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Mathematical models to predict the energy requirements of Japanese quails from 01-35 days age

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

Modelos matemáticos para predecir los requerimientos de energía de las codornices japonesas de 01 a 35 días de edad

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Danilo Vargas Gonçalves Vieira
ORCID: https://orcid.org/0000-0002-7407-9597
Universidade Federal do Tocantins, Brazil
Bolsista Produtividade – Fundação de Amparo à Pesquisa do Tocantins (FAPT)
E-mail: danilovargaszoo@mail.uft.edu.br
Everton José do Nascimento Oliveira
ORCID: https://orcid.org/0000-0001-9045-4652
Universidade Federal do Tocantins, Brazil
E-mail: tobr27@yahoo.com.br
Rannyelle Gomes Souza
ORCID: https://orcid.org/0000-0003-2717-0053
Universidade Federal do Tocantins, Brazil
E-mail: rannyellegomes@gmail.com
Venúcia de Diniella Santos Bourdon
ORCID: https://orcid.org/0000-0001-9240-7251
Universidade Federal do Tocantins, Brazil
E-mail: venuciabourdonzootecnia@gmail.com
Thalita Rodrigues de Oliveira
ORCID: https://orcid.org/0000-0003-4216-2887
Universidade Federal do Tocantins, Brazil
E-mail: thalitarood@gmail.com
Kaynan Emanuel Campos da Silva
ORCID: https://orcid.org/0000-0002-7710-9798
Universidade Federal do Tocantins, Brazil
E-mail: kaynan.campus@uft.edu.br

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Jossiel Santos Cruz

ORCID: https://orcid.org/0000-0002-1928-6366

Universidade Federal do Tocantins, Brazil

E-mail: jossiel.shancruz.1819@gmail.com

Tádia Emanuele Stivanin

ORCID: https://orcid.org/0000-0002-1382-4573

Universidade Estadual Paulista – Campus Jaboticabal, Brazil

E-mail: tstivanin@zootecnista.com.br

Tobias Aguiar Souza

ORCID: https://orcid.org/0000-0002-1452-3772

Vicami® Nordeste – Incubatório de Codornas, Brazil

E-mail: vicaminordeste@yahoo.com.br

Cassio Nascimento

ORCID: https://orcid.org/0000-0002-1282-7043

Universidade Federal do Tocantins, Brazil

E-mail: cassio21_nascimento@hotmail.com

Kênia Ferreira Rodrigues

ORCID: https://orcid.org/0000-0002-2750-8870

Universidade Federal do Tocantins, Brazil

E-mail: rodrigueskf@uft.edu.br

Roberta Gomes Marçal Vieira Vaz

ORCID: https://orcid.org/0000-0002-5490-5492

Universidade Federal do Tocantins, Brazil

E-mail: betagmvvaz@yahoo.com.br

Matheus Ramalho de Lima

ORCID: https://orcid.org/0000-0002-9897-6209

Universidade Federal do Sul da Bahia, Brazil

E-mail: mrlmatheus@gmail.com

Danilo Teixeira Cavalcante

ORCID: https://orcid.org/0000-0001-8102-3738

Universidade Federal do Agreste Pernambuco, Brazil

E-mail: danilo.zootec@hotmail.com

Fernando Guilherme Perazzo Costa
ORCID: https://orcid.org/0000-0003-4075-1792
Universidade Federal da Paraíba, Brazil
E-mail: perazzo63@gmail.com

Abstract

The objective of the work was to estimate maintenance and energy gain requirements in the phases: 01 to 15 and 15 to 35 days of age. For maintenance energy, 240 quails (per phase) were used according to a completely randomized design, with four treatments (ad libitum, 75%, 50% and 25%), six replicates, and ten quails per experimental unit (n = 655). Comparative slaughter group (35-initial phase; 25-growth phase). To estimate energy 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 growth phase. All slaughter was performed after a 12-hour fast. The equation of energy retained as a function of consumption made it possible to estimate an endogenous energy loss around 9.30 and 19.59 kcal/kg0.67/day and maintenance requirements at 54.96 and 91.48 kcal/kg0.67/day, respectively for the initial and growth phases. The angular coefficient of the line obtained by the linear relationship between energy retained and carcass weight over time allowed estimating the net weight gain requirements around 1.40 and 1.89 kcal/g, respectively, for the initial and growth. $EMA_{1–15d} = (54.96 \times P^{0.67}) + (8.30 \times WG)$. $EMA_{15-35d} = (92.11 \times P^{0.67}) + (8.91 \times WG)$. EMA - apparent metabolizable energy, (Kcal/quail /d); P, live weight (kg); WG, weight gain (g/quail/d).

Keywords: Comparative slaughter; Gain requirement; Maintenance requirement; Metabolizable energy; Prediction equations.

Resumo

O objetivo do trabalho foi o de estimar exigencias de mantença e ganho de energia nas fases: 01 a 15 e 15 a 35 dias de idade. Para a energia de mantença, 240 codornas (por fase) foram utilizadas de acordo com um delineamento inteiramente casualizado, com quatro tratamentos (ad libitum, 75%, 50% e 25%), seis repetições, e dez codornas por unidade experimental (n=655). Grupo de abate comparativo (35 fase inicial; 25 fase crescimento). Para estimar a energia para ganho, foram abatidos grupos de 15 codornas 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. Todo o abate foi realizado após jejum de 12 horas. A equação da energia retida em função do consumo possibilitou estimar uma perda de energia endógena em torno de 9,30 e 19,59 kcal/kg^{0,67}/dia e exigencias de mantença em 54,96 e 91,48 kcal/kg^{0,67}/dia, respectivamente para as fases inicial e crescimento. O coeficiente angular da reta obtido pela relação linear entre energia retida e peso da carcaça ao longo do tempo permitiu estimar as exigencias de ganho de peso líquido em torno de 1,40 e 1,89 kcal/g, respectivamente, para as fases inicial e de crescimento. EMA (1–15d) = (54,96 × $P^{0,67}$) + (8,30 × GP). EMA (15-35d) = (92,11 × $P^{0,67}$) + (8,91 × GP). EMA - energia metabolizável aparente, (Kcal/codorna/d); P, peso vivo (kg); GP, ganho de peso (g/codorna/d).

Palavras-chave: Abate comparativo; energia metabolizável; equações de previsão; exigência de ganho; exigência de mantença

Resumen

El objetivo del trabajo fue estimar los requisitos de mantenimiento y la ganancia de energía en las fases: 01 a 15 y 15 a 35 días de edad. Para la energía de mantenimiento, se utilizaron 240 codornices (por fase) de acuerdo con un diseño completamente al azar, con cuatro tratamientos (ad libitum, 75%, 50% y 25%), seis réplicas y diez codornices por unidad experimental (n = 655). Grupo de sacrificio comparativo (35 fases iniciales; 25 fases de crecimiento). Para estimar la energía para la ganancia, 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 energía retenida en función del consumo permitió estimar una pérdida de energía endógena alrededor de 9.30 y 19.59 kcal/kg$^{0.67}$/día y requisitos de mantenimiento en 54.96 y 91.48 kcal/kg$^{0.67}$/día, respectivamente, para las fases iniciales y de crecimiento. El coeficiente angular de la línea obtenida por la relación lineal entre la energía retenida y el peso de la carcasa a lo largo del tiempo permitió estimar los requisitos de ganancia de peso neto alrededor de 1.40 y 1.89 kcal/g, respectivamente, para la inicial y crecimiento. $EMA_{1–15d}$ = (54.96 × $P^{0.67}$) + (8.30 × GP). EMA_{15-35d} = (92.11 × $P^{0.67}$) + (8.91 × GP). EMA - energía metabolizable aparente, (Kcal/codorniz/d); P, peso vivo (kg); GP, aumento de peso (g/codorniz/d).

Palabras clave: Sacrificio comparativo; Energía metabolizable; Ecuaciones de predicción; Requisito de ganancia; Requisito de mantenimiento

1. Introduction

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.

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; Filho et al., 2011a, 2011b).

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 $kg^{0.75}$.

Few data are available on the requirements of Japanese quails, based on the factorial methodology. Given the above, this research aims to develop models of energy-nutritional requirements for Japanese quails from 01 to 35 days old, using the factorial methodology.

2. Materials and Methods

This work was identified as field research, carried out in an Experimental Shed, with qualitative and quantitative treatments (Pereira et al., 2018). 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 research project was approved and registered with the UFT Animal Use Ethics Committee, under no. nº 23.101.00179/2.017-53.

The experimental shed had side curtains in a blue color and was equipped with 24 galvanized wire cages. The cages measured 0.52 x 0.51 x 0.3 m (0.26 m^2/quail) and had a 70 W 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. The experimental diets (Table 1) were formulated according to Table Brazilian for Poultry and Swine (Rostagno et al., 2017).

A total of 655 female Japanese quails were used. The experiment was divided into two parts, first, (1 to 15 days old) using 350 quails with an initial average weight of 6.71 ± 0.5 g/quail, 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 46.84 ± 0.5 g/quail; 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 energy requirements for quail maintenance and gain in the above-mentioned phases were estimated using the methodology of comparative slaughter (Sakomura & Rostagno 2016).

For this, a group of 35 quails (initial phase) were slaughtered at 1 day of age (reference slaughter), and all quails in the plots were slaughtered at the end of the experiment when the birds were 15 days old.

For the growth phase, a group of 25 quails was slaughtered at 15 days of age (reference slaughter), and all quails in the plots were slaughtered at the end of the experiment when the quails reached 35 days of age.

Table 1. Chemical composition and percentage of experimental diets.

Ingredients (g/100g)	01-15 days age	15-36 days age
	Percent composition of diets	
Corn	57.805	59.811
Soybean meal	36.862	36.082
Degummed oil	1.278	0.763
Dicalcium phosphate	2.207	1.749
Calcitic limestone	1.099	0.923
Common 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
Digestible phenylalanine + tyrosine	1.722	1.705
Digestible leucine	1.680	1.674

†Composition per 100kg: 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.

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.

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), six repetitions with ten quails per experimental unit.

Were used 75 quails to estimate the gain requirements in the initial phase with the slaughter of 15 animals every three days (3, 6, 9, 12, and 15 days age). Forty quails in the growth phase with slaughter of 10 quails every five days (20, 25, 30, and 35 days age).

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) and measurement of the gross energy values of the samples.

With the data obtained, it was possible to calculate feed intake (g/quail/day), metabolizable energy consumption (kcal/quail/day), energy retention (kcal/quail/day), heat production (kcal/quail/day), gross carcass energy (kcal/g), carcass dry matter (%) and fasting quail weight (g/quail).

The energy requirement for maintenance (E_m) was obtained by linear regression of retention as a function of energy consumption. Making an extrapolation for zero retention, the maintenance requirement was given by the ratio 'a/b' expressed in metabolic weight KG0.67 (Dodds, Rothman and Weitz, 2001). The efficiency of use (kg) of energy was given by parameter 'b'.

The net maintenance requirement (NE_m) was estimated by the exponential relationship of heat production as a function of energy consumption expressed in metabolic weight. The efficiency of using the Em of the diet in NE_m was given by the relationship between the requirements of NE_m/E_m.

The net energy for gain (NE_g) was determined to be the slope of the linear ratio of gross body energy as a function of the fasting carcass weight. The dietary requirement for gain was obtained considering the efficiency of energy use for maintenance (NE_g/kg).

The metabolic weight (Kim, 1995) of the initial and growth phase were estimated as follows respectively $[(0.0067 + 0.04626) / 2]^{0.67}$ = 0.088 kg and $[(0.0484 + 0.11075) / 2]^{0.67}$ = 0.183 kg.

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 (SAS, 9.0, Proc GLM). Linear and exponential equations ($\alpha = 0.01$) were estimated (SAS, 9.0, Proc NLin), and graphs were made using the Excel 2019 software. 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. Resulted e 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 possible to observe (Table 2) a significant drop in the live weight of the carcass, in the consumption of feed and metabolizable energy, in the retained energy, in the gross body energy and heat production of Japanese quails from 01 to 35 days old. Such reductions were also observed by (Silva et al., 2004a, 2004b; Longo et al., 2006; Filho et al., 2011a, 2011b; Sakomura et al., 2005).

A drop in the feed consumption of the quails, and consequently, a drop in energy intake accompany the drop observed in these variables (Table 2). 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 energy for quails in the initial (01 to 15 days old) phase (RE = (0.1692 ± 0.004) × EC – (0.8183 ± 0.082), adjusted r^2 = 0.98) and was estimated in relation to the metabolic weight (0.088 kg/quail) in 54.96 kcal/kg$^{0.67}$/quail/day (Figure 1), where RE is the energy retained and EC the energy consumed.

The estimated maintenance requirement for energy for quails in the growth (15 to 35 days old) phase (RE = (0.2127 ± 0.007) × EC – (3.5854 ± 0.232), adjusted r^2 = 0.97) and was estimated in relation to the metabolic weight (0.183 kg/quail) in 92.11 kcal/kg$^{0.67}$/quail/day (Figure 1), where RE is the energy retained and EC the energy consumed.

Silva et al. (2004a) for quails in the initial phase (1 to 12 days old) estimated maintenance at 77.07 kcal/kg$^{0.75}$/day. For the 15 to 32-day phase, Silva et al. (2004b) estimated values of 91.48 kcal/kg$^{0.75}$/day, Filho et al. (2011a) for Japanese quails in the growth phase (16 to 36 days old) estimated maintenance at (98.37 - 0.205×T) × $kg^{0.75}$ kcal/$kg^{0.75}$/day and European quails at (115.08 - 0.3939×T) × $kg^{0.75}$ kcal/$kg^{0.75}$/day. These researches were made with quails housed in cages.

These values differ from those found in the present research, which were respectively 54.96 and 92.11 kcal/$kg^{0.67}$/day for quails in the phases from one to 15 and 15 to 35 days of age. In Silva's (2004a; 2004b) and Filho's (2011a) 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.

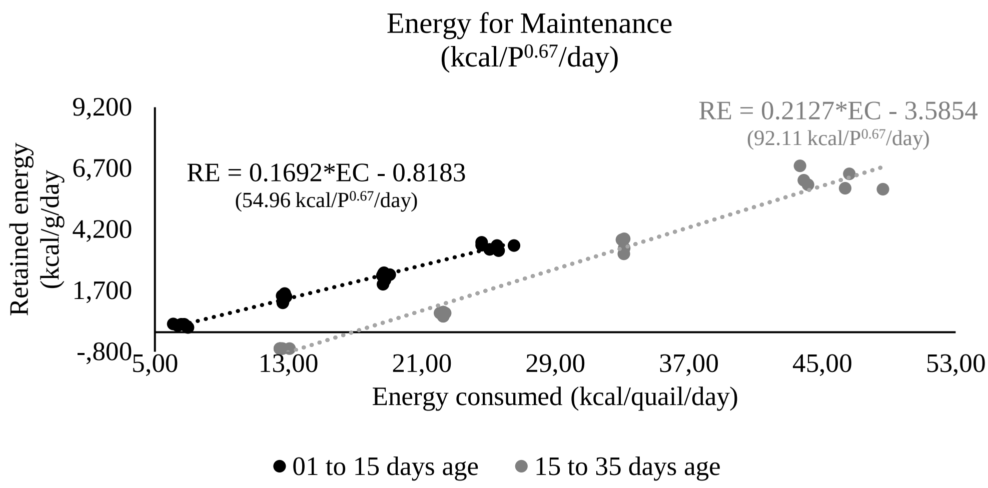
Table 2. Fasting carcass weight (FCW - g/quail), Metabolizable energy consumption (MEC - kcal/quail/day), Gross carcass energy (GC - kcal/dry matter), Gross body energy (GB_c - kcal/g), Retained energy (ER - kcal/g/day) and Heat production (HP - kcal/day) of Japanese quails according to age, feed supply levels (FSL - %), reference slaughter (RS).

	Maintenance (01 to 15day)					
RS (1° day)	FCW	†MEC	GC‡	GB_c§	RE¶	HP¥
	6.71	-	1.25	8.35	-	-
FSL	Final Slaughter - 15° day					
100	46.36±0.60	25.32±0.74	1.24±0.03	57.48±1.77	3.51±0.13	21.81±0.79
75	34.97±1.16	18.77±0.16	1.14±0.06	40.04±2.54	2.26±0.18	16.51±0.22
50	24.33±1.33	12.74±0.09	1.14±0.02	27.86±1.98	1.40±0.14	11.34±0.14
25	12.89±0.77	6.62±0.32	0.96±0.01	12.34±0.74	0.29±0.05	6.34±0.36
Age (days)	Gain (01 to 15day)					
01	6.71	-	1.25	8.37	-	-
03	8.33	-	1.08	8.98	-	-
06	14.67	-	1.16	17.06	-	-
09	24.33	-	1.33	32.25	-	-
12	34.33	-	1.35	46.20	-	-
15	48.40	-	1.36	65.64	-	-
	Maintenance (15 to 35 day)					
RS (15° day)	FCW	MEC†	GC‡	GB_c§	RE¶	HP¥
	48.40	-	1.356	65.65	-	-
FSL	Final Slaughter - 35° day					
100	110.75±2.50	45.57±1.98	1.72±0.08	189.86±7.44	6.21±0.37	39.36±2.20
75	98.13±7.15	33.11±0.07	1.40±0.11	136.87±5.82	3.56±0.29	29.54±0.32
50	65.45±1.40	22.28±0.09	1.23±0.02	80.67±1.61	0.75±0.08	21.53±0.13
25	43.00±0.15	12.64±0.22	1.21±0.01	52.28±0.09	-0.67±0.10	13.31±0.22
Age (days)	Gain (15 to 35day)					
15	48.40	-	1.36	65.64	-	-
20	70.00	-	1.54	107.51	-	-
25	90.50	-	1.57	142.48	-	-
30	97.00	-	1.58	153.44	-	-
35	102.50	-	1.69	173.14	-	-
35	102.50	-	1.69	173.14	-	-

†MEC = obtained by multiplying the energy content of the diet and the FC. ‡GC = Energy corrected for carcass dry matter content. §GB_c = obtained by multiplying the GC and the FCW. ¶RE = subtraction of the GB_c at the end of the experiment by the GB_c of the reference slaughter, by day. ¥HP = MEC - RE. Averages in columns with different letters are statistically different by the Tukey test (α = 0.05). Source: own research.

Dodds (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 of 9.30 kcal/kg$^{0.67}$/day; quails from phase from 15 to 35 days of age, recorded a loss of around 19.59 kcal/kg$^{0.67}$/day.

Figure 1. Relationship between energy retention in the carcass and metabolizable energy consumption of quails Japanese from 01 to 35 days age.



Source: own research.

A possible explanation for this characteristic is that in the initial phase, the maintenance was around 54.96 kcal/kg$^{0.67}$/day while in the growth phase it was around 92.11 kcal/kg$^{0.67}$/day, with this, a greater demand can reflect in a greater need and thereby break the tissues to obtain energy. This premise validates the need to split the requirement for keeping quails according to age.

Another explanation is that the lower energy requirement for maintenance initial phase (54.96), 40% less, may be due to the heating of the environment with incandescent lamps, as there was a reduction in energy expenditure to control homoeothermic.

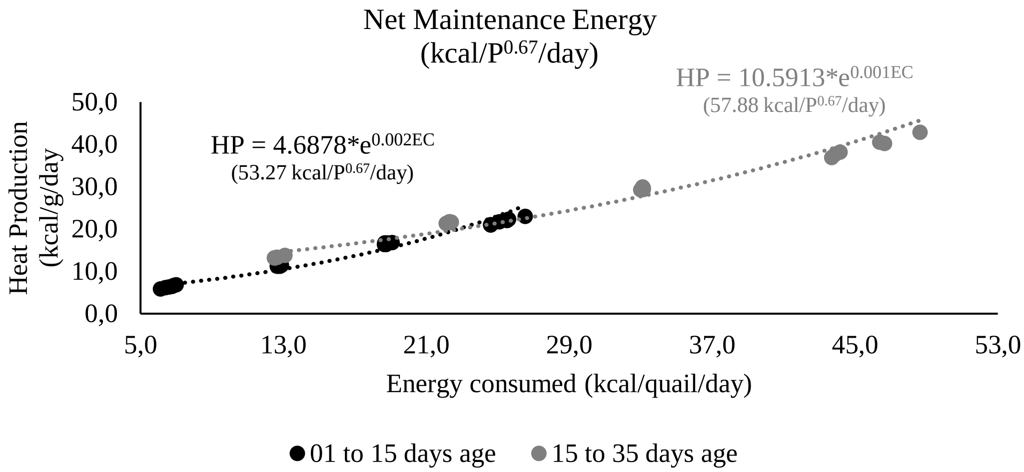
In the second phase, the maximum temperatures reached 35.9ºC, which can have the opposite effect, that is, greater energy expenditure for maintenance (92.11) in order to maintain homoeothermic, by example.

In the works of Silva et al. (2004a, 2004b) the values were closer (77.07 vs 91.48 kcal/KG0.75/day), this difference was mainly attributed to the difference in the weight of the birds in the two phases studied by Silva et al. (2004a, 2004b).

The above finding (present research) can be verified when comparing the efficiency of using energy for maintenance. Extrapolating to zero energy intake, the efficiencies for both phases were 96.93% and 62.84%, respectively (Figure 2), for the initial and growth phases. However, a difference between the phases was already expected, since quails in the second phase (15 to 35 days) have higher weights and greater weight gains (Table 2).

The estimate of the net requirement energy (Initial phase, Figure 2) for maintenance was estimated by the exponential relationship of heat production and energy consumption (HP = $(4.6878 \pm 0.257) \times e^{(0.0528 \pm 0.002)*EC}$, adjusted $r^2 = 0.99$), expressed in a metabolic weight, of 53.27 kcal/kg0.67/day. Therefore, it was possible to calculate the efficiency of use of Em of the diet in NE_m as 96.93%.

Figure 2. Relationship between heat production and metabolizable energy consumption of quails Japanese from 01 to 35 days age.



Source: own research.

The estimate of the net requirement (Growth phase, Figure 2) for maintenance was estimated by the exponential relationship of heat production and energy consumption (HP = $(10.5913 \pm 0.428) \times e^{(0.0291 \pm 0.001)*EC}$, $r^2 = 0.99$), expressed in a metabolic weight of 57.88 kcal/kg0.67/day.

It was possible to calculate the efficiency of use of E_m of the diet in NE_m as 62.84%. The maintenance requirement of 54.96 $kcal/kg_{0.67}$/day was less than that observed by Albino et al. (1994), of 142 and 164 $kcal/kg^{0.75}$/day, respectively, for pullets of light lines EMB-011 and Lohmann LSL. Filho et al. (2011) observed values of (98.37 - 0.205×T) $kcal/kg^{0.75}$/day.

Comparing the energy use efficiencies, it was observed that in this research, for the initial (1 to 15) and growth (15 to 35 days old) phases were 16.92% and 21.27%, respectively.

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 28.56% and 23.60%, respectively.

Filho et al. (2011a) observed the efficiency in the use of diet energy at around 17% to 25% for quails housed, respectively, at temperatures of 18, 24, and 28ºC. For quails at room temperature and housed in Filho et al. (2011a), they registered 23% efficiency. All the efficiencies compared were greater than those presented in this research were.

It is inferred that the lesser use of energy, by quails in this research in the first phase, may be related to the absolute digestive capacity of quails. 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, and 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 ingested energy showed the efficiency of use as 16.92% and 21.27%, respectively, for the initial and growth phases. Albino et al. (1994), registered for chickens of lines EMB-011 and Lohmann 47% and 55%, respectively.

One possible explanation may be related to a greater loss of heat in relation to quail mass and body surface (Macleod & Dabhuta, 1997; Dodds, 2001), what in this research was related to 2/3. The lower relative weight of the quail intestine, consequently greater speed in the passage of feed (Murakami & Furlan, 2002) may explain the lower digestive efficiency among quails, hens, and laying hens.

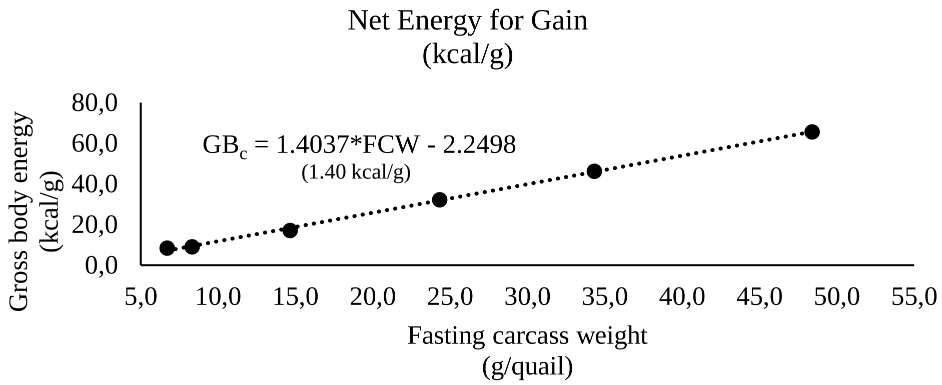
Another possible explanation is that quails are animals with wild habits, that is, they are more affected with the presence of human beings, or even, they present greater agitation and movement inside the installations/cages.

In Filho's (2011a) works, comparing Japanese quails housed (93.58 kcal/kg$^{0.75}$/day) in cages and on the ground (95.23 kcal/kg$^{0.75}$/day), it was evident that there is a greater need for energy for maintenance when animals have space to move, that is, raised on the ground in detriment of cages.

The net requirement for gain (NE_g) was estimated by the linear relationship between body energy retentions (Figure 3) over time (01, 03, 06, 09, 12, and 15 days of age) as a function of fasting carcass weight of quails and the following equation was obtained: BEr = (1.4037 ± 0.025) × FCW – (2.2498 ± 0.697), adjusted r^2 = 0.99 which was 1.40 kcal/g. The dietary requirement for gain was obtained through the NE_g ratio by the efficiency of use (*kg*) of energy by the animals, resulting in 8.30 kcal/g.

The net requirement for gain (NE_g) was estimated by the linear relationship between body energy retentions (Figure 4) over time (15, 20, 25, 30, and 35 days of age) as a function of the fasting carcass weight of the quails and the following equation was obtained: $BEr = (1.8955 \pm 0.094) \times FCW – (26.382 \pm 7.881)$, adjusted $r^2 = 0.99$ which was 1.896 kcal/g. The dietary requirement for gain was obtained through the NE_g ratio by the efficiency of use (*kg*) of energy by the animals, resulting in 8.92 kcal/g.

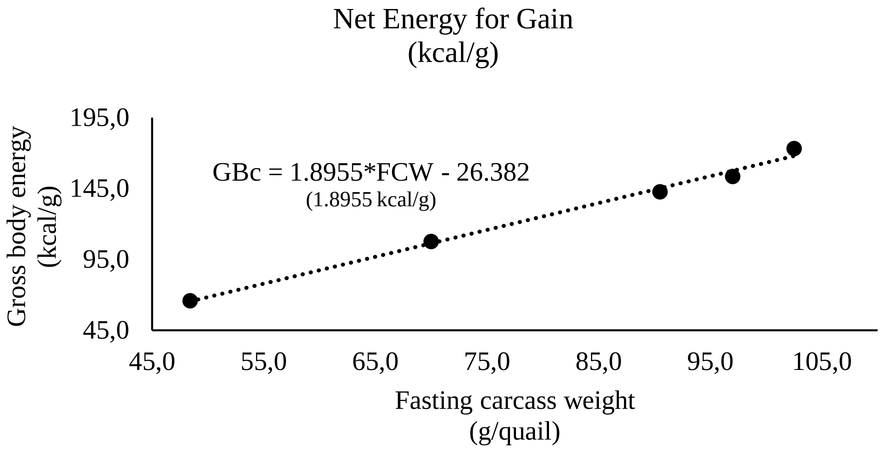
Figure 3. Relationship between gross body energy retained in the carcass over time as a function of fasting carcass weight of quails Japanese from 01 to 15 days age.



Source: own research.

Silva et al. (2004a; 2004b) found values of dietary energy for weight gain respectively of 4.64 and 9.32 kcal/g for the phases of 01 to 12 and 15 to 32 days of the age of Japanese quails. A 100.86% 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 (2.45 g/quail/day) and also the energy smallest efficiency in the second phase (22%) compared to the first (28%).

Figure 4. Relationship between energy retained in the carcass over time as a function of fasting carcass weight of quails Japanese from 15 to 35 days age.



Source: own research.

In the present study, the values of dietary energy for weight gain were 8.30 and 8.92 kcal/g respectively (01 to 15 and 15 to 35 days age) which represents an increase of 7.47%. The observed weight gains were greater in the first phase (2.78 g/quail/day) compared to the second phase (2.71 g/quail/day. Regarding energy use efficiencies, 16.92 were observed in the initial phase and 21.27% in the growth phase. That explains the smaller variation between the dietary requirements observed in the present research in relation to Silva's findings (7.47 vs 100.86%).

4. Conclusion and Suggestions

Finally, it is important that more research is 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 energy.

The predictions equations to estimate the daily maintenance and energy gain requirements in Japanese quails in the initial and growth phases were, where AME is the apparent metabolizable energy requirement; W, live weight (kg); WG, weight gain (g/quail/day).

1. The initial phase AME (Kcal/quail/day) = $54.96 \times W^{0.67} + 8.30 \times WG$.
2. The growth phase AME (Kcal/quail/day) = $92.11 \times W^{0.67} + 8.91 \times WG$.

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Conflict of interest

The authors declare that there is no conflict of interest.

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Percentage of contribution of each author in the manuscript

Danilo Vargas Gonçalves Vieira – 15%

Everton José do Nascimento Oliveira – 20%

Rannyelle Gomes Souza – 5%

Venúcia de Diniella Santos Bourdon – 5%

Thalita Rodrigues de Oliveira – 5%

Kaynan Emanuel Campos da Silva – 5%

Jossiel Santos Cruz – 5%

Tádia Emanuele Stivanin – 5%

Tobias Aguiar Souza – 5%

Cassio Nascimento – 5%

Kênia Ferreira Rodrigues – 5%

Roberta Gomes Marçal Vieira Vaz – 5%

Matheus Ramalho de Lima – 5%

Danilo Teixeira Cavalcante – 5%

Fernando Guilherme Perazzo Costa – 5%