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ANIMAL PRODUCTION

Levels of metabolizable energy and crude protein on laying rate and egg quality of laying quails

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ABSTRACT: This study evaluated the zootechnical performance of 192 laying quails, receiving diets with different levels of crude protein (18 and 19%) and metabolizable energy (2,500, 2,600, 2,700 and 2,800 kcal/kg), in a 2 x 4 factorial arrangement. The experiment consists of four experimental periods of 28 days each, where feed intake (g/bird), feed conversion (by dozens of eggs and egg mass), laying rate, weight and mass of eggs and indices of egg quality (yolk, shell and albumen content, shell thickness, Haugh unit). Results indicated that reducing feed energy levels to 2,500 and 2,600 kcal/kg increased feed intake ($P < 0.05$). However, reducing protein levels to 18% did not change ($P > 0.05$) feed intake. No differences ($P > 0.05$) were observed in laying rate, feed conversion per dozen eggs and egg mass, and egg quality indices, in relation to energy or protein levels. There were no interactions between dietary energy and protein levels. In conclusion, the reduction of metabolizable energy levels to 2,500 kcal/kg and crude protein to 18% in diets for laying quails, from 52 to 68 weeks of age, is a viable alternative to reduce production costs, without harming performance and egg quality.
Key words: coturniculture, *Coturnix coturnix japonica,* feed intake, quail performance.

Níveis de energia metabolizável e proteína bruta sobre a taxa de postura e a qualidade de ovos de codornas em fase de postura

RESUMO: Este trabalho teve como objetivo avaliar o desempenho zootécnico de 192 codornas em fase de postura, recebendo dietas com diferentes níveis de proteína bruta (18 e 19%) e energia metabolizável (2.500, 2.600, 2.700 e 2.800 kcal/kg), em um arranjo fatorial 2x4. O experimento consistiu em quatro períodos experimentais de 28 dias cada, em que foi avaliado o consumo de ração (g/ave), conversão alimentar (por dúzias e por massa de ovos), taxa de postura, peso e massa dos ovos e índices de qualidade dos ovos (índice de gema, casca e albúmen, espessura da casca, unidade Haugh). Os resultados indicaram que a redução dos níveis de energia da ração para 2.500 e 2.600 kcal/kg aumentou o consumo de ração ($P < 0,05$). No entanto, a redução dos níveis de proteína para 18% não alterou ($P > 0,05$) o consumo de ração. Não foram observadas diferenças ($P > 0,05$) na taxa de postura, conversão alimentar por dúzias de ovos e massa de ovos e nos índices de qualidade dos ovos, em relação aos níveis de energia ou proteína. Não houve interação entre os níveis de energia e proteína da dieta. Em conclusão, a redução dos níveis de energia metabolizável para 2.500 kcal/kg e proteína bruta para 18% em dietas de codornas em fase de postura, de 52 a 68 semanas de idade, é uma alternativa viável para reduzir custos de produção sem perdas no desempenho e qualidade dos ovos.
Palavras-chave: consumo de ração, coturnicultura, *Coturnix coturnix japonica,* desempenho de codornas.

INTRODUCTION

Agribusiness has played a fundamental role in the Brazilian economy, in which poultry farming has stood out and represents one of the most developed sectors. Coturniculture, a segment of poultry farming that creates, improves and invests in the production of quails, fits into one of the aspects of this large area, which has been advancing continuously through technologies and investments in genetic improvement, nutrition, management and production equipment (SILVA et al., 2018).

Currently, there are two subspecies of quail expanding in Brazil, *Coturnix coturnix japonica*, exclusively for egg production, and Coturnix *coturnix coturnix*, of European origin, used both for egg production and for meat production. As general characteristics, quails have fast growth, sexual precocity, low feed intake and high laying index. When well managed, birds can produce more

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than 300 eggs per year (PETROLLI et al., 2011). However, the relationship between egg quality and quantity it is a very important point for the breeders (EL-ATTROUNY & IRAQI, 2021), which can be changed by nutritional management.

To expand quail farming and make it more profitable, it is necessary to provide adequate energy and nutritional levels, so that the birds express all their genetic potential. Nutrients must be supplied in sufficient quantities, providing the best performance at the lowest production cost. Additionally, it should be noted that intrinsic characteristics of the animal, such as body weight, posture phase, age, maintenance levels and environmental characteristics interfere with the nutritional requirement, and the amount of feed ingested by the animals is directly related to the concentration of energy of the diet based on the theory of intake regulation (BARRETO et al., 2007; NERY et al., 2013).

The level of energy in diet exerts an important influence on the hypolamic control in lateral region, where the hunger center is located, and the ventromedial region, where the satiety center is located. Thus, dietary energy levels play an important role in adjusting voluntary intake. Changing the energy content of the diet influences feed intake and, consequently, protein intake.

Therefore, GUNAWARDANA et al. (2009) stated that the increase in dietary energy linearly decreased protein intake. ALAGAWANY et al. (2014) demonstrated that it is possible to reduce protein levels, with the use of purified amino acids, without causing damage to performance of laying quails. Furthermore, reductions in protein levels are strategies to reduce costs and ammonia emissions.

In addition, in an experiment carried out with Japanese quails aged 45 days, it was verified that the best productive performance occurred in the diet with 2,850kcal of metabolizable energy/kg (ME) and 22.42% of crude protein (CP). Another aspect addressed is the correlation between protein intake and egg weight. The percentage of shell was improved up to the level of 21.30 % of protein inclusion in diet (PINTO et al., 2002).

In line with previous authors, FREITAS et al. (2005) verified a trend of higher feed consumption when there is a reduction in energy density of diet, where, for each increase in kcal, there was a reduction of 0.01172g in consumption, providing the possibility of formulating feeds with 2,585kcal ME/ kg and 18% CP. It is important to emphasize that the increase in ME levels in diet is not synonymous with better productivity, since, when analyzed separately, it causes a linear reduction in egg and yolk weights, due to the reduction in protein consumption by the bird (BARRETO et al., 2007; LOPES et al., 2006). Besides, the increase in energy levels, enhance costs of production.

Another aspect addressed in studies is the amount of protein ingested by the birds, since this data not only reflects the availability in diet, but also the combination of energy and protein so that it has an adequate daily intake to maintain production. In addition to general aspects of protein levels, there are experiments that reported the importance of dietary supplementation with specific amino acids (RATRIYANTO et al., 2018).

Considering all 16 constituents of animal diets, protein and energy sources have stood out with most of the costs related to feed, since protein represents 25% of the total cost. Most works published in literature recommends high levels of protein and energy for laying quails.The hypothesis and innovation of this research is that energy levels can be reduced to 2,500 kcal/kg and protein to 18%, while maintaining laying rate and egg quality, which will represent great savings and practical applicability for the producers.

In this context, this study evaluated the zootechnical performance and the quality of quail eggs by providing the quails with diets containing different levels of crude protein (18 and 19%) and metabolizable energy (2,500, 2,600, 2,700 and 2,800 kcal/kg), seeking to reduce production costs and provide profitability to egg producer.

MATERIALS AND METHODS

The experiment was carried out in an experimental aviary in Poultry Sector of Department of Animal Production and Food Science, Agroveterinary Science Center, Santa Catarina State University (UDESC), located at geographic coordinates 27º48′11.9′′ S and 50º18’17.9′′ W, southern Brazil, from December 2020 to April 2021. The poultry house is of the open type, with plastic side curtains and anti-bird screens.

Animals and experimental units

Coturnix coturnix japonica with 52 weeks of age, weighing between 150 and 205 grams, obtaining an average initial weight of 171.33g were selected. The quails were housed in specific cages (0.33 m x 0.35 m x 0.15 m), randomly arranged in four rows containing nine cages each.

Each cage housed six birds and was equipped with a trough and feeder. The lighting program used was continuous, 16:8 hours, light/dark photoperiod per day (REDOY et al., 2017). It should be noted that artificial LED lamps were used to ensure the recommended light program. Eggs were collected twice a day, at 8 am and 6 pm. Feed was given *ad libitum* and water was continuously available from nipple drinkers throughout the day.

The experiment was carried out in a 4 x 2 factorial scheme, with four levels of metabolizable energy (2,500, 2,600, 2,700 and 2,800 kcal/kg of feed) and two levels of crude protein (18 and 19%), totalizing eight treatments, in a completely randomized design. Each treatment had four replicates of six birds.

The experimental diets (Table 1) were formulated based on corn, soybean meal and soybean oil, to meet the nutritional requirements of laying quails, described by ROSTAGNO et al. (2017), with variation only in the levels of metabolizable energy and crude protein, according to description of treatments. The birds received the experimental diets for 119 days, with seven adaptation days and four periods of 28 days each.

Performance and egg quality

To monitor the zootechnical performance of the birds, the following variables were evaluated: feed intake (g/bird), laying rate (%), average egg weight (g) and feed conversion (kg of feed/dozens of eggs and kg of feed/egg mass). These variables were calculated weekly and presented at the end of each period. Egg quality, yolk index, shell index, albumen index, Haugh unit and shell thickness were measured at the end of each period (SILVERSIDES & BUDGELL, 2004).

Statistical analysis

The statistical analysis was carried out in accordance with a completely randomized design. The collected data were initially tested for normality using the Shapiro-Wilk Test. Means were submitted to analysis of variance using the PROC GLM (General Linear Model) of the SAS statistical program (SAS Institute Inc., 2002). First, the presence of interactions between the evaluated factors, energy and protein, was verified. The differences among means were determined using Student's test for protein and Tukey's test for energy. The LSMEANS procedure was used to calculate mean values considering a 5% significance level in determining the differences between treatment means.

Table 1 - Composition of laying quails aged 52 to 68 weeks diets containing different levels of energy and protein, during the experimental period.

Ingredients	2,500kcal ME/kg		2,600kcal ME/kg		2,700kcal ME/kg		2,800kcal ME/kg	
	18% PC	19% PC	18% PC	19% CP	18% CP	19% CP	18% PC	19% PC
Corn (7.88%)	49.39	48.85	55.63	55.09	60.69	56.98	58.32	54.61
Soybean meal 46% CP	25.56	13.29	27.22	30.78	28.70	31.82	13.29	32.25
Wheat bran	14.77	11.86	6.84	3.93	0.00	0.00	0.00	0.00
Limestone	7.56	7.52	7.46	7.43	7.38	7.38	7.38	7.37
Dicalcium phosphate	0.89	0.93	1.06	1.09	1.20	1.18	1.20	1.18
L-lysine (78%)	0.404	0.308	0.382	0.286	0.362	0.271	0.354	0.263
Mycotoxin adsorbent	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
Quail premix	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
Common salt	0.358	0.360	0.359	0.360	0.361	0.360	0.361	0.360
DL-methionine (99%)	0.252	0.236	0.247	0.231	0.243	0.229	0.244	0.230
Soybean oil	0.000	0.000	0.000	0.000	0.267	0.980	2,211	2,924
Total	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
----------------Calculated nutritional composition----------------								
Linoleic acid (%)	1.320	1.292	1.332	1.299	1.351	1.349	1.443	1.441
Calcium (%)	3.158	3.158	3.158	3.158	3.158	3.158	3.158	3.158
Metabolizable energy (Kcal/kg)	2,500	2,500	2,600	2,600	2,700	2,700	2,800	2,800
Available phosphorus (%)	0.327	0.327	0.327	0.327	0.327	0.327	0.327	0.327
Digestible lysine (%)	1.107	1.107	1.107	1.107	1.107	1.107	1.107	1.107
Digestible methionine (%)	0.498	0.498	0.498	0.498	0.498	0.498	0.498	0.498
Crude protein (%)	18.0	19.0	18.0	19.0	18.0	19.0	18.0	19.0
Sodium (%)	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155

RESULTS AND DISCUSSION

The general data of the four periods analyzed from the average results of zootechnical performance and egg quality are described on table 2. No interactions (P > 0.05) were observed between protein and energy levels for the zootechnical performance or egg quality variables.

It was observed significant differences (P < 0.05) in feed intake regarding metabolizable energy levels, where the birds that received diet with 2,500 kcal/kg had the highest feed intake, followed by birds that received diet with 2,600 kcal/kg. kcal/kg. The lowest feed intake was observed in quails that received diets with 2,700 and 2,800 kcal ME/kg, showing similar results (P > 0.05). It is important to emphasize that the birds that received the diet with 2,500 kcal ME/kg had consumption 12.46% higher than those fed with the diet with 2,800 kcal ME/kg.

The increase in feed intake with energy density reduction in diet indicates that quails probably adjusted their consumption to meet their need for metabolizable energy, which was the inicial hipotesis of this work that was confirmed. RATRIYANTO et al. (2018) also concluded that Japanese quails regulated their consumption according to energy concentration of diet. It is noteworthy that this statement corroborates the chemostatic theory, which describes the regulation of intake based on the energy requirements of animals.

No differences (P > 0.05) were observed in feed intake in relation to the protein levels studied (Table 2). The most plausible explanation is that the increase in consumption caused by the energy reduction in the diet was sufficient to compensate for the protein deficit in the diet, meaning that the 1% reduction in crude protein content did not change consumption. It is interesting for future studies to see whether larger reductions in protein levels can alter intake.

The data presented by AGBOOLA et al. (2016) suggested that reducing protein diet level provides an increase in consumption to meet the nutritional requirements of the animal, which was not observed in the present study. It is important highlighted that levels os lysine and methionine was sustained at 1.107% and 0.498%, respectively, to meet the nutritional requirements of laying quails, described by ROSTAGNO et al. (2017). Some authors claim that amino acid that initiates protein synthesis and influences layng rate and eggs weight is methionine (RODRIGUES et al., 2023).

Laying rate (posture) did not change (P > 0.05) in relation to energy or protein levels in diet (Table 2). Selection birds for egg number can be effective in improvement on egg weight and egg quality (EL-ATTROUNY & IRAQI, 2021). The results are in agreement with that reported by PINTO et al. (2002)

Table 2 - Feed intake, laying rate (posture), egg mass, feed conversion per dozen eggs (FC1), feed conversion per egg mass (FC2), egg weight, albumen index, shell index, yolk index, Haugh unit and shell thickness of laying quail fed diets with different levels of metabolizable energy and crude protein, for all periods analyzed.

Variable	Feed intake (g)	Posture (%)	Egg mass (g)	FC1 (kg/dz)	FC2 (kg/kg)	Egg weight (g)	Albumen index (%)	Shell index (%)	Yolk index (%)	Haugh unit	Shell thickness (mm)
----------Metabolizable energy (kcal/kg)----------											
2,500	30.50a	79.40	9.16	0.47	3.36	11.65	62.2	7.2	31.0	92.43	0.220
2,600	28.87b	75.60	8.57	0.48	3.53	11.39	61.9	7.3	310	92.22	0.220
2,700	27.12c	73.90	8.29	0.46	3.38	11.20	61.2	7.4	31.0	92.51	0.220
2,800	27.12c	80.70	9.23	0.41	2.96	11.36	62.2	7.3	31.0	92.42	0.220
----------Crude protein (%)----------											
18	28.44	75.00	8.49	0.47	3.44	11.32	61.7	7.3	31.0	92.33	0.220
19	28.37	79.80	9.13	0.44	3.17	11.48	62.1	7.3	31.0	92.46	0.220
----------P-value----------											
Energy	<.001	0.610	0.412	0.201	0.157	0.250	0.279	0.856	0.350	0.972	0.950
Protein	0.857	0.240	0.175	0.232	0.147	0.295	0.405	0.820	0.370	0.783	0.810
ME*CP	0.133	0.910	0.941	0.858	0.858	0.170	0.900	0.721	0.830	0.187	0.520
CV (%)	3.43	14.70	14.68	15.08	15.22	3.77	1.92	5.26	3.40	1.36	5.52

Values followed by distinct letters in the column differ statistically by Tukey's test (P < 0.05).
CV = coefficient of variation; dz = dozens of eggs produced; ME = metabolizable energy; PC = crude protein

and BARRETO et al. (2007), who also did not find significant data between these variables. Egg weight and egg mass were not influenced (P > 0,05) regardless of the reduction in protein and energy levels (Table 2), demonstrating that the increase in feed intake caused by the reduction in energy levels met the energy and protein requirements of the birds for maintenance and production. This is a very promising and decisive result for practical recommendations of energy and protein levels studied. The increase in consumption caused by reduced levels of energy, can promote greater protein intake by the birds (SUCUPIRA et a., 2007). Besides, feeding with high levels of nutrients in diet might produce high metabolic heat, which can damage the optimal performance of quails (RATRIYANTO et al., 2018).

The absence of a significant effect of protein on laying rate and egg mass contradicts the results found by PINTO et al. (2002), who observed a quadratic effect of protein on posture, with its best value in the inclusion of 22.42% CP and a quadratic effect on egg mass, being maximized in diets with 23.45% CP, values much higher to those tested in the present study. However, RATRIYANTO et al. (2018) observed that quails fed 2,800 kcal/kg and 18% CP had better egg mass data compared to those fed 2,600 kcal/kg and 17.3% CP.

AGBOOLA et al. (2016) described no statistical differences for average egg weight with birds fed different levels of energy and a low variation for birds fed with different levels of protein. The data corroborate the most likely explanation, which determines that small variations in the diet can be compensated by a higher feed intake. The weight of eggs depends on the amino acid levels in the diet (RODRIGUES et al., 2023). It is important to point out that;although, the protein content decreased from 19% to 18%, the digestible lysine and methionine contents remained constant in all diets, which may contribute to the absence of differences in laying rate or quality of eggs (SIQUEIRA et al, 2021).

Feed conversion per dozen eggs or per egg mass (Table 2) did not differ statistically (P > 0,05). This result was also reported by FREITAS et al. (2005), who did not find interference of energy levels in feed conversion. However, this author demonstrated differences in absolute data for this same variable when related to protein levels. In contrast, BARRETO et al. (2007) found an improvement in feed conversion as the energy levels of the diets were increased. The absence of differences in egg mass and feed conversion is possible related to no differences in laying rate. Despite the differences reported in feed intake, they were not able to change feed conversion.

The albumen index ranged from 61.2 to 62.2%, shell index ranged from 7.2 to 7.4% and yolk index was 31% (Table 2). No stastistical differences were reported (P > 0,05). The data demonstrated that leves of energy and protein intake by the birds was enough for maintein all the proportions of eggs components. It is understood that the equalization of protein absorption is due to probable regulation of feed intake. So, this confirmed that the reduction for 2,500 kcal/kg ME and 18% of crude protein, it is possible, with no damages to the laying rate or egg quality.

The yolk is formed by liver lipoprotein, and if the bird were subjected to protein deprivation, its synthesis could be reduced, reflecting on the yolk index. The absence of differences demonstrated that the 18% CP level is sufficient to maintain protein synthesis for egg production. These results are in agreement with those of previous studies, who verified not statistical differences in yolk weight analyzed for birds receiving different levels (17.5, 19.0, 20.5, 22%) of protein (NERY et al., 2015).

The levels of energy and protein did not change (P > 0,05) shell index ou thickness (Table 2), demonstrated that nutrient intake for shell synthesis was enough. NERY et al. (2015) reported that the weight of the shell and its thickness were not affected by different levels of energy and protein diet. It is noteworthy that the bark is a structure composed mostly of mineral nutrients present in the correct balance for the requirements, regardless of the proposed treatment. Previous studies demonstrated that egg quality characteristics have genetic genetic correlation values between them, showing that the selection of just one can brought correlated gains in the other traits (TEIXEIRA et al., 2012).

No statistical differences (P > 0,05) was found on Haugh Unit (Table 2). The Haugh unit ranged from 92.22 to 92.51, been ideal values in all periods and treatments. It is noteworthy that the Haugh unit is a mathematical expression that relates the weight of the egg to the height of the dense albumen. Therefore, the higher its value, the better the egg quality (ALLEONI & ANTUNES, 2001). The increase on Haugh Unit indicates firmer and stronger albumen, and can enhance economic viability of the egg industry (EL-ATTROUNY& IRAQI, 2021)

It is important to emphasize that the data reported in the present study differ from the guidelines indicated by the NRC (1994) and ROSTAGNO et al. (2017), who suggested energy levels of 2,900 kcal/kg and 2,800 kcal/kg respectively, for laying quails. In the present study, the production of feeds with energy levels of 2,500 and 2,600 kcal/kg did not require the inclusion of vegetable oil in the diet, which directly impacts the final cost of the feed. This is impossible in feed production above 2,700 kcal/kg due to the higher energy density. Therefore, reducing the energy content of the feed is a measure of practical applicability, which will contribute to reducing the final cost of egg production.

It can be said that the energy and protein levels reduced to 2,500 kcal/kg and 18% CP in diets can lower the cost of the feed, considering the absence or reduced variation in zootechnical performance and in eggs quality, benefiting the producer and maintaining the standard of production. However, more studies are needed to verify the possibility of a greater reduction in energy and protein levels considering the regulation of consumption by birds to meet their energy and nutritional requirements.

CONCLUSION

We recommend levels of 2,500 kcal/kg of metabolizable energy and 18% crude protein, with maintenance of levels of digestible lysine at 1.107% and digestible methionine at 0.498% in the diet of quails in the laying phase from 52 to 68 weeks, as a viable alternative to reduce production costs and maintain egg production and quality.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR'S CONTRIBUTIONS

The authors contributed equally to the design and writing of the manuscript. All authors critically reviewed the manuscript and approved the final version.

BIOETHICS AND BIOSECURITY COMMITTEE APPROVAL

The project was submitted and approved by the Comissão de Ética no Uso de Animais (CEUA-UFSC) under protocol number 9523231020 and is therefore in accordance with the obligations of Law 11.794/2008 (BRASIL, 2008), with Decree 6,899/2009, and with the norms established by the National Council for the Control of Animal Experimentation.

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