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Modelagem fatorial das exigências de proteína bruta em codornas japonesas

Modeling factorial crude protein requirements in Japanese quail

Modelado factorial de los requerimientos de proteína cruda en codornices japonesa

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Resumo

Este estudo quantificou as exigências de proteína bruta (PB) para mantença e ganho em codornas japonesas fêmeas de 1-35 dias de idade, combinando a metodologia fatorial com a técnica de abate comparativo. Utilizaram-se 655 codornas em duas fases: inicial (1-14 dias) e crescimento (15-35 dias). Para mantença as codornas nas gaiolas receberam 100, 75, 50 ou

25% do consumo *ad libitum*; para ganho, realizaram-se abates de referência e sequenciais. Registraram-se o consumo de ração, o consumo de proteína bruta (PB_{con}), o peso da carcaça em jejum (PCJ), a proteína da carcaça (PB_c), a proteína na matéria seca da carcaça (PB_{MS}), a proteína retida (PB_{ret}). A proteína bruta de mantença (PB_m) foi estimada por regressões lineares de PB_{ret} em função de PB_{con}, corrigida para o peso metabólico ($PV^{0,67}$). Na fase inicial, PB_m = 2,095 PB/kg^{0,67}/dia e a eficiência de uso da PB para ganho (*k*) foi 33,4%; no crescimento, PB_m = 6,301 PB/kg^{0,67}/dia e *k* = 34,77%. A proteína bruta líquida para ganho (PB_g) foi 0,284 e 0,310 g/g/dia, resultando em exigências dietéticas para ganho de peso de 0,851 e 0,894 g/g/dia. As equações foram: Inicial - PB (g/codorna/dia) = 2,095 × $PV^{0,67}$ + 0,851 × GP; Crescimento – PB (g/codorna/dia) = 6,301 × $PV^{0,67}$ + 0,894 × GP; em que PV é o peso vivo (kg) e GP o ganho de peso (g/codorna/dia). A temperatura ambiente média foi 24,05 °C (máx. 35,2 °C), evidenciando efeitos ambientais na mantença.
Palavras-chave: Abate comparativo; Exigência de ganho; Exigência de mantença; Equações de predição; Proteína bruta.

Abstract

This study quantified crude protein (CP) requirements for maintenance and gain in female Japanese quail from 1-35 d, using a factorial approach combined with the comparative slaughter technique. A total of 655 quail were evaluated in two phases: starter (1-14 d) and grower (15-35 d). For maintenance, caged birds received 100, 75, 50, or 25% of ad libitum intake; for gain, reference and sequential slaughters were performed. Recorded variables included feed intake, CP intake (CP_I), fasted carcass weight (FCW), carcass protein (CP_c), protein in carcass dry matter (CP_{DM}), and retained crude protein (CP_{ret}). The maintenance CP requirement (CP_m) was estimated by linear regressions of CP_{ret} on CP_I and expressed per metabolic body weight ($BW^{0.67}$). In the starter phase, CP_m = 2.095 g.kg$^{-0.67}$.d^{-1} and the efficiency of CP use for gain (*k*) was 33.4%; in the grower phase, CP_m = 6.30 g.kg$^{-0.67}$.d^{-1} with *k* = 34.77%. The net protein requirement for gain was 0.284 and 0.310 g.g^{-1}.d^{-1}, yielding dietary CP_g requirements per unit of weight gain of 0.851 and 0.894 g.g^{-1}.d^{-1} for starter and grower, respectively. For context from the companion energy analysis, the prediction equations were: Starter PB (g.quail^{-1}.d^{-1}) = 2.095 × $BW^{0.67}$ + 0.851 × WG; Grower – PB (g.quail^{-1}.d^{-1}) = 6.30 × $BW^{0.67}$ + 0.894 × WG; where BW is live body weight (kg) and WG is daily weight gain (g.quail^{-1}.d^{-1}). Mean ambient temperature was 24.05°C (max 35.2°C), indicating environmental effects on maintenance requirements.
Keywords: Comparative slaughter; Gain requirement; Maintenance requirement; Prediction equations; Crude protein.

Resumen

Este estudio cuantificó los requerimientos de proteína bruta (PB) para mantenimiento y ganancia en codornices japonesas hembras de 1 a 35 días de edad, mediante un enfoque factorial combinado con la técnica de sacrificio comparativo. Se evaluaron 655 codornices en dos fases: inicial (1-14 días) y crecimiento (15-35 días). Para mantenimiento, las aves enjauladas recibieron 100, 75, 50 o 25% del consumo ad libitum; para ganancia, se realizaron sacrificios de referencia y secuenciales. Se registraron consumo de alimento, ingesta de PB (PB_I), peso de la canal en ayuno (PCA), proteína de la canal (PB_c), proteína en la MS de la canal (PB_{MS}) y proteína cruda retenida (PC_{ret}). El requerimiento de PB para mantenimiento (PB_m) se estimó mediante regresiones lineales de P_R en función de PB_I y se expresó por peso metabólico ($PV^{0,67}$). En la fase inicial, PB_m = 2,095 g/kg^{0,67}/día y la eficiencia de uso de la PB para ganancia (*k*) fue 33,4%; en la fase de crecimiento, PB_m = 6,301 g/kg^{0,67}/día con *k* = 34,77%. La eficiencia neta de ganancia proteica fue 0,284 y 0,310 g/g/día, lo que resultó en requerimientos dietéticos de PB por unidad de ganancia de peso de 0,851 y 0,894 g/g/día para las fases inicial y de crecimiento, respectivamente. Las ecuaciones de predicción fueron: Inicial - PB (g/codorniz/día) = 2,095 × $PV^{0,67}$ + 0,851 × GP; Crecimiento - PB (g/codorniz/día) = 6,301 × $PV^{0,67}$ + 0,894 × GP; donde PV es el peso vivo (kg) y GP la ganancia diaria de peso (g/ave/día). La temperatura ambiente media fue 24,05 °C (máx. 35,2 °C), lo que indica efectos ambientales sobre los requerimientos de mantenimiento.

Palabras clave: Sacrificio comparativo; Requerimiento de ganancia; Requerimiento de mantenimiento; Ecuaciones de predicción; Proteína cruda.

1. Introduction

Raised for various purposes (hunting, meat, ornamental purposes, eggs), the production of quail is widespread worldwide. Countries such as Spain, France, China and the United States stand out for meat production; however, for egg production, countries such as China, Japan, and Brazil stand out (Vieira et al., 2017). Quail farming in Brazil in 2018 reached a total of 16.8 million head, for meat and eggs, and 297.3 million dozen eggs, an increase of 3.9% compared with 2017, whereas quail egg production fell by 2.1% (IBGE, 2018).

Several methodologies applied to chickens and laying hens (Sakomura and Rostagno, 2016) are effective for quail; however, they require more careful evaluation due to peculiarities inherent to the genus *Coturnix* to ensure consistent results. Quail, whether intended for laying or meat production, mature early, with growth rate related to body size (Tholon et al., 2012; Drumond et al., 2013; Mota et al., 2015; Demuner et al., 2017; Grieser et al., 2017; Grieser et al., 2018), thus, smaller animals have higher growth rates and **a** lower age at maturity.

Growth precocity defined as the time required to achieve sexual maturity—is a key parameter in breeding programs and implies different requirements among animals. In this sense, models that describe growth curves (Drumond et al., 2013; Mota et al., 2015; Demuner et al., 2017; Grieser et al., 2018) validate the premise that each species/lineage and animal category has different nutritional requirements.

Comparing the Gompertz growth curves for Japanese quail (Mota et al., 2015; Grieser et al., 2017), meat-type quail (Drumond et al., 2013; Grieser et al., 2017), light and semi-heavy laying hens (Neme et al., 2006) and broilers (Demuner et al., 2017), Japanese quail have the highest maturity rate, indicating higher nutritional needs for protein and amino acids.

There are two basic methods (dose–response and the factorial approach) for determining the nutritional requirements of birds. In practice, mathematical models for diet formulation are coupled to dose–response trials, whereas techniques such as comparative slaughter (CS) and nitrogen balance (NB) are used within the factorial approach to predict requirements for crude protein and amino acids.

The dose–response method (Sakomura and Rostagno, 2016) to estimate the requirements of birds is based on altering dietary nutrient levels in increasing doses and then evaluating animal performance (e.g., weight gain, feed conversion), with the aid of mathematical models (linear, quadratic, linear-plateau) to estimate the ideal level (Rostagno et al., 2007; Pesti et al., 2009).

The factorial method for estimating the requirements differs from the dose–response approach in that it partitions requirements into maintenance, gain, and production (Sakomura and Rostagno, 2016), and may incorporate environmental variables such as temperature and humidity (Filho et al., 2011a, 2011b) and provides simplified representations of animal metabolism (Oviedo-Rondón and Waldroup, 2002).

The development of prediction models based on the factorial methodology is valuable for its flexibility and simplicity, being readily used by poultry-company technicians, who, with the model and a calculator, can quickly infer the nutritional requirements of the birds and update formulations without additional biological trials or laboratory analyses (Silva et al., 2004a, 2004b).

Among the different models for predicting nutritional requirements based on the factorial methodology be it for broilers (Longo et al., 2001), growing quail (Silva et al., 2004a, 2004b), laying hens (Sakomura et al., 2002) and Japanese and European quail in growth and laying (Filho et al., 2011a, 2011b) these authors suggested that metabolic rate (the relationship between body weight and surface area) scales to the 3/4 power of body weight (i.e., metabolic weight $kg/^{0.75}$).

Dodds (2001), in a comprehensive review of the subject, proposed that for animals weighing less than 10 kg, metabolic rate is more accurately scaled to 2/3 rather than the commonly accepted 3/4.

Few data are available on Japanese quail requirements, based on factorial methodology. Given the above, this study developed protein requirement models for Japanese quail at 1-14 and 15-35 d using the factorial methodology.

2. Materials and Methods

The experiment was carried out at the Center for Agricultural Sciences (CCA), Federal University of Northern Tocantins (UFNT), Araguaína, Tocantins, Brazil. It was conducted from November 19 to December 22, 2019. The research project was approved and registered by the UFT Animal Use Ethics Committee, under protocol no. 23.101.00179/2.017-53.

The experimental shed had side curtains in blue and was equipped with 24 galvanized wire cages. The cages measured 0.52 × 0.51 × 0.30 m (0.026 m^2/quail) and had a 70-watt incandescent lamp. Quail assigned to the maintenance-requirement experiment were housed in the cages.

Quail designated to establish crude protein requirements for gain were placed on the floor, which was covered with wood chips. The pen was equipped with a 70-watt incandescent lamp. The shed had 70-watt incandescent lamps, drinking fountains, and pressure feeders. The water and diet were provided *ad libitum* for the quail present in this environment. A commercial digital hygrometer was used to measure the temperature and humidity inside the shed during the experimental period.

To estimate the protein requirements for maintenance (CP_m) and weight gain (CP_g) in the phases from 1-14 and 15-35 d, the comparative slaughter technique was adopted (Sakomura and Rostagno, 2016)

A sample of 655 female Japanese quail was used. The experiment was divided into two parts: first (1-14 d), using 350 quail with an initial average weight of 6.58 ± 0.28 g (mean ± SD); 240 were housed in cages, 75 on the floor, and 35 were slaughtered at 1 d as the reference slaughter for the initial phase. Second (15-35 d), 305 female quail were used, with an initial average weight of 48.31 ± 0.16 g (mean ± SD); 240, 40, and 25 corresponded, respectively, to the numbers used for maintenance, gain, and reference slaughter groups.

The quail used to estimate maintenance in the initial and growing phases were distributed in the cages and received treatments according to a completely randomized design, with four levels of feed supply (ad libitum, 75, 50 and 25% of consumption ad libitum) with six replicates of ten quail per experimental unit. The experimental diets in each phase were

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formulated according to Rostagno et al. (2017) recommendations (Table 1).

To estimate the protein gain requirements in the starter phase (1-14 d), 15 quail were slaughtered each d (3; 6; 9; 12 and 15 d). In the grower phase (15-35 d), 10 quail were slaughtered every five d (20, 25, 30, and 35).

In each test, quail destined for slaughter were fasted from solids for 12 hours, reweighed, and slaughtered by cervical dislocation, to avoid loss of blood and feathers. The slaughtered carcasses were identified, placed in plastic bags, stored in the freezer, and then ground twice in a cutter meat grinder, weighed, and placed in a forced-ventilation oven at 55°C for approximately 72 hours for predrying and subsequent grinding. Then, the samples were processed two more times in the "cutter" mill and once in the "Wile**y**" mill to obtain more homogeneous samples for further chemical analysis (AOAC**,** 2005).

At the end of each phase, the quail were fasted from solids for 12 hours, reweighed, and slaughtered by cervical dislocation, to avoid loss of blood and feathers, to allow the evaluation of the deposition of nutrients in the carcass.

With the data obtained, it was possible to calculate feed intake (FI – $g.quail^{-1}.d^{-1}$), crude protein consumption (CP_{con} – $g.quail^{-1}.d^{-1}$), protein in carcass dry matter (P_{DM} – $g.DM^{-1}$), carcass protein (C_p – $g.g^{-1}$), retention crude protein (CP_{ret}) and fasting carcass weight (FCW – $g.quail^{-1}$).

The crude protein requirement for maintenance (CP_m) was obtained by linear regression of retention crude protein (CP_{ret}) as a function of crude protein consumption (CP_{con}). By extrapolating to zero protein retention, the maintenance requirement was given by the ratio *a/b*, expressed per unit of metabolic weight ($BW^{0.67}$) (Dodds, 2001). The efficiency of protein use (*k*) was given by parameter *b*. The parameter *a* (intercept), corrected for metabolic weight, represents endogenous loss of body protein.

Table 1. Chemical composition and percentage of experimental diets.

Ingredients	01-14 d - **(g/kg)**	15-35 d - **(g/kg)**
Corn	578.05	598.11
Soybean meal	368.62	360.82
Degummed oil	12.78	7.63
Dicalcium phosphate	22.07	17.49
Calcitic limestone	10.99	9.23
Common salt	4.83	5.06
DL-Methionine 99%	1.61	1.13
L-Lysine HCl 78.4%	0.63	0.05
L-Threonine 98.5%	0.02	0.09
Premix†	0.40	0.40
Total	1000.0	1000.0
Metabolizable energy (MJ/kg)	12.13	12.13
Electrolytic balance (mEq/kg)	204.5	290.35

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Nutrients	Chemical composition (g/kg)	
Crude protein	212.8	210.9
Calcium	10.92	9.11
Available phosphorus	5.13	4.28
Sodium	2.05	2.14
Potassium	8.60	8.52
Chlorine	3.71	3.74
Digestible amino acids	**Chemical composition (g/kg)**	
Lysine	10.95	10.34
Methionine + cystine	7.44	6.93
Threonine	7.33	7.34
Valine	8.98	8.89
Isoleucine	8.35	8.26
Tryptophan	2.45	2.42
Arginine	13.43	13.26
Histidine	5.22	5.18
Glycine + serine	17.34	17.16
Phenylalanine + tyrosine	17.22	17.05
Leucine	16.80	16.74

† Premix: 12.000 UI de vitamina A; 2.200 UI de vitamina D_3; 30 mg de vitamina E; 3 mg de vitamina K_3; 2,5 mg de tiamina (B_1); 6 mg de riboflavina (B_2); 40 mg de niacina; 13 mg de ácido pantotênico (B_5); 4 mg de piridoxina (B_6); 0,6 mg de ácido fólico; 0,01 mg de cianocobalamina (B_{12}); 0,10 mg de biotina; 500 mg de colina; 110 mg de manganês; 55 mg de zinco; 100 mg de ferro; 10 mg de cobre; 0,4 mg de iodo; 0,3 mg de selênio. Contém ainda antioxidante (25 mg/kg de ração), coccidiostático (salinomicina, 50–60 mg/kg de ração) e promotor de crescimento (halquinol, 60 mg/kg de ração; faixa técnica 30–120 mg/kg)

The net protein for gain (CP_g) was determined as the slope of the linear relationship between carcass protein (C_p) and fasting carcass weight (FCW). The dietary requirement for crude protein for gain was obtained by accounting for the efficiency of crude protein use (*k*).

The residuals were subjected to the Kolmogorov–Smirnov normality test (α = 0.05). The homogeneity of variances was evaluated by Levene's test (α = 0.05), and all variables exhibited a normal distribution of errors and homoscedasticity. Linear models were estimated to use SAS 9.0 (PROC REG) at α = 0.05. All proposed models showed a significant effect (t-test, α = 0.05) on the parameters β_0 and β_1, with α = 0.05.

The average, minimum, and maximum temperatures were 24.05 °C, 22.1 °C, and 35.2 °C, respectively; the corresponding values for relative humidity were 84.9%, 73%, and 95%.

3. Results and Discussion

It is observed (Table 2) that live weight of the carcass, consumption of crude protein, retained protein, protein body of Japanese quail from 1-35 d. A drop in the feed consumption of the quail, and consequently, a drop in crude protein intake accompany the drop observed in these variables. Such reductions were also observed by (Silva et al. 2004a, 2004b; Filho et al. 2011a; Sakomura et al. 2005). This finding is relevant and valid for the method used to

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understand the phases of animal metabolism: maintenance and weight gain in the phases, one to 15, and 15 to 35 d.

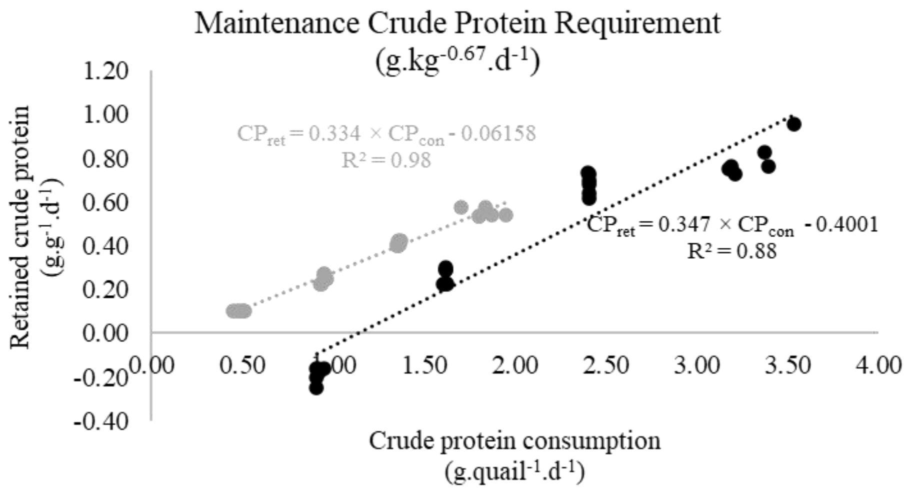
Table 2. Fasting carcass weight (FCW - g.quail^{-1}), feed intake (FI - g.quail^{-1}.d^{-1}), crude protein consumption (CP_{con} - g.quail^{-1}.d^{-1}), protein carcass (P_{DM} – g.DM^{-1}), carcass protein (C_p - g.g^{-1}), retained crude protein (CP_{ret} - g.g^{-1}.d^{-1}) of Japanese quail according to age, feed supply levels (FSL - %), reference slaughter (RS).

	Maintenance (01-14 d)					
RS (1° d)	FCW	FI	CP_{con}†	P_{DM}‡	C_p§	CP_{ret}¶
	6.58±0.28	-	-	20.95±0.41	1.42±0.06	-
FSL	Final Slaughter - 15º d					
100	46.92±1.54	8.73±0.25	1.86±0.05	19.25±0.29	9.12±0.30	0.55±0.02
75	34.54±0.58	6.47±0.06	1.38±0.01	20.59±0.48	7.15±0.16	0.41±0.01
50	24.54±0.51	4.39±0.03	0.94±0.01	19.77±1.02	4.91±0.27	0.25±0.02
25	13.36±0.32	2.28±0.11	0.49±0.02	20.87±0.47	2.88±0.07	0.09±0.01
	Maintenance (15-35 d)					
RS (15º d)	FCW	FI	CP_{con}†	P_{DM}‡	C_p§	CP_{ret}¶
	48.31±0.16	-	-	27.38±0.47	13.23±0.22	-
FSL	Final Slaughter - 35º d					
100	110.75±2.50	15.71±0.68	3.31±0.14	23.69±1.84	26.23±2.03	0.68±0.10
75	98.105±5.54	11.42±0.02	2.41±0.01	24.31±0.85	23.88±2.16	0.58±0.10
50	65.55±1.40	7.68±0.03	1.62±0.01	24.41±1.45	16.01±1.28	0.14±0.07
25	42.91±0.26	4.36±0.08	0.92±0.02	25.15±0.30	10.79±0.16	-0.11±0.03

†CP_{con} = obtained by multiplying the crude protein content of the diet and the FI. ‡P_{DM} = Protein corrected for carcass dry matter content. §C_p = obtained by multiplying the P_{DM} and the FCW. ¶CP_{ret} = subtraction of the C_p at the end of the experiment by the C_p of the reference slaughter. Source: Authors.

The estimated maintenance requirement for crude protein (CP_m) for quail in the starter (01-14 d): [$CP_{ret} = (0.3340 \pm 0.004) \times CP_{con} - (0.06158 \pm 0.0092)$, $R^2 = 0.98$] and was estimated in relation to the metabolic weight (0.088 kg.quail^{-1}) in 2.095 g.kg$^{-0.67}$.d^{-1} (Figure 1), where CP_{ret} is the protein retained and CP_{con} the crude protein consumed.

Figure 1. Relationship between protein retention (CP_{ret}) in the carcass and crude protein consumption (CP_{con}) of Japanese quail from 01-14 (●) and 15-35 d (●)



Source: Authors.

The estimated maintenance requirement for protein (CP_m) for quail in the grower (15-35 d): [$CP_{ret} = (0.3470 \pm 0.02611) \times CP_{con} - (0.4001 \pm 0.0593)$, $R^2 = 0.88$] and was estimated in relation to the metabolic weight (0.183 $kg.quail^{-1}$) in 6.3 $g.kg^{-0.67}.d^{-1}$ (Figure 1), where CP_{ret} is the protein retained and CP_{con} the crude protein consumed.

Silva et al. (2004a) for quail in the initial phase (1-12 d) estimated maintenance at 2.85 $g.kg^{-0.75}.d^{-1}$, for the growth phase (15-32 d), Silva et al. (2004b) estimated values of 4.75 $g.kg^{-0.75}.d^{-1}$. Filho et al. (2011b) working with Japanese quail in the growth phase (16-36 d) estimated maintenance at $(4.8421 + 0.0111 \times T) \times BW^{0.75}$ and European quail at $(4.8374 + 0.0137 \times T) \times BW^{0.75}$, where T is the temperature in degrees Celsius.

Nogueira et al. (2019) working with nitrogen-balance technique to meat quail were estimate the requirement for maintenance at 2.94 $g.kg^{-0.75}.d^{-1}$, using the comparative-slaughter technique, estimate the maintenance requirement at 6.63 $g.kg^{-0.75}.d^{-1}$. This research was made with quail housed in cages.

The values of the present research differ from those found mentioned above, and which were respectively 2.095 and 6.30 $g.kg^{-0.67}.d^{-1}$ for quail in the phases from 1-14 and 15-35 d. In Silva's (2004a, 2004b), Filho's (2011a, 2011b) and Nogueira's (2019) works, the researchers used a mass ratio and body surface of 3/4 ($BW^{0.75}$), while in the present research, the ratio of 2/3 ($BW^{0.67}$) was used, which can reduce the metabolic rate in 1/12 weight for maintenance crude protein. Dodds et al. (2001) reported that for quail, the correct approach is to relate to the animal's metabolic rate to 2/3 of its mass and body surface.

It can also be inferred that, in the first phase (1-14 d), quail that consumed only 25% of the ration, in relation to the treatment of consumption at will, presented a loss endogenous of protein in 0.7 $g.kg^{-0.67}.d^{-1}$. Quail from phase from 15-35 d, recorded a loss endogenous protein in 2.2 $g.kg^{-0.67}.d^{-1}$.

A possible explanation for this characteristic is that, in the initial phase, maintenance was around 2.095 $g.kg^{-0.67}.d^{-1}$, while in the growth phase it was around 6.30 $g.kg^{-0.67}.d^{-1}$, with that, a greater demand reflects greater need and, therefore, greater amount of body protein, reflecting greater nitrogen loss in the carcass (Silva et al., 2004a, 2004b; Filho et al. 2011a, 2011b; Nogueira et al., 2019).

The diets contained the same amount of metabolizable energy, it is suggested that quail in the growth phase require a greater amount of energy in the feed. A lower energy/protein ratio may reflect the use of body protein as a source of crude protein for maintenance, which would lead to a higher requirement for protein maintenance. This premise validates the need to divide the quail maintenance requirement according to age.

Another explanation is that the lower crude protein requirement for maintenance in the starter (2.095 $g.kg^{-0.67}.d^{-1}$), 67% lower, may be due to lower carcass weight, although quail, at this age, Japanese quail and European, present high growth rates. However, there is a lower body weight, since the maintenance requirement is related to metabolic weight $BW^{0.67}$ (relationship between body mass and body surface area).

In the grower, the average body weight are higher, respectively (79.53 vs 26.75 g), i.e., higher crude protein expenditures for maintenance (6.30 $g.kg^{-0.67}.d^{-1}$). In the works of Silva et al. (2004a, 2004b) the values were closer (2.85 vs 4.75 $g.kg^{-0.67}.d^{-1}$), respectively starter and grower phase.

Comparing the protein use efficiencies, it was observed that in this research, for the starter (01-14) and grower (15-35 d) phases were 33.4 and 34.7%, respectively, which represents an increase in efficiency of 3.9%. This increase may be due to the older quail already being set in the climatic conditions of the premises and having their thermoregulator device more efficient (Dionello et al. 2002; Lin et al. 2005) thus reducing the efficiency of utilization of nutrients in the diet.

These results contradict the findings by Silva et al. (2004a, 2004b) since the authors observed greater efficiency for the first phase under study (1-12 d) compared to the second (15-32 d), efficiencies of 40 and 23%, respectively. Filho et al. (2011b) observed the efficiency in the use of diet protein at around 19% to 27% (mean = 24%) for quail housed, respectively, at temperatures of 18, 24, and 28ºC. For quail at room temperature and housed in Filho et al. (2011b), they registered 25% efficiency.

Apart from the work by Silva et al. 2004a, the other studies mentioned above show efficiency in the use of protein in the diet in relation to the findings of the present study.

Longo et al. (2001) observed 72% for broilers. Albino et al. (1994), registered for chickens of lines EMB-011 and Lohmann 62 and 55%, respectively. Sakomura et al. (2002) observed 58.94% for laying hens.

The lowest efficiency in the first phase of this study is inferred that the lesser use of crude protein by quail, may be related to the absolute digestive capacity of birds. Iji et al. (2001) and Murakami et al. (1992) reported that the maximum relative growth of the intestine occurs up to seven d, however, Grieser et al. (2015) demonstrate that the maximum absolute weight occurs at 20 d, that is, greater volumetric capacity and capacity to obtain energy from the feed.

The rapid relative growth of the intestine up to seven d (Iji et al., 2001; Murakami et al., 1992) did not reflect greater utilization, which may suggest that greater emptying of the intestine due to its lower absolute weight at this age, with this low total digestive capacity.

The liquid protein requirement for gain (CP_g) was estimated by the linear relationship between body protein (C_p) retentions over time (Table 3).

Table 3. Fasting carcass weight (FCW - g.quail^{-1}), protein carcass dry matter (P_{DM} – g.DM^{-1}) and carcass protein (C_p – g.g^{-1}) of Japanese quail according to age.

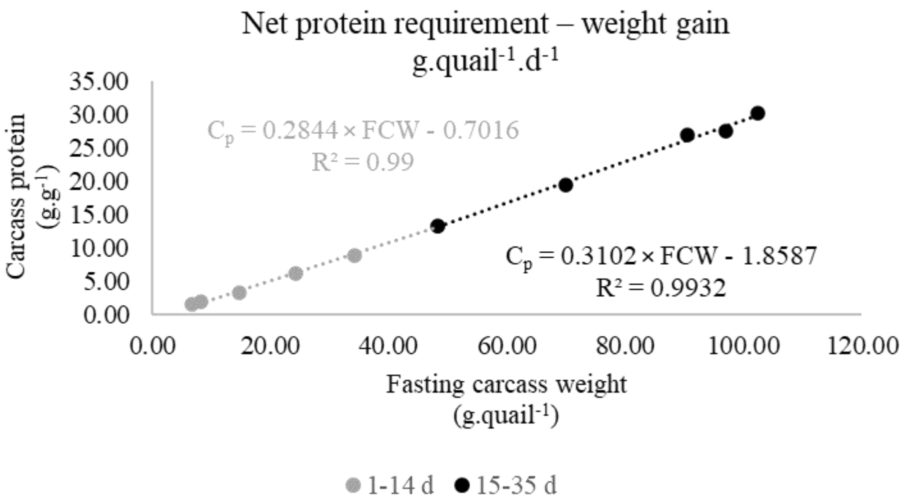
Gain (01-14 d)				Gain (15- 35 d)			
Age (d)	FCW	P_{DM}†	C_p‡	Age (d)	FCW	P_{DM}†	C_p‡
1	6.71	21.12	1.417	15	48.40	27.49	13.305
3	8.33	21.65	1.803	20	70.00	27.82	19.474
6	14.67	22.11	3.242	25	90.50	29.73	26.906
9	24.33	24.96	6.072	30	97.00	28.32	27.407
12	34.33	25.76	8.843	35	102.50	29.49	30.227
15	48.40	27.49	13.305	---	---	---	---

†P_{DM} = Protein corrected for carcass dry matter content. C_p = obtained by multiplying the ‡P_{DM} and the FCW. Source: Authors.

The liquid protein requirement for gain 1-14 d (1; 3; 6; 9; 12 and 15 d) as a function of fasting carcass weight of quail (Figure 2) and the following equation was obtained $C_p = (0.2844 \pm 0.01) \times FCW - (0.7016 \pm 0.183)$, $R^2 = 0.99$, which was 0.284 g.quail^{-1}.d^{-1}. The dietary requirement for gain was obtained through the CP_g ratio by the efficiency of use (*k*) of protein by the animals, resulting in 0.851 g.quail^{-1}.d^{-1}.

The liquid protein requirement for gain (15-35 d) was estimated by the linear relationship between body protein retentions (Figure 2) over time (15, 20, 25, 30, and 35 d) as a function of fasting carcass weight of quail and the following equation was obtained: $C_p = (0.3102 \pm 0.015) \times FCW - (1.8586 \pm 1.24)$, $R^2 = 0.99$ which was 0.3102 $g.quail^{-1}.d^{-1}$. The dietary requirement for gain was obtained through the CP_g ratio by the efficiency of use (*k*) of protein by the animals, resulting in 0.894 $g.quail^{-1}.d^{-1}$.

Figure 2. Relationship between carcass protein (C_p) over time as a function of fasting carcass weight (FCW) of Japanese quail from 01-14 d (●) and 15-35 d (●)



Source: Authors.

Silva et al. (2004a; 2004b) found values of dietary crude protein for weight gain respectively of 0.461 and 0.843 $g.quail^{-1}.d^{-1}$ or the phases of 01-12 and 15-32 d of Japanese quail, 83% increase in the requirement. This difference must be the biggest weight gain in the growth phase (3.5 $g.quail^{-1}.d^{-1}$) in relation to the initial phase (2.25 $g.quail^{-1}.d^{-1}$) and the protein smallest efficiency in the second phase (24%) compared to the first (40%), respectively 40% less efficient.

In the present study, the values of dietary crude protein for weight gain were 0.851 and 0.894 $g.quail^{-1}.d^{-1}$ (1-14 and 15-35 d) which represents an increase of 5%. The observed weight gains were in the first phase (2.78 $g.quail^{-1}.d^{-1}$) and to the second phase (2.71 $g.quail^{-1}.d^{-1}$). Regarding protein use efficiencies, 33.4 were observed in the starter and 34.7% in the grower phase. That explains the smaller variation between the dietary requirements observed in the present research in relation to Silva's (2004a; 2004b) findings (5 vs 83%), respectively.

4. Conclusions

The prediction equations to estimate daily maintenance and gain crude protein requirements in Japanese quail were: Starter - [CP = (2.095 × $BW^{0.67}$) + (0.851 × WG)] and the grower [CP = (6.30 × $BW^{0.67}$) + (0.894 × WG)]; where W is body weight (kg) and WG is weight gain ($g.quail^{-1}.d^{-1}$).

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Conflict of interest

The authors declare that there is no conflict of interest.

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