21.07 + 0.003x$, $R^2 = 0.27$.

It was observed that quails that received diets containing 3,000 kcal kg^{-1} of AME in their composition besides presenting the lowest feed consumption (31.57 g; Table 4), produced eggs with higher proportion of shell and yolk and lower proportion of albumen, compared to the other treatments. There was no effect of energy levels on shell percentage during the first experimental cycle ($p > 0.05$; Table 5).

For Schmidt et al. (2011), the albumen ratio is directly affected by the protein:aminoacid and protein:energy ratios of the diets offered. When the diet is formulated with apparent metabolizable energy, changes in its dietary concentration are accompanied by changes in amino acid specifications, and this may affect protein deposition in the albumen according to the energy level of the diet. Thus, it is observed that quails during the first experimental cycle had their feed consumption reduced (Table 4) with the increase in the energy density of the diets, which promoted a possible reduction in the intake of nutrients, especially amino acids, since the amount of protein per kilogram of energy consumed decreased as the levels of apparent metabolizable energy of the diet increased (AME:CP ratio: 122.73, 127.27, 131.82, 136.36, 140.91:1) which directly affected the albumen ratio and contributed to a higher yolk ratio.

This change in the proportion of egg constituents as the AME:CP ratio of the diet increased may also explain the results observed for feed conversion per egg mass, since no significant effect was observed for egg weight, but was observed for yolk and albumen percentage.

In addition, the reduction in albumen proportion with the linear increase in yolk proportion of quail eggs at 129 to 156 days of age may also have been affected by biochemical reactions that occur in the egg, in which enzymes in the albumen hydrolyze the amino acid chains and release the water that is associated with the proteins, which causes the albumen to become fluid, leaving it more spread out. Free water migrates from the albumen to the yolk providing an increase in its weight and proportion (Feddern et al., 2017). Because the eggs were kept at room temperature (26.6 °C) after collection, they were more susceptible to these chemical reactions.

For the second experimental cycle, although the levels of apparent metabolizable energy tested did not provide significant effect for the variables analyzed ($p > 0.05$; Table 5), the quails that received 3,000 kcal kg^{-1} of AME in their diet showed the proportions of egg components similar to the first cycle.

Conclusion

The best levels of apparent metabolizable energy for European quails is 2,700 kcal kg^{-1} for a diet with 22% CP (AME: CP 122.73), when aiming for best performance (feed intake, egg production and feed conversion per dozen eggs) of birds from 129 to 185 days and for egg production from 157 to 185 days.

The inclusion of 3,000 kcal kg^{-1} of AME in the diets provided eggs with a higher proportion of yolk and a lower proportion of albumen.

Compliance with Ethical Standards

Author contributions: Conceptualization: DCOC; MAAQ; RGCSJ; Data curation: MRBS; MFSL; Formal analysis: DCOC; Investigation: MRBS; Methodology: MRBS; MFSL; Project administration: DCOC; Supervision: DCOC; Validation: DCOC; Visualization: MRBS; DCOC; GCG; Writing - original draft: DCOC; GCG; Writing - review & editing: DCOC; GCG.

Conflict of interest: The authors declare that there are no conflicts of interest.

Financing source: The present research was not funded.

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