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Mathematical models to predict japanese quail crude protein requirements from 01 to 35 days old

Modelos matemáticos para predizer as exigências de proteína bruta de codornas japonesas de 01 a 35 dias de idade

Modelos matemáticos para predecir los requerimientos de proteína cruda de codorniz japoneses de 01 a 35 días de edad

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Abstract

Six hundred and fifty five female Japanese quails were used to estimate the maintenance and protein gain requirements from one to 15 and 15 to 35 days of age. To estimate the protein for maintenance, 240 quails (per phase) were used according to a completely randomized design, with four levels of feed supply (ad libitum, 75%, 50% and 25%) and six replicates of ten birds. Comparative slaughter group (35 and 25 quails, respectively, in the first and in the second phase). To estimate the protein for gain, groups of 15 quails were slaughtered at 3, 6, 9, 12 and 15 days of age, in the initial phase, and groups of 10 quails at 20, 25, 30 and 35 days of age, in the phase growth. All slaughter was performed after a 12-hour fasting. The linear regression equation of the protein retained as a function of crude protein consumption made it possible to estimate an endogenous protein loss around 0.7 and 2.19 g/kg$^{0.67}$/day and the maintenance requirements at 2.095 and 6.301 g/kg$^{0.67}$/day, respectively for the initial and growth phases. The angular coefficient of the line obtained by the linear relationship between the retained protein and the carcass weight over time allowed to estimate the net gain efficiencies around 0.284 g/g (initial phase) and 0.310 g/g (growth phase). The equations for predicts daily protein requirements from one to 15 ($PB_{1\text{-}15d}$) and from 15 to 35 days ($PB_{15\text{-}35d}$) were respectively: $PB_{1\text{-}15d} = (2.095 \times P^{0.67}) + (0.851 \times WG)$ and $PB_{15\text{-}35d} = (6.30 \times P^{0.67}) + (0.894 \times WG)$, were P is live weight (kg) and WG is weight gain (g/quail/d).

Keywords: Comparative slaughter; Crude protein; Gain requirement; Maintenance requirement; Prediction equations.

Resumo

Seiscentos e cinquenta e cinco codornas japonesas foram usadas para estimar as exigências de mantença e ganho de proteína de um a 15 e 15 a 35 dias de idade. Para estimar a proteína para mantença, 240 codornas (por fase) foram utilizadas de acordo com um delineamento inteiramente casualizado, com quatro níveis de fornecimento de ração (ad libitum, 75%, 50% e 25%) e seis repetições de dez aves. Grupo de abate comparativo (35 e 25 codornas, respectivamente, na primeira e na segunda fase). Para estimar a proteína para ganho, grupos de 15 codornas foram abatidas aos 3, 6, 9, 12 e 15 dias de idade, na fase inicial, e grupos de 10 codornas aos 20, 25, 30 e 35 dias de idade, na fase de crescimento. Todos os abates foram realizados após jejum de 12 horas. A equação de regressão linear da proteína retida em função do consumo de proteína bruta possibilitou estimar perda endógena de proteína em torno de 0,7 e 2,19 g/kg^{0,67}/dia e os requisitos de mantença em 2,095 e 6,301 g/kg^{0,67}/dia, respectivamente para as fases: inicial e de crescimento. O coeficiente angular obtido pela relação linear entre a proteína retida e o peso da carcaça ao longo do tempo permitiu estimar as eficiências de ganho líquido em torno de 0,284g/g (fase inicial) e 0,310 g/g (fase de crescimento). As equações para predizer a necessidade diária de proteína de um a 15 (PB_{1-15d}) e de 15 a 35 dias (PB_{15-35d}) foram respectivamente: $PB_{1-15d} = (2{,}095 \times P^{0,67}) + (0{,}851 \times GP)$ e $PB_{15-35d} = (6{,}30 \times P^{0,67}) + (0{,}894 \times GP)$, onde P é peso vivo (kg) e GP é ganho de peso (g/codorna/d).

Palavras-chave: Abate comparativo; Exigência de ganho; Exigência de mantença; Equações de predição; Proteína bruta.

Resumen

Se utilizaron seiscientas cincuenta y cinco codornices japonesas para estimar los requisitos de mantenimiento y ganancia de proteínas de uno a 15 y de 15 a 35 días de edad. Para estimar la proteína para el mantenimiento, se usaron 240 codornices (por fase) de acuerdo con un diseño completamente al azar, con cuatro niveles de suministro de alimento (ad libitum, 75%, 50% y 25%) y seis réplicas de diez aves. Grupo de sacrificio comparativo (35 y 25 codornices, respectivamente, en la primera y en la segunda fase). Para estimar la ganancia de proteína, se sacrificaron grupos de 15 codornices a los 3, 6, 9, 12 y 15 días de edad, en la fase inicial, y grupos de 10 codornices a los 20, 25, 30 y 35 días de edad, en La fase de crecimiento. Toda la matanza se realizó después de un ayuno de 12 horas. La ecuación de regresión lineal de la proteína retenida en función del consumo de proteína cruda permitió estimar una pérdida de proteína endógena alrededor de 0.7 y 2.19 g/kg$^{0.67}$/día y los requisitos de mantenimiento en 2.095 y 6.301 g/kg$^{0.67}$/día , respectivamente para las fases inicial y de crecimiento. El coeficiente angular de la línea obtenida por la relación lineal entre la proteína retenida y el peso de la carcasa a lo largo del tiempo permitió estimar las eficiencias de ganancia netas alrededor de 0.284 g/g (fase inicial) y 0.310 g/g (fase crecimiento). Las ecuaciones para predicen los requerimientos diarios de proteínas de uno a 15 (PB_{1-15d}) y de 15 a 35 días (PB_{15-35d}) fueron respectivamente: $PB_{1-15d} = (2.095 \times P^{0.67}) + (0.851 \times GP)$ y $PB_{15-35d} = (6.30 \times P^{0.67}) + (0.894 \times GP)$, donde P es peso vivo (kg) y GP es ganancia de peso (g/codorniz/d).

Palabras clave: Ecuaciones de predicción; Matanza comparativa; Requisito de ganancia; Requisito de mantenimiento; Poteína cruda.

1. Introduction

Created for various purposes (hunting, meat, ornamentation, eggs) the production of quail is a reality worldwide. Countries such as Spain, France, China and the United States stand out for the production of meat, however, when the production is intended to egg production, countries, as China, Japan and Brazil are highlights (Vieira et al., 2017). Quail farming in Brazil in the year 2018 reached a total of 16.8 million head, either for meat or for eggs, and 297.3 million dozens of eggs, growth of 3.9% compared to 2017, while the production of eggs quail fell 2.1% (IBGE, 2019).

Several methodologies applied to chickens and laying hens (Sakomura & Rostagno, 2016) are effective in quail use, however, they need a more careful evaluation, due to peculiarities inherent to the Coturnix genus, in order to provide consistent results. Quails, whether intended for laying or cutting, have early maturity, and are related to growth rate, and to size of animals (Arango & Van Vleck, 2002; 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 lower age to maturity.

Precocity in growth is related to the time the animal takes to achieve sexual maturity, and is a guiding parameter in breeding programs, and also denotes different requirements for animals. In this sense the 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/lineages, animal category have different nutritional requirements. Comparing the Gompertz growth curves for Japanese quails (Mota et al., 2015; Grieser et al., 2017), meat quails (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 quails have the highest maturity rate, which refers to higher nutritional needs, protein and amino acids.

There are two basic methods (dose response and factorial method) for determining the nutritional requirements of birds. However, several mathematical models and techniques for formulating diets that are allied, to the dose response method, and techniques such as comparative slaughter (CS) and nitrogen balance (NB), used in the factorial model to predict the nutritional requirement values of crude protein and amino acids for birds.

The response dose method (Sakomura & Rostagno, 2016) to estimate the requirements of birds is based on the change of nutrient data in the diet at increasing doses and after evaluating the performance of the animals (e.g., weight gain, feed conversion) and with the aid of mathematical models (linear, quadratic, linear response plateau) the ideal level is estimated

(Rostagno et al., 2007; Pesti et al., 2009).

The factorial method for estimating the requirements differs from the first because it is possible to estimate the requirements by separating the components of maintenance, gain and production (Sakomura & Rostagno, 2016), and may also include other variables in the models, such as temperature and humidity (Filho et al., 2011a, 2011b) and are simplified representations of understanding animal metabolism (Oviedo-Rondón & Waldroup 2002).

The development of prediction models based on the factorial methodology gains importance due to the flexibility and simplicity of use, being suitable for manipulation by technicians from poultry companies, who, with the model and the calculator, can obtain, indirectly and quickly, the nutritional requirements of the birds and update the formulations, without the need for biological tests and laboratory analyzes (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 quails (Silva et al. 2004a, 2004b), laying hens (Sakomura et al., 2002) and Japanese and European quails in growth and laying (Filho et al., 2011a, 2011b), these authors suggested that the metabolic rate (relationship between weight and body surface) is related to ¾ of weight, that is, they suggest metabolic weight of $kg^{0.75}$.

Dodds (2001) in an extensive review on the topic suggests that the metabolic rate in animals with body weight less than 10 kilos is related to 2/3 and not to ¾. Nobrega et al. (2018) working with quails, suggest that when the metabolic weight ($kg^{0.67}$) was used, the amount of energy retained in the body, retained in the egg, retained in total and the production of heat, increased in relation to the use of weight metabolic rate of $kg^{0.75}$.

There are few data available on Japanese quail requirements, based on factorial methodology. In view of the above, this research was based on the elaboration of models of protein-nutritional requirements for Japanese quails from one to 35 days of age, using the factorial methodology.

2. Materials and Methods

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to and the appropriate ethical review committee approval has been received with the approval of the Committee for Animal Use in Experimentation CEUA/UFT under (nº 23.101.00179/2.017-53).

The experiment was conducted at the Poultry Sector of the School of Veterinary Medicine and Animal Science at the Federal University of Tocantins (FUT), Araguaina/TO, Brazil. The experiment was carried out from November 19 to December 22, 2019.

The experimental shed had side curtains in a blue color and was equipped with 24 galvanized wire cages. The cages measured 0.52x0.51x0.3 m (0.26 m^2/quail) and had a 70-Watts incandescent lamp. The quails were distributed as intended for the experiment to determine maintenance requirements in the cages.

Quails destined to establish energy requirements for gain were placed on the floor, covered with wood chips. The box was equipped with a 70-Watts incandescent lamp. The shed had 70-Watts incandescent lamps, drinking fountains, and pressure feeders. The water and diet were provided at will for the quails 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 one to 15 and from 15 to 35 days of age, the comparative slaughter technique was adopted (Sakomura & Rostagno, 2016)

A sample of 655 female Japanese quails were used. The experiment was divided into two parts, first, (01 to 15 days old) using 350 quails with an initial average weight of 6.58 ± 0.28 g (mean ± SD), 240 were placed in the cages, 75 on the floor and 35 slaughtered at one day to be of the reference slaughter of the initial phase. Second, (15 to 35 days of age) 305 female quails were used with an average initial weight of 48.31 ± 0.16 g (mean ± SD); 240, 40, and 25 correspond respectively to the total number of quails to estimate the requirements for the maintenance, gain, and reference slaughter group.

The quails 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 repetitions with ten quails per experimental unit. The experimental diets in each phase were formulated according to Rostagno et al. (2017) recommendation (Table 1).

To estimate the protein gain requirements in the initial phase 15 quails were slaughtered every three days (at 3, 6, 9, 12 and 15 day's age). In the growth phase, a group of 10 quails was slaughters every five days (at 20, 25, 30 and 35 day's age).

In each test, quails destined for slaughter were fasted from solids for 12 hours, again weighed and slaughtered by cervical dislocation, avoiding the loss of blood and feathers. The slaughtered carcasses were identified, placed in plastic bags, stored in the freezer, and then crushed twice in a consecutive cutter meat grinder, weighed and placed in a forced ventilation oven at 55°C for approximately 72 hours to perform the pre-drying and then grinding. Ahead, the samples were processed two more times in the "cutter" mill and once in the "willey" mill to obtain more homogeneous samples for further chemical analysis (AOAC 2005).

At the end of each phase, the quails were fasted from solids for 12 hours, again weighed and slaughtered by cervical dislocation, avoiding the 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/day), crude protein consumption (CP_{con} - g/quail/day), body protein carcass dry matter (P_c - %), body protein carcass (P_b - g/g), retention of protein (R_p) and fasting carcass weight (FCW - g/quail).

Table 1. Composition and calculated values of the experimental diets

Ingredients (%)	01-15 days age	15-35 days age
Corn	57.805	59.811
Soybean meal	36.862	36.082
Degummed soybean oil	1.278	0.763
Dicalcium phosphate	2.207	1.749
Calcitic limestone	1.099	0.923
Salt	0.483	0.506
DL-Methionine 99%	0.161	0.113
L-Lysine HCl 78%	0.063	0.005
L-Threonine 98.5%	0.002	0.009
Premix†	0.040	0.040
Total	100.00	100.00
Nutrients (%)	Chemical composition of diets g/kg dried matter	
Metabolizable energy (Mcal/kg of diet)	2.9	2.9
Crude protein	21.28	21.09
Calcium	1.092	0.911
Available phosphorus	0.513	0.428
Sodium	0.205	0.214
Potassium	0.860	0.852
Chlorine	0.371	0.374
Electrolytic balance (mEq/kg)	204.50	290.35
Digestible lysine	1.095	1.034
Digestible methionine + cystine	0.744	0.693
Digestible threonine	0.733	0.734
Digestible valine	0.898	0.889
Digestible isoleucine	0.835	0.826
Digestible tryptophan	0.245	0.242
Digestible arginine	1.343	1.326
Digestible histidine	0.522	0.518
Digestible glycine + serine	1.734	1.716
Digesible phenylalanine + tyrosine	1.722	1.705
Digestible leucine	1.680	1.674

†Composition per 100 kg: Manganese 18.17mg, Zinc 17.50mg, Iron 11.25mg, Copper 2,000mg, Iodine 187.50mg, Selenium 75mg, Vitamin A 1,400 IU, Vitamin D_3 300 IU, Vitamin E 2.50mg, Vitamin K_3 300mg, Vitamin B_1 380mg, Vitamin B_2 1,000mg, Vitamin B_5 520mg, Vitamin B_{12} 2,000mg, Folic acid 162.50mg, Pantothenic acid 2,600mg, Niacin 7,000mg, Choline, 593.49mg, Antioxidant additive 25mg, Halquinol 7,500mg, Salinomycin 16.50mg. Source: own research.

The crude protein requirement for maintenance (CP_m) was obtained by linear regression of retention of protein (R_p) as a function of CP_{con}. Making an extrapolation for zero retention of protein, the maintenance requirement was given by the ratio 'a/b' expressed in metabolic weight $kg^{0.67}$ (Dodds et al., 2001). The efficiency of use (kg) of protein was given by parameter 'b'. The parameter 'a' (intercept), corrected for metabolic weight represents endogenous loss of body protein.

The liquid protein for gain (CP_g) was determined to be the slope of the linear ratio of body protein (P_b) as a function of the fasting carcass weight (FCW). The dietary requirement for crude protein to gain was obtained considering the efficiency of crude protein use for maintenance (CP_g/k_g) by phase.

The errors were submitted to the Kolmogorov–Smirnov's normality test ($\alpha = 0.01$). The homogeneity of variances was evaluated by the Levene's test ($\alpha = 0.01$), and all variables showed a normal distribution of errors and homoscedasticity. Linear equations ($\alpha = 0.01$) were estimated (SAS 9.0 - Proc Reg). All proposed models had a significant effect (t-test, $\alpha = 0.01$) on the parameters of the equations 'β_0' and 'β_1', with a probability of $P<0.05$.

3. Results and Discussion

The average, minimum and maximum temperatures and humidity observed during the phases under study, respectively, were 24.05, 22.1, and 35.2ºC, the humidity was 84.9, 73, and 95%.

It is observe (Table 2) that live weight of the carcass, consumption of crude protein, retained protein, protein body of Japanese quails from one to 35 days old. A drop in the feed consumption of the quails, 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. 2011; Sakomura et al. 2005). This finding is relevant and valid for the method used to understand the phases of animal metabolism: maintenance and weight gain in the phases, one to 15, and 15 to 35 days of age.

The estimated maintenance requirement for crude protein (CP_m) for quails in the initial (01 to 15 days old) phase [$P_{ret} = (0.3340 \pm 0.004) \times CP_{con} - (0.06158 \pm 0.0092)$, adjusted r^2 = 0.98] and was estimated in relation to the metabolic weight (0.088 kg/quail) in 2.095 $g/kg^{0.67}$/quail/day (Figure 1), where Pret is the protein retained and CP^{con} the crude protein consumed. The estimated maintenance requirement for protein (CP_m) for quails in the growth (15 to 35 days old) phase [$P_{ret} = (0.3470 \pm 0.02611) \times CP_{con} - (0.4001 \pm 0.0593)$, adjusted r^2 =

0.88] and was estimated in relation to the metabolic weight (0.183 kg/quail) in 6.32 g/kg$^{0.67}$/quail/day (Figure 1), where Pret is the protein retained and CPcon the crude protein consumed.

Table 2. Fasting carcass weight (FCW - g/quail), feed intake (FI - g/quail/day), crude protein consumption (CP_{con} - g/quail/day), protein carcass (P_c - %/dry matter), protein body (P_b - g/g), retained protein (P_{ret} - g/g/day) of Japanese quails according to age, feed supply levels (FSL - %), reference slaughter (RS)

Maintenance (01 to 15day)						
RS (1° day)	FCW	FI	CP_{con}†	P_c‡	P_b§	P_{ret}¶
	6.58±0.28	-	-	20.95±0.41	1.38±0.06	-
FSL	Final Slaughter - 15° day					
100	46.92±1.54	8.73±0.25	1.84±0.05	19.25±0.29	9.03±0.30	0.55±0.02
75	34.54±0.58	6.47±0.06	1.37±0.01	20.59±0.48	7.11±0.16	0.41±0.01
50	24.54±0.51	4.39±0.03	0.92±0.01	19.77±1.02	4.85±0.27	0.25±0.02
25	13.36±0.32	2.28±0.11	0.48±0.02	20.87±0.47	2.79±0.07	0.09±0.01
Maintenance (15 to 35 day)						
RS (15° day)	FCW	FI	CP_{con}†	P_c‡	P_b§	P_{ret}¶
	48.31±0.16	-	-	27.38±0.47	13.23±0.22	-
FSL	Final Slaughter - 35° day					
100	110.75±2.50	15.71±0.68	3.34±0.14	23.69±1.84	26.23±2.03	0.68±0.10
75	98.105±5.54	11.42±0.02	2.43±0.01	24.31±0.85	23.88±2.16	0.58±0.10
50	65.55±1.40	7.68±0.03	1.63±0.01	24.41±1.45	16.01±1.28	0.14±0.07
25	42.91±0.26	4.36±0.08	0.93±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_c = Protein corrected for carcass dry matter content. §P_b = obtained by multiplying the P_c and the FCW. ¶P_{ret} = subtraction of the P_b at the end of the experiment by the P_b of the reference slaughter, by day (14 days). Source: own research.

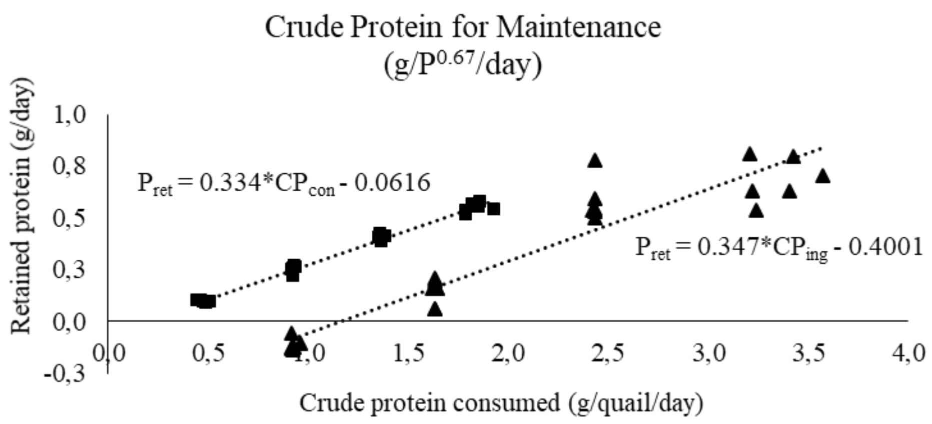
Silva et al. (2004a) for quails in the initial phase (1 to 12 days old) estimated maintenance at 2.85 g/kg$^{0.75}$/day, for the growth phase (15 to 32 days old), Silva et al. (2004b) estimated values of 4.75 g/kg$^{0.75}$/day. Filho et al. (2011) working with Japanese quails in the growth phase (16 to 36 days old) estimated maintenance at $(4.8421 + 0.0111 \times T) \times kg^{0.75}$ and European quails at $(4.8374 + 0.0137 \times T) \times kg^{0.75}$, 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$^{0.75}$, using the comparative-slaughter technique, estimate the maintenance requirement at 6.63 g/kg$^{0.75}$. These researches were made with quails housed in cages.

The values the present research differ from those found mentioned above, and which were respectively 2.095 and 6.32 g/kg$^{0.67}$/day for quails in the phases from one to 15 and 15 to

35 days of age. 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 ($kg^{0.75}$), while in the present research, the ratio of 2/3 ($kg^{0.67}$) was used, which can reduce the metabolic rate in 1/12 weight for maintenance energy. Dodds et al. (2001) reported that for quails, 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 to 15 days), quails that consumed only 25% of the ration, in relation to the treatment of consumption at will, presented a loss endogenous of 0.7 g of protein by $kg^{0.67}$/day. Quails from phase from 15 to 35 days of age, recorded a loss endogenous of around 2.2 g of protein by $kg^{0.67}$/day.

Figure 1. Relationship between protein retention (Pret) in the carcass and crude protein consumption (CPcon) of quails Japanese from 01 to 15 (■) and 15 to 35 (▲) days age.



Source: own research.

A possible explanation for this characteristic is that, in the initial phase, maintenance was around 2.095 g/$kg^{0.67}$/day, while in the growth phase it was around 6.32 g/$kg^{0.67}$/day, 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 quails 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 energy 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 initial phase (2.095 g/$kg^{0.67}$), 67% lower, may be due to lower carcass weight, although quails, at this age, Japanese quails (Silva & Ribeiro, 2001) and European (Du Preez & Sales 1997), present high growth rates. However, lower body weight, since the maintenance requirement is related to metabolic weight $kg^{0.67}$ (relationship between body mass and body surface area). In the second phase, the average weight body are higher, respectively (79.53 vs 26.75 g), i.e., higher crude protein expenditures for maintenance (6.32 $g/kg^{0.67}$). In the works of Silva et al. (2004a, 2004b) the values were closer (2.85 vs 4.75 $g/kg^{0.75}$/day), respectively initial and growth phase.

Comparing the protein use efficiencies, it was observed that in this research, for the initial (01 to 15) and growth (15 to 35 days old) 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 quails already being set in the climatic conditions of the premises and have 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 to 12) compared to the second (15 to 32 days of age), efficiencies of 40 and 23%, respectively. Filho et al. (2011) observed the efficiency in the use of diet protein at around 19% to 27% (mean = 24%) for quails housed, respectively, at temperatures of 18, 24, and 28ºC. For quails at room temperature and housed in Filho et al. (2011), they registered 25% efficiency.

With the exception of the work by Silva et al. 2004a, the other studies mentioned above, showed less 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, it is inferred that the lesser use of crude protein by quails, 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 days of age, however, Grieser et al. (2015) demonstrate that the maximum absolute weight occurs at 20 days of age, that is, greater volumetric capacity and capacity to obtain energy from the feed. The rapid relative growth of the intestine up to seven days (Iji et al., 2001; Murakami et al., 1992) did not reflect in 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 (P_b) retentions over time (Table 3).

The liquid protein requirement for gain (1 to 15 days - CP_g) (01, 03, 06, 09, 12 and 15 days of age) as a function of fasting carcass weight of quails (Figure 2) and the following equation was obtained $P_b = (0.2844 \pm 0.01) \times FCW - (0.7016 \pm 0.183)$, adjusted $r^2 = 0.99$, which was 0.284 g/g. The dietary requirement for gain was obtained through the CP_g ratio by the efficiency of use (*kg*) of protein by the animals, resulting in 0.851 g/g.

The liquid protein requirement for gain (15 to 35 days - CP_g) was estimated by the linear relationship between body protein retentions (Figure 3) over time (15, 20, 25, 30, and 35 days of age) as a function of fasting carcass weight of quails and the following equation was obtained: $P_b = (0.3102 \pm 0.015) \times FCW - (1.8586 \pm 1.24)$, adjusted $r^2 = 0.99$ which was 0.3102 g/g. The dietary requirement for gain was obtained through the CPg ratio by the efficiency of use (kg) of protein by the animals, resulting in 0.894 g/g.

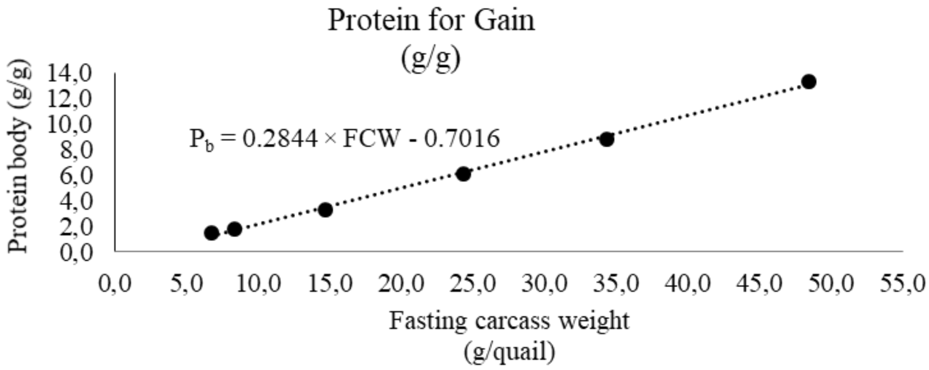
Table 3. Fasting carcass weight (FCW - g/quail), ail/day), protein carcass (P_c - %/dry matter) and protein body (P_b - g/g) of Japanese quails according to age.

Age (days)	Gain (01 to 15day)			Gain (15 to 35day)		
	FCW	P_c†	P_b‡	FCW	P_c†	P_b‡
01	6.71	21.12	1.417	48.40	27.49	13.305
03	8.33	21.65	1.803	70.00	27.82	19.474
06	14.67	22.11	3.242	90.50	29.73	26.906
09	24.33	24.96	6.072	97.00	28.32	27.407
12	34.33	25.76	8.843	102.50	29.49	30.227

†P_c = Protein corrected for carcass dry matter content. P_b = obtained by multiplying the ‡P_c and the FCW. Source: own research.

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

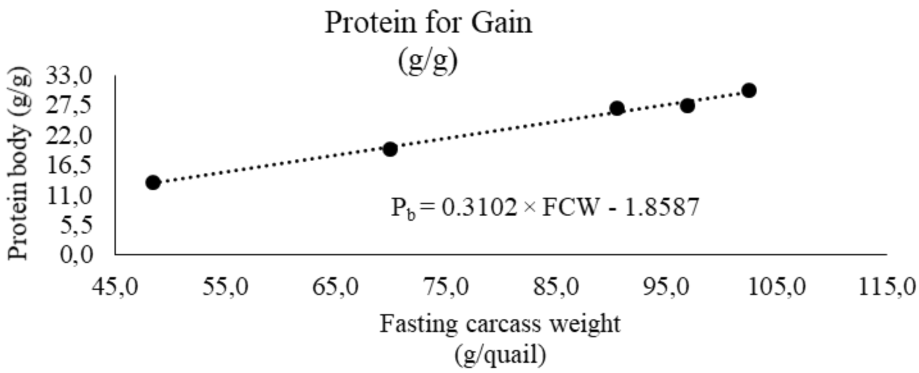
Figure 2. Relationship between protein body (P_b) retained in the carcass over time as a function of fasting carcass weight (FCW) of quails Japanese from 01 to 15 days age.



Source: own research.

In the present study, the values of dietary crude protein for weight gain were 0.851 and 0.894 g/g respectively (01 to 15 and 15 to 35 days age) which represents an increase of 5%. The observed weight gains were in the first phase (2.78 g/quail/day) and to the second phase (2.71 g/quail/day). Regarding protein use efficiencies, 33.4 were observed in the initial phase and 34.7% in the growth 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.

Figure 3. Relationship between protein body (P_b) retained in the carcass over time as a function of fasting carcass weight (FCW) of quails Japanese from 15 to 35 days age.



Source: own research.

4. Final Considerations

Finally, it is important that more research be carried out, as there is still little data available on the requirements of Japanese quails, based on the factorial methodology in the initial and growth phases with regard to crude protein. In conclusion, the predictions equations to estimate the Japanese quail daily requirements of crude protein (CP, g/quail/day) for maintenance and gain based on live weight (W, kg) and weight gain (WG, g/quail/day) were the initial phase [CP = (2.095 × $W^{0.67}$) + (0.851 × WG)] and the growth phase [CP = (6.30 × $W^{0.67}$) + (0.894 × WG)].

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Conflict of interest

The authors declare that there is no conflict of interest.

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