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Crude protein in diets for European quail (*Coturnix coturnix*)

Proteína bruta em dietas para codornas europeias (*Coturnix coturnix*)

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Highlights:
Diets with 21% crude protein are recommended for European quail aged one to 35 days.
Amino acid supplementation is essential for the maintenance of quail performance.
Diets with reduced crude protein contents reduce the pollution potential of wastes.

Abstract

The aim of this study was to evaluate the influence of dietary crude protein (CP) levels on the production performance, carcass traits and dietary nutrient metabolizability of European quail from one to 35 days of age. A total of 250 quail were allotted to one of five treatments (21, 22, 23, 24 and 25% CP) in a completely randomized experimental design with five replicates of 10 birds per plot. The following variables were evaluated: feed intake; weight gain; feed conversion; energy and protein intakes; weight and yield of carcass, cuts and edible offal; metabolizability coefficients (MC) of dry matter, crude protein, ether extract and gross energy; and nitrogen intake, excretion, retention and metabolizability. Weight gain rose linearly ($P < 0.05$) from one to 14 days of age. From 15 to 35 days of age, weight gain decreased ($P < 0.05$) and feed conversion ratio worsened ($P < 0.05$). The CP levels did not influence ($P > 0.05$) feed intake, weight gain or feed conversion from one to 35 days of age. Protein intake increased linearly ($P < 0.05$) in all evaluated periods. The absolute and relative weights of legs responded quadratically ($P < 0.05$). At 35 days of age, the absolute and relative weights of liver had decreased linearly ($P < 0.05$). In the metabolism trial, a linear decrease was observed ($P < 0.05$) for the MC of dry matter, crude protein and nitrogen, whereas the MC of ether extract, nitrogen intake and nitrogen excretion increased linearly ($P < 0.05$). Diets with 21% CP are recommended for European quail from 1 to 35 days of age.

Key words: Carcass. Metabolism. Metabolizability coefficients. Production performance. Yield.

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Resumo

Objetivou-se avaliar níveis de proteína bruta (PB) sobre o desempenho produtivo, as características de carcaça de codornas europeias de um a 35 dias de idade e a metabolizabilidade dos nutrientes dietéticos. Utilizou-se 250 codornas distribuídas em delineamento inteiramente casualizado, em cinco tratamentos (21, 22, 23, 24 e 25% de PB) com cinco repetições de 10 aves por parcela. Foram avaliados o consumo de ração, ganho de peso, conversão alimentar, ingestão de energia e proteína; peso e rendimento de carcaça, cortes e vísceras comestíveis; coeficientes de metabolizabilidade (CM) da matéria seca, da proteína bruta, do extrato etéreo e da energia bruta; ingestão, excreção, retenção e metabolizabilidade de nitrogênio. O ganho de peso das aves aumentou linearmente ($P < 0,05$) na fase de um a 14 dias de idade. Constatou-se para a fase de 15 a 35 dias de idade redução linear ($P < 0,05$) no ganho de peso e piora ($P < 0,05$) no índice de conversão alimentar das codornas. Os níveis de PB avaliados não influenciaram ($P > 0,05$) o consumo de ração, ganho de peso e conversão alimentar durante a fase de um a 35 dias de idade. Houve efeito linear crescente ($P < 0,05$) para a ingestão de proteína para todos os períodos avaliados. Foi observado efeito quadrático ($P < 0,05$) para o peso absoluto e relativo de pernas. Verificou-se redução linear ($P < 0,05$) para o peso absoluto e relativo de fígado das aves aos 35 dias de idade. No ensaio de metabolismo, constatou-se efeito linear decrescente ($P < 0,05$) para os coeficientes de metabolizabilidade da matéria seca, proteína bruta e do nitrogênio, enquanto, o CM do extrato etéreo, ingestão e excreção de nitrogênio foram influenciados de forma linear crescente ($P < 0,05$). Recomenda-se rações com 21% de PB para codornas europeias de um a 35 dias.

Palavras-chave: Carcaça. Coeficientes de metabolizabilidade. Desempenho produtivo. Metabolismo. Rendimento**.**

Introduction

The quail farming sector has gained considerable ground in recent years, which is a reflection of the increasing consumption of products generated by this industry. Quail farming is characterized as a rather promising activity of low investment and rapid economic return.

Of all the production factors involved in the activity, feeding accounts for the largest share of costs. However, the evolution of nutrition knowledge has made it possible to reduce production costs, since diet formulations started to include industrialized amino acids, which allows their balance at lower crude protein levels.

To enhance the effectiveness of animal nutrition, a balanced diet must be provided so that feed conversion can be improved and the amount of nutrients excreted in the environment reduced. In many countries, awareness with environmental issues has imposed a new challenge to nutritionists and a new drive for research. Quail have low efficiency in utilizing dietary protein, which results in large outputs of nitrogen in their excreta (Ton et al., 2013).

The existing information on crude protein levels for European quail is contradictory. There are clear controversies about recommendations for quail in terms of inclusion level, growth phase and quail production ability. Therefore, studies addressing nutritional requirements are essential to improve feed utilization, optimize quail performance and provide greater economic return to the producer.

On these bases, the present study proposes to investigate the influence of dietary crude protein (CP) levels on the production performance, carcass characteristics and dietary nutrient metabolizability of Japanese quail (*Coturnix coturnix*) from one to 35 days of age.

Material and Methods

All the procedures performed in this study were approved by the Ethics Committee on Animal Use (CEUSA) of the Federal University of Alagoas (UFAL) (approval no. 57/2018). The experiment was conducted in the Quail Farming Unit at the Center for Agrarian Sciences at the Federal University of Alagoas (UFAL), located in Rio Largo - AL, Brazil.

A total of 250 mixed, unsexed European quail (9.99 ± 0.28 g average initial weight) were housed in battery cages (50 cm long × 60 cm wide × 30 cm high) in a concrete-floor shed from one to 35 days of age. Feed was provided in appropriate feeders and drinkers for the growing phase and water was available *ad libitum* throughout the experimental period.

A continuous lighting regime was adopted throughout the experimental period. Climatic variables were measured using maximum-minimum thermometers, a thermohygrometer and a black-globe thermometer. The black globe humidity index (BGHI) was calculated by the following formula proposed by Buffington et al. (1981): BGHI = $T_{bg} + 0.36 * T_{dp} + 41.5$, where T_{bg} = black globe temperature and T_{dp} = dew point temperature (ºC). The average maximum and minimum temperatures, air relative humidity and BGHI values recorded during the experimental period were 29.52 °C, 26.90 °C, 79.49% and 77.55, respectively.

The experiment was set up as a completely randomized design with five treatments, five replicates and ten birds per experimental unit. The treatments consisted of different levels of crude protein (21, 22, 23, 24 and 25%). To choose the levels, the crude protein (CP) content of 23% was used in the intermediate diet, as recommended by J. H. V. Silva and Costa (2009) for the total rearing period, and the other levels varied by one percentage point more or less.

Feed composition data were based on Rostagno et al. (2017), except for the DM and CP contents of ground corn and soybean meal, which were determined based on samples of the ingredients acquired for the formulation of the experimental diets, in accordance with D. J. Silva and Queiroz (2002).

The experimental diets were isoenergetic, following the recommendations of J. H. V. Silva and Costa (2009) for metabolizable energy (ME), which was 2,950 Kcal/kg of diet, based on digestible amino acids. The diets were also supplemented with the industrial amino acids DL-methionine, L-lysine HCL and L-threonine, possibly meeting or exceeding the essential-amino-acid requirements (Table 1).

Feed intake (FI), weight gain (WG), feed conversion (FC) and the intakes of protein (PI) and energy (EI) were calculated as a function of the amount of CP and ME consumed per gram of feed ingested, in the periods of one to 14; 15 to 35; and one to 35 days of age. In the case of mortality, the performance variables of the plot were adjusted according to the methodology described by Sakomura and Rostagno (2016).

At 35 days of age, the birds were weighed after a six-hour fast. Two quail (one male and one female) were selected per experimental unit, with a maximum weight variation of 5% in relation to the average weight of the respective plot, for the subsequent normal slaughter procedures (stunning, bleeding and plucking), as established by decree no. 9,013 (Decreto n. 9.013, 2017). The birds were eviscerated and their carcass and offal were weighed for a later calculation of carcass yield. The following parameters were evaluated: absolute (g) and relative (%) weights of carcass, prime cuts (breast and legs) and edible offal (heart, liver and gizzard). The relative carcass weight was calculated as a function of live weight, and the relative weights of cuts and edible offal were calculated as a function of carcass weight.

The metabolism trial lasted nine days, consisting of five days of adaptation plus four days of excreta collection, from the 19th to the 27th day of age. To mark the start and end of the collection period, 1% ferric oxide was used in the diets. The total excreta collection method was applied, as described by Sibbald and Slinger (1963).

Feed intake and the total excreta of each plot were determined during the collection period. The collected excreta were weighed, packed in labeled plastic bags and preserved in a freezer at -18 ºC. At the end of the experimental period, they were homogenized, dried in a forced-air oven (55 ºC for 72 h) and ground for later analysis.

Table 1
Centesimal composition and calculated nutritional values of diets with different levels of crude protein for European quail from one to 35 days of age

Ingredient (kg)	Crude protein level (%)				
	21	22	23	24	25
Ground corn (7.86%)	58.3110	54.4533	50.5957	46.7380	42.8803
Soybean meal (43.73%)	35.8108	39.1066	42.4024	45.6981	48.9939
Soybean oil	2.1213	2.8763	3.6312	4.3861	5.1411
Dicalcium phosphate	1.2769	1.2502	1.2236	1.1969	1.1702
Limestone	0.9007	0.8991	0.8975	0.8959	0.8943
DL-methionine	0.4292	0.4035	0.3778	0.3521	0.3263
L-lysine	0.3890	0.2929	0.1968	0.1006	0.0045
Common salt	0.3703	0.3696	0.3689	0.3682	0.3675
L-threonine	0.1807	0.1385	0.0963	0.0541	0.0119
Vitamin supplement[1]	0.1000	0.1000	0.1000	0.1000	0.1000
Mineral supplement[2]	0.0500	0.0500	0.0500	0.0500	0.0500
Zinc bacitracin	0.0300	0.0300	0.0300	0.0300	0.0300
Sodium monensin*	0.0300	0.0300	0.0300	0.0300	0.0300
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Nutritional composition					
Metabolizable energy (Kcal/kg)	2.950	2.950	2.950	2.950	2.950
Crude protein (%)	21.00	22.00	23.00	24.00	25.00
Calcium (%)	0.750	0.750	0.750	0.750	0.750
Available phosphorus (%)	0.350	0.350	0.350	0.350	0.350
Sodium (%)	0.160	0.160	0.160	0.160	0.160
Digestible lysine (%)	1.300	1.300	1.300	1.300	1.300
Digestible methionine (%)	0.705	0.692	0.679	0.666	0.653
Digestible methionine + cystine (%)	0.990	0.990	0.990	0.990	0.990
Digestible tryptophan (%)	0.235	0.256	0.268	0.284	0.300
Digestible arginine (%)	1.287	1.374	1.461	1.548	1.635
Digestible phenylalanine (%)	0.936	0.989	1.044	1.100	1.156
Digestible phenyl. + tyrosine (%)	1.621	1.715	1.809	1.903	1.997
Digestible histidine (%)	0.501	0.526	0.552	0.578	0.604
Digestible isoleucine (%)	0.802	0.854	0.906	0.958	1.009
Digestible leucine (%)	1.626	1.692	1.758	1.826	1.889
Digestible threonine (%)	0.870	0.870	0.870	0.870	0.870
Digestible valine (%)	0.865	0.916	0.967	1.016	1.069

[1]Vitamin supplement per kilogram: vit. A 13,440.000 IU; vit. D 3,200.000 IU vit. E 28,000 mg/kg; vit. K 2,880 mg/kg; thiamin 3,500 mg/kg; riboflavin 9,600 mg/kg; pyridoxine 5,000 mg/kg; cyanocobalamin 19,200 mcg/kg; folic acid 1,600 mg/kg; pantothenic acid 25,000 mg/kg; niacin 67,200 mg/kg; biotin 80,000 mcg/kg; antioxidant 0.40 g/kg. [2]Mineral supplement per kilogram: Mg 150,000 ppm; Zn 140,000 ppm; Fe 100,000 ppm; Cu 16,000 ppm; Se 600 ppm; I 1,500 ppm.*Until 21 days only.

The DM, CP, EE and GE contents of the diets and excreta were analyzed in accordance with the methodologies described by D. J. Silva and Queiroz (2002). The metabolizability coefficient (MC) for total excreta collection was calculated using the following equation: MC (%) = Dietary nutrient intake - Nutrient content in the excreta / Nutrient content in the diet × 100, as suggested by Roll et al. (2018).

Nitrogen intake (NI) was determined based on FI data. Nitrogen excretion (NE) was calculated based on the produced excreta and its N content. Nitrogen metabolizability coefficient (NMC) and retention (NR) were also determined, following the methodology described by Matterson, Potter, Stutz and Singsen (1965). Nitrogen balance was calculated as the difference between NI and NE.

The evaluated parameters were subjected to analysis of variance using R Core Team (2016) software at the 5% probability level for acceptance or rejection of null hypothesis. In case of rejection, linear and/or quadratic regression analysis was applied.

Results and Discussion

The dietary CP levels did not influence (P>0.05) FI, FC or EI in the period of one to 14 days of age (Table 2). However, WG and PI rose linearly with the CP levels. According to the results, FI is only fitted as a function of the energy levels. Thus, animals tend to regulate their FI so as to ingest a constant amount of energy (Freitas et al., 2006; Leeson, Caston, & Summers, 1996; Veloso et al., 2012).

Table 2
Feed intake (FI), weight gain (WG), feed conversion (FC), energy intake (EI) and protein intake (PI) of European quail fed diets with different levels of crude protein

Variable	Crude protein level (%)						
	21	22	23	24	25	P-value	CV (%)
	1 to 14 days of age						
FI (g/quail/day)	9.70	9.81	9.92	10.21	10.31	0.1842	4.42
WG (g/quail/day)[1]	5.72	5.90	6.05	6.32	6.41	0.0029	4.35
FC (g/g)	1.69	1.66	1.64	1.62	1.61	0.3278	4.19
EI (Kcal/quail/day)	28.61	28.93	29.28	30.11	30.41	0.1846	4.43
PI (g/quail/day)[1]	2.04	2.16	2.28	2.45	2.58	<0.0001	4.54
Regression equation							
WG = 1.9727 + 0.1786CP (R^2 = 0.98)							
PI = -0.8552 + 0.1372CP (R^2 = 0.99)							
Variable	**15 to 35 days of age**					**P-value**	**CV (%)**
FI (g/quail/day)	25.34	25.83	25.58	25.69	24.53	0.4659	4.64
WG (g/quail/day)[1]	7.90	7.66	7.66	7.34	7.02	0.0413	5.76
FC (g/g)[1]	3.20	3.37	3.34	3.50	3.50	0.0358	4.22
EI (Kcal/quail/day)	74.77	76.20	75.46	75.78	72.38	0.4664	4.64
PI (g/quail/day)[1]	5.32	5.68	5.88	6.17	6.13	0.0014	4.65
Regression equation							
WG = 12.323 - 0.209CP (R^2 = 0.93)							
FC = 1.7189 + 0.0724CP (R^2 = 0.85)							
PI = 0.9954 + 0.2105CP (R^2 = 0.91)							

continue

continuation

Variable	1 to 35 days of age					P-value	CV (%)
FI (g/quail/day)	18.37	18.68	18.59	18.70	18.14	0.7765	4.21
WG (g/quail/day)	6.81	6.74	6.80	6.74	6.57	0.7584	4.47
FC (g/g)	2.70	2.78	2.74	2.78	2.76	0.6761	3.21
EI (Kcal/quail/day)	54.19	55.12	54.83	55.17	53.52	0.7773	4.22
PI (g/quail/day)[1]	3.86	4.11	4.27	4.49	4.54	0.0002	4.54
Regression equation							
$PI = 0.2634 + 0.1735CP$ ($R^2 = 0.96$)							

[1]Linear effect (P<0.05); CV - coefficient of variation.

Each 1% increase in CP led WG to increase by 0.179 g/quail/day. Similar findings were reported in studies testing CP levels higher than 25%. E. L. Silva et al. (2006) and Otutumi et al. (2009) described a linear effect and maximum WG in European quail in the starter phase at the CP levels of 27 and 28%, respectively. Veloso et al. (2012) and Teixeira et al. (2013), on the other hand, found this effect at the CP level of 26%. Additionally, Corrêa et al. (2007) and Reis et al. (2014) reported a quadratic response from WG, with maximum values achieved at the respective CP levels of 30.1 and 28.8%.

The nutritional requirements of quail vary according to the physiological factor of age, with the protein and amino acid requirements being higher in the first weeks of life due to the accelerated growth, especially in pectoral muscles, bones and offal (Scherer, Furlan, Martins, Scapinello, & Ton, 2011; J. H. V. Silva et al., 2012). During this growth period, there is greater deposition of protein and water in the quail carcass (Grieser et al., 2015). However, the difference in WG was not sufficient to provide significance to FC.

From 15 to 35 days of age, no significant effect occurred (P>0.05) for FI or EI. However, WG decreased linearly (P<0.05) as the dietary CP level was increased, which was the opposite effect as seen in the previous phase. Every 1% increase in dietary CP content reduced WG by 0.209 g/quail/day. These findings are in agreement with those obtained by Wen et al. (2017), who evaluated the effect of reducing the levels of CP with similar total amino acid profiles for French quail in the growth phase and observed that 20.4% was the minimum CP value to maintain WG similar to that of quail fed diets containing 25.3% CP.

As stated by J. H. V. Silva and Costa (2009), WG decreases in the growth period, possibly because protein and water deposition give place to fat deposition in the carcass and also because the organs require a larger amount of energy from the diet. Moreover, the excess protein and amino acids which are deaminated and N excretion in the form of uric acid by the birds incur energy expenditure by the animal (Dumont et al., 2017). Therefore, excess amino acids or protein does not contribute to improving bird performance.

Feed conversion worsened linearly (P<0.05) in the period of 15 to 35 days of age, with each 1% CP resulting in a 0.072 increase in the conversion ratio. According to Jordão et al. (2012), for any excess in CP catabolism, more energy is rerouted by the organism to synthesize uric acid, which results in decreased WG and, consequently, worsened FC.

In the total rearing period (01 to 35 days), there was no significant difference (P>0.05) for the performance variables, except PI. Quail apparently benefit from compensatory gains when they receive a diet with a marginally low CP content that can meet the limiting-amino-acid requirements through adequate supplementation, during the initial growth period (Blake & Hess, 2013).

For all evaluated periods, PI increased linearly (P<0.05) as the CP levels were increased. This response was because the increasing CP levels naturally elevated the protein concentration in the diet by 1 g. Thus, the quail consumed more CP per gram of diet consumed, since there was no difference in FI.

The results of absolute weights and yields of carcass, breast, leg and edible offal are presented in Table 3. There was a quadratic effect (P<0.05) only for the 'legs' variable, which showed decreasing absolute weight and yield values from the CP% levels of 23.4 and 23.6% onwards, respectively. The absolute and relative weights of liver decreased (P<0.05) as the dietary CP levels were increased.

Similar results were found by Pinheiro et al. (2015) and Wen et al. (2017), who reported that reducing the CP levels did not affect the yields of carcass, breast, or legs in European quail which received amino acid supplementation. However, Cavalcante et al. (2010) observed a decreasing linear effect for leg yield at the CP levels of 16 to 28%. The authors reported that excess protein can be detrimental to muscle mass formation, as it promotes increased catabolism of amino acids.

Table 3
Absolute weights (g) at slaughter and relative weights (%) of carcass, prime cuts and edible offal of 35-day-old European quail fed diets with different levels of crude protein

Variable	Crude protein level (%)						
	21	22	23	24	25	P-value	CV (%)
	Absolute weight (g)						
Live weight	243.80	248.60	241.20	246.20	234.60	0.3765	4.69
Carcass	184.25	190.58	187.67	190.79	183.62	0.3142	3.58
Breast	74.90	76.91	76.50	77.14	74.55	0.8500	6.05
Legs[2]	35.53	39.43	40.23	40.38	38.55	0.0027	4.71
Heart	2.13	2.13	2.14	2.03	2.19	0.7094	8.34
Liver[1]	5.75	5.18	4.58	4.28	4.16	0.0273	14.87
Gizzard	4.07	4.76	4.32	4.49	4.54	0.4438	13.17
	Regression equation						
Legs	$AW_{Le} = -433.11 + 40.489CP - 0.865CP^2$ ($R^2 = 0.98$)						
Liver	$AW_{Li} = 13.04 - 0.354CP$ ($R^2 = 0.86$)						
	Relative weight (%)					**P-value**	**CV (%)**
Carcass	75.60	76.72	77.83	77.61	78.30	0.3410	2.82
Breast	40.66	40.35	40.73	40.41	40.57	0.9945	3.93
Legs[2]	19.28	20.69	21.45	21.16	21.02	0.0062	4.12
Heart	0.88	0.86	0.89	0.82	0.93	0.1505	7.66
Liver[1]	2.35	2.08	1.90	1.86	1.77	0.0179	12.47
Gizzard	1.67	1.91	1.79	1.82	1.94	0.4052	12.72
	Regression equation						
Legs	$W_{Le} = -143.64 + 13.95CP - 0.2947CP^2$ ($R^2 = 0.97$)						
Liver	$W_{Li} = 4.9752 - 0.1289CP$ ($R^2 = 0.86$)						

[1]Linear effect (P<0.05); [2]Quadratic effect (P<0.05); CV - coefficient of variation.

The fact that the nutritional requirements of essential amino acids like lysine, methionine and threonine were maintained at rates that met the birds' requirements might have contributed to the lack of differences for these variables, regardless of the CP level. In addition to elevating production costs, excessing CP promotes an unnecessary increase in body heat, since the amino acid surplus must be catabolized, which incurs energy expenditure. This explains the worse results of cut yields, as was observed for the 'legs' parameter evaluated in this study.

Regarding the liver, excessive amino acids in the bloodstream are toxic to the animal body. This excess is rapidly removed usually by this organ, which results in higher catabolism and excretion of the ingested N than the body needs (Nelson & Cox, 2014). According to Bertechini (2012), diets with elevated protein levels overload the digestion, absorption and elimination of the non-reusable N, ultimately overloading the liver.

Results pertaining to the metabolism trial are given in Table 4. There was a linear decrease ($P<0.05$) in the metabolizability coefficients of DM (MCDM) and CP (MCCP) and a linear increase ($P<0.05$) in the metabolizability coefficient of EE (MCEE) as the CP levels of the diets were increased. However, no significant effect was observed ($P>0.05$) for the metabolizability coefficient of gross energy (MCGE).

Table 4
Metabolizability coefficients of dry matter (MCDM), crude protein (MCCP), ether extract (MCEE) and gross energy (MCGE) and N intake (NI), excretion (NE), retention (NR) and metabolizability coefficient (NMC) in 35-day-old European quail fed diets with different levels of crude protein

Variable	Crude protein level (%)						
	21	22	23	24	25	P-value	CV (%)
MCDM (%)[1]	71.46	71.26	69.72	67.43	68.17	0.0010	1.99
MCCP (%)[1]	35.82	35.21	31.22	26.33	28.97	0.0074	12.12
MCEE (%)[1]	89.61	91.14	90.93	91.93	93.05	0.0008	1.14
MCGE (%)	78.18	77.68	76.38	76.46	77.23	0.2011	1.75
NI (mg/quail/day)[1]	759.2	811.6	832.2	845.5	886.0	0.0002	3.87
NE (mg/quail/day)[1]	487.0	526.0	573.0	649.0	629.0	0.0003	8.43
NR (mg/quail/day)	272.0	286.0	258.8	222.3	256.5	0.0960	12.34
NMC (%)[1]	35.82	35.21	31.22	26.33	28.97	0.0074	12.12

Regression equation
MCDM = 93.53 - 1.04CP (R^2 = 0.83)
MCCP = 83.46 - 2.26CP (R^2 = 0.78)
MCEE = 73.71 + 0.77CP (R^2 = 0.91)
NI = 167.47 + 28.672CP (R^2 = 0.95)
NE = -365.3 + 40.8CP (R^2 = 0.90)
NMC = 83.46 - 2.2587CP (R^2 = 0.78)

[1]Linear effect ($P<0.05$); CV - coefficient of variation.

The metabolizability coefficients of DM and CP decreased by 1.04% and 2.26%, respectively, with every 1% increase in the dietary CP level. These findings are in line with those reported by Vasconcelos et al. (2011), who tested CP levels (15 to 21%) in the diet of broiler chickens and observed that the increasing levels reduced MCDM and MCCP. This indicates that nutrient waste will be less if a lower protein content is used.

Every 1% CP added to the diet resulted in a 0.77% increase in MCEE. For the diet formulation, 0.75% soybean oil had to be included from one treatment to another as the CP levels were increased, reaching a maximum inclusion level of 5.14%. According to Roll et al. (2018), a diet with higher proportions of unsaturated fatty acids will be better utilized.

Nitrogen intake rose linearly ($P<0.05$), by 28.67 mg/quail/day, at every 1% CP added to the diet. The same effect was observed for NE, which increased by 40.8 mg/quail/day with every percentage unit of CP included in the diet. Results for NI and NE were parallel with the increasing CP levels. Thus, considering that NR is the difference between NI and NE, the difference at every evaluated level was similar, resulting in a lack of significance. The adequate balance of amino acids allowed their efficient utilization without losses to quail performance.

A decreasing linear effect was observed ($P<0.05$) for the nitrogen metabolizability coefficient (NMC) as the CP levels were increased. Nitrogen intake was higher than NR, which caused the NR/NI ratio to reduce as the CP levels were elevated. Thus, for every 1% increase in the CP level, NMC decreased by 2.26%. This shows that the birds' ability to retain N does not follow its increased intake provided by the elevation of CP levels, and all excess N is excreted.

The birds fed diets with high levels of CP exhibited lower N utilization efficiency, which is likely related to the excess N to be eliminated. Therefore, there was a considerable reduction in the elimination of N and also an increase in its utilization efficiency when diets with lower CP contents were used, which translates into reduced pollution potential of the waste generated in the production of European quail.

Conclusions

Diets with up to 21% crude protein are recommended for European quail (*Coturnix coturnix*) from one to 35 days of age provided that the first-limiting-amino acid requirements are met.

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